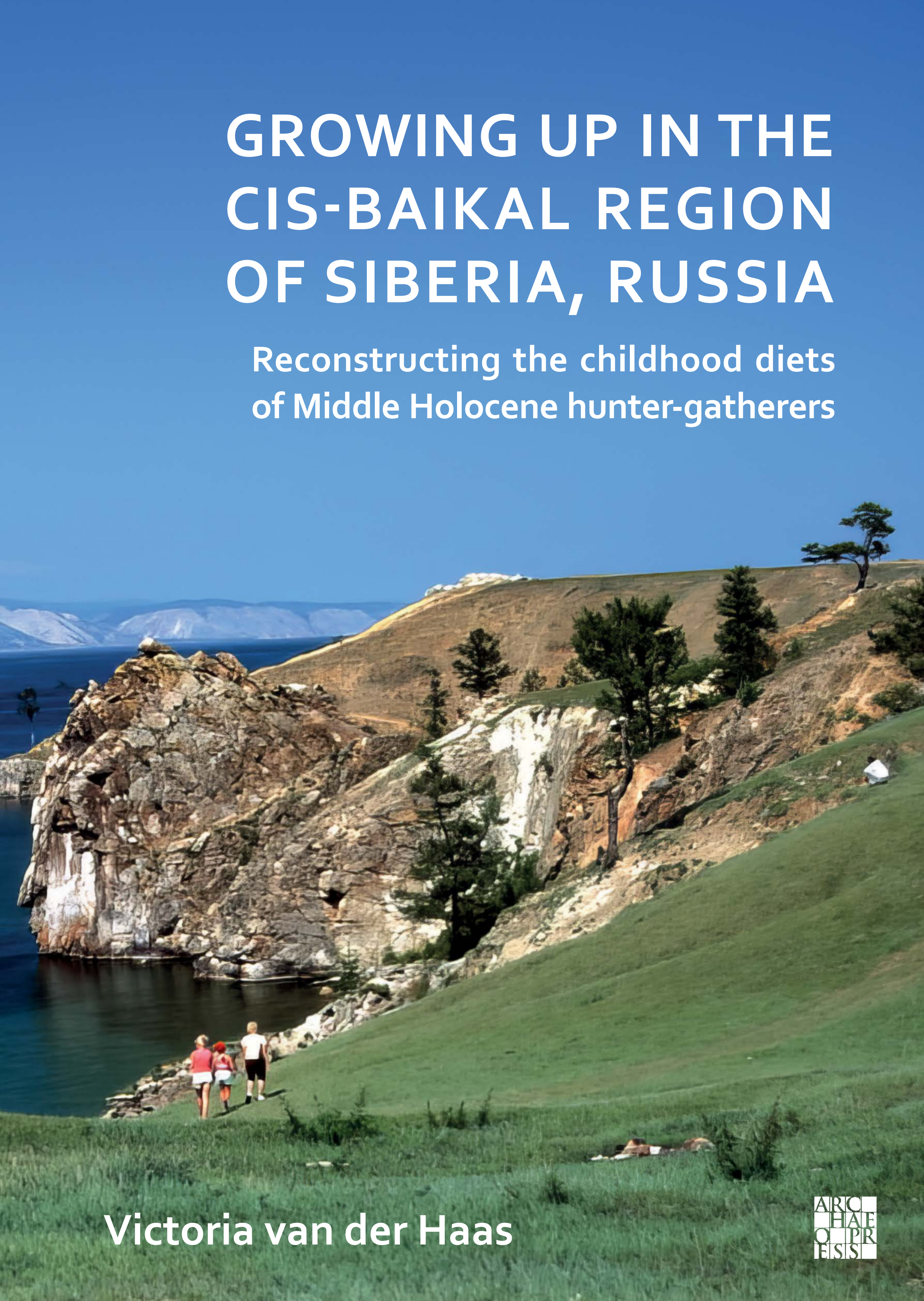


GROWING UP IN THE CIS-BAIKAL REGION OF SIBERIA, RUSSIA

Reconstructing the childhood diets of Middle Holocene hunter-gatherers

Victoria van der Haas

ARCHAEOPRESS

Growing Up in the Cis-Baikal Region of Siberia, Russia

Reconstructing the childhood diets of Middle Holocene hunter-gatherers

Victoria van der Haas

Archaeopress Archaeology

ARCHAEOPRESS PUBLISHING LTD
Summertown Pavilion
18-24 Middle Way
Summertown
Oxford OX2 7LG
www.archaeopress.com

ISBN 978-1-80327-493-5
ISBN 978-1-80327-494-2 (e-Pdf)

Cover: View of Shamanskii Mys ('Shaman's Cape'), west coast of Ol'khon Island, Lake Baikal.

This book is available direct from Archaeopress or from our website www.archaeopress.com

Contents

List of Figures and Tables .... **iii**

Preface .... **vii**

Acknowledgements .... **viii**

Chapter 1: Introduction **1**
- Significance of the research 1
- Research goals 3
- Organization of the monograph 3

Chapter 2: Geographic and archaeological background **4**
- Biogeography 4
- Flora and fauna 5
- Climate 8
- The importance of studying Holocene hunter-gatherers 9
- Archaeological context 9
- Cemeteries 12
- Summary 15

Chapter 3: Stable isotope analysis for dietary reconstruction **16**
- Stable isotope analysis 16
- Collagen 20
- Isotopic data and childhood diets 21
- Sources of isotopic uncertainty 24
- Stable isotope analysis in the Cis-Baikal region 30
- Strontium analysis of Cis-Baikal faunal and human remains 36
- Summary 37

Chapter 4: Tooth formation **38**
- Dental anatomy and morphology 38
- Dental development 40
- Enamel formation 40
- Dentine formation 41
- Dental maturation 42
- Using the dentition for examining human life history 45
- Summary 45

Chapter 5: Materials and methods **46**
- Materials 46
- Methods 49
- Summary 55

Chapter 6: Dietary life-histories in the Upper Lena 56
General patterns in dentine stable isotope signatures 56
Manzurka 57
Obkhoi 59
Ust'-Ilga 64
Summary 77

Chapter 7: Dietary life-histories in the Angara 79
General patterns in dentine stable isotope signatures 79
Late Neolithic Ust'-Ida I 80
Early Bronze Age Ust'-Ida I 93
Summary 99

Chapter 8: Dietary life-histories in the Little Sea 100
General patterns in dentine stable isotope signatures 100
Shamanskii Mys 101
Khuzhir-Nuge XIV 104
Summary 130

Chapter 9: Discussion 131
Limitations of dentine micro-sampling 131
General dentine stable isotope patterns 139
Dietary patterns in Cis-Baikal 146
Migratory patterns in Cis-Baikal 151
The importance of studying hunter-gatherer life histories 153
Growing up in Baikal 154
Summary 174

Chapter 10: Conclusions 174
Early life dietary patterns in Cis-Baikal 175
Migration patterns in Cis-Baikal 177
Future directions 178
Final remarks 181

Appendix A: Images of the molar occlusal surfaces 182
Upper Lena micro-region 182
Angara micro-region 186
Little Sea micro-region 190

Appendix B: Molar wear assessment of all 49 Cis-Baikal individuals 197
Upper Lena individuals 197
Angara individuals 198
Little Sea individuals 199

Appendix C: Stable carbon and nitrogen isotope values for all micro-samples 200

Bibliography 223

List of Figures and Tables

Table 1. Summary of the sites and samples 2

Figure 1. Map of East Asia. Source: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data from Jarvis *et al.* 2008 4

Figure 2. Topographic map of the Cis-Baikal region and the mortuary sites examined in this research. Adapted from: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data from Jarvis *et al.* 2008 5

Figure 3. Ol'khon Island in the Little Sea micro-region. Created by: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data (Jarvis *et al.* 2008) 7

Table 2. Current cultural history model for Cis-Baikal based on radiocarbon dating (Weber *et al.* 2016) 10

Figure 4. Expected changes in $\delta^{15}N$ with age during nursing and weaning (Schurr 1998: 330) 23

Figure 5. Stable isotope ecology of main Cis-Baikal food groups (adopted from Weber *et al.* 2002 using unpublished BAP data) 32

Figure 6. Stable isotope data for Cis-Baikal hunter-gatherers (Weber *et al.* 2011: 541). Data shown are from (a) all 4 micro-regions, (b) Angara valley, (c) Little Sea, (d) Upper Lena and Southwest Baikal 34

Figure 7. The internal structure of a tooth (Townsend *et al.* 2015: 17) 39

Figure 8. Dentine and enamel secretion in a mammalian tooth (Piesco and Avery 2002: 91) 42

Table 3. Teeth of Cis-Baikal Middle Holocene hunter-gatherers selected for this study. L = Left; R = Right; $M^{1,\ 2\ \mathrm{or}\ 3}$ = Upper 1st, 2nd or 3rd molar; $M_{1,\ 2\ \mathrm{or}\ 3}$ = Lower 1st, 2nd or 3rd molar 46

Table 4. Molar wear stages and descriptions according to Smith (1984: 45–46) 51

Table 5. Formation time of the permanent molars according to the London Atlas (AlQahtani *et al.* 2010) 54

Figure 9. Multi-molar dentine profile for individual MNZ_1974.002 58

Figure 10. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values of individual MNZ_1974.002 59

Figure 11. Multi-molar dentine profile for individual OBK_1971.005 60

Figure 12. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values of individual OBK_1971.005 60

Figure 13. Multi-molar dentine profile for individual OBK_1971.007 62

Figure 14. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values of individual OBK_1971.007 62

Figure 15. Multi-molar dentine profile for individual OBK_1971.013 63

Figure 16. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values of individual OBK_1971.013 64

Figure 17. Single molar dentine profile for individual UIL_1989.001 65

Figure 18. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UIL_1989.001 65

Figure 19. Single molar dentine profile for individual UIL_1989.002 as M2 66

Figure 20. Single molar dentine profile for individual UIL_1989.002 as M3 67
Figure 21. Single molar dentine profile for individual UIL_1989.003 68
Figure 22. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UIL_1989.003 68
Figure 23. Single molar dentine profile for individual UIL_1989.004.0? 69
Figure 24. Single molar dentine profile for individual UIL_1989.005 as M2 70
Figure 25. Single molar dentine profile for individual UIL_1989.005 as M3 70
Figure 26. Single molar dentine profile for individual UIL_1990.009 71
Figure 27. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UIL_1990.009 72
Figure 28. Single molar dentine profile for individual UIL_1990.010 73
Figure 29. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UIL_1990.010 73
Figure 30. Single molar dentine profile for individual UIL_1990.011 74
Figure 31. Single molar dentine profile for individual UIL_1990.012 75
Figure 32. Single molar dentine profile for individual UIL_1991.013.01 76
Figure 33. Single molar dentine profile for individual UIL_1991.013.02 77
Figure 34. Multi-molar dentine profile for individual UID_1987.006...................................... 80
Figure 35. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1987.006 81
Figure 36. Multi-molar dentine profile for individual UID_1987.011...................................... 82
Figure 37. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1987.011 82
Figure 38. Multi-molar dentine profile for individual UID_1988.014...................................... 83
Figure 39. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1988.014 84
Figure 40. Multi-molar dentine profile for individual UID_1989.020.01................................. 85
Figure 41. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.020.01 85
Figure 42. Multi-molar dentine profile for individual UID_1989.020.02................................. 86
Figure 43. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.020.02 87
Figure 44. Multi-molar dentine profile for individual UID_1989.022...................................... 88
Figure 45. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.022 88
Figure 46. Multi-molar dentine profile for individual UID_1989.030...................................... 89
Figure 47. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.030 90
Figure 48. Multi-molar dentine profile for individual UID_1991.038...................................... 91
Figure 49. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1991.038 91
Figure 50. Multi-molar dentine profile for individual UID_1995.056.01................................. 92
Figure 51. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1995.056.01 93
Figure 52. Multi-molar dentine profile for individual UID_1989.019...................................... 94
Figure 53. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.019 94

Figure 54. Single molar dentine profile for individual UID_1989.029 95
Figure 55. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.029 96
Figure 56. Multi-molar dentine profile for individual UID_1993.045 97
Figure 57. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1993.045 97
Figure 58. Multi-molar dentine profile for individual UID_1994.048 98
Figure 59. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1994.048 98
Figure 60. Single molar dentine profile for individual SHM_1975.001 102
Figure 61. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual SHM_1975.001 102
Figure 62. Multi-molar dentine profile for individual SHM_1972.002 103
Figure 63. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual SHM_1972.002 103
Figure 64. Single molar dentine profile for individual K14_1997.011 104
Figure 65. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.011 105
Figure 66. Multi-molar dentine profile for individual K14_1997.012 106
Figure 67. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.012 106
Figure 68. Single molar dentine profile for individual K14_1997.014 107
Figure 69. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.014 107
Figure 70. Single molar dentine profile for individual K14_1997.015 108
Figure 71. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.015 109
Figure 72. Single molar dentine profile for individual K14_1997.016 110
Figure 73. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.016 110
Figure 74. Multi-molar dentine profile for individual K14_1997.019 111
Figure 75. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.019 112
Figure 76. Single molar dentine profile for individual K14_1998.035.02 113
Figure 77. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.035.02 113
Figure 78. Single molar dentine profile for individual K14_1998.036.01 114
Figure 79. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.036.01 114
Figure 80. Single molar dentine profile for individual K14_1998.037.02 115
Figure 81. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.037.02 115
Figure 82. Multi-molar dentine profile for individual K14_1998.038 117
Figure 83. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.038 117
Figure 84. Multi-molar dentine profile for individual K14_1998.039 118

Figure 85. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.039 118
Figure 86. Multi-molar dentine profile for individual K14_1999.044 120
Figure 87. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.044 120
Figure 88. Multi-molar dentine profile for individual K14_1999.045 121
Figure 89. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.045 121
Figure 90. Single molar dentine profile for individual K14_1999.046 122
Figure 91. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.046 123
Figure 92. Multi-molar dentine profile for individual K14_1999.051 124
Figure 93. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.051 124
Figure 94. Single molar dentine profile for individual K14_1999.057.02 125
Figure 95. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.057.02 125
Figure 96. Multi-molar dentine profile for individual K14_2000.063 126
Figure 97. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_2000.063 127
Figure 98. Multi-molar dentine profile for individual K14_2000.064 128
Figure 99. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_2000.064 128
Figure 100. Single molar dentine profile for individual K14_2000.077 129
Figure 101. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_2000.077 130
Table 6. Isotopic shifts in $\delta^{15}N$ and $\delta^{13}C$ across single molars for all 49 Cis-Baikal individuals. L = Left; R = Right; $M^{1, 2 \text{ or } 3}$ = Upper 1st, 2nd or 3rd molar; $M_{1, 2 \text{ or } 3}$ = Lower 1st, 2nd or 3rd molar 135
Figure 102. Potential isotopic noise seen in S-09 and S-10 $\delta^{15}N$ (M1) of K14_1997.012 138
Figure 103. 'Typical' weaning pattern with a decline in $\delta^{15}N$ and $\delta^{13}C$ in individual UID_1989.020.01 140
Figure 104. 'Typical' weaning pattern with a gradual decline in $\delta^{15}N$ in individual OBK_1971.013 141
Figure 105. No weaning signature in the M1 of UIL_1990.011 142
Figure 106. Negative relationship between $\delta^{13}C$ and $\delta^{15}N$ in UIL_1989.002 (M2) 143
Figure 107. A continuous oscillation of both $\delta^{13}C$ and $\delta^{15}N$ in UID_1989.022 (M3) 145
Figure 108. A continuous oscillation of both $\delta^{13}C$ and $\delta^{15}N$ in UID_1989.029 (M3) 145
Table 7. Weaning ages of the Cis-Baikal individuals 148
Figure 109. Stable isotope results for UID_1989.020.01 and UID_1989.020.02 150
Figure 110. Stable isotope results for SHM_1975.001 and SHM_1972.002 151
Figure 111. Stable isotope results for the EBA Ust'-Ida I individuals: UID_1989.019; UID_1989.029; UID_1993.045; UID_1994.048 171
Figure 112. Stable isotope results for the EBA Khuzhir-Nuge XIV individuals: K14_1997.011; K14_1997.012; K14_1998.036.01; K14_1999.046 172

Preface

This is an original work by Victoria M. van der Haas. The research project received research ethics approval from the University of Alberta Research Ethics Board under Pro00021280_AME (March 3, 2016) and Pro00021280_REN7 (February 2, 2017). Apart from formatting to meet the publisher's requirements, the work presented in this monograph has not been updated since January 2020.

Acknowledgements

Examining the fascinating life histories of these prehistoric hunter-gatherers would not have been possible without the support of various institutions and individuals.

This work received funding from the Social Sciences and Humanities Research Council of Canada (Major Collaborative Research Initiative Grants Nos. 410-2000-1000, 412-2005-1004, and 412-2011-1001) as well as AMIDEX, Aix-Marseille University funding (WEBERRHR/SOCA/AM15AVHRXX). The Department of Anthropology and Faculty of Arts at the University of Alberta both provided travel grants (the Department of Anthropology Travel Award and Clifford H. Skitch Travel Fund Award) that allowed me to present my research abroad, strengthening its quality. Additional financial support was made possible by the Baikal Archaeology Project in the form of Research and Teaching Assistantships at the Department of Anthropology, University of Alberta.

Use of the Baikal osteological samples was made possible by the Baikal Archaeology Project and its members. Thank you to Professor Andrzej Weber, director of the project and supervisor of the dissertation, which led to this publication. I am also grateful to our Russian colleagues: Drs. Olga I. Goriunova, Alexei Novikov, Sergei Peskov, Vladimir I. Bazaliiskii, and Irkutsk State University.

Closer to home, I owe thanks to the scholars at the University of Alberta for contributing their expertise, guidance, feedback, and resources over the years this work was being carried out. In particular, I would like to thank Professor Sandra Garvie-Lok, Dr. Lesley Harrington, Professor Pamela Willoughby and Professor Kisha Supernant. I am also grateful to Professor Janet Montgomery at Durham University, who provided excellent comments and suggestions.

Furthermore, the work presented here would not have been possible without the tremendous laboratory and administrative help of several people. I thank Dr. Mingsheng Ma and Alvin Kwan from the Biological Sciences Research Laboratory at the University of Alberta. Thank you to Harvey Friebe, Director of Laboratories, University of Alberta. I owe gratitude to Heather Cook and Professor Andie Palmer. Furthermore, this work would have been less enjoyable had it not been for the great support of, and thought-provoking conversations with, Dr. Katherine Bishop and Dr. Jennifer Miller.

Over the past few years, the members of the Baikal Archaeology Project have become more than just colleagues; they have become friends. I am thankful for their support and for always making every project meeting and workshop a great environment. I particularly would like to thank Erin Jessup for her tremendous help in getting this monograph ready for publication, as well as for her support and friendship over the years. I had the privilege of working with her in Japan and sharing an office with her in Canada. Erin is an invaluable member of the Baikal Archaeology Project. I am also extremely grateful for BAP manager Andrea Hiob, who provided much more than excellent administrative support. While she would never admit to it, Andrea is an absolute rock for BAP graduate students and team members. I am also grateful

to Professor Rick Schulting for providing great feedback whenever I presented my work at conferences and workshops.

Of course, I must acknowledge my parents, Robert and Christine van der Haas, who unintentionally put me on the path to archaeology. Although, on second thought, it might have been intentional after all. Having a historian as a father resulted in numerous museum trips, which sparked my interest in the past and a desire to touch objects behind glass. Last but not least, I am grateful for the support given to me by my husband, Tyler Cantwell. Not only did he put up with me spending nights on end crouched over my laptop or spending my weekends in the laboratory, but he probably listened to me talk more about teeth and isotopic values than he would have liked.

Chapter 1

Introduction

Significance of the research

The Cis-Baikal is a vast region in Northeast Asia encompassing the western part of Lake Baikal in Siberia, Russia. During the middle Holocene (*c. 8200–3700* cal BP[1]), the Cis-Baikal was inhabited by many individuals who left behind a rich archaeological and mortuary record. Archaeological research in the Cis-Baikal has been ongoing since the 19th century and has uncovered and documented many cemeteries, human and faunal remains, as well as cultural assemblages. The human burials are assigned to mortuary traditions dating to the region's Late Mesolithic (LM) between *c. 8200–7500* cal BP, the Early Neolithic (EN) between *c. 7500–7000* cal BP, the Late Neolithic (LN) between *c. 5500–4500* cal BP, and the Early Bronze Age (EBA) between *c. 4500–3700* cal BP. During the Middle Neolithic (*c. 7000–5500* cal BP) the use of formal cemeteries is abandoned for over a 1000-year period. Understanding the discontinuity in cemetery use, as well as the development of hunter-gatherer adaptations in the Cis-Baikal, has been the underlying goal of the Baikal Archaeology Project (BAP) over the last three decades (Weber 1995; Weber and Bettinger 2010; Weber *et al.* 2002, 2010, 2016). The BAP is an international and collaborative team of scholars that use a multidisciplinary approach to examine the Cis-Baikal's Middle Holocene hunter-gatherers. The BAP utilizes an approach known as life-history theory, which is a framework designed to study important events (i.e. birth, childhood development, reproduction, and death) that occur during an individual's lifetime. Each individual can provide important information on biological as well as cultural variation.

The skeletal remains, excavated from the Cis-Baikal cemeteries, underwent extensive examination and research, which resulted in a large set of isotopic data ($^{87}Sr/^{86}Sr$, ^{14}C, $\delta^{13}C$, and $\delta^{15}N$). This work produced information on diet, subsistence, migrations, and social relations (Katzenberg *et al.* 2009, 2010, 2012; Weber and Bettinger 2010; Weber and Goriunova 2013; Weber *et al.* 2002, 2011). Particularly interesting, is that the stable isotope research demonstrated that several individuals migrated from the north of the Cis-Baikal area (known as the Upper Lena micro-region), toward the coast of Lake Baikal (the Little Sea micro-region) during the Early Bronze Age (Haverkort *et al.* 2008; Scharlotta and Weber 2014). Research further demonstrated that people from both micro-regions formed what appears to be a very cohesive social structure. In some cases, elements of cultural identity (dietary patterns) from the Upper Lena micro-region were retained by individuals after migrating to the Little Sea micro-region (Weber and Goriunova 2013). However, not all individuals retained these cultural elements and some instead adopted new dietary patterns. Furthermore, the migrations between these two micro-regions appear to have been asymmetrical: people migrated from the Upper Lena to the Little Sea but not the other way around (Scharlotta and Weber 2014; Weber and Goriunova 2013; Weber *et al.* 2011).

---

[1] All modelled dates are presented in italics, following Weber *et al.* 2016.

The work presented here further investigates these dietary and migratory patterns at the individual level, by applying stable carbon and nitrogen isotope analysis on human tooth dentine of Late Neolithic and Early Bronze Age hunter-gatherers. While the former stable isotope analyses (Katzenberg *et al.* 2009, 2010, 2012; Weber and Goriunova 2013; Weber *et al.* 2011) on long bones (i.e. bulk bone sampling) revealed information relating to the diet and migration of individuals during the last stages of life, this research reveals information on diet and migration during the first 20 years of life on some of the same individuals. The studies complement each other to establish an unprecedented glimpse into past human lifeways.

For this research, a novel technique known as dentine micro-sampling was used. Dentine micro-sampling is the sectioning of primary dentine of permanent human molars into 1mm sections from crown to root (Beaumont *et al.* 2013a, 2013b). Each dentine sample was analyzed for stable carbon and nitrogen isotopes, which were embedded into the tooth's tissue via consumption during dental development. As tooth tissues (enamel and dentine) form at genetically controlled time intervals (Avery 1992; Hillson 2005), and the timing of tooth formation is relatively well established (AlQahtani *et al.* 2010), it is possible to pinpoint the age at which an individual completed breastfeeding, changed diet, or endured periods of nutritional stress. The dentine of the three permanent molars represents their development time from birth to around the age of 20 years. The first molar (M1), begins to mineralize around birth and is completed by approximately nine to 10 years; the second molar (M2) develops between approximately two and 16 years; and the third molar (M3) between ~12–20 years (Beaumont 2013a; Eerkens *et al.* 2011; Henderson *et al.* 2014; Hillson 1996; Sandberg *et al.* 2014). In contrast to bone, primary dentine does not undergo remodeling during an individual's life (Nanci 2018) and remains chemically inactive once formed. Therefore, a tooth retains the chemical signatures of the food ingested during dental development, whereas bone has a turnover rate, which provides a dietary average of the individual's last years of life. How much time the average will represent will be dependent on the type of bone examined. For example, a rib will represent the carbon and nitrogen isotope ratios of roughly the last two to five years of an individual's life, whereas a long bone (e.g. femur) will represent the last ~10 (Cox and Sealy 1997; Hedges *et al.* 2007; Parfitt 2002; Tsutaya and Yoneda 2015).

Table 1. Summary of the sites and samples.

Cemetery and micro-region	**Number of teeth**	**Number of individuals**	**Culture period**
Khuzhir-Nuge XIV – Little Sea	30	19	EBA
Shamanskii Mys – Little Sea	3	2	EBA
Ust'-Ida I – Angara	27	13 (9 LN, 4 EBA)	LN/EBA
Ust'-Ilga – Upper Lena	11	11	EBA
Obkhoi – Upper Lena	6	3	EBA
Manzurka – Upper Lena	3	1	EN
Total	80	49	

A total of 80 permanent molars taken from 49 hunter-gatherers have been used for this research. These samples come from six cemeteries within the Cis-Baikal region: Khuzhir-Nuge XIV (EBA) and Shamanskii Mys (EN/LN/EBA) in the Little Sea area; Ust'-Ida I (LN/EBA) in the Angara valley; and Obkhoi (EBA), Ust'-Ilga (EBA), and Manzurka (EN/EBA) in the Upper Lena valley (Table 1).

Research goals

The two main research goals are to further investigate (1) the dietary patterns and (2) the migratory patterns of mid-Holocene hunter-gatherers from Cis-Baikal. While the previous bulk bone sampling methods are useful for examining individuals at a population level, there are limitations to tracking individual life histories as it entirely masks short-term events as well as events that occur during the first segment of life. Dentine micro-sampling overcomes these issues and has the potential to generate new knowledge regarding intra- and inter-individual dietary variation as well as subsistence and migration.

Insight and answers will be drawn from dentine collagen using stable isotope analysis, targeting carbon and nitrogen isotopes. To increase our understanding of the Cis-Baikal hunter-gatherers, the two primary goals (examining diet and migration) are subdivided into the three following research questions:

1. How did infant feeding practices look during the Late Neolithic and Early Bronze Age?
2. Was childhood diet similar to adult diet in Late Neolithic and Early Bronze Age hunter-gatherers?
3. What inferences can be made on migration based on dietary reconstruction alone?

Organization of the monograph

Chapter 2 presents a biogeography alongside a historical and cultural background of the Cis-Baikal region. The region is discussed, providing insight into the geography, flora, fauna, and climate. Previous archaeological research and the current cultural history model (which has evolved) are also explained. In Chapter 3, a background of stable isotope analysis is provided, elaborating on carbon and nitrogen isotopes in more detail. Previous stable isotope results from the region are also presented. Chapter 4 discusses the development of teeth, particularly dentine and how this tissue relates to examining life-histories. Chapter 5 focuses on the materials and methods used for this study and explains the laboratory protocol, the micro-sampling method, collagen extraction, and preparation of samples for mass spectrometry. The analytical chapters start with Chapter 6, which examines the early life dietary history of individuals who were buried in the Upper Lena micro-region during the EBA. Chapter 7 examines the early life dietary history of LN and EBA individuals interred at Ust'-Ida I in the Angara micro-region, while Chapter 8 focuses on reconstructing the early dietary life histories of the EBA individuals in the Little Sea micro-region. Discussion and conclusions are presented in Chapters 9 and 10, respectively.

Chapter 2

Geographic and archaeological background

The Baikal region has a long history of human habitation, diverse environments, and a rich archaeological record. Together, these elements provide information on the nature of hunter-gatherer adaptations in Cis-Baikal. Understanding the prehistoric people of the region requires an understanding of the region itself.

Biogeography

The Cis-Baikal region is situated in Eastern Siberia, Russia, between 52°N and 58°N latitude and 101°E and 110°E longitude, just under 200km north of the Mongolian border (Figure 1). The Cis-Baikal area (Figure 2) includes the northern and western shore of Lake Baikal, Ol'khon Island, the basin of the Angara River from the Lake down to Ust'-Ilimsk, and the drainage of the Upper Lena down to Kirensk (Michael 1958). The area to the south and east of Lake Baikal is referred to as the Trans-Baikal, which together with the Cis-Baikal makes up the Baikal mountain region (Weber *et al.* 2002). Lake Baikal formed *c.* 25 million years ago, making it the oldest freshwater lake in the world. With 636km in length, up to 80km wide, 1620m deep and

Figure 1. Map of East Asia. Source: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data from Jarvis *et al.* 2008.

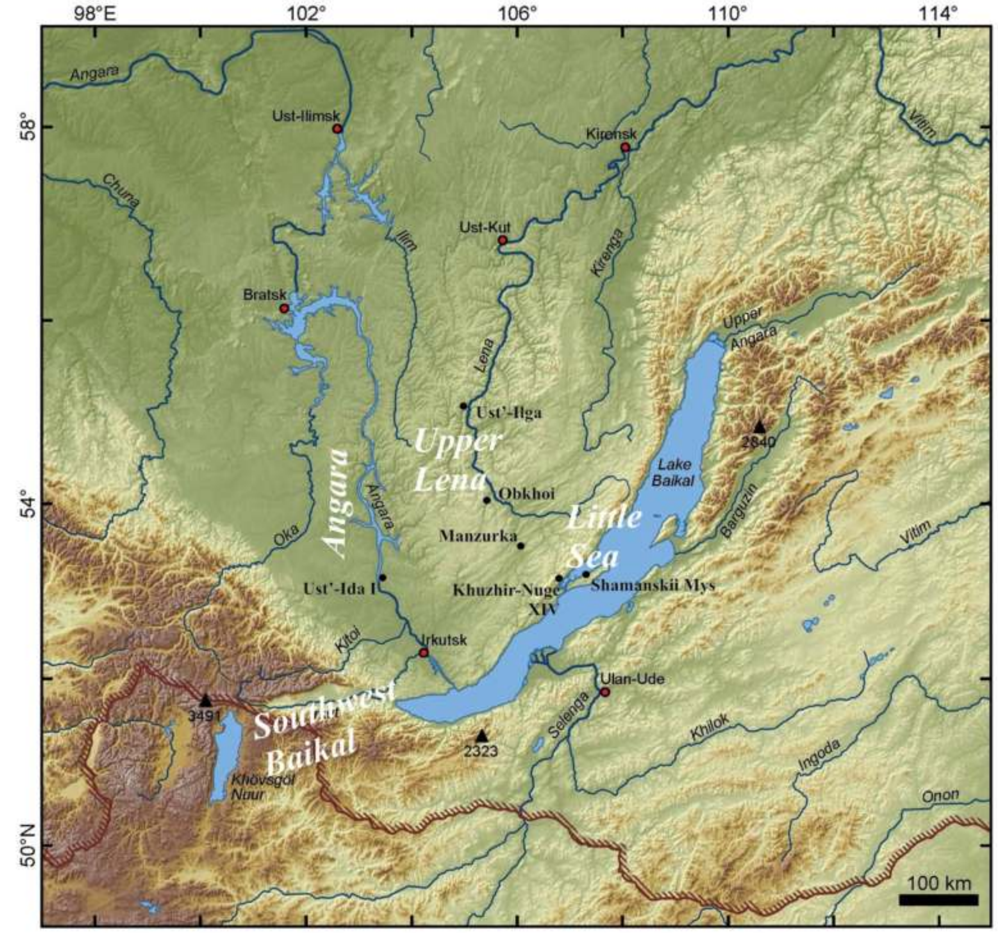


Figure 2. Topographic map of the Cis-Baikal region and the mortuary sites examined in this research. Adapted from: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data from Jarvis *et al.* 2008.

containing roughly 20% of the entire world's freshwater reservoir, Lake Baikal is the deepest and largest freshwater lake by volume (Kozhova and Izmest'eva 1998). It has over 300 rivers feeding into it, with the Angara being the only river to flow out of the lake on the southwest end. The upper sections of the Angara and Lena Rivers, along with the Baikal lakeshore, have been the prime focus of human habitation (Weber *et al.* 2002) during the Holocene.

Cis-Baikal can be further divided into four archaeological micro-regions (Weber *et al.* 2011): the Angara, the Upper Lena, the Little Sea, and Southwest Baikal. All four contain a variety of seasonal resources (Scharlotta and Weber 2014; Weber 2003; Weber *et al.* 2002).

Flora and fauna

Flora

The physiography of the Cis-Baikal has shaped a mosaic vegetation pattern. Lake Baikal is situated at a transitional zone between a boreal forest to the north—referred to as taiga in Russian—and steppe to the south, an open landscape with grasses and shrubs. A steppe landscape is also found in the middle of the Irkut valley, which lies west of Lake Baikal (Weber and Bettinger 2010), the first ~380km of the Angara valley, the southwest half of Ol'khon Island on Lake Baikal, and the shoreline (Weber *et al.* 2002). Examples of arboreal vegetation in Cis-Baikal include species such as larch (*Larix sp.*), pine (*Pinus sp.*), spruce (*Picea sp.*), fir (*Abies sp.*), birch (*Betula sp.*), aspen (*Populus sp.*), willow (*Salix sp.*) and alder (*Alnus sp.*) (Soja *et al.* 2007).

Terrestrial fauna

Terrestrial fauna in the Baikal region consists of three large Eurasian faunal complexes (European/Siberian, Central Asiatic, and Eastern Asiatic) that overlap, making the region rich and diverse in terrestrial food resources (Weber *et al.* 2002). Depending on the season and micro-region, the past inhabitants of Cis-Baikal could have been consuming big- and medium-sized game such as moose (*Alces alces*), caribou (*Rangifer tarandus*), red deer (*Cervus elaphus*), roe deer (*Capreolus pygargus*), Siberian musk-deer (*Moschus moschiferus*), wild boar (*Sus scrofa*), and Siberian ibex (*Capra sibirica*) (Losey and Nomokonova 2017; Weber *et al.* 2002). Small game consumption could have consisted of hare (*Lepus sp.*), marmot (*Marmota sibirica*), Eurasian otter (*Lutra lutra*) and ground squirrel (*Spermophilus citellus*) (Scharlotta *et al.* 2013; Weber *et al.* 2002). However, terrestrial animals would have been exploited for more than just food. The animal's hides and bones could have been used for clothing, shelter, ornamentation, and tools. Such items could also have been made from the region's large fur-bearers like the brown bear (*Ursus arctos*), gray wolf (*Canis lupus*), Eurasian lynx (*Felis lynx*), bobcat (*Lynx rufus*) and even smaller fur-bearers such as sable (*Martes zibellina*), squirrel (*Sciurus vulgaris*), steppe polecat (*Mustela eversmanii*), fox (*Vulpes vuples*), ermine (*Mustela erminea*) and the Siberian chipmunk (*Eutamias sibiricus*) (Losey *et al.* 2011; Weber *et al.* 2002).

Aquatic fauna

Fishes are abundant in Cis-Baikal, but as with terrestrial fauna, quantity varies between micro-regions and seasons (Weber and Bettinger 2010). According to Kozhov (1950, 1963, 1972), whose work in Russian has been summarized by Weber (2003) and McKenzie (2006), the Angara fishery can be divided into four distinct sections. The first section starts at Lake Baikal and ends where the Angara meets the Irkut River. This section contains mainly Baikal black grayling (*Thymallus baicalensis* Dybowski), and a small amount of lenok (*Brachymystax lenok* Pallas) and taimen' (*Hucho taimen* Pallas). The second section starts at the mouth of the Irkut River and ends at the mouth of the Oka River near the city of Bratsk. This section is home to a few fish species that are found in several tributaries including the Irkut, the Kitoi, the Belaia, and the Oka. Species here include Siberian dace (*Leuciscus baicalensis* Dybowski), arctic grayling (*Thymallus arcticus* Pallas), perch (*Perca fluviatilis* Linnaeus), northern pike (*Esox lucius* Linnaeus), burbot (*Lota lota* Linnaeus), roach (*Rutilus rutilus* Pallas), humpback whitefish (*Coregonus pidschan* Gmelin), lenok, and taimen'. The third section of the Angara River flows from Bratsk to Ilimsk, located at the mouth of the Ilim River. This section contains humpback whitefish, Siberian sturgeon (*Acipenser baerii* Brandt), Siberian starlet (*Acipenser ruthenus ruthenus* Brandt), Siberian dace, and arctic grayling. The fourth and final section, although not a part of Cis-Baikal, stretches from Ilimsk to the Yenisei River that flows north into the Arctic Ocean.

It must be stressed that Kozhov's research was carried out prior to the construction of three hydroelectric power plants and dams between the 1950s and 1970s, which completely altered the ecology and migration of fish species (McKenzie 2006; Weber 1995). Since then, the Angara River has not been considered a suitable representation of past fish ecology. Lake Baikal, however, is. The modern aquatic population of the lake is thought to be an adequate model for the fish ecology during the Middle Holocene as the size and depth of the lake has provided a stable ecosystem over time (Weber *et al.* 2002). The Upper Lena River is inhabited by fishes such as taimen', lenok, ide (*Leuciscus idus* Linnaeus), Lena tugun (*Coregonus tugun lenensis* Berg), arctic grayling, Siberian dace, roach, northern pike, perch, burbot, omul (*Coregonus autumnalis migratorius* Georgi) and Siberian sturgeon (Weber *et al.* 2002). The Lena River fishery has been researched the least and is an order of magnitude smaller than the Angara River.

The Little Sea micro-region (Figure 3) consists of Ol'khon Island, the water situated between the lake's coast and Ol'khon (referred to as the Little Sea), and ~120km of the northwestern

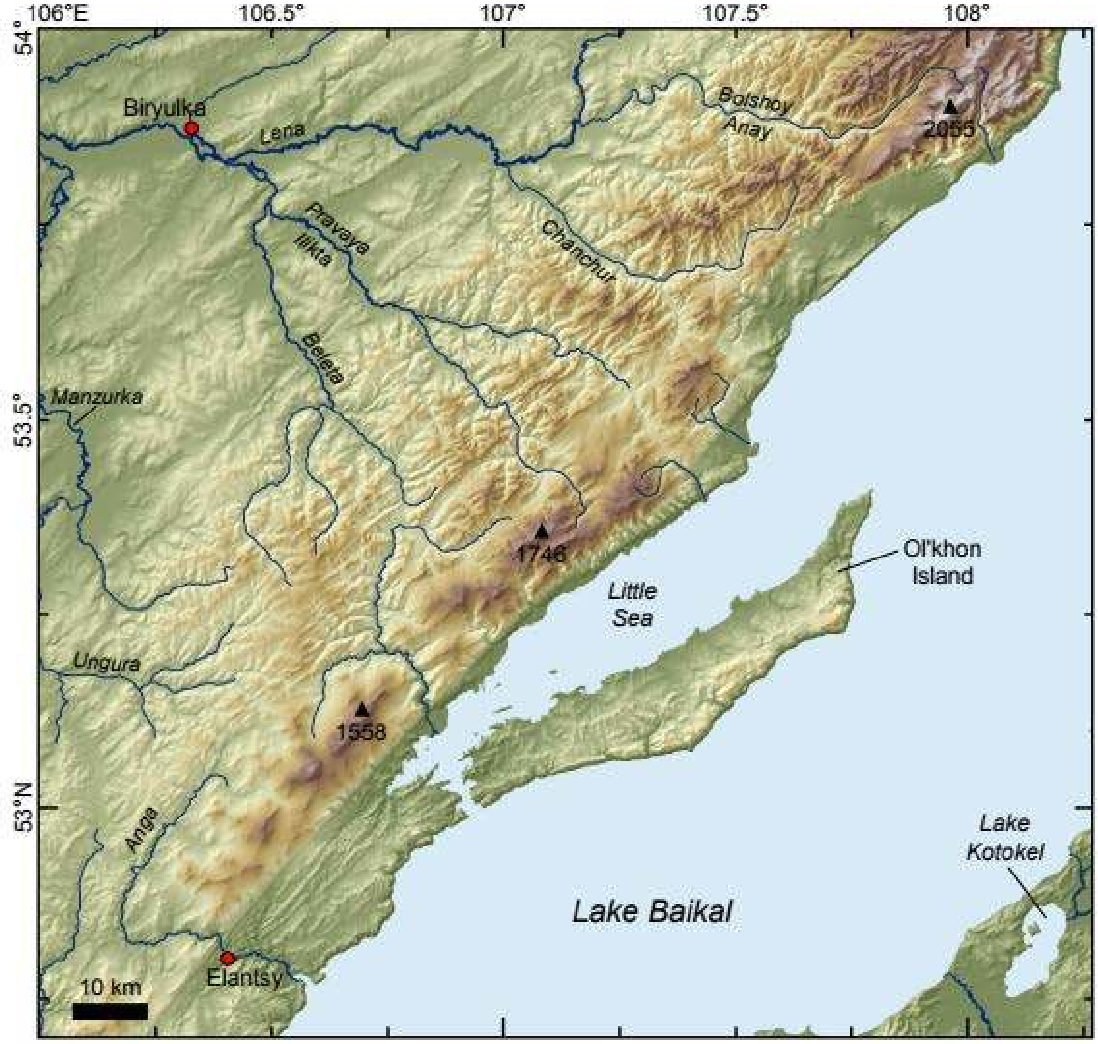


Figure 3. Ol'khon Island in the Little Sea micro-region. Created by: Dr. Christian Leipe (FU Berlin), Shuttle Radar Topography Mission (SRTM) v4.1 data (Jarvis *et al.* 2008).

coast of Lake Baikal (McKenzie 2006). Ol'khon Island is ~71.7km long and ~10.5km wide (Kozhova and Izmest'eva 1998). The types of fishes found within the lake depend on the area, bathymetry, and season. Fish species available to procurement by prehistoric hunter-gatherers include roach, northern pike, perch, ide, burbot, dace, taimen', whitefish (*Coregonus lavaretus*), omul, Baikal black grayling and white grayling (*Thymallus baicalensis brevipinnis*), and Baikal sturgeon (*Acipenser baerii stenorrhynchus natio baicalensis*) (Losey *et al.* 2008). The largest animal within the Lake is the freshwater seal (*Phoca sibirica*), which was hunted throughout the Holocene (Nomokonova *et al.* 2010, 2015; Weber *et al.* 1993). The Little Sea area consists of shallow waters and coves, which would have provided decent opportunities for fishing (Losey *et al.* 2012; Weber and Bettinger 2010).

Climate

Reconstructions of Holocene environments have aided in the understanding of climatic variability and the impact it had on past human lives. The Cis-Baikal region provides a rich variety of vegetation and organisms for reconstructing past environments. The Lake Baikal basin creates an area where the effects of local and non-local climatic factors are minimized by a decrease in long-distant pollen transportation (Tarasov *et al.* 2005). This allows for a regional environmental reconstruction. However, this can also be considered a disadvantage for studies on the Cis-Baikal hunter-gatherers as the Lake Baikal basin is large and the environment differs per micro-region. Climatic changes on a regional scale will not adequately represent change on a smaller and more local scale.

In Cis-Baikal, there are approximately five months of winter and two months of summer with long transitional seasons in between (Weber *et al.* 2002). According to Kozhov (1963), the lake influences the climate along the coastline, causing milder temperatures in winter (~10°C warmer) and summer (~7°C colder) compared to the rest of the Baikal region. This creates slightly more suitable living conditions. The month of August has temperatures varying around 14°C while January has temperatures ranging from –7 to –25°C (Kozhov 1963). In winter, permafrost in Cis-Baikal appears in patches, freezing the soil to a depth ranging between 120 and 220cm (Weber *et al.* 2002). From January until mid-March the lake is completely frozen.

Furthermore, recent research on climate and environmental history (Tarasov *et al.* 2017; White and Bush 2010) postulates that the region experienced fluctuations in temperature and vegetation during the Middle Holocene. In both the Trans-Baikal and Cis-Baikal regions, field data have shown a cooling trend transitioning to more dry conditions between 8000–7000 BP (Demske *et al.* 2005), causing the interior part of East Asia to become more arid. Tarasov *et al.* (2007) indicate this cooling took place later; around 6500–5000 BP. Regardless of its exact date, it remains unclear as to how this climatic shift would have impacted the Cis-Baikal hunter-gatherers. White and Bush (2010) postulate that an increase in aridity and temperature fluctuations would have resulted in lower water levels and a decrease in nutrient input that would potentially have affected aquatic species habitats, spawning behaviour, survival and growth, and ultimately a reduction in the abundance of fishes. Depending on the overall severity of aridity, this could also have affected the terrestrial landscape by leading to a reduction in forest coverage and causing animals to migrate. If terrestrial and aquatic resources were disrupted, this would have had consequences for the subsistence base of

Cis-Baikal hunter-gatherers. Potentially, a change in climate and environment caused a shift in the subsistence and settlement of mid-Holocene Cis-Baikal groups.

The importance of studying Holocene hunter-gatherers

Hunter-gatherer research has grown exponentially over the last few decades since the 1966 symposium 'Man the Hunter' that prompted discussion on the concepts of ethnographic studies on hunter-gatherers as well as addressed conceptual issues between social anthropologists and archaeologists (Lee and DeVore 1968). Several new theoretical approaches to studying hunter-gatherer lifeways have emerged since then. This includes an increasing body of work which has focused on defining hunter-gatherer complexity (e.g. Arnold 1996; Binford 2001; Fitzhugh 2003; Sassaman 2004) including recognition of the environmental, along with biological and cultural processes that drive change in prehistoric groups. Yet, despite advances over the last few decades, Holocene hunter-gatherers are often examined as isolated groups with a focus on macro-regional changes. As such, technological advances, subsistence behaviours, and cultural dynamism over time remain quite poorly understood in many pre-agricultural populations.

Fortunately, the Cis-Baikal individuals serve as an extraordinary case for examining change in Holocene hunter-gatherers over thousands of years. Not only does the region provide researchers with an abundance of osteological and archaeological materials, but the hunter-gatherers that were buried in the Lake Baikal area can be placed in a chronological context as a result of radiocarbon dating (Weber *et al.* 2006, 2016). Together, the rich osteological and archaeological record provide insight into subsistence patterns, migratory patterns, population dynamics, and genetic variation across thousands of years. While cultural transitions between the periods in Cis-Baikal have been observed (e.g. the Late Neolithic to Early Bronze Age with the emergence of copper and bronze objects), the driving forces behind them remain largely unclear (Weber *et al.* 2010).

Archaeological context

The beginnings of archaeological research in the Baikal region date to the 19th century (Weber 1995). Okladnikov, a Soviet archaeologist, was one of the first to study the prehistoric population of Siberia and its cultures (1961). During the 1950s, Okladnikov published his work on the Neolithic and Early Bronze Age periods of the Lake Baikal Region (Okladnikov 1950, 1955). He defined a number of hunter-gatherer stages of development (Khin'–Isakovo–Serovo–Kitoi–Glazkovo–Shivera) based almost exclusively on the region's mortuary archaeological record. While most Siberian scholars subscribed to this classification, it also received heavy criticism and was later proven to be incorrect when the chronology of these cultures was based on radiocarbon dating (McKenzie 2006; Weber 1995, Weber *et al.* 2006). However, the names Okladnikov assigned to these stages are still in use today.

Currently, the Middle Holocene hunter-gatherer archaeological record in the Baikal region can be divided into the following periods: Late Mesolithic, Early, Middle, and Late Neolithic, and the Early and Late Bronze Age (Table 2). The Late Bronze Age, which directly follows the Glazkovo mortuary tradition, is still rather unknown.

Table 2. Current cultural history model for Cis-Baikal based on radiocarbon dating (Weber *et al.* 2016).

Period	Mortuary tradition(s)	Cal years BP
Late Mesolithic	Highly variable	*8277±176* to *7503±14*
Early Neolithic	Kitoi and other micro-regionally specific traditions	*7503±14* to *7027±33*
Middle Neolithic	Lack of archaeologically visible mortuary sites	*7027±33* to *5571±88*
Late Neolithic	Isakovo and Serovo	*5571±88* to *4597±76*
Early Bronze Age	Glazkovo	*4597±76* to *3726±34*
Late Bronze Age	Currently unknown	Currently unknown

Late Mesolithic Khin'

The Khin' tradition was first assigned to the Late Mesolithic by Okladnikov (1950). This mortuary tradition is described as highly variable with most interments characterized by a flexed body position with an orientation to the north, northwest, or east, and use of red ochre ranging from a few spots to complete coverage (Bazaliiskii 2010; Weber *et al.* 2016). Five graves, from the Lena-Angara plateau, were assigned to the Khin' mortuary tradition based on morphological characteristics of the grave goods (Bazaliiskii 2010). These consist of composite fishhooks, stone scrapers, prismatic blades, as well as red deer canine and boar tusk pendants (Bazaliiskii 2010), although ornaments are uncommon (Weber *et al.* 2016). Now, with radiocarbon date corrections after the discovery of a freshwater reservoir effect, the presence of multiple graves across the Cis-Baikal which pre-date the Early Neolithic Kitoi has been confirmed (Weber *et al.* 2016). Several graves (~12) have been assigned to the Late Mesolithic by Bazaliiskii (2010) based on radiocarbon and typological criteria (Weber *et al.* 2016). For a more detailed description of the Early and Late Mesolithic see Bazaliiskii (2010).

The Early Neolithic and Kitoi

The Kitoi culture was first defined to separate Neolithic from Bronze Age graves (Bazaliiskii 2010), but recently its chronology has been demonstrated to be much older. The Kitoi mortuary tradition is known from a few large cemeteries in the Angara and Southwest Baikal micro-regions. It is important to note that while Early Neolithic graves are also known from the Upper Lena and Little Sea micro-regions, although quite rare (Weber *et al.* 2016), these graves are not considered to be part of the Kitoi culture as they do not display all distinctive Kitoi characteristics. These include the use of red ochre, extended body position with the head oriented to the north—although flexed or bundled burials also appear—a lack of stone structures and grave goods that are represented by composite fishhooks, bifacial arrowheads, knives and adzes of green nephrite, tools (bone, stone, or antler), red deer canine pendants, and zoomorphic art (Weber *et al.* 2016).

The Middle Neolithic

Data have shown that there were two distinct phases of hunter-gatherer continuity in formal cemetery use during the Holocene in the Baikal area, separated by a *c.* 1000-year discontinuity (Link 1999; Weber 1995; Weber *et al.* 2002, 2016). However, zooarchaeological data (Losey *et al.*

2017; Nomokonova *et al.* 2015) have shown that there were still people in the region during the Middle Neolithic. Several hypotheses have attempted to explain this absence in formal cemetery use, but it is not yet fully understood. The first hypothesis is that the discontinuity is the result of a climatic and environmental change. However, paleoenvironmental investigations (Tarasov *et al.* 2007; White and Bush 2010) show that there was a time of relative ecological stability despite the region becoming more arid during this period. Weber *et al.* (2002, 2005, 2016) and Weber and Bettinger (2010) assume that this discontinuity is more likely the result of social-cultural processes where the Early Neolithic and Kitoi changed their customs and practices and did not continue with formal cemeteries. Potentially these groups shifted to a different hunter-gathering lifestyle. However, more research and fieldwork are needed to understand the socio-economic system of the Kitoi and other Early Neolithic groups better.

The Late Neolithic Isakovo and Serovo

After the 1000-year discontinuity, formal cemeteries re-emerge in the Cis-Baikal region. While it has been suggested that new populations came into the region sometime during the Middle Neolithic (White and Bush 2010), there is still uncertainty as to where these other populations came from. Some have stated that the Isakovo and Serovo might have originated in West Siberia, possibly around the Altai region (Schurr *et al.* 2010; Weber *et al.* 2002). This notion is based on similarities seen in pottery style and cranial morphology between the two groups (Weber 1995; Weber *et al.* 2002). Analysis of mitochondrial DNA data does suggest that the Serovo and Early Bronze Age Glazkovo are genetically distinct from the Early Neolithic hunter-gatherers of Cis-Baikal (Mooder *et al.* 2010).

Mortuary traditions Isakovo and Serovo, which were first described by Okladnikov (1950), appear in the Cis-Baikal around *6000–5800* cal BP (Weber *et al.* 2016). Differences between these two groups include the body positioning and orientation of the individual in the grave. Nonetheless, these mortuary traditions co-exist at several cemeteries in the Angara micro-region (Weber *et al.* 2016). The Isakovo mortuary tradition, which is only known from the Angara, is characterized by an extended-supine body position with a southeast or south/southeast orientation (heads pointing upstream along the Angara River) (Weber *et al.* 2002, 2016). At Ust'-Ida I, 60% of the burials belonging to this tradition were dominated by children of various ages (Bazaliiskii 2010). Ust'-Ida I Isakovo graves contained bone points and harpoons, spearheads, as well as clay vessels decorated with net impressions and punctuations (Bazaliiskii 2010). From this cemetery, 13 individuals have been examined for the micro-sampling research. The Serovo mortuary tradition, which is known from the Angara, Little Sea, and Upper Lena micro-regions, is also characterized by extended-supine body positioning, but oriented perpendicular to the river with heads pointing away from the water. The meaning of the difference in body positioning and orientation remains unknown. Serovo grave goods are more abundant than Isakovo with 30–35 identified categories grave goods (Bazaliiski 2010) including tools (bone, stone, antler), pottery, and spearheads.

The Early Bronze Age Glazkovo

The Late Neolithic and Early Bronze Age can be distinguished from one another by a technological change: the appearance of copper and bronze objects (Okladnikov 1964;

Weber 1995). Additionally, differences in mortuary practice, particularly pertaining to burial orientation, distinguish the Late Neolithic from the Early Bronze Age. Glazkovo is the only mortuary tradition that is known from all four micro-regions (Weber 1995; Weber *et al.* 2012, 2016).

The largest known Early Bronze Age cemetery in the entire Baikal region is Khuzhir-Nuge XIV. This is also the most extensively researched cemetery in the Little Sea micro-region (Katzenberg *et al.* 2009, 2012; McKenzie 2010; Scharlotta *et al.* 2013; Weber and Goriunova 2013; Weber *et al.* 2007a, 2008a). McKenzie (2006, 2010) described the Early Bronze Age mortuary practices of the Little Sea in detail, as well as the spatial distribution of interments and grave goods. In the Little Sea, Early Bronze Age individuals are buried with their head oriented southwest/west (Weber and Bettinger 2010).

Cemeteries

The cemeteries, from which the materials come, will be described here in greater detail. However, in a few instances, the archaeological information on the cemeteries is limited due to an inability to access Russian fieldwork reports outside of Siberia. Cemeteries are presented per micro-region, leaving out Southwest Baikal as no materials from this micro-region were used in this study.

Little Sea micro-region

Khuzhir-Nuge XIV

The cemetery is situated on a southeast-facing slope 16–30m above Lake Baikal (McKenzie 2010; Weber *et al.* 2008a) and has yielded a total of 89 individuals from 79 graves (McKenzie 2006; Weber *et al.* 2007b, 2008a). Of the total 79 graves, 78 (containing 88 individuals) belong to the Glazkovo mortuary tradition and bodies are positioned with the head to the southwest (McKenzie 2006). In one grave (No. 7), the body orientation has the head to the north and belongs to the Early Neolithic as confirmed by radiocarbon dating, although its initial chronological classification was Late Neolithic (Dr. Andrzej Weber, personal communication, 2018; Weber *et al.* 2006). All graves were between 30 and 60cm deep and covered with stone cairns (McKenzie *et al.* 2008; Weber *et al.* 2007b, 2008b). The cemetery extends 260m from west to east between two bedrock ridges (McKenzie 2010). BAP has published two monographs on the osteological (Weber *et al.* 2007a) and archaeological materials (Weber *et al.* 2008a) of this site. The quantity, type, and arrangement of Khuzhir-Nuge XIV grave goods varied between individuals depending on age and sex. For instance, beads were typically found in association with children under the age of 15 and copper or lithic knives were usually associated with adult males.

The Khuzhir-Nuge XIV cemetery can be divided into three sectors: West, Centre, and East. McKenzie (2006, 2010), who examined variability in Bronze Age mortuary practices, classified the Khuzhir-Nuge XIV graves based on their spatial relationship with neighbouring graves. He divided the graves into the following spatial units of analysis: graves in rows, graves in groups, and scattered graves. A row of graves is defined as: '...at least three closely associated parallel graves arranged in a more-or-less straight line' (McKenzie 2006: 109). The graves in the West

Sector are mainly scattered, while the graves in the Centre Sector are arranged in distinct north-south rows and the graves in the East Sector form three clusters (McKenzie *et al.* 2008).

Biochemical analyses ($^{87/86}Sr$, ^{13}C, ^{15}N, ^{14}C) on the individuals displayed even more patterns within the rows, sectors and scattered graves. Strontium isotope analysis has shown that the birthplace of the individuals was important regarding where they were interred at Khuzhir-Nuge XIV. Weber and Goriunova (2013) mention that while all sectors, scattered graves, and rows include individuals that were born within and outside of the Little Sea micro-region, the situation differs within smaller spatial units. For instance, all individuals interred in Row D of the cemetery appear to have been non-locals. Stable carbon and nitrogen isotope analysis on bone also showed interesting spatial distributions patterns regarding diet (Weber and Goriunova 2013). This will be further explained in Chapter 3.

The Glazkovo component of the cemetery has five females, 27 males, and 56 individuals whose sex could not be determined due to poor preservation (Lieverse 2007; McKenzie *et al.* 2008; Weber and Goriunova 2013). The Early Neolithic individual (Grave 7) has been estimated as a probable male. Out of the 56 individuals who could not be sexed, 18 are children, and seven could be neither sexed nor aged (McKenzie 2006). This leaves 31 adults with unknown sex, roughly one third of the cemetery population. Although Khuzhir-Nuge XIV shows a difference in mortuary treatment among the individuals, it is not clear whether one or several hunter-gatherer groups utilized the cemetery. While it is plausible to suggest that several groups or families were interred here it can only be assumed until further evidence suggests otherwise. DNA analysis of the Khuzhir-Nuge XIV individuals might shed some light regarding genealogy.

Shamanskii Mys

On the west coast of Ol'khon Island lies Shamanskii Mys ('Shaman's cape' in Russian) with a small cemetery (Losey *et al.* 2014; Weber 1993; Weber et al. 1998). The cemetery is located on a narrow cape that is 10 to 20m wide, with graves reaching a depth of 20 to 25cm below the surface (Weber *et al.* 2006). Fieldwork in the 1970s produced a total of 10 graves: one Early Neolithic, two Late Neolithic and seven Early Bronze Age graves (McKenzie 2006; Weber *et al.* 2006). Based on many seal remains, Weber and colleagues (1993, 1998, 2002) proposed this to be a place of special ritual significance. The seals would have been transported to the site from where they were caught on the east side of Ol'khon Island (Mckenzie 2010; Weber *et al.* 1993, 1998). Shamanskii Mys has also exhibited more nephrite grave goods and arrowheads compared to other small cemeteries in the region (McKenzie 2010). The cemetery contained only adults except for one Early Bronze Age sub-adult buried with an adult female. The sub-adult was most likely killed by an arrowhead lodged in his or her scapula (McKenzie 2006). Dietary analyses of two of the Early Bronze Age individuals (individuals SHA_1972.002 and SHA_1975.001) have been conducted for this study.

SHM_ 1972.002 was defined as a seal hunter by Okladnikov and Konopatskii (1975: 304; after McKenzie 2006: 239) based on grave goods and seal remains surrounding the grave. However, the importance of the individuals, the males, might be slightly biased. McKenzie (2006) mentioned that Okladnikov and Konopaskii (1975) failed to acknowledge another burial, SHM_1972.001 that consisted of a female who had as equally rich and interesting a grave as SHM_1972.002 and even included a rare lunar pendant. Such information in primary Russian sources can potentially lead to an inconsistent interpretation. Had McKenzie failed to notice this, one could suggest that males were treated differently than females in terms of body disposal and perhaps regarded as having a higher status within the population.

Angara micro-region

Ust'-Ida I

The Ust'-Ida I cemetery is situated on the East bank of the Angara River at the confluence of the Ida River, 180km north of Lake Baikal (Weber *et al.* 2006). Fieldwork conducted between 1987 and 1996, under the direction of V.I. Bazaliiskii from Irkutsk State University, produced one Kitoi grave (Early Neolithic), 33 Isakovo graves (Late Neolithic), and 19 Glazkovo graves (Early Bronze Age) (Bazaliiskii 2010; Weber *et al.* 2006). According to Bazaliiskii (2010), graves of the Isakovo mortuary tradition in the Angara are dominated by child burials (60%). The graves at Ust'-Ida I reached a depth between 60 and 120cm below the surface and were covered by local limestone slabs (Weber *et al.* 2006). The Isakovo and Glazkovo graves were parallel to the Angara River with Isakovo individuals buried with their head pointing upstream, and Glazkovo individuals buried with their head pointing downstream. Grave goods belonging to either mortuary tradition included green nephrite knives, harpoons, bone composite tools, pendants, anthropomorphic figurines, needle boxes, lithic and bone harpoons, clay vessels, bifacial stone knives as well as bronze and copper objects in Glazkovo graves (Bazaliiskii 2010; Shepard 2012; Weber *et al.* 2002).

Upper Lena micro-region

All three Upper Lena cemeteries included in this study were excavated during the 1960s, 70s and 80s by Russian scholars. Unfortunately, only a small amount of information on the excavations at Obkhoi, Ust'-Ilga, and Manzurka is known from a few Russian fieldwork reports (Okladnikov 1971).

Manzurka

One Early Neolithic and four Early Bronze Age graves were found at Manzurka (Konopatskii 1977). Only one individual (MNZ_1974.002) from this cemetery was analyzed for this study. While the individual was initially assigned to the Early Bronze Age, it appears to belong to the Early Neolithic based on radiocarbon dating. Three molars were used to test the micro-sampling method (van der Haas *et al.* 2018) before applying the method to the additional 48 Late Neolithic and Early Bronze Age individuals.

Obkhoi

The Obkhoi cemetery was excavated in the early 1970s by A.P. Okladnikov and produced 12 Early Bronze Age graves (Weber 1995). Three of the Obkhoi individuals were examined for this study (OBK_1971.007, OBK_1971.005, and OBK_1971.013). No fieldwork reports or papers have been published on this site.

Ust'-Ilga

The Early Bronze Age cemetery Ust'-Ilga is situated on the left bank of the Upper Lena River. It was first excavated in 1930 by A.P. Okladnikov (Peskov *et al.* 2016). A report written by Peskov *et al.* (2016), which is based on Okladnikov's publications (1946, 1950, 1955), provides some information on the location and content of two burials. The 11 individuals examined for this research, excavated in the 1970s, are not mentioned in this report. Therefore, nothing can be stated about those specific burials. However, a short summary of the data on the two Early Bronze Age graves is provided here.

Grave 1 contained a double burial with an adult and an individual listed as 'teenager'. The grave contained stone objects such as a dark green nephrite axe, a white nephrite ring, a white nephrite disk, three flint arrowheads, a scraper, and red deer canine pendants. A few objects such as blades made of bone and horn were also uncovered along with ceramics decorated with round holes at the rim. Similarly, decorated ceramics have been uncovered from Late Neolithic and Early Bronze Age graves in other parts of Cis-Baikal (Bazaliiskii 2010). Grave 2, also a double burial, contained stone pendants, pottery fragments, deer canine pendants, bone and horn objects, bear molar pendants, and a bone figurine of what appears to be a human face. Overall, the burial context has several similarities with Early Bronze Age cemeteries elsewhere in the Upper Lena and other Cis-Baikal micro-regions.

Summary

Archaeological research has been carried out within the four archaeological micro-regions of Cis-Baikal since the 19th century, with A.P. Okladnikov providing the first comprehensive synthesis of the region's Holocene prehistory. The BAP's main research objective is to examine the long-term organization of hunter-gatherers within this region of Siberia. This work is being done through extensive examination of the Cis-Baikal's mortuary, faunal, floral, climatic, and cultural records. The cultural history model for the Cis-Baikal has seen several modifications since Okladnikov's work as radiocarbon dating had provided more reliable corrections. Although not much is known for some of the cemeteries mentioned above, at least some biological and biochemical information is known for the individuals examined in this monograph.

Chapter 3

Stable isotope analysis for dietary reconstruction

It is often said that stable isotope analysis is based on the principle that 'you are what you eat.' Its theoretical base lies in physics and its early applications in chemistry. Over the past few decades, stable isotope analysis has become an invaluable application for the understanding of dietary and metabolic processes. Whether it is to better understand the paleoecology of hominins, the importance of aquatic foods to those living in coastal areas, or in this case, dietary shifts in middle-Holocene hunter-gatherers from Cis-Baikal, stable isotope analysis has widespread applicability. Food is essential for the survival of every living organism. It provides energy for growth and development, its nutrients contribute to the repair and structure of tissues such as muscle and bones, it can be stored as a secondary energy source (fat) and it has wide-reaching social and cultural importance. Through the use of carbon and nitrogen stable isotope analysis, it is possible to reconstruct past food choices and resource availability. This chapter explains the principles, processes, and approaches used in stable isotope research on human diets. It begins with an explanation of isotopes, particularly targeting stable carbon and nitrogen isotopes, followed by a discussion of their importance for studies on breastfeeding, weaning, and childhood diet. A number of factors that can potentially lead to isotopic uncertainty are explained as well. Finally, a summary of previous stable isotope work on Cis-Baikal flora, fauna, and human skeletal remains is presented.

Stable isotope analysis

What are isotopes?

Isotopes are atoms belonging to the same element that differ from one another in mass as a result of a different number of neutrons in their nuclei (Schoeninger 1995). Most elements on the periodic table have two or more naturally occurring isotopes (Sharp 2007). These can be further divided into stable and non-stable isotopes (often referred to as radioactive isotopes), the latter decaying over time as a result of an unstable nucleus. The proportion of protons to neutrons will determine the stability of the isotope (Malainey 2011). While the physical and mechanical properties of the isotopes of an element differ, their chemical properties do not. This causes isotopes to participate in the same chemical reactions, but with different reaction times dependent on their mass. For example, carbon has two stable isotopes, ^{12}C and ^{13}C, and one radioactive isotope, ^{14}C. The isotope ^{13}C is heavier than ^{12}C as it has an extra neutron, causing molecules containing ^{13}C to respond more slowly during chemical or physical processes than molecules containing ^{12}C. This leads to isotopic fractionation, which is a change in the ratio of one isotope to another caused by a physical (e.g. diffusion, evaporation) or chemical (e.g. combustion, decomposition) reaction. In other words, one isotope is favoured over another.

Expression, standards, and mass spectrometry

The stable isotope content of most light elements (e.g. O, C, N) is expressed per mille (‰) in terms of the ratio of heavy to light isotopes (e.g. $^{15}N/^{14}N$) in relation to an internationally set standard, allowing for consistency and comparisons across laboratories (Ben-David and Flaherty 2012). Through gas chromatography-isotope ratio mass spectrometry (GC-IRMS), which is a mass spectrometric technique used for light isotope ratios of biomaterials such as collagen, the isotopic composition of a sample is determined. High-precision isotopic measurements are reported using the delta notation δ/Δ (Schwarcz and Schoeninger 1991; Tykot 2004). The following equation is used to convert the isotopic abundances to a delta value:

$$\delta R‰ = ((Rsample/Rstandard)-1) \times 1000$$

where Rsample is the ratio of the abundance of the heavy to the light isotope in the sample and Rstandard represents the content of the international standard (Sharp 2007). Delta (δ/Δ or d) values can be expressed as positive or negative values, relative to the standard. The δ value that is expressed will depend on whether the analyzed samples contain more or less of the heavy isotope than the standard. Samples that contain a greater amount of the isotope being analyzed than the standard are isotopically enriched (more positive). Samples that contain a lesser amount of the isotope being analyzed are isotopically depleted (more negative).

Stable isotopes in archaeology

Over the last 40+ years, stable isotope analysis has been applied to the field of archaeology to understand past human behaviour, particularly concerning diet and provenience of past individuals. Stable isotope analyses of bones, teeth, plant remains, and even soils have made a remarkable contribution to our field of research. The first stable isotope studies in archaeology were concerned with the rise of maize agriculture in past populations of North America (van der Merwe and Vogel 1978; Vogel and van der Merwe 1977). These studies had built on important advances related to radiocarbon dating (Libby 1955) and the study of carbon pathways during photosynthesis (Calvin and Benson 1948; Hatch and Slack 1966). Soon after, it was demonstrated that stable carbon isotopes can also be used to distinguish between terrestrial and marine protein and that together with the use of stable nitrogen isotopes ($^{15}N/^{14}N$), it is possible to assess trophic level position and dependence on marine and freshwater resources (Chisholm *et al.* 1982; Schoeninger *et al.* 1983). Since that era, stable isotope analysis has revolutionized the way archaeologists study human and faunal remains (Lee-Thorp 2008; Price 2015).

Carbon isotopes

Carbon is an atom with six protons in its nucleus. It has three naturally occurring isotopes: two stable ones, ^{12}C (six protons, six neutrons) and ^{13}C (six protons, seven neutrons), and one unstable one, ^{14}C (six protons, eight neutrons). ^{12}C is the most abundant stable isotope, with an abundance of roughly 99:1 compared to ^{13}C (Chisholm 1989). Both stable carbon isotopes occur naturally in biological materials such as flora and fauna and vary between environments. In the original stable isotope literature, the international standard used to report $\delta^{13}C$ values was PDB (Pee Dee Belemnite formation of South Carolina). However, since then, this standard has been depleted (Coplen 1994; Hut 1987), and stable carbon isotope ratios are reported instead relative to the VPDB (Vienna Pee Dee Belemnite) standard with the $\delta^{13}C$ value of VPDB set to zero (0‰). Because PDB and VPDB have the same isotopic content, this does not affect comparisons between results obtained using the two different standards. As VPDB contains proportionately more ^{13}C than most organic matter, the $\delta^{13}C$ values of most biological samples are expressed in negative numbers.

The uptake of atmospheric carbon dioxide (CO_2) by plants leads to fractionation of stable carbon isotopes during plant photosynthesis (O'Leary 1988). In other words, fractionation causes the difference in the isotopic ratio between the carbon in CO_2 and the carbon in plants (Katzenberg 2008). During photosynthesis, the CO_2 is converted into glucose and incorporated into the plant's various tissues (Katzenberg 2008). In terrestrial plants, there are two dominant pathways, known as C3 and C4 (Calvin and Benson 1948; Slack and Hatch 1967), which received their name from forming either a three or four carbon compound. C3 plant photosynthesis strongly discriminates against ^{13}C during CO_2 fixation, resulting in lower $\delta^{13}C$ values (ranging between −36‰ and −24‰) while C4 plant photosynthesis discriminates less against the heavier isotope, resulting in higher values (ranging between −19‰ and −6‰) (Bender 1971; Deines 1980; O'Leary 1988; Smith and Epstein 1971).

C3 plants (e.g. trees, temperate grasses, shrubs) are typically found in temperate environments, whereas C4 plants (e.g. subtropical grasses) are found in hotter and more arid environments that require plants to minimize their loss of water (Katzenberg 2008; Tykot 2004). Hatch and Slack (1966) later discovered that certain plants can use either photosynthetic pathway for the uptake of carbon. These are known as CAM (crassulacean acid metabolism) plants and will switch between the C3 and C4 pathway depending on the environment, causing intermediate values (Katzenberg 2008). Examples of CAM plants are succulents, cacti, and agave. In the cold Cis-Baikal environment, only C3 plants are known (Katzenberg *et al.* 2010; Lam 1994; Twiss 1992). Freshwater plants also take up carbon from CO_2 as well as from other sources such as carbonate and bicarbonate in rocks and soils, CO_2 in the water, and waste organic carbon which has been decomposed by other freshwater plants and aquatic animals (Zohary *et al.* 1994). This can also cause aquatic consumers to display a wide variety of $\delta^{13}C$ depending on their habitat (Katzenberg 2008).

Living organisms incorporate stable isotopes from the environment into their system through diet. When plants are consumed, carbon atoms from plant protein are preferentially routed to collagen, which is the main structural protein found in animal and human tissues such as bone, teeth, skin, muscles, and blood vessels. Collagen is also the main organic compound that is utilized for examining past diet as it represents primarily the protein portion of the diet (Ambrose and Norr 1993; Krueger and Sullivan 1984; Tieszen and Fagre 1993a). Van der Merwe and Vogel (1978) were the first to observe that bone collagen $\delta^{13}C$ of free-ranging herbivores is generally elevated about 5‰ above the $\delta^{13}C$ of their diet. Not long after this observation, DeNiro and Epstein (1981) further demonstrated that while the whole-body $\delta^{13}C$ of an animal is indeed close to the $\delta^{13}C$ value of its diet, there is also $\delta^{13}C$ partitioning among various tissues.

Furthering upon these studies, two feeding experiments (Ambrose and Norr 1993; Tieszen and Fagre 1993a) on mice and rats demonstrated that although this elevation is relative to dietary protein, carbon from dietary lipids and carbohydrates also participates in collagen synthesis. This leads to a substantial departure from the +5‰ elevation value under particular conditions such as during periods of poor protein nutrition. Terrestrial animals from the modern context differ from archaeological mammals in their $\delta^{13}C$ values as a result of CO_2

being less enriched, due to widespread burning of fossil fuels. The average value of $\delta^{13}C$ in the atmosphere has changed to around –7.9‰, a decrease of around 1‰ (Keeling *et al.* 1979), post-fossil fuel burning.

The carbon in freshwater and marine environments comes mainly from dissolved CO_2 and is less depleted in carbon (0‰) compared to atmospheric CO_2 (–7.9‰). As a result, freshwater and marine organisms tend to have higher $\delta^{13}C$ values compared to terrestrial organisms. This difference allows distinguishing between the stable carbon isotope ratios of aquatic and terrestrial animals. However, it does not always allow distinguishing between the various species within a freshwater ecosystem, such as Lake Baikal, as tremendous $\delta^{13}C$ variation between and within some species has been observed (Katzenberg and Weber 1999). This variation is most likely controlled by the lake's bathymetry and will be discussed in greater detail later in this chapter.

Nitrogen isotopes

Nitrogen (N_2) is the largest component of the atmosphere (Schoeninger 1995; Sharp 2007). Its two stable isotopes are ^{14}N and ^{15}N. In archaeological stable isotope analysis, nitrogen is mostly used in combination with carbon to illustrate predator-prey relations in terrestrial as well as in aquatic environments. The reference standard for stable nitrogen isotope ratios is atmospheric nitrogen (AIR) (Sharp 2007: 29) with a $\delta^{15}N$ value set to zero (0‰).

Nitrogen can enter terrestrial plants in two ways. One, via nitrogen fixers, which are plants and bacteria that can fix N_2 directly from the air, and two, via plants that can only acquire nitrogen through the soil as a result of bacterial degradation (Larsen 1997). Leguminous plants (e.g. beans, peas, clover) have a symbiotic relationship with bacteria which live in the plant roots and are capable of fixing nitrogen and making it available to the plant (Brill 1977; Katzenberg 2008; Price 2015). These plants have $\delta^{15}N$ values close to that of N_2 (0‰) (Larsen 1997). Non-leguminous plants get their nitrogen from decomposed organic matter (Katzenberg 2008) by assimilating ammonium (NH_4) and nitrate (NO_3) from soil and are more enriched in ^{15}N, with values ranging between 2‰ and 5‰ (Sharp 2007). The $\delta^{15}N$ values of plants strongly depend on the $\delta^{15}N$ values of the soil (Sharp 2007). In drier regions, the $\delta^{15}N$ will most likely be higher in plants and animals (Ambrose 1991).

The majority of the literature focuses on the isotopic content of marine plants rather than freshwater plants. The stable nitrogen isotope ratios in marine plants are different from those in terrestrial plants (Minagawa and Wada 1984; Wada and Hattori 1978). Oceans have their own nitrogen cycle with rain, river runoff, and the fixation of N_2 by blue-green algae being the major inputs (Sharp 2007), while the composition of marine sediments is largely determined by the source of organic matter (Hoefs 2009). However, a similar nitrogen cycle might be true for Lake Baikal as a result of its volume and connection to over 300 rivers that feed into the lake. According to Kiyashko *et al.* (1998), the biota of Lake Baikal is more similar to that of an ocean than other large lakes.

Animals get their nitrogen through the consumption of plants and other animals (DeNiro and Epstein 1981). Their observed tissue $\delta^{15}N$ values are higher than those of their diet as nitrogen isotopes vary with trophic level (Katzenberg 2008; Lee-Thorp 2008), causing isotopic differences between diet and consumer. These values are also tied to a preferential loss of ^{14}N during excretion of urea (Steele and Daniel 1978). The trophic-level effect is present in terrestrial (DeNiro and Epstein 1981) as well as aquatic (Minagawa and Wada 1984) ecosystems. It causes organisms higher up the food chain to have higher δ^{15}N values. A δ^{15}N increase will range from ~2-3‰ (Fogel *et al.* 1989; Fuller *et al.* 2003; Tykot 2004) to as much as 5‰ per trophic-level and reflects the predator-prey relationship, while the degree of elevation depends on the overall health and development of the organism (Bocherens and Drucker 2003; Caut *et al.* 2009; DeNiro and Epstein 1981; Fuller *et al.* 2005; O'Connell *et al.* 2012; Schoeninger and DeNiro 1984).

In aquatic systems, organisms pass through a trophic chain that contains more steps than in terrestrial systems, causing stable nitrogen isotope values to be generally higher in aquatic than in terrestrial animals (Katzenberg *et al.* 2010). The trophic-level effect can, therefore, indicate whether an individual was mainly consuming aquatic or terrestrial protein (Schoeninger *et al.* 1983).

Collagen

As previously mentioned, the tissue examined in this study is tooth dentine. While dentine is described in greater detail in Chapter 4, the composition of this tissue and the isotopic chemistry of its collagen will be discussed here. The skeletal tissues bone and dentine are primarily made up of a matrix composed of organic materials (protein) and non-organic material (minerals). The former accounts for ~30% of the matrix by weight and the latter, often referred to as hydroxyapatite, makes up the remaining ~70%. Collagen is the most abundant protein in mammals (Fratzl 2008) and is found in the body's connective tissues. This organic component accounts for the majority of bone and dentine with a small portion consisting of lipids and non-collagenous proteins (Ambrose 1990). The main function of collagen is to provide stability, strength, and elasticity for the body (Fratzl 2008). There are numerous types of collagen in the human body. According to Miller (1984), the five most common types are:

- Type I collagen, which is found in skin, bone, dentine, and tendons
- Type II collagen, found in cartilage
- Type III collagen, found in blood vessels and minor amounts in the skin
- Type IV collagen, found in the membranes of epithelial cell layers
- Type V collagen, which is described as 'associated with the exoskeletons of fibroblasts, other mesenchymal cells and bone' (Miller 1984: 46).

As mentioned, Type I collagen is found in dentine and represents the majority of its organic portion (Fratzl 2008; Hillson 1996). While collagen is susceptible to diagenesis, dentine is protected by enamel which, due to its structure, is usually little affected (Hillson 1996). Collagen and other proteins are constructed of amino acids. They can be divided into essential and non-essential amino acids. Essential amino acids are defined as those which cannot be synthesized and can only be incorporated into the body through the diet. The non-essential amino acids can be synthesized by the body. Together, these amino acids bond to form proteins that build and repair tissue. A study conducted on pigs (Hare *et al.* 1991) demonstrates some of the reasons why collagen has its typical isotopic separations from other tissues. For this, the authors isolated amino acids in modern and fossil proteins to assess the factors that impact the isotopic composition of bone. Results show that the δ^{13}C values for individual amino acids in pig collagen and the diet are affected not only by the incorporation of dietary isotope signals but also by differential fractionation during synthesis within the body. Furthermore, the study by Hare *et al.* (1991) also found that bone collagen is rich in some amino acids that tend to have relatively high $\delta^{13}C$ values. The incorporation of these amino acids is what causes the $\delta^{13}C$ value of bulk collagen to be so elevated relative to the dietary protein. The unique composition of collagen makes it isotopically distinctive.

Isotopic data and childhood diets

Age categories

It is important to explain the age categories (e.g. infant, childhood, adulthood) used here, as there are several ways to determine one's age. The actual (or chronological) age of an individual refers to the number of years lived. However, humans can also be given a biological age which does not correspond one-to-one with chronological age. The biological age is based on the stage of development, growth or senescence reached at time of death. This age can either be expressed in terms of skeletal or dental age (Scheuer and Black 2004), depending on the availability of the remains and the training and preferences of the osteologist. The terminology used to describe certain periods in an individual's life will differ between clinicians, osteologists, behavioural biologists, and even between researchers trained in different countries. The age and sex assessments of all Baikal individuals were not carried out by the same researcher. While it is entirely possible the same age and sex determination methods were used for each individual and that results are completely comparable, there are differences in how individuals are categorized according to age. For instance, some individuals are categorized as a 'young adult' and elsewhere they are categorized as an 'adult' even though the same age at death is provided. Therefore, the terms used here are to allow for a proper comparison between the individuals examined.

As mentioned, biological age does not correspond one-to-one with chronological age, nor does either correspond with social age. Childhood, for instance, is a biological as well as a social phenomenon (Halcrow and Tayles 2008). The concept of childhood will differ between cultures and groups and can even change over time. Nonetheless, these terms are to be used only as support for age stages and are not meant to describe the social experiences of the individuals. Tooth formation (following AlQahtani *et al.* 2010) has been used here as a criterion for determining age categories.

- Infancy: the time from birth until the age of three. While three years of age does not serve as a dental boundary between infancy and early childhood stages, it was selected for this particular study as the majority of the individuals were still being breastfed at this age.
- Early Childhood: From the age of three until the completion of the first molar (around nine years).
- Late Childhood: Period between completion of the first molar (around nine years) and the second molar (~16 years).
- Early Adulthood: After completion of the second molar (16+ years).

The importance of studying breastfeeding and weaning

The study of breastfeeding and weaning behaviour in historic and prehistoric populations has become an important aspect of life-history studies as it impacts the health of the individual later in life and it impacts the overall health of the population being examined (Beaumont and Montgomery 2016; Beaumont *et al.* 2013a, 2013b; Bourbou *et al.* 2013; Dettwyler and Fishman 1992; Dupras and Tocheri 2007; Eerkens and Bartelink 2013; Eerkens *et al.* 2011, 2016; Fuller *et al.* 2003; Henderson *et al.* 2014; Herring *et al.* 1998; Katzenberg *et al.* 1995; King *et al.* 2018a, 2018b; Richards *et al.* 2002; Sandberg *et al.* 2014; Tsutaya *et al.* 2014; van der Sluis *et al.* 2015; Waters-Rist *et al.* 2014; Xia *et al.* 2018). Breastfeeding is critical to the survival and health of a child as the mother's milk provides not only nutrition but also protects the infant by creating an immunological tolerance (Cunningham 1995; Ip *et al.* 2007; Lawrence and Lawrence 2010; Silvia and Clements 1997). According to modern medical knowledge, when an infant reaches the age of approximately six months, additional foods should be introduced as breastmilk will no longer provide all the necessary nutrients and energy required for development (Dewey 2013). This begins the process of the introduction of supplementary foods known as weaning. Eventually, this process will lead to a complete replacement of breastmilk by solid food, at which point weaning is complete (Buikstra *et al.* 1986; Sellen 2009). The total duration of breastfeeding will vary between different groups and individuals as they are influenced by external variables such as the environment, economy, and culture (Dettwyler and Fishman 1992; Dupras *et al.* 2001; Wright and Schwarcz 1998). In addition to breastmilk having a highly important dietary and immunological component, lactation also affects the behavioural and social links between mother and infant (Sellen 2009). The duration of breastfeeding can also affect fertility and either increase or decrease the birthing space (Dettwyler and Fishman 1992), therefore influencing the size of a population. Not breastfeeding an infant or abruptly ending breastfeeding can result in nutritional stress, affecting the growth and development of the child, and eventually result in death. Therefore, the examination of weaning patterns provides insights into the energetic expenses of the mothers, the care of children within the society (parental investment), cultural factors that influence the duration and use of weaning foods, differences between and within cemetery populations, and possibly even on differential treatment between infants based on their sex.

Stable carbon and nitrogen isotopes for the detection of weaning

Weaning in archaeological populations can be studied through bone chemistry. Detecting the duration of breastfeeding and weaning via stable isotope analysis on human bone was first proposed by Fogel *et al.* (1989). Since then, multiple studies have shown that when an infant begins to shift from breastmilk to solid food, $\delta^{15}N$ values will start to decrease as the infant consumes fewer milk proteins from its mother (Katzenberg and Pfeiffer 1995; Katzenberg *et al.* 1993; Schurr 1998). This is a result of the aforementioned trophic level effect. Infants who are breastfed will generally show a ~2 to 3‰ elevation in $\delta^{15}N$ compared to the value of their mothers (Fogel *et al.* 1989; Fuller *et al.* 2003). When an infant is being breastfed, it is only consuming food (and proteins) directly from the mother. Breastmilk, which has a $\delta^{15}N$ value similar to the rest of the mother's body tissues, will cause the infant to be one trophic level higher. To roughly calculate when the introduction of proteins from solid foods began, is to identify the point where $\delta^{15}N$ values start to decline as a result of consuming foods that are lower in $\delta^{15}N$ relative to the mother's milk. Schurr (1998) illustrates this with an expected

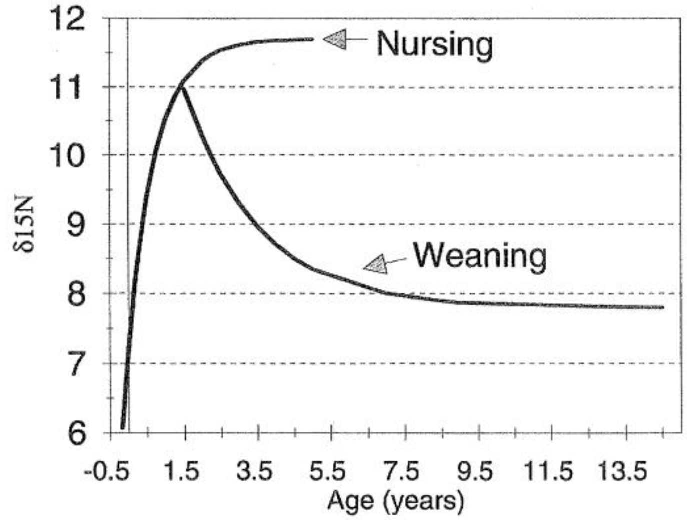


Figure 4. Expected changes in $\delta^{15}N$ with age during nursing and weaning (Schurr 1998: 330).

change in $\delta^{15}N$ values of bone collagen (Figure 4). In a previous study Schurr (1997) mentions that the shape of the curve depends on several factors:

1. The age at which solid foods are introduced to the child's diet.
2. The rate of collagen synthesis in growing infants. For instance, if the child grows rapidly, the first portion of the curve will drop faster.
3. The age at which the child will have completely ceased breastfeeding. Once the child has completely been weaned off breastmilk, the $\delta^{15}N$ values of its tissues will be similar to that of the mother or caretaker, assuming the child is consuming a similar diet.
4. The isotopic composition of the new diet.

Although stable nitrogen isotopes are most frequently used for examining and reconstructing weaning behaviour, stable carbon isotopes can also be used as an indicator for the introduction of solid foods. The $\delta^{13}C$ values of breastfed infants also exhibit a carbon trophic level shift and infants are typically ~1‰ higher in $\delta^{13}C$ values compared to their mothers (Fuller *et al.* 2006). When supplementary foods are added, $\delta^{13}C$ values will start to decrease (Dupras *et al.* 2001; Tsutaya and Yoneda 2013). However, $\delta^{15}N$ generally declines at a slower and more gradual rate than $\delta^{13}C$ (Fuller *et al.* 2006). While $\delta^{15}N$ can still be effectively used in association with $\delta^{13}C$ to detect breastfeeding and weaning in some populations, the $\delta^{13}C$ enrichment might not always be visible in others. Fuller and colleagues (2006) speculate that this is due to two reasons. First, $\delta^{13}C$ enrichment is smaller compared to the enrichment of $\delta^{15}N$, making it harder to detect. Second, the infant's carbon pool will be diluted faster than the nitrogen pool if weaning foods are richer in carbohydrates than protein.

Stable isotope analysis of bone and dentine

As previously mentioned, prior to the discovery of micro-sampling analysis in teeth, weaning could only be investigated via bulk sampling of bone collagen (Fogel *et al.* 1989; Katzenberg and Pfeiffer 1995; Katzenberg *et al.* 1993; Schurr 1998; Waters-Rist *et al.* 2011). This is done by sampling the bones of various infants and children in order to provide cross-sectional data of a population. The application of bone bulk sampling is most useful when examining the diets of individuals at different points in time. The application of bulk sampling provides dietary information on the last years of an individual's life as a result of a bone turnover rate. How much time is represented will depend on the bone utilized for research and the age at death of the individuals. For instance, an adult rib will provide biochemical information representing roughly the last five years before death whereas long bones represent a much longer period ranging from 10 to 30 years (Cheung *et al.* 2017; Cox and Sealy 1997; Hedges *et al.* 2007; Parfitt 2002; Pollard *et al.* 2012; Tsutaya and Yoneda 2015; Xia *et al.* 2018). Infant bone has been shown to have a very rapid turnover, with a suggested rate of 31 weeks (Tsutaya and Yoneda 2013), which slows down around the age of three (Sedlin *et al.* 1963; Szulc *et al.* 2002).

While bulk bone sampling can also provide weaning models at the population level, it does contain mortality bias (Wood *et al.* 1992). For example, King *et al.* (2018b) state that the weaning behaviour can be given as a cause of death for infants and young children, when in fact additional factors (e.g., disease, injury) could have been responsible. This issue can be avoided by micro-sampling the dentine of those who survived this fragile stage of life. While dentine has not been used as much as bone collagen it is becoming increasingly popular as it allows us to examine dietary change at a higher temporal resolution than bone collagen analysis alone (e.g. Beaumont *et al.* 2013a, 2015, 2018; Eerkens *et al.* 2011, 2016; Fuller *et al.* 2003; van der Sluis *et al.* 2015; Whitmore *et al.* 2019). Rather than representing an average signal for the protein portion of an individual's diet over a period of years, intervals as short as nine to 12 months can be seen and therefore offer the ability to gain a better understanding of variation throughout a person's life. By comparing the stable isotopic values from dentine with those from the bulk bone of the same individuals, it is possible, in some cases, to track dietary change from birth until time of death. Combining these two applications allows for a more detailed examination of diet over time and ultimately increases our understanding of past hunter-gatherer lifeways.

Sources of isotopic uncertainty

Multiple studies have shown that several factors can influence stable isotope values. As Reitsema (2013: 445) stated, 'Diet and nutrition, though related, are not conterminous, and an understanding of diet is not necessarily an understanding of nutrition or health.' This next section highlights sources of uncertainty when interpreting isotopic results focusing on three factors in particular: physiological factors, anthropogenic factors and climate factors. Only those that could have possibly influenced the diet and biochemical markers of the Cis-Baikal hunter-gatherers will be addressed here.

Physiological impacts on stable isotope values

Undernutrition

If an individual does not obtain enough nutrients necessary for healthy upkeep, the body will respond in such a way that it aims to minimize damaging effects (Osmani 1992). These effects can either be short-term or long-term, with the former leaving no visible trace when the body returns to equilibrium (Srinivasan 1992). As a short-term response, the body will improve metabolic efficiency by recycling nutrients already stored within the body (Beaumont *et al.* 2015; Fuller *et al.* 2005; Katzenberg and Lovell 1999), also known as catabolism. As mentioned earlier, when an individual consumed food, the proteins are routed to body tissues to build and repair. Nitrogen isotopic fractionation, which is the result of processes affecting the relative abundance of isotopes, such as transamination (the synthesization of non-essential amino acids in vivo) and deamination (the breakdown of excess protein not utilized for tissue building), elevating the body's nitrogen pool (Reitsema 2013). Post fractionation, the body is enriched in ^{15}N.

However, multiple isotopic studies have shown that undernutrition can also lead to a $\delta^{15}N$ elevation of the body tissues (Hobson and Clark 1992; Hobson *et al.* 1993; Katzenberg and Lovell 1999). If an individual does not obtain enough protein from its diet, the body can catabolize its tissues and repeat transamination and deamination which, again, will elevate the nitrogen pool (Reitsema 2013). Hatch *et al.* (2006) and Mekota *et al.* (2006) investigated stable carbon and nitrogen isotope values in sectioned hair of anorexic and bulimic patients to see what food restrictions do to the body's nitrogen pool. Although both are considered to be severe eating disorders with possible fatal effects, only the anorexic patients showed signs of elevated $\delta^{15}N$ while the bulimic patients showed none. The study shows that while severe nutritional stress will often elevate $\delta^{15}N$ values it remains unclear as to why certain cases result in an unpredictable isotopic effect. Although, Hatch and colleagues (2006) did suggest that bulimics were perhaps ingesting enough protein to avoid elevated $\delta^{15}N$ values. In the study by Mekota *et al.* (2006) they found that $\delta^{15}N$ and $\delta^{13}C$ were inversely related and that $\delta^{13}C$ would increase when the body mass index (BMI) increased, which they argue is mostly due to greater protein intake. This expression of $\delta^{13}C$ was also visible in a later study on serial samples of hair (Neuberger *et al.* 2013) to investigate malnutrition and starvation for its use in legal medicine. In addition, this study also observed a decline in $\delta^{13}C$ during weight loss, which was suggested to be the result of low energy in the consumed diet as well as a breakdown of the body's fat deposits, which are ~3‰ lower than other tissues such as muscle (Tieszen and Fagre 1993b).

Long-term effects from undernutrition will result in permanent changes in metabolism, modification of bone, and even behavioural change (Beaumont *et al.* 2015). Through osteological analysis of human remains, it is possible to see some of these changes. For example, if a child suffers from a serious vitamin D deficiency, this will cause rickets, a condition in which the bones do not mineralize properly, leading to bone deformities that can be seen by the osteologist. Nonetheless, traces are not always left behind in bone. There are two explanations for this: (1) the osteological paradox (Wood *et al.* 1992), which is a concept addressing heterogeneity in disease and risk of death. For example, an individual may have died from disease before the bone had the ability to leave a mark, potentially leading to incorrect analysis by the osteologist. If bony lesions are in fact present, it will most likely be assumed that the individual died as a result from illness, when in fact that individual could have built up an immunological response over time but died from unrelated trauma (e.g. asphyxiation or heart disease). (2) If an individual survives undernutrition, it is possible that healing and (bone) growth will erase its visible effects.

A recent biochemical study on serial samples of hair suggested undernourishment to be a contributing factor in the death of a young girl. A mummified one-and-a-half to three-and-a-half-year-old was examined to further the understanding of health and disease among children during the 19th century in San Francisco, California (Eerkens *et al.* 2017). The protein targeted for stable carbon and nitrogen isotope analysis in this study was keratin, which is the main structural component in hair and nails. The serial sections, which are each 5mm in length, roughly represented the last 10 to 14 months of the child's life. Results showed an increase in $\delta^{15}N$ over time (the maximum difference is 1.5‰), with an abrupt increase in 0.8‰ $\delta^{15}N$ between 2.4 and 1.7 months before death. The $\delta^{13}C$ values gradually increased (the maximum difference is 1.2‰), with 0.4‰ two to three months before death. The authors suggest that the rise in $\delta^{15}N$ towards the end of life is a result of severe undernutrition or starvation. The rise in $\delta^{13}C$ is postulated to represent the introduction of oils or carbohydrates whether it was through food, liquid or medication. However, oils seem unlikely as they are high in lipids, which would cause $\delta^{13}C$ values to become lower. Seeing as the individual exhibits a rise in $\delta^{13}C$ and $\delta^{15}N$ measurement over the last few months, the authors (Eerkens *et al.* 2017) state that the data are consistent with a prolonged illness rather than an accident or acute disease that resulted in death not long after. It has also been suggested the increase in $\delta^{13}C$ potentially represents the catabolizing of internal carbon sources. In follow up comments to this study, the authors report they received positive DNA confirmation that the individual was indeed a female and was able to be matched to a living relative. They further confirmed that the child died at two years from marasmus (severe malnutrition) according to funeral records.

The effect of growth on bone collagen nitrogen values

Waters-Rist and Katzenberg (2010) showed that $\delta^{15}N$ values in various parts of long bones do not differ from one another as a result of growth. The authors examined the effect of rapid growth on $\delta^{15}N$ through intra-long bone stable isotope analysis. This intra-individual study compared sections of long bone formed at different ages (proximal metaphysis, diaphysis, and distal metaphysis) for stable isotope analysis in order to evaluate if rapid growth will alter the $\delta^{15}N$ diet to tissue spacing. The authors concluded that collagen accretion does not affect the stable nitrogen isotopic ratio and that there is no significant difference among the various long bone sections. This method of sampling various parts of the long bones was then applied to Cis-Baikal infants and children (Waters-Rist *et al.* 2011) and will be discussed further on in this chapter.

While a difference in $\delta^{15}N$ between various parts of a bone could not be found, $\delta^{15}N$ is said to be influenced overall during anabolic states (growth). Fuller *et al.* (2004) found that $\delta^{15}N$ values are affected by not only periods of nutrition stress, but also during growth such as the gestation period in pregnant women. During such periods of rapid growth, dietary protein can be routed directly to body tissues, bypassing transamination and deamination (Reitsema 2013), causing the amino acids to be directly deposited into new tissue (Water-Rist and Katzenberg 2010). In another study (Fuller *et al.* 2006), modern breastfed infants showed a wide range in $\delta^{15}N$ elevation (1.7‰ – 2.8‰) relative to their mothers. The authors attribute this to a positive nitrogen balance (growth). This could also be the case for some of the Baikal individuals. However, it is also possible a lower trophic shift is a result of illness, variation in weaning, or not being breastfed (Waters-Rist and Katzenberg 2010).

Nutritional deficiency in dentine micro-samples

Beaumont and Montgomery (2016) examined the dentine profiles of individuals who were victims of the Great Irish Famine during the 19th century. The authors were able to obtain historical documents from this period, providing written evidence on the experience of the Irish poor. First, short-term dietary changes from C3 to C4 foods (introduction of maize) were visible in δ^{13}C and δ^{15}N, resulting in a simultaneous increase for δ^{13}C and a decrease in δ^{15}N, which the authors suggest might be the result of a maize-based diet. Furthermore, the study also shows changes in δ^{13}C and δ^{15}N as a result of nutritional stress. In all individuals, δ^{15}N rose just prior to the switch from a C3 to C4 diet, as well as a rise in δ^{15}N shortly before death in most children. During these times δ^{13}C remained either unchanged or declined. The authors state that the rise in δ^{15}N is unlikely to be the result of diet (moving to a higher trophic level) as δ^{13}C would be expected to rise as well, albeit to a smaller degree. This pattern, where δ^{15}N rises and δ^{13}C either stays the same or declines, is seen as a result of nutritional stress. The analysis provided for the expression of δ^{13}C (Beaumont and Montgomery 2016) is in keeping with the study by Neuberger *et al.* (2013) which mentions the recyclizing of the body fat stores, leading to a decline in δ^{13}C. Consequently, the dentine micro-sampling study by Beaumont and Montgomery (2016) was able to identify changes in diet as well as physiology.

Moreover, a meta-analysis of fasting experiments on the δ^{13}C and δ^{15}N of starving animals (Doi *et al.* 2017) showed a wide range of variability in δ^{13}C, which can either increase, decrease, or appear to remain stable during starvation. The explanation given for a decrease in δ^{13}C is that this is caused by reliance on the animal's internal lipid reserves, which are lower in δ^{13}C values. Furthermore, the authors note that the large variation in δ^{13}C could not be easily explained, leading them to conclude that the mechanisms underlying the fasting effects on stable carbon isotopes are more complex than previously thought. The explanation given for the expression in δ^{15}N, which increased with fasting/starvation time, is similar to results from previous studies. Δ^{15}N will increase as a result of the body catabolizing its nitrogen pool.

Anthropogenic factors

Cooking

The effects of heating food (e.g. cooking) on stable isotopes was first investigated by DeNiro *et al.* (1985). The study showed a shift <1.0‰ in δ^{13}C and δ^{15}N of animal bone collagen as a result of either roasting or boiling (except for llama rib which shows δ^{15}N values of 1.5‰ and 1.7‰). Authors also showed that extreme heat, such as burning discarded bones or cremation can cause a significant shift of 4 to 5‰ in both values. However, there are two conclusions to be drawn from this. First, the study was carried out by only heating bone (roasting or boiling), not by heating the tissues that are normally used for consumption. Second, although extreme heat shows a rather large shift in both values, extreme heat is not a suitable method for food preparation.

Katzenberg and colleagues (2002) conducted a study to see how food preparation would have affected stable isotope ratios. For this, foods were cooked using recipes from 19th century documents and traditional cookware. Results indicate that there is a minor difference (< 1.2‰) between raw and baked foods. Another study (Fernandes *et al.* 2014a) examined the influence of cooking on the isotopic composition of mackerel and haddock and showed that shifts were less than 1.0‰ when cooked fish were compared to raw fish. Mackerel and haddock were selected by Fernandes *et al.* (2014a) as the former has a high fat content and the latter does not. The fish were prepared on three separated occasions by boiling in a ceramic pot, steamed in hot sand, and grilled next to open fire.

While the study by DeNiro and colleagues (1985) focused only on bones, Fernandes and colleagues (2014a) examined multiple parts of the fish: flesh, bone, lipids, lipid-extracted flesh, water-extracted flesh, and water-soluble compounds. A study conducted by Royer and colleagues (2017) also examined how cooking can alter the isotopic composition of different foods by sampling different types of meat (red meat, white meat, lean meat, fatty meat) and fish. The results of this study differ from the rest. Their data show that the carbon, nitrogen, and oxygen isotopic differences between raw and cooked food are much larger than previously estimated. Isotopic shifts were produced up to 1.8‰ for $\delta^{13}C$, 3.5‰ for $\delta^{15}N$, and 5.2‰ for $\delta^{18}O$.

In addition, fish $\delta^{15}N$ is said to increase with 2‰ or more when cooked. It is suggested that these differences are a result of biochemical reactions such as dehydration and the thermal degradation of lipids, peptides, and amino acids. If the preparation of meats and fish do cause substantial differences for the isotopic composition, then food preparation needs to be taken into account as a source of variability considering the amount of terrestrial and aquatic meat consumed by the Cis-Baikal hunter-gatherers. However, the problem with this is that it is not known how exactly they were preparing their foods.

With this in mind, food preparation raises another potential source of error: fish processing methods, as fish has proven to be an important food source in Cis-Baikal (Katzenberg and Weber 1999; Katzenberg *et al.* 2009, 2010, 2012; Losey *et al.* 2008, 2012; Weber and Goriunova 2013; Weber *et al.* 2002). While removing fish bones prior to consumption is considered the norm in many cultures, others do not debone their fish and often consume the bones as well. Fishbones can contain large amounts of lipids, which have low $\delta^{13}C$ values (Guiry *et al.* 2016b). If fish, particularly smaller fish, were not deboned prior to consumption, this would affect the overall $\delta^{13}C$ of the food. However, there is no knowing whether bones were indeed consumed and whether it would affect everyone equally. For example, some groups could have preferred smaller fish species that do not require deboning for consumption, whereas others might have targeted larger fishes and deboned them prior to consumption. The fish processing methods also affect the distribution of the fish remains at archaeological sites and even their preservation.

Climatic factors

Canopy effect

In a canopy effect, $\delta^{13}C$ will be higher at the top of the canopy while plants situated beneath the closed canopy of the forest will have lower ^{13}C values (Drucker *et al.* 2008; Van der Merwe and Medina 1991). Soil respiration will produce ^{13}C depleted CO_2, which is then recycled during photosynthesis as a result of low light that is caused by the density of the vegetation (Malainey 2011). This canopy effect is passed on via the food chain to consumers that feed off the lower-lying plants and canopy. While the canopy effect has been observed in the

Amazonian forest (van der Merwe and Medina 1991), it has also been observed in forests with a more temperate climate such as Upper Bavaria, Germany (Vogel 1978), a wooded area near Oxford, England (Bonafini *et al.* 2013), and potentially even the boreal forest-steppe in Cis-Baikal, Siberia (Drucker *et al.* 2008). For the latter study, the $\delta^{13}C$ of modern and archaeological ungulates were measured to examine whether the canopy effect caused a decrease of $\delta^{13}C$ in the tissues of herbivores and whether the $\delta^{13}C$ varied according to species and between ranges during the Late-Glacial and Early Holocene. Drucker *et al.* (2008) used data on ungulates from Weber *et al.* (2002).

Overall results show that ungulate populations from closed canopy habitats do exhibit lower $\delta^{13}C$ compared to those living in more open environments. However, for one of the roe deer (sample 93.052), the wrong $\delta^{13}C$ value is presented in the study by Drucker *et al.* (2008). In addition, the authors mention that multiple factors can cause variation in $\delta^{13}C$ values of plants such as temperature, humidity, abiotic and biotic factors, and air circulation. Finally, it is said that not all dense woodland areas will generate a canopy effect as multiple factors are responsible for this effect (Drucker *et al.* 2008). The Cis-Baikal has been described to vary geographically and topographically. White and Bush (2010) mention that an increase in aridity during the middle-Holocene might have reduced forest coverage. This would have potentially limited the possibility of a canopy effect (if there was one) even further in an already vegetative mosaic. Nonetheless, reducing forest coverage could still cause isotopic shifts in diets as a result of possible resource depletion.

Bathymetry

As previously mentioned, the extensive variation in the $\delta^{13}C$ values of Lake Baikal's aquatic food resources is most likely affected by the lake's bathymetry. Kozhov (1963: 29) mentions that Lake Baikal is not thermally uniform and that the temperature within the lake will be dependent on depth (shallow vs. pelagic zones), the relief of the lake's floor, distances from the mouth of the numerous rivers, and the profile of the lake's coastline. The extensive depth of Lake Baikal (up to ~1600m) also influences the mixing of nutrients in various zones. Weber *et al.* (2011: 532) refer to the lake as being an 'oligotrophic ecosystem' and, therefore, variability is expected in the primary productivity of the lake. In this oligotrophic ecosystem, nutrients are recycled intensively in the upper sections of Lake Baikal (Yoshida *et al.* 2003). Additionally, 12.5% of Lake Baikal's deep water goes through a process referred to as deep-water renewal (or water ventilation) on an annual basis, which is the mixing and renewing of water by surface layers sinking to the bottom layer of the lake known as the hypolimion (Piccolroaz and Toffolon 2013; Weiss *et al.* 1991). Together, the recycling of primary productivity in the upper sections of the lake and the deep-water renewal in the lower sections influence the aquatic food web through the spatial distribution of phytoplankton and other nutrients (Goldman *et al.* 1996). Thus, depending on an organism's habitat within the lake and the nutrients consumed, its $\delta^{13}C$ values will be affected. This results in differences in $\delta^{13}C$ between and within various aquatic species, and in turn, those who consume them. The Angara and Lena rivers are obviously much smaller and far less deep than Lake Baikal and known as lotic ecosystems. As opposed to Lake Baikal, the primary productivity in the rivers is more evenly distributed by the flow of water and hydraulic forces (Giller and Malmqvist 1998), causing less variation in $\delta^{13}C$. However, the flow of water will vary throughout the rivers and certain parts may contain rapids, whereas others may be calmer. This will notably affect δ^{13}C but results in less variation than that seen in Lake Baikal.

Stable isotope analysis in the Cis-Baikal region

Archaeological and modern bone specimens from the Cis-Baikal region representing avian, aquatic, and terrestrial fauna have been analyzed over the last two decades (Katzenberg and Weber 1999; Katzenberg *et al.* 2009, 2010, 2012; Lam 1994; Weber and Goriunova 2013; Weber *et al.* 2002, 2011). Samples represent surface finds, archaeological collections, modern specimens, and fish harvested by BAP researchers (Figure 5). A summary of the main findings on food groups and human diets in the Cis-Baikal are outlined here.

Main food groups in Cis-Baikal

Large game (e.g. moose, red deer, roe deer)

Prehistoric specimens of big game are characterized by relatively low δ^{13}C and δ^{15}N as a result of a C3 diet (Katzenberg and Weber 1999; Katzenberg *et al.* 2009, 2010, 2012; Weber *et al.* 2002). Mean δ^{15}N mean values range from 2‰ for moose to 6‰ in roe deer (Katzenberg *et al.* 2009). The study further mentions that if hunter-gatherers were exclusively consuming terrestrial herbivores, their δ^{15}N values would be no greater than 9‰. All individuals examined thus far exceed this (Katzenberg *et al.* 2009; 2010; 2012; Lam 1994; Weber and Goriunova 2013; Weber and Katzenberg 1999; Weber *et al.* 2002).

Small game (e.g. squirrel, hare, duck)

Small game will most likely have been consumed to a lesser extent than large game. Nonetheless, some species are still a source of protein, especially during harsher times. The Siberian ground squirrel (Citellus undulatus) was collected as an indicator of local environments even though they are not considered to be a major food source (Katzenberg *et al.* 2012). The δ^{13}C values of the animal indicate the absence of C4 plants, leading the authors to believe that an elevated δ^{13}C in the human diet is a result of fish consumption and, potentially, migratory waterfowl. Ethnographic studies on northern hunter-gatherers have shown that waterfowl were exploited seasonally (Alekseenko 1999; Anderson 1999) and that there is a gathering place for waterfowl south of the Little Sea and Angara (Katzenberg *et al.* 2012). Unfortunately, there is no stable isotope data for the (prehistoric) waterfowl from the Baikal region. However, stable isotope data for other modern bird specimens have exhibited quite a substantial elevation in δ^{15}N. The Herring gull (*Larus argentatus*) showed δ^{15}N values ranging between 13.5‰ and 14.6‰ (n=7), while the Gray duck (*Anas strepera*) (n=1) and Baikal teal (*Anas formosa*) (n=1) have values of 14.8‰ and 19.1‰, respectively. Elevated δ^{15}N has also been observed in some hares (*Lepus timidus*), with values ranging from 1.7‰ to 15.2‰ (n=10) but is said to most likely be a result of caecotrophy, which is the consumption of feces (Katzenberg *et al.* 2012; Weber *et al.* 2011). Interestingly, Katzenberg and colleagues (2012) observed that the δ^{15}N of lynx and ground squirrel overlap, concluding that nitrogen isotopic fractionation does not always follow trophic levels. Potential reasons given for this overlap are δ^{15}N is linked to location, hibernation could lead to catabolism, or, again, caecotrophy and eating human leftovers.

Plants

All plants within the Cis-Baikal region follow a C3 pathway (–36‰ to –24‰) (Katzenberg *et al.* 2010; Lam 1994; Twiss 1992). Berries, mushrooms, and pine nuts (sometimes also referred to as cedar nuts) are available seasonally (Lam 1994; Weber *et al.* 2002). Modern pine nuts from the Cis-Baikal region have δ^{13}C values of –22.7‰ and δ^{15}N of 1.3‰ (Weber *et al.* 2002). Additional plant values from the region would be beneficial for further investigating the isotopic variation among the flora.

Freshwater systems in Cis-Baikal

There are 52 known fish species and one aquatic mammal (seal) in Lake Baikal (Katzenberg and Weber 1999). Several of the fishes and the seal are unique to this part of the world. The freshwater ecosystems of the Angara and Lena Rivers and Lake Baikal are ecologically very different from one another, resulting in different stable isotopic values (Figure 5). All the isotopic values for fish were taken from modern specimens. The seal is the only aquatic species for which there are prehistoric and modern samples (Katzenberg *et al.* 2012). In Katzenberg *et al.* (2010) it was reported that the aquatic fauna in Lake Baikal exhibits a wide range of δ^{13}C from –24.6‰ to –12.9‰ as a result of the multiple carbon sources within the lake (Katzenberg and Weber 1999). However, later research (Weber *et al.* 2011) has shown this range to be even greater; spanning 20‰ (δ^{13}C –30.5 ± 2.2‰ to –10.9 ± 2.4‰). The planktonic and benthic autotrophs (e.g. grasses, algae) in the lake show a range of 21.5‰ in δ^{13}C (Kiyashko *et al.* 1998). This causes great variation not only between species but also within species. Due to the many freshwater ecosystems in the Cis-Baikal region, a modified list of definitions has been adopted following Kozhov (1963) and Weber *et al.* (2011) to provide a list of four fish habitats:

1. Fishes in shallow coves and lagoons

The types of fishes that are commonly found throughout the year in these areas are perch, roach, dace, and pike, and all are abundant in the Little Sea area (Losey *et al.* 2008, 2012). These fishes also showcase variation in stable isotopic values. Most fishes in the Little Sea are higher in δ^{13}C with some reaching values as high as –10.0‰ (Katzenberg *et al.* 2009). Weber and colleagues (2011) also examined modern samples (n=23) from the shallower waters with δ^{13}C values ranging between –17.0‰ and –11.9‰ and δ^{15}N values ranging between 10.6‰ and 11.6‰.

The modern carp has one of the lowest δ^{15}N values of all aquatic species with a δ^{15}N of 7.8‰ and a carbon value of δ^{13}C –21.4‰ (Weber *et al.* 2002). Perch shows a large variation in carbon with one sample at δ^{13}C –23.6‰ and another at –10.5‰ (Katzenberg *et al.* 2010). This could be a result of inhabiting various parts of the lake.

Gulf fishes

These fishes (whitefish, omul’ and grayling) are found in the Little Sea at the depth between 5 to 200–300m (Losey and Nomokonova 2017; Weber *et al.* 2011). The fishes exhibit greater range in δ^{13}C and δ^{15}N values than those from the shallower parts of the lake. Weber and colleagues (2011) analyzed 23 modern specimens from the gulf. Results show δ^{13}C values ranging from

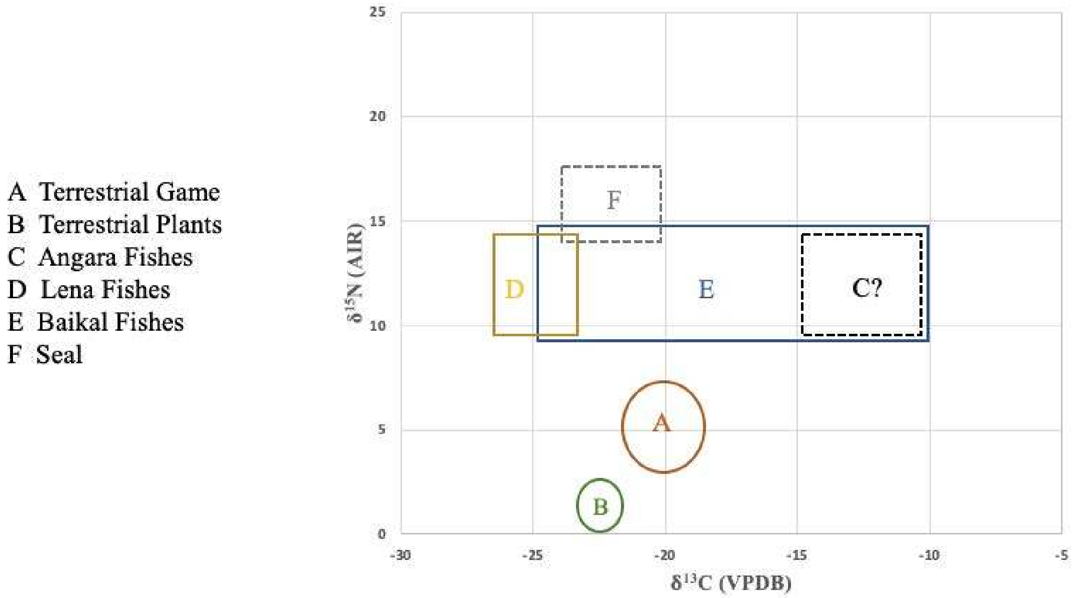


Figure 5. Stable isotope ecology of main Cis-Baikal food groups (adopted from Weber *et al.* 2002 using unpublished BAP data).

–20.5‰ to –9.9‰ and δ^{15}N from 9.2 to 12.6‰. There are two types of grayling in Lake Baikal: black and white grayling. Both species inhabit areas along the coast at small depths, as well as spawn at the beginning of spring in the small streams and rivers entering Lake Baikal (Kozhov 1963; Losey *et al.* 2012).

2. Pelagic fishes

Pelagic fishes are found in the open, deeper, and colder parts of the lake (up to ~1600m deep). The omul' is the most important fish harvested from these parts today (Kozhova and Izmest'eva 1998; Losey *et al.* 2008). Omul' could have been important to the mid-Holocene hunter-gatherers as well, albeit archaeological evidence for pelagic fishing has not been found. While these fish are found in the deep regions of the lake during winter (Kozhov 1963), they can also be found along the open coast littoral waters in spring and summer (Losey and Nomokonova 2017; Weber *et al.* 2002). The omul' also moves from the shores toward the open part of the Lake, feeding in the upper layers (Kozhov 1963). The fish is harvested with the use of nets by commercial fishermen (Losey *et al.* 2008). While nets or traps have not been found in Cis-Baikal, net sinkers and net impression on pottery have (Bazaliiskii 2010; Losey *et al.* 2008; Weber 1995). Modern omul' from the lake (n=9) has δ^{13}C values ranging between –24.9‰ and –14.0‰, and δ^{15}N values ranging between 9.2‰ and 11.9‰ (Weber *et al.* 2011). According to Losey and colleagues (2008), some omul' are quite difficult to catch with small hooks due to their small mouths.

While the seal also inhabits the deep and open sections of the lake, it can also be found in various sections of the lake depending on the season (Nomokonova *et al.* 2013). The seal was thought to occupy the highest trophic level with a mean δ^{15}N value of 14.0‰ (n=8) (Katzenberg and Weber 1999). However, Katzenberg *et al.* (2010) demonstrated that the δ^{15}N values in pike (n=7) from the lake and the Angara River are sometimes equal to (mean of 11.6‰ from Baikal) or higher than (mean of 19.6‰ from Angara) the seal. A study done by Weber *et al.* (2011) placed the seal δ^{15}N values between 11.4‰ and 15.6‰. The δ^{13}C values for this animal are similar to those of the large game animals and to the Lake Baikal omul'.

3. Large rivers

The Angara, which is a lake outlet, is roughly 1km wide (post damming in the 1950s) where it leaves its source (Weber *et al.* 2011). Data obtained from this river do not provide much assistance in the analysis of archaeological data. The construction of three dams (McKenzie 2006; Weber 1995) changed the ecology, fish abundance and bathymetry of the river. As a result, the δ^{13}C and δ^{15}N values of modern fish samples from the Angara are deemed to be not representative of the archaeological specimens. This complicates the analysis of the δ^{13}C and δ^{15}N values of hunter-gatherers that were buried along the river.

The Lena River is not connected to the lake or the Angara, with no possibility of fishes migrating from one to the other. Despite having little information on the aquatic fauna of the Lena River, it is known that the specimens have lower δ^{13}C compared to the Angara River and Lake Baikal. Most fishes from the Lena and surrounding rivers in the area have δ^{13}C values of around −25‰ (Katzenberg *et al.* 2012). One of the most prominent fish species in the rivers and certain parts of the lake is the sturgeon (Losey and Nomokonova 2017; Losey *et al.* 2012). The modern samples (n=2) are low in δ^{13}C (−22.9‰ and −22.3‰) and high in δ^{15}N (14.6‰ and 14.1‰) (Katzenberg *et al.* 2012). Several lake species, which can be found close to the shoreline, such as whitefish, grayling, taimen', lenok, and burbot can also be found in the large and smaller rivers (Dr. Robert Losey, personal communication, January 24, 2019).

Main adult diet groups in Cis-Baikal

Data have shown that contributions to human diets from terrestrial resources are masked by the high δ^{15}N values of aquatic resources (Katzenberg and Weber 1999, Katzenberg *et al.* 2009, 2010, 2012; Weber 2011). The Cis-Baikal hunter-gatherers did not solely depend on terrestrial foods, as this would have caused δ^{15}N to be around 8–9‰ (Katzenberg *et al.* 2010, 2012), which is not seen in any of the bulk bone or dentine samples. Data do not rule out the possibility of complete dependence on fish, although this seems highly unlikely considering the amount of terrestrial fauna bones that have been recovered from graves and habitation sites. The adult diets fall into three separate clusters based on place of burial: the Little Sea, the Angara, and the Upper Lena micro-regions.

i. Little Sea: GFS and GF diets

Two diets were identified by Weber and Goriunova (2013) at the Khuzhir-Nuge XIV cemetery, displaying not only a difference in food consumption but also a spatial distribution in relation to the burials. In regard to the former, these two diets are known as the GFS (Game-Fish-Seal) diet, which is considered to be the local Little Sea diet, and the GF (Game-Fish) diet that is local to the Angara and Upper Lena areas. This dietary difference is primarily based on the δ^{15}N signatures. Stable isotope analysis on bone collagen shows that 45 individuals at

Khuzhir-Nuge XIV had an isotopic signature ranging from δ^{15}N 13.5 to 16.5‰, suggesting a GFS diet and 26 individuals had a range between 10.3 and 12.8‰, suggesting a GF diet (Weber and Goriunova 2013). The Little Sea diets are characterized by high δ^{15}N and highly variable δ^{13}C (Figure 6a, c). In addition to this, individuals were further divided into locals (born in the Little Sea area) and non-locals (born outside of the Little Sea area), based on strontium isotope analysis on tooth and bone. Weber and Goriunova (2013) found that all individuals with a GF diet were non-locals, while those with a GFS diet were either local or non-local.

ii. Upper Lena

The individuals from the Upper Lena have been examined to a much lesser extent than those from the Little Sea or Angara regions. The first isotopic study on Upper Lena individuals by Katzenberg and Weber (1999) analyzed individuals from five sites (Makrushina, Turuka,

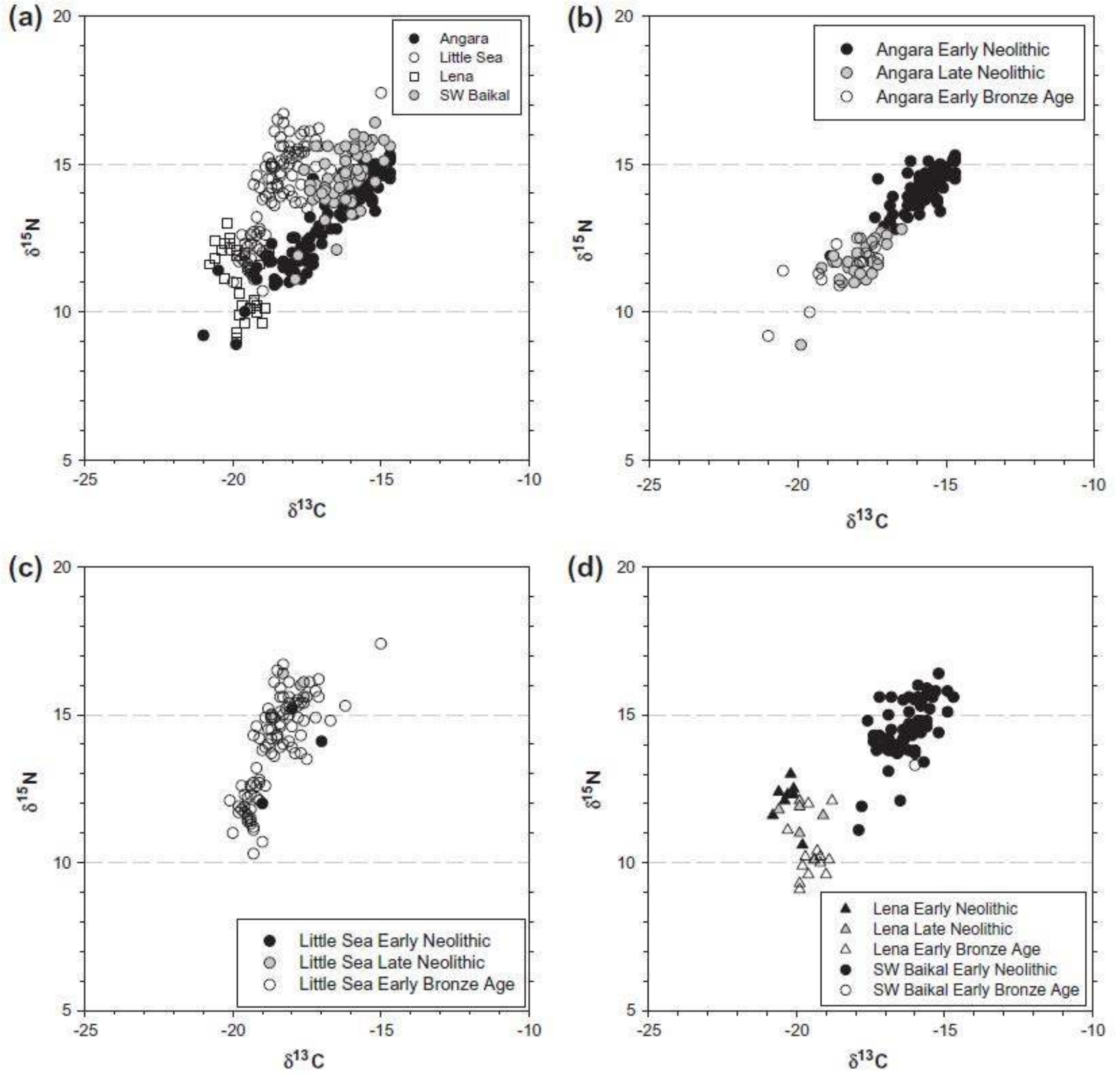


Figure 6. Stable isotope data for Cis-Baikal hunter-gatherers (Weber *et al.* 2011: 541). Data shown are from (a) all 4 micro-regions, (b) Angara valley, (c) Little Sea, (d) Upper Lena and Southwest Baikal.

Nikol'skaia Skala, Obkhoi, Borki) as well as individuals from the Angara (Lokomotiv, Ust'-Belaia, Ust'-Ida) and Lake Baikal (Khotoruk and Khuzhir). Stable carbon and nitrogen isotope analysis were conducted on human bone samples (adults only), modern fishes, and prehistoric mammals. Individuals in the Upper Lena have $\delta^{13}C$ as low as −20.2‰, suggesting they relied on terrestrial resources as their main source of protein rather than fish. Additional research (Katzenberg *et al.* 2010; Weber *et al.* 2011) further corroborates these findings. Stable isotope analysis on bulk bone collagen has shown hunter-gatherers from the Upper Lena display lower $\delta^{15}N$ and $\delta^{13}C$ values (Figure 6a, d) when compared to hunter-gatherers from the Angara and Little Sea micro-regions.

iii. Angara

The bone collagen of 119 individuals from the Angara River Valley were examined with stable carbon and nitrogen isotope analysis in a study by Weber *et al.* (2011). Interestingly, the authors mention that a few individuals from the Ust'-Ida I cemetery showed not only lower $\delta^{13}C$ and $\delta^{15}N$ values in comparison to other individuals from the same micro-region (Figure 6b), but they overlap with the LN-EBA component from the Upper Lena micro-region. Nine of the Ust'-Ida I individuals from the Weber *et al.* 2011 study are included in this work. However, stable isotope values of the bone samples of these nine individuals did not overlap with the LN-EBA Upper Lena individuals.

Weaning and childhood diets in Cis-Baikal

As mentioned, infant remains are rare in the Cis-Baikal and their numbers vary between cemeteries. The same is seen for individuals who fall into the age groups 11 to 15 and 20 to 25 years (McKenzie 2006). For example, Khuzhir-Nuge XIV, the largest EBA cemetery in the region mainly consists of adults. Another cemetery on the western shore of Lake Baikal, Kurma XI (EN/EBA), contains no child burials (Lieverse 2012; McKenzie 2006). It seems highly impossible that there were no cases of infant death at all during this period. It has been postulated that infants were disposed of differently (McKenzie 2006). Perhaps they were buried at a different cemetery or disposed of in a manner that did not involve burial. Infant and childhood diets from Early and Late Neolithic Cis-Baikal individuals were examined through intra-long bone stable isotope analysis (Waters-Rist *et al.* 2011). Per individual, three areas were targeted for collagen extraction: the proximal metaphysis, the diaphysis, and the distal metaphysis. The reason for this is that the metaphysis consists of bone that was laid down recently and allows for comparison with the diaphysis (older bone). Waters-Rist and colleagues (2011) analyzed the bone collagen of 26 children/adolescents (ages: four to 10) and 23 infants (ages: birth to three years) belonging to the Cis-Baikal's Neolithic. Results show that Early Neolithic children were weaned at a later age (weaned at three-and-a-half to four years) and over a shorter amount of time than Late Neolithic children (weaned at three years). While some of the individuals from the study by Waters-Rist *et al.* (2011) came from the Ust'-Ida I cemetery, none of them were used in this micro-sampling study. Nonetheless, the results from that study and this one can be compared to see if they are similar in time of weaning and overall childhood diet. This will allow insight into the cultural customs and ideas surrounding the childhood of the Baikal hunter-gatherers.

Previous research on Baikal food groups (e.g. ungulates, fish, seal) in combination with the micro-sampling results might also provide some insight into the type of weaning foods that were being given. As mentioned, infants need complementary foods after the age of six months to support growth and development. Foods with high nutrient density are required for infants and young children (Dewey 2013). Depending on the season, Cis-Baikal infants would most likely have consumed a good amount of protein, fats, and vitamins from wild plant foods, game, or freshwater resources as they did not have access to the typical cereal-based weaning foods which were common during the agricultural revolution (Dewey 2013). A molar micro-sampling study on Early Neolithic hunter-gatherers from the Shamanka II cemetery in South-Baikal showed a difference in the timing and rate of weaning among individuals (Scharlotta *et al.* 2018b). Another study on the same materials also showed that the dentine initiation and growth rates differed from most European reference populations (Scharlotta *et al.* 2018a).

Ethnographic research might also provide some insight into the foods that could have been consumed during weaning. For example, soft foods such as fats and fish could have been given as well as foods that were pre-masticated by a parent. Jochelson (1908: 757) describes the treatment of children among the Koryak, an indigenous group from Kamchatka in East Russia, and mentions that a child is typically nursed until the age of two to three but is also given reindeer or seal fat at a very early age to suck on. It is also mentioned that if the mother dies early on, the infant will also be killed as artificial feeding is not possible with the means of existence. Reindeer and seal fat could also have been a weaning food for the Cis-Baikal individuals as it is soft and high in fats. During early childhood, post-weaning, diets can also differ from the adult diets as children can, to a certain extent, forage, learn to sustain themselves, and thrive in their environment (Bird and Bliege Bird 2000; Hawkes *et al.* 1995). Children learn through observing their elders or siblings (Kelly 2013), through playing and exploring. They have the ability to figure things out for themselves and decide whether the experience will benefit them. The process of acquiring a certain skillset can either be a specific task such as hunting or fishing, knowing how to track animals in various environments, how to use a specific tool, or simply making clothes and building shelters (Osipov 2018). Knowledge is passed on from one generation to the next. Whether that knowledge is utilized is up to the individual. For instance, the diet may change if an adult role that requires more absence from the home base is adopted.

Strontium analysis of Cis-Baikal faunal and human remains

Strontium isotopic (^{87}Sr/^{86}Sr) analysis has also been conducted using Cis-Baikal faunal samples and a number of individuals examined in this study (Haverkort *et al.* 2008, 2010; Scharlotta and Weber 2014; Weber *et al.* 2003). Strontium is a trace element in the environment that can be used to infer the geographic location of animals and humans (Åberg 1995; Bentley 2006; Ericson 1989). Strontium, an alkaline element in the earth, occurs naturally in the ecosystem with four stable isotopes (^{84}Sr, ^{86}Sr, ^{87}Sr, ^{88}Sr), one of which (^{87}Sr) is also radiogenic (Bentley 2006). In addition to occurring naturally in the environment, the ^{87}Sr isotope can be the by-product of decayed rubidium (^{87}Rb), which happens at a fixed rate over time (Bentley 2006). Since the creation of ^{87}Sr is time-sensitive, each location will have an ^{87}Sr/^{86}Sr based on the age of the sediment formation, erosion factors, the type of rock as well as the amount of rubidium originally present in the geological formations there (Bentley 2006; Ericson 1989). Strontium enters soils, water, and the food chain through the erosion process (Bentley 2006).

Strontium is incorporated into the body through diet and stored in the hydroxyapatite portion of bone and teeth as it operates as a substitute for calcium (Åberg *et al.* 1990). Unlike carbon and nitrogen, there is no measurable isotopic fractionation for $^{87}Sr/^{86}Sr$. This means that $^{87}Sr/^{86}Sr$ values recorded in tissues (i.e. bone and teeth) can be compared to those recorded from environmental markers (e.g. water, plants, faunal bones, soil) to indicate when there are locally or non-locally recorded $^{87}Sr/^{86}Sr$ values. As a result, the $^{87}Sr/^{86}Sr$ recorded in bone and/or teeth can be used as a marker of locality (Haverkort *et al.* 2010: 219), therefore permitting insight into travel patterns related to seasonal movement or migration. However, this is dependent on whether enough time has been allocated for tissue turnover, thus allowing for a change in strontium values. Furthermore, a change in strontium values can occur if food is collected outside of the home range and brought back to the main residential area for shared consumption (e.g. by a small hunting party). This can be misinterpreted as travel by an individual to a region they have not been to through the consumption of non-local food sources (represented in the $^{87}Sr/^{86}Sr$ values) brought back to camp. The geological information provided for each individual in this study will be presented in their respective results chapters.

Summary

Stable isotope analysis of elements such as carbon and nitrogen in bone and teeth can be used to reconstruct diet in the past. The former allows us to distinguish between various plants based on the pathway for photosynthesis, and the latter allows us to distinguish between food choices according to trophic level. Collagen, the targeted structural protein in bone, provides insight into the protein portion of one's diet. However, factors such as physiology and climate can cause isotopic uncertainty and need to be taken into consideration when interpreting the isotopic data. In Cis-Baikal, diet reconstruction has shown that there is dietary variation between individuals from different micro-regions. This is most likely the result of their reliance on the region's aquatic and terrestrial resources to varying degrees, the differences in $\delta^{13}C$ and $\delta^{15}N$ between and within species, and the differences in species and their quantity within each micro-region. Micro-sampling permanent molars for stable carbon and nitrogen isotope analysis on tooth collagen will provide more insights into these dietary differences and changes during childhood and early adulthood. This study will contribute to the biochemical and archaeological interpretation of the Cis-Baikal region and its prehistoric hunter-gatherers.

Chapter 4

Tooth formation

In bioanthropology, the dentition is an excellent source of information regarding health, diet, demography, culture, development, and evolution. This is in part due to a tooth's tough exterior, as the enamel covering the tooth crown makes it more resistant and therefore less susceptible to diagenesis and weathering than bone. The formation of teeth begins in utero, spans childhood, and is completed in early adulthood. This long developmental time is what permits insights into dietary changes during human growth and maturation. This chapter starts with a brief introduction into the anatomy and morphology of teeth. Hereafter, a description of dental development is given, followed by an explanation of how enamel and dentine are formed. Ways to assess the age of developing teeth and the advantages and difficulties that come with it is also explained. Finally, this chapter discusses the importance of using teeth for examining human life history.

Dental anatomy and morphology

Humans and other primates have four types of teeth: incisors, canines, premolars and molars, each with their own morphology (Scott 2008). Each tooth consists of three essential hard tissues: enamel, dentine, cementum, and one soft tissue—pulp (Figure 7). Enamel covers the crown of the tooth, dentine makes up the bulk of the tooth interior, cementum covers the root surface, and the soft pulp chamber contains blood vessels and nerves.

To correctly label each tooth, the dentition is divided into 4 quadrants: upper left, upper right, lower left, and lower right (Hillson 1996). In the deciduous dentition, each quadrant consists of two incisors, one canine, and two molars. In the permanent dentition, each quadrant consists of two incisors, one canine, two premolars, and three molars. The incisors and canines are referred to as the anterior teeth and the premolars and molars are referred to as the cheek teeth. Teeth can further be described based on their position within the mouth. For the anterior teeth, the frontal side is referred to as the labial side and the back (towards the tongue) as the lingual side. The point closest to the middle of the mouth (midline) is the mesial side, and the distal side is furthest away from the midpoint. The top of a tooth is referred to as the occlusal surface and the bottom, which is the root tip(s), the apex.

Teeth are generally divided into two portions, the crown and the root(s). The crown, covered by enamel, is visible when the tooth is situated within the jaw and the roots are embedded in maxilla and mandible. All teeth have cementum on the roots, which is a thin layer that attaches the tooth to the surrounding alveolar bone via fibres known as periodontal ligament (Townsend *et al.* 2015). Teeth also have cusps, which are projections on the occlusal surface of the crown. In molars, normally four or five cusps are present per tooth.

The identification of teeth that are no longer situated within the jaw, as is often the case with archaeological collections, is based on the tooth morphology. All incisors, canines, and premolars (apart from the first maxillary premolar) have one root, whereas molars usually

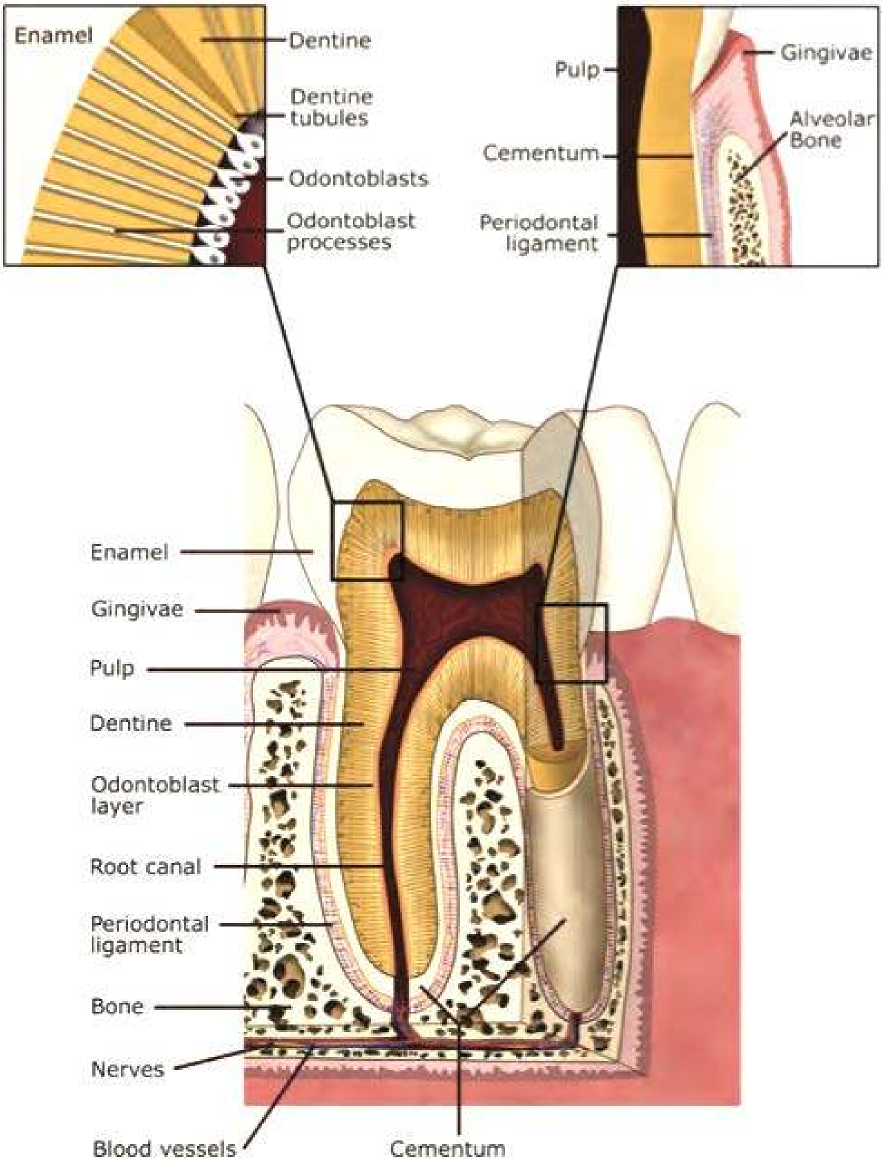


Figure 7. The internal structure of a tooth (Townsend *et al.* 2015: 17).

have two or three roots. In our species, the first molar is normally the largest, followed by the second and the third molars (Hillson 1996). One way of distinguishing molars from one another is by the number of cusps on the occlusal surface. For instance, the upper first molar has four cusps arranged in a diamond (rhombic) shape, whereas the lower first molar has five cusps arranged in a Y-shaped pattern (White and Folkens 2005). However, this becomes difficult if a molar is heavily worn, which is the case for some of the Cis-Baikal teeth. A number of permanent molars from the Ust'-Ilga cemetery could not be properly identified as a result of wear. They have been micro-sampled none the less to examine dietary patterns in the Upper Lena micro-region. Despite not being able to provide a developmental age, the molars will still permit insights into the individual's life history.

Tooth notation

Whenever possible, teeth in the BAP database are described using the Fédération Dentaire Internationale (FDI) tooth system (Fédération Dentaire Internationale 1971). This is a two-digit dental notation used to assign every tooth in the jaw with a specific code. The codes consist of the quadrant and tooth code. The first digit refers to the quadrant, while the second digit refers to the tooth position within the quadrant. For example, an upper right second permanent molar would be noted as 17. However, for this study, teeth have been assigned using a different notation to allow for the identification and siding for readers that might not be familiar with the FDI system. The notation used here is based on dividing the jaws into a left and a right side and denoting each molar with a number in superscript or subscript ranging from one to three (e.g. L M^3 or R M_1). L refers to the left side of the mouth, R refers to the right side of the mouth, and M is the abbreviation for a molar. A superscript number means the tooth is from the maxilla, and a subscript number means the tooth is from the mandible. The numbers 1, 2 and 3 refer to first, second, or third molar. For example, R M^3 is a right third upper molar.

Dental development

In humans, the dentition starts to form around six weeks after conception (Scheuer and Black 2004). Two tissues known as the epithelium and mesenchyme are responsible for this process during embryonic development. The epithelium tissue covers the developing mouth and sits on top of the underlying mesenchyme, which eventually develops into various tissues such as bone, muscle, dentine, cartilage, tendons, and blood vessels (Hillson 1996). During and after the gestation period, the jaws and teeth continue to grow until all permanent teeth have fully developed. Once teeth are formed and mineralized, the $\delta^{13}C$ and $\delta^{15}N$ of primary dentine and $\delta^{13}C$ of enamel do not change (Fuller *et al.* 2003; Nanci 2018). The first teeth to be formed are the first deciduous incisors, which happens around 14–16 weeks post-fertilization, followed by the formation of the second incisors about two weeks later (Hillson 1996). The last teeth to be initiated in utero, right around birth, are the first permanent molars (Hillson 2014). This means that each child will have two sets of dentitions within its jaws: the deciduous and the permanent dentition (Hillson 1996). It takes two to three years for each deciduous tooth to form and eight to 12 years for each permanent tooth (Scheuer and Black 2004). While there is intra and inter-individual variation regarding the timing of tooth eruption, the emergence of each deciduous and permanent tooth generally follows a set sequence that is largely controlled genetically. Deciduous teeth are shed once the permanent teeth start pushing their way through the gingiva, normally starting with the upper central incisors and ending with the third molars.

Enamel formation

Although the focus of this study is on dentine, enamel formation is briefly discussed as it happens in conjunction with dentine development. Tooth enamel is a white mineral substance which overlays the crown portions of teeth. It is a glassy and shiny opaque (sometimes semi-translucent) layer that protects the underlying structure of the tooth. The bulk of enamel is constructed of a mineral known as hydroxyapatite, with only a small portion consisting of organic material and water (Antoine and Hillson 2016). The enamel is deposited by cells known as ameloblasts during a process referred to as enamel formation or amelogenesis. This process begins with the deposition of the enamel matrix (the matrix secretion stage), followed by mineralization through the break down of the organic component within the matrix (the maturation stage) (Hillson 1996). Once enamel is formed, the chemical composition remains unchanged throughout life; in contrast to bone, it is not remodelled (Nanci 2018).

During the development of the crown, enamel and dentine first develop along the enamel-dentine junction (EDJ), where ameloblasts move away from the EDJ and secrete the enamel matrix (Antoine and Hillson 2016). For enamel, the initiation begins at the top of each incisal edge or cusp, followed by moving down the sides of the crowns (Antoine and Hillson 2016; Hillson 1996, 2014). Although this matrix is partially mineralized during the initial secretion phase, the process is continued and completed during the maturation phase (Antoine and Hillson 2016). The deposition of enamel and dentine is marked by incremental structures that can be seen microscopically as short (circadian), and long (circaseptan) period lines (Fitzgerald 1998, Hillson 2014). In enamel, these lines are referred to as prism cross-striations and striae of Retzius (Hillson 1996). The short lines are rhythmic changes in the production of enamel and fall between the striae of Retzius (Smith *et al.* 2003), the latter being deposited every six to 10 days (Dean and Scandrett 1996). The periodicity of these lines allows for a deposition time of enamel to be calculated.

Dentine formation

Dentine, which forms the bulk of a tooth, is softer than enamel as it contains organic material as well as mineral. It lies directly below the enamel and is normally yellow in colour. There are three types of dentine in human teeth:

1. Primary dentine, which is formed during tooth formation;
2. Secondary dentine, which is a continued secretion of dentine in the pulp chamber once the tooth has already been formed;
3. and Tertiary dentine, which is laid down as a response to tooth trauma (Zilberman and Smith 2001). Therefore, dentine has the ability to repair itself (Smith *et al.* 1995).

Dentine formation, or dentinogenesis, begins at the EDJ and is secreted and mineralized in a two-phase process by cells known as odontoblasts (Hillson 1996). A pre-dentine matrix is first deposited, which will eventually mineralize into mature dentine as non-collagenous proteins are introduced at the mineralization front (Nanci 2018; Tang *et al.* 2016). This mineralization front follows the same path as the deposition front, mineralizing the dentine in about three to eight days (Beaumont *et al.* 2018).

Dentine further consists of dentinal tubules, which are small tube-like structures, that are the result of odontoblasts moving from the EDJ toward the pulp chamber (Tang *et al.* 2016) and which form a network for the dispersion of nutrients (Nanci 2018). The dentinal tubules are lined by peritubular dentine, a matrix with few collagen fibrils (Hillson 1996; Tang *et al.* 2016). Aside from peritubular dentine, there are two other types of dentine matrix. Mantle dentine, which is deposited first (Hillson 1996) and separates the enamel from the intertubular (circumpulpar) dentine, which makes up the bulk of the tooth. Intertubular dentine is also found between the dentinal tubules (Hillson 2014). Multiple studies have shown the growth rate to be quite variable throughout a tooth (Dean 2009; Dean and Scandrett 1995; Dean *et al.* 1993). According to Dean and Scandrett (1995), the dentine in a permanent tooth is deposited at 3.8µm a day throughout the cuspal areas and 1.3–1.5µm a day in the cervical region, with the fastest growth rate in the apical portion of the roots at 4–6µm a day.

Dentine is further divided into coronal and root dentine (Smith 2008). The way dentine is deposited throughout a tooth is not entirely linear. In the coronal portion, the dentine is deposited horizontally. Figure 8 shows the incremental growth lines (Andresen lines), which are only visible microscopically (Kawasaki *et al.* 1980). The formation of root dentine starts from the cementodentinal junction (CDJ). The closer the dentine moves towards the pulp chamber and the roots; the more dentine is deposited at an angle. This oblique deposition of dentine complicates the sampling and ageing of each increment. As micro-sampling is done by slicing 1mm horizontal sections from crown to root, each micro-sample contains a portion of dentine from at least two, sometimes more, adjacent increments. This will cause sections to be more time-averaged, particularly in the roots.

Dental maturation

Formation, initiation, and completion

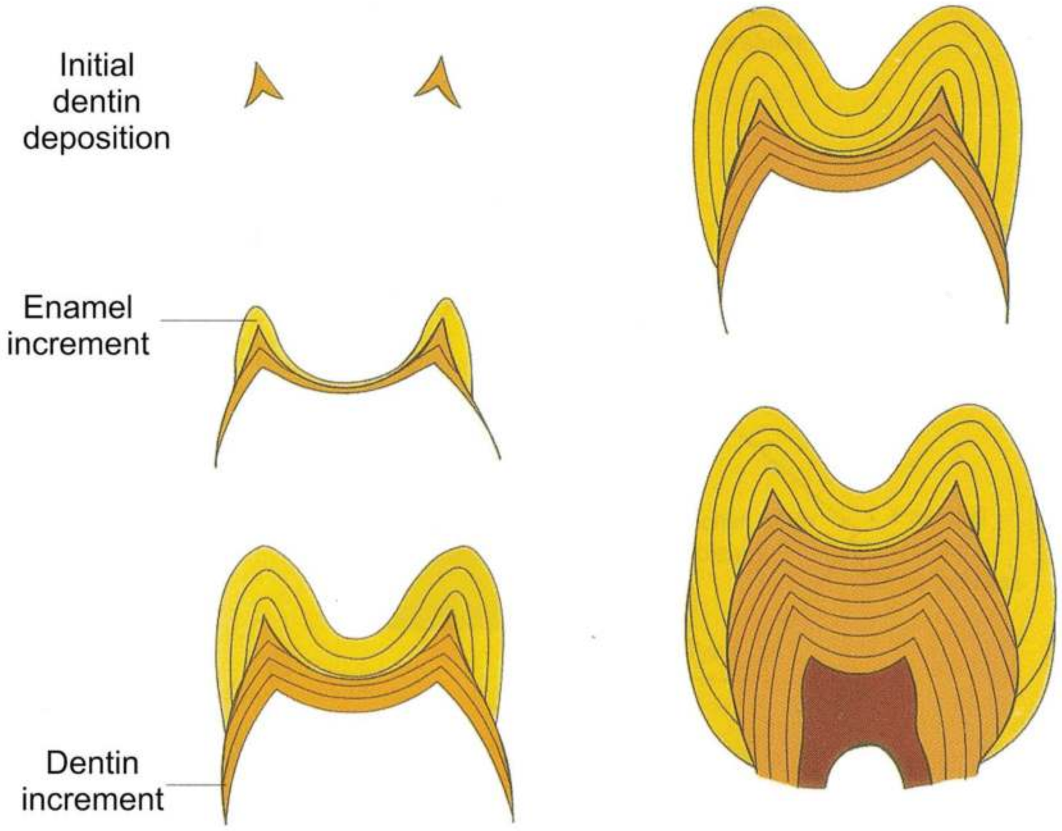


Figure 8. Dentine and enamel secretion in a mammalian tooth (Piesco and Avery 2002: 91).

Hillson (2014: 32) describes four key events in the development of every single tooth:

1. Initiation of the crown: the age at which the secretion of enamel and dentine commence.
2. Crown completion: the age at which matrix secretion is complete.
3. Tooth eruption: the age at which the tooth emerges.
4. Apex closure: the age at which root development is complete.

Hillson (2014) further mentions that none of these key events are sharply defined. The variation between and within individuals will cause differences in eruption and completion times. In addition, for the third key event, tooth eruption, it is important to note that tooth emergence through gingiva is not equal to emergence through the alveolar bone (Liversidge 2008). Meaning, the eruption timing in a living individual will not be the same for the emergence that is seen in dry (archaeological) samples.

Age-assessment methods

Numerous studies have examined the dentition of children of known age to estimate dental eruption in relation to chronological age (e.g. AlQahtani *et al.* 2010; Demirjian *et al.* 1973; Gustafson and Koch 1974; Haavikko 1970; Moorrees *et al.* 1963; Schour and Massler 1941a, 1941b; Willems *et al.* 2001). Dental charts and atlases have been created for the identification of distinct stages in tooth growth in living as well as deceased individuals by displaying the formation stages of crowns and roots over time. Chronological age may be estimated by evaluating progress in tooth development.

A frequently used method for tooth age-assessment in anthropology is based on radiography, an imaging technique using x-rays of the upper and lower jaws. This non-invasive and non-destructive method, although time-consuming, allows for the examination of features such as tooth growth, eruption, crown completion, root resorption, and the size of the pulp chamber. A depiction of the various tooth developmental stages, which is based on radiographs, is referred to as the atlas approach (Willems *et al.* 2001).

The age-assessment model used in this research is referred to as the London Atlas (AlQahtani *et al.* 2010). This atlas is based on the examination of dental radiographs of living individuals of European and Bangladeshi ancestry as well as the Spitalfields skeletal collection housed at the Royal College of Surgeons of England and the Natural History Museum in London, England. The Spitalfields collection is a well-documented assemblage from a large cemetery in London, England, where individuals were interred between 1729 and 1852 (Molleson *et al.* 1993). The sex and exact ages of the individuals have been identified through the presence of written documentation, allowing for dental development to be compared with living individuals of the same sex and age, thus providing a comprehensive atlas with greater accuracy. The atlas has 31 dental development stages ranging from 28 weeks in utero to 23.5 years of age. Therefore, the London atlas (AlQahtani *et al.* 2010) includes age estimations for dentition as early as infancy. This is particularly beneficial for the present research as the first permanent molars (M1) start to form right around birth. Early dental ages are not always present in other age-assessment models (e.g. Haavikko 1970; Moorrees *et al.* 1963) and cannot provide an age estimation for the development of the M1. Without this, it would not be possible to estimate the onset and timing of the weaning period, an important event in an individual's life. Finally, the atlas is designed for application to large samples as it looks at the entire dental arcade rather than a few individual teeth.

For the AlQahtani atlas, the developing teeth of 72 prenatal remains and 104 postnatal remains were examined. Age-at-death is known for all individuals, with 91 males, 72 females, and 13 individuals of unknown sex. Data were also collected from living individuals with the use of dental radiographs. For this, a total of 528 individuals were examined: 264 males and 264 females.

The reasons for choosing this atlas are to calculate the age represented per increment (described in Chapter 5), because the atlas was used successfully for several published micro-sampling studies (Beaumont and Montgomery 2015, 2016; Beaumont *et al.* 2013a; van der Sluis *et al.* 2015), and because the atlas is in large part based on the development of healthy individuals.

Advantages and disadvantages of using age-assessment charts

There are several benefits to using dental atlases for age-assessment. First, as mentioned, teeth are generally more durable than bone and there is less chance of destruction. Second, it allows for age estimation in young individuals (Cardoso 2007a) as teeth are less susceptible to growth disruptions (e.g. stunting), and therefore are a better indicator of chronological age (AlQahtani *et al.* 2010; Elamin and Liversidge 2013; Smith 1991). Third, the dental assessment charts are commonly used by anthropologists which often allow for the comparison between individuals and populations. Nonetheless, the latter is also considered to be a limitation. While teeth are less variable than other skeletal features, there are still differences between and within populations regarding tooth initiation and growth. Many of the studies have focused on Caucasian European populations. As a result, these modern populations may not accurately reflect the dental growth patterns of prehistoric hunter-gatherer groups as they differ genetically.

Furthermore, most charts are based on radiographs, which also come with a few disadvantages. Only when enamel and dentine are sufficiently mineralized are teeth entirely visible on radiographs (Hillson 1996). This means that if teeth are still in the mineralization phase, whether it be the crown or roots, it can be difficult to define the stage of development properly and this can lead to a substantial inter-observer error. Therefore, the age given for a molar based on a dental chart might not fully comply with the actual developmental stage of the tooth. In addition, the timing of crown initiation and the earliest phases of tooth development have not yet been accurately defined.

One chart that was frequently used by anthropologists in the past, and was the basis for some later charts (e.g. Ubelaker 1987), is that of Schour and Massler (1941a, 1941b). This chart divides dental development into 22 stages, starting at five months in utero and leading up to 35 years. However, it has been said that the chart is possibly based on a previous study by Logan and Kronfeld (1933) who used the dentition of terminally ill children to create their age assessment model (Hillson 1996). Although dental development is said not to be significantly affected by malnutrition (Elamin and Liversidge 2013), there is a certain degree of developmental delay in particular cases (Cardoso 2007b; Conceição and Cardoso 2011; Gaur and Kumar 2012). Potentially, this could have affected the age estimates of children who suffered from some form of malnutrition due to socioeconomic or environmental stressors. This could have been the case for the Logan and Kronfeld (1933) study as it is based on the dentition of terminally ill children (Hillson 1996).

Using the dentition for examining human life history

Enamel and dentine have become important tissues for examining human and non-human life histories. Life history theory, a framework which falls under the umbrella of evolutionary ecology, aims to explain how evolutionary forces influence and shape the survival, reproduction, and overall fitness of organisms when encountering environmental challenges (Stearns 1992). Life history theory offers evolutionary explanations for the timing of certain events. Some examples of such biological events are birth, weaning, maturation (childhood), sexual maturity, menopause, and longevity. Cultural examples may include participation in specific ceremonial events, becoming a parent, and marriage. While life-history theory was initially developed to examine non-human animals (Stearns 1992), it is now widely applied to the study of events in human and non-human primates (Austin *et al.* 2013; Dean 2006; Fuller *et al.* 2003; Hill and Kaplan 1999; Smith 2008; Smith *et al.* 2017). Compared to other primates, modern humans differ in gestation length, the timing of weaning, childhood length and development, reproduction, and longevity (Bogin and Smith 2000; Smith 2013; Smith *et al.* 2017). Recent studies on biochemical markers in dentine are leading to new ways of examining the timing of life-history events such as breastfeeding and weaning (Beaumont *et al.* 2013a; Burt and Amin 2014; Burt and Garvie-Lok 2013; Fuller *et al.* 2003; Tang *et al.* 2016). Applying such methods to Cis-Baikal hunter-gatherers that lived into adulthood allows for the examination of early life-history events that are non-visible in bone.

Summary

The known rate of development and eruption of teeth allow anthropologists to examine the growth processes of past and present populations. As the formation of the permanent teeth spans infancy, childhood, and early adulthood, they have become very useful for estimating growth and maturation. This also brings with it a number of challenges. While variations in and between individuals cause difficulties, teeth are a more reliable source of biological age than bone as they are impacted much less by stressors (Cardoso 2007b; Conceição and Cardoso 2011; Elamin and Liversidge 2013). The composition and structure of the main tooth tissues, enamel and dentine, reveal not only information on the sequence of developmental events, but also permit insights at the biochemical level. This has led to the development of exciting novel techniques such as micro-sampling. Life history information such as age, weaning, stress, migration, and even death can be provided just by examining such a small portion of an individual.

Chapter 5

Materials and methods

The materials and laboratory methods utilized for examination of dietary patterns among the Cis-Baikal hunter-gatherers are outlined in this chapter. First, the selection process for the materials is summarized, followed by the protocol to document each tooth. Then, all laboratory procedures are described in detail, followed by how collagen quality is assessed. Finally, the procedure used for calculating the chronology of each increment is explained.

Materials

The teeth used for this study (Table 3) come from six cemeteries within the Cis-Baikal region. Each individual has received a corrected radiocarbon date after the discovery of a Freshwater Reservoir Effect (Weber *et al.* 2016). The cemeteries, described in Chapter 2, lie within three of the four archaeological micro-regions: The Little Sea area, The Angara valley, and The Upper Lena valley. With the exception of six individuals, all other (n=43) burials have been dated by radiocarbon. The majority of examined cases belong to the Early Bronze Age (*c. 4700–3700* cal BP), a few from the Ust'-Ida I cemetery date to the Late Neolithic (*c. 5600-4700* cal BP), and one individual from the Manzurka cemetery belongs to the Early Neolithic (*c. 7500-7000* cal BP).

Table 3. Teeth of Cis-Baikal Middle Holocene hunter-gatherers selected for this study. L = Left; R = Right; $M^{1,\,2\text{ or }3}$ = Upper 1st, 2nd or 3rd molar; $M_{1,\,2\text{ or }3}$ = Lower 1st, 2nd or 3rd molar.

Master ID	Sample ID	Cemetery	Micro-region	Period	Tooth type	Sex	Age (yrs)	^{14}C date
K14_1997.011	H1997.224	Khuzhir-Nuge XIV	Little Sea	EBA	R M^3	M	35–50	3518±61
K14_1997.012	H1997.191	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	25–35	3523±61
K14_1997.012	H1997.214	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	U	25–35	3523±61
K14_1997.012	H1997.225	Khuzhir-Nuge XIV	Little Sea	EBA	L M_3	U	25–35	3523±61
K14_1997.014	H1997.215	Khuzhir-Nuge XIV	Little Sea	EBA	L M^2	PM	35–50	3499±61
K14_1997.015	H1997.227	Khuzhir-Nuge XIV	Little Sea	EBA	L M_3	M	25–35	3715±60
K14_1997.016	H1997.194	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	7.5–9.0	3380±61
K14_1997.019	H1997.219	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	F	35–50	3593±61
K14_1997.019	H1997.229	Khuzhir-Nuge XIV	Little Sea	EBA	L M_3	F	35–50	3593±61
K14_1998.035.02	H1998.359	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	U	8.0–10	3552±61

Master ID	Sample ID	Cemetery	Micro-region	Period	Tooth type	Sex	Age (yrs)	^{14}C date
K14_1998.036.01	H2003.646	Khuzhir-Nuge XIV	Little Sea	EBA	R M_1	U	35–50	3582±60
K14_1998.037.02	H1998.372	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	14–17	3538±56
K14_1998.038	H1998.376	Khuzhir-Nuge XIV	Little Sea	EBA	L M^1	M	35–50	3618±60
K14_1998.038	H1998.377	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	M	35–50	3618±60
K14_1998.039	H1998.379	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	9.0–11	3509±61
K14_1998.039	H1998.380	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	U	9.0–11	3509±61
K14_1999.044	H1999.163	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	M	35–50	3392±61
K14_1999.044	H1999.164	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	M	35–50	3392±61
K14_1999.044	H1999.165	Khuzhir-Nuge XIV	Little Sea	EBA	R M^3	M	35–50	3392±61
K14_1999.045	H1999.156	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	8.0–10	3540±59
K14_1999.045	H1999.157	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	U	8.0–10	3540±59
K14_1999.046	H1999.130	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	M	25–35	3527±61
K14_1999.051	H1999.134	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	M	18–20	3645±61
K14_1999.051	H1999.135	Khuzhir-Nuge XIV	Little Sea	EBA	L M_2	M	18–20	3645±61
K14_1999.057.02	H2001.645	Khuzhir-Nuge XIV	Little Sea	EBA	L M^2	M	35–50	3639±59
K14_2000.063	H2000.141	Khuzhir-Nuge XIV	Little Sea	EBA	L M^1	U	16–18	3529±62
K14_2000.063	H2000.143	Khuzhir-Nuge XIV	Little Sea	EBA	L M^3	U	16–18	3529±62
K14_2000.064	H2000.126	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	M	25–35	3637±61
K14_2000.064	H2000.128	Khuzhir-Nuge XIV	Little Sea	EBA	L M_3	M	25–35	3637±61
K14_2000.077	H2000.166	Khuzhir-Nuge XIV	Little Sea	EBA	L M_1	U	12–15	3776±56
MNZ_1974.002	H2000.224	Manzurka	Upper Lena	EN	R M_1	U	14–19	6206±133
MNZ_1974.002	H2000.225	Manzurka	Upper Lena	EN	R M_2	U	14–19	6206±133
MNZ_1974.002	H2000.226	Manzurka	Upper Lena	EN	R M_3	U	14–19	6206±133
OBK_1971.005	H2000.216	Obkhoi	Upper Lena	EBA	R M_1	U	20	3608±51
OBK_1971.005	H2000.218	Obkhoi	Upper Lena	EBA	R M_3	U	20	3608±51
OBK_1971.007	H2000.209	Obkhoi	Upper Lena	EBA	L or R M_1	U	20	3852±50
OBK_1971.007	H2000.210	Obkhoi	Upper Lena	EBA	L or R M_2	U	20	3852±50
OBK_1971.013	H2000.212	Obkhoi	Upper Lena	EBA	R M_1	U	20	4021±51
OBK_1971.013	H2000.213	Obkhoi	Upper Lena	EBA	L M_1	U	20	4021±51

Master ID	Sample ID	Cemetery	Micro-region	Period	Tooth type	Sex	Age (yrs)	^{14}C date
SHM_1972.002	H2000.206	Shamanskii Mys	Little Sea	EBA	R M^2	M	36–55	3634±43
SHM_1972.002	H2000.207	Shamanskii Mys	Little Sea	EBA	R M^3	M	36–55	3634±43
SHM_1975.001	H2000.201	Shamanskii Mys	Little Sea	EBA	L M^1	M	20–35	3634±43
UID_1987.006	H2001.530	Ust’-Ida I	Angara	LN	L M^3	M	35–50	4641±71
UID_1987.006	H2001.532	Ust’-Ida I	Angara	LN	R M^1	M	35–50	4641±71
UID_1987.011	H2001.533	Ust’-Ida I	Angara	LN	R M_3	F	35–50	4701±70
UID_1987.011	H2001.534	Ust’-Ida I	Angara	LN	L M_2	F	35–50	4701±70
UID_1987.011	H2001.535	Ust’-Ida I	Angara	LN	L M_1	F	35–50	4701±70
UID_1988.014	H2001.517	Ust’-Ida I	Angara	LN	L M^1	M	18–20	4774±71
UID_1988.014	H2001.518	Ust’-Ida I	Angara	LN	L M_3	M	18–20	4774±71
UID_1989.019	H2001.524	Ust’-Ida I	Angara	EBA	R M_3	M	30–35	4284±71
UID_1989.019	H2001.525	Ust’-Ida I	Angara	EBA	R M_1	M	30–35	4284±71
UID_1989.020.01	H2001.419	Ust’-Ida I	Angara	LN	R M_3	M	18–24	4584±71
UID_1989.020.01	H2001.420	Ust’-Ida I	Angara	LN	R M_1	M	18–24	4584±71
UID_1989.020.02	H2001.415	Ust’-Ida I	Angara	LN	R M_1	F	30–40	4655±75
UID_1989.020.02	H2001.416	Ust’-Ida I	Angara	LN	R M_2	F	30–40	4655±75
UID_1989.020.02	H2001.417	Ust’-Ida I	Angara	LN	R M_3	F	30–40	4655±75
UID_1989.022	H2001.499	Ust’-Ida I	Angara	LN	L M_3	F	15–20	4543±71
UID_1989.022	H2001.501	Ust’-Ida I	Angara	LN	L M_1	F	15–20	4543±71
UID_1989.029	H2001.488	Ust’-Ida I	Angara	EBA	R M_3	M	50	3822±71
UID_1989.030	H2001.496	Ust’-Ida I	Angara	LN	R M_3	M	50	4750±72
UID_1989.030	H2001.498	Ust’-Ida I	Angara	LN	R M_1	M	50	4750±72
UID_1991.038	H2001.558	Ust’-Ida I	Angara	LN	L M_1	M	45–60	4670±75
UID_1991.038	H2001.560	Ust’-Ida I	Angara	LN	L M_3	M	45–60	4670±75
UID_1993.045	H2001.345	Ust’-Ida I	Angara	EBA	L M_1	M	22–30	3738±72
UID_1993.045	H2001.346	Ust’-Ida I	Angara	EBA	L M_3	M	22–30	3738±72
UID_1994.048	H2001.481	Ust’-Ida I	Angara	EBA	R M_1	M	50	3437±71
UID_1994.048	H2001.483	Ust’-Ida I	Angara	EBA	R M_3	M	50	3437±71
UID_1995.056.01	H2001.456	Ust’-Ida I	Angara	LN	R M_1	M	35–50	4680±73
UID_1995.056.01	H2001.458	Ust’-Ida I	Angara	LN	R M_3	M	35–50	4680±73
UIL_1989.001	H2016.015	Ust’-Ilga	Upper Lena	EBA	R M^2	F	25–30	3870±49
UIL_1989.002	H2016.018	Ust’-Ilga	Upper Lena	EBA	M	n/a	n/a	n/a
UIL_1989.003	H2016.020	Ust’-Ilga	Upper Lena	EBA	M	M	40–45	3917±50
UIL_1989.004	H2016.022	Ust’-Ilga	Upper Lena	EBA	M3	U	35	3872±49
UIL_1989.005	H2016.014	Ust’-Ilga	Upper Lena	EBA	M2 or M3	n/a	n/a	n/a
UIL_1990.009	H2016.007	Ust’-Ilga	Upper Lena	EBA	M3	M	20–25	3550±49
UIL_1990.010	H2016.028	Ust’-Ilga	Upper Lena	EBA	R or L M^2	M	20	4164±50
UIL_1990.011	H2016.010	Ust’-Ilga	Upper Lena	EBA	L M^1	n/a	n/a	n/a
UIL_1990.012	H2016.030	Ust’-Ilga	Upper Lena	EBA	L M_1	n/a	n/a	n/a
UIL_1991.013.01	H2016.032	Ust’-Ilga	Upper Lena	EBA	R M^1	n/a	n/a	n/a
UIL_1991.013.02	H2016.009	Ust’-Ilga	Upper Lena	EBA	L M^1	n/a	n/a	n/a

Material preservation

The skeletal and dental preservation at these six sites is highly variable. Although some molars were selected based on their condition (e.g. presence of crown and roots, little fracture), most of the samples were selected based on what was available for destructive analysis. Each tooth is stored separately and has been assessed, described, and sided by the project's bioanthropologists. However, for this research, each tooth was examined again to confirm these assessments, and stages of wear have been now also recorded for each molar. This is described later in this chapter. When possible, the skeletons were also assigned age and sex by the project's bioanthropologists according to the methods of Buikstra and Ubelaker (1994).

Selection and documentation of the materials

Prior to this study, data were collected and organized in the project's database, which includes information on burial site, grave type, skeletal preservation, and identification of the element (e.g. first left molar). In addition, for this research, photographic documentation was made with a Nikon D800 camera at the University of Alberta. Each tooth was photographed in colour from six views: buccal, lingual, mesial, distal, apical, occlusal. Additionally, six images of each tooth were taken at 10× magnification using a Keyence VHX-2000 digital microscope at the Department of Anthropology, University of Alberta. While the macro photos will be useful for general documentation and possible future publications, the micro photos can be used to examine dental wear and allow for measurements to be taken.

Teeth that had little to no wear, intact roots and no signs of calculus were used for creating two negative moulds. For this, dental putty was used to make a base, followed by covering the enamel portion of the tooth, including the cementum enamel junction (CEJ), with silicone-based impression material. Teeth were left to dry for roughly 10 minutes until they were removed from the impression material, leaving behind a negative mould (imprint) of the crown. Negative molds allow for the creation of casts, the positive replica of the original tooth, which can be used for future studies focusing on the surface of the enamel.

Methods

After photographic documentation, the teeth were examined for calculus, which is calcified dental plaque (also known as tartar). Calculus has proven to be a useful substance for dietary analysis (van der Sluis *et al.* 2015). A recent discovery (Ozga *et al.* 2016) has shown ancient human mitochondrial DNA can sometimes be extracted from it. The calculus of some of the Cis-Baikal teeth was removed with a dental probe and stored in a labelled micro vial for potential future analysis. The majority of the teeth did not have calculus.

Each tooth was cleaned by either placing it in an ultrasonicator or a sandblasting chamber (Bego Duostar). For the ultrasonicator, each tooth was put inside a labelled beaker filled with double distilled water (ddH_2O) for 20 minutes and air-dried for 24 hours. For the sandblaster, each tooth was placed inside a chamber and cleaned with the use of two fine-jet pencils. This is a commonly used tool in dentistry to smooth, shape, and clean surfaces of ceramic crowns. Each jet releases fine sand at a high velocity, cleaning the tooth by means of abrasion. This technique is only suitable for strong and intact teeth. No drying was needed afterwards. Once cleaned, teeth were sectioned longitudinally using a Dremel handheld tool with a diamond wheel saw. Following Beaumont *et al.* (2013a, 2013b), the longest root (measured from CEJ to apex) was selected for this study. Depending on the tooth's preservation, occasionally an enamel spall was collected by cutting a section from the top of the crown to the CEJ. The enamel spalls will be used by the BAP in the near future for additional studies. The pulp cavity of each tooth was cleaned with a small dental burr or with the sandblaster to remove any secondary dentine. Roots were also cleaned with a dental burr or sandblaster to remove cementum.

Assessment of molar wear

The wear of each molar was assessed using Smith's (1984) eight stages of wear (Table 4). The diagrams and descriptions given by Smith provide a standardized way of recording tooth wear. This measurement is based on the examination of modern and prehistoric hunter-gatherer and agriculturalist dentition. The micro photos, that provide six close-up views per molar, allow easy comparison between individuals from different cemeteries in order to provide scoring consistency throughout the entire assemblage. While Smith's wear stages allow for systematic assessment of all molars, this approach is subjective as the scoring relies on the judgement of the evaluator. This issue is inherent to all qualitative scoring systems. Wear was examined for tooth documentation as well as assessing whether the assigned ages of the first forming increments would have been affected. All photos of the occlusal surfaces of the molars used in this study are provided in Appendix A. The wear assessment of the individuals is presented in Appendix B.

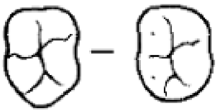
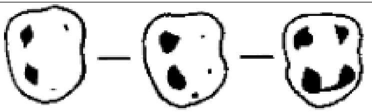
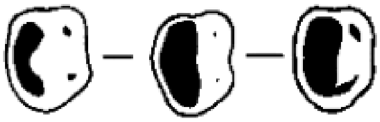
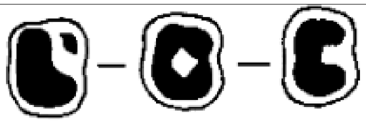
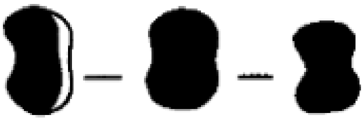
Demineralization

Collagen was isolated from the tooth by first removing the mineral content by soaking it in hydrochloric acid (HCl). HCl demineralizes teeth, removing any remaining minerals (e.g. enamel), and making the remaining portion of the tooth softer in structure—an almost rubber-like consistency. A concentration of 0.5M HCl was used on well-preserved teeth and 0.3M HCl for the fragile teeth from Khuzhir-Nuge XIV. Both 0.3M and 0.5M HCl are considered low concentrations. While anything higher than 0.5M will speed up the process of demineralization, it will also increase the risk of degradation of the archaeological tooth material. The HCl solution was changed every other day. The time it took to demineralize half a tooth depended on tooth preservation and ranged anywhere between 12 and 21 days. The dentine, or collagen pseudomorph, remained its original size and shape. If bone or tooth preservation is good, a pseudomorph will preserve its structural integrity because the collagen chains are still bonded (Sealy *et al.* 2014). After demineralization, the teeth were rinsed in double-distilled water (ddH$_2$O) three times and left to soak for 24 hours to remove the remaining chemical.

Micro-sampling dentine

Each tooth was sectioned longitudinally following Method 2 by Beaumont *et al.* (2013a, 2013b). Samples H2001.415 and H2001.417, both belonging to the same individual (UID_1989.020.02) from Ust'-Ida I, were sectioned differently. These two samples were also cut longitudinally (crown to root), but along the mesial and distal side, cutting through two roots as was done

Table 4. Molar wear stages and descriptions according to Smith (1984: 45–46).

Wear stage	Description of wear	Diagrams of the occlusal surface (lower molars)
0	Tooth is missing or cannot be coded.	**n/a**
1	Unworn to polished or small facets (no dentine exposure).	
2	Moderate cusp removal (blunting). Thin enamelled teeth (human deciduous molars, chimpanzee molars) may show cusp tip dentine but human permanent molars show no more than one or two pinpoint exposures.	
3	Full cusp removal and/or some dentine exposure, pinpoint to moderate.	
4	Several large dentin exposures, still discrete.	
5	Two dentinal areas coalesced.	
6	Three dentinal areas coalesced, or four coalesced with enamel island.	
7	Dentine exposed on entire surface; enamel rim largely intact.	
8	Severe loss of crown height, breakdown of enamel rim; crown surface takes on the shape of roots.	

by Scharlotta *et al.* (2018b). The reason for this was to compare what method was easiest for slicing the dentine and removing secondary dentine. Method 2 by Beaumont *et al.* (2013a, 2013b) proved to be the least complicated.

For sectioning, each dentine sample was placed on a non-slip cutting board covered with parafilm and placed next to ruler. Then, 1mm sections were cut with a handheld scalpel. Each such section was placed in a labelled micro vial containing the sample number and section number. After each cut, the scalpel was cleaned with ethanol to avoid inter-sample contamination. The earliest forming dentine section was labeled as S-01 while the last forming dentine section (the root tip) was labelled with the last number (e.g.: S-12). The lowest and highest number of sections per tooth were four and 18, respectively, with 12 the average, depending on the preservation, size, and development stage of the tooth.

Removal of soil humates

After sectioning, dentine micro-samples were soaked in sodium hydroxide (0.125M NaOH) to remove any soil humates (Ambrose 1990; Chisholm *et al.* 1983). Humates are organic substances that can be taken up through the soil and have the ability to alter the $\delta^{13}C$ in a sample (Katzenberg *et al.* 1995; Liden *et al.* 1995). NaOH is a frequently used additive for purifying collagen prior to hydrolyzing it for stable isotope analysis.

NaOH was first applied to one tooth (M1 from individual MNZ_1974.002) in a trial-run, alongside five modern teeth which had been donated by a local dentist in Edmonton, Canada. The reason for this trial run was to test this approach prior to processing all archaeological teeth. However, after inspecting all micro-sampling studies conducted on human teeth, it appeared that the majority of these studies (Beaumont and Montgomery 2016; Beaumont *et al.* 2013a, 2013b; Burt and Amin 2014; Fuller *et al.* 2003; Henderson *et al.* 2014; Sandberg *et al.* 2014; van der Sluis *et al.* 2015) did not apply an NaOH soak, or ultra-filtration, to remove soil humates. As mentioned previously, this is a necessary step to remove humates from the sample as it can alter the $\delta^{13}C$. While these studies do not mention their reason for not employing this step, it is reasonable to assume they have a concern about the loss of collagen in already very small samples. Therefore, an experiment which involved altering the soaking time of NaOH became the second goal of this trial run. The time was changed from the commonly used 20 hours (Boutton *et al.* 1984; Katzenberg 1989), to six hours. This altered treatment time is considered usual practice for fragile samples at the University of Alberta's bioarchaeology laboratory.

The modern specimens (named VPS 1, 2, 3, 4, 5) served as control as their intact and unburied dentine was not at risk of damage from the standard 20-hour soak. Two of the samples, VPS 1 and VPS 2 were an upper and a lower M3 belonging to the same individual. VPS 3 (M_2), VPS 4 (M^2), and VPS 5 (a damaged M1 fragment – siding unknown) came from three additional individuals. The prehistoric M_1 comes from an Early Neolithic individual (*c. 7500 to c. 7000* cal BP) from the Manzurka cemetery in the Upper Lena valley. All six teeth were sectioned longitudinally with a Dremel handheld diamond blade saw. For the Manzurka tooth, the distal root was selected for micro-sampling because the mesial root was broken post-mortem at its apex. Results, which have been published (van der Haas *et al.* 2018), showed all micro-samples passed several quality assessments, indicating the collagen is of good quality and has not been altered. The significance of this will be discussed later.

A second trial run was carried out on two teeth from Khuzhir-Nuge XIV (H2003.646 and H1998.379), as samples from this cemetery are most poorly preserved and thus perhaps the most susceptible to diagenesis. Sample H2003.646 (Image 37, Appendix A) was classified as a well-preserved tooth and H1998.379 (Image 40a, Appendix A) as a poorly preserved tooth based on macroscopic assessment. Both teeth were subjected to a soak in 0.5M HCl, which was changed every other day, followed by a 0.125 M NaOH soak of six hours. Interestingly, tooth H2003.646 demineralized faster, only needing 10 days while tooth H1998.379 took 14 days and appeared to have more firmness. Even though both teeth provided a sufficient amount of collagen, it was decided to lower the HCL to 0.3M for the remaining Khuzhir-Nuge XIV samples in order to slow down the demineralized process. After applying the six hour soak to the additional teeth from Cis-Baikal, it can be concluded with confidence that this adjustment to a commonly used method for the removal of soil humates from bone collagen will suffice for removing humates from dentine micro-samples from poorly preserved archaeological teeth. A full description of this experiment is provided in van der Haas *et al.* (2018).

Isolating collagen

There are several methods to isolate collagen for stable isotope analysis (Brown *et al.* 1988; Longin 1971; Sealy 1986; Tuross *et al.* 1988), also known as solubilization. Although methods differ from one another, all isolate collagen through the removal of minerals and impurities. Dentine samples were prepared using a modified Longin Method (Longin 1971). For this, each micro-sample was submerged in PH_3 acidulated ddH_2O and placed in a hot water bath for 48 hours at 80°C. During this slow hydrolysis process, collagen is extracted from bone or tooth. Once removed from the water bath, samples were centrifuged in an Eppendorf Centrifuge at 6500 rmp at 21°C for 15 minutes before the supernatant was drawn off and transferred to a new vial. Vials were placed inside a freezer prior to lyophilization (freeze-drying) which was carried out at the University of Alberta, Biochemical Analytical Service Laboratory, under the direction of Mr. Alvin Kwan and Dr. Mingsheng Ma. Lyophilization removes all water from the frozen sample leaving only the collagen.

The purified collagen was weighed on a microbalance and about 1.0mg per micro-sample was packed into a tin capsule for analysis. Micro-samples that failed to yield the required amount were sometimes combined with an adjacent micro-sample, therefore doubling the approximate age represented per slice. This happened in two cases. At other times micro-samples provided no result either due to no collagen or an instrumental error. This happened in 16 cases. All samples were analyzed for $\delta^{15}N$ and $\delta^{13}C$ at the Biogeochemical Analytical Service Laboratory, University of Alberta, using a EuroVector EuroEA3028-HT elemental analyzer coupled to a GV Instruments IsoPrime continuous-flow isotope ratio mass spectrometer. NIST 8415 whole egg powder SRM was used as an in-house $\delta^{15}N$ and $\delta^{13}C$ QA/QC check throughout analyses, with instrumental errors of ±0.2‰ and ±0.1‰ respectively. The dentine collagen micro-samples are expressed using the delta notation (δ/Δ) in parts per thousand (‰) relative to international set standards. For carbon, the VPDB (Vienna Pee Dee Belemnite) standard was used, and for nitrogen, AIR was used.

Collagen Quality Assessment

Several criteria can be used to assess the integrity of collagen. The most commonly recognized are collagen yield, carbon (wtC %) and nitrogen (wtN %) content, and C:N (Ambrose 1990; Sealy *et al.* 2014; van Klinken 1999). Collagen yield is expressed as a weight percentage of the total weight of the original sample. The collagen yield is the amount of protein that is left post demineralization. This can be calculated using the following formula:

$$\%\ \text{collagen yield} = \frac{(\text{weight of vial + collagen}) - (\text{weight of vial}) \times 100}{\text{original weight of sample}}$$

Normally, the weight of the original (dry) sample is compared with the weight of the collagen produced. However, as the molars contained the enamel portion prior to demineralizing the dentine (too fragile to remove with a dental bur), it was not possible to calculate the collagen yield as no original weights could be measured. A dry weight of the sample would not have reflected the original (dentine) weight and would not be a useful indicator for quality assessment. While a collagen yield of 1% or higher is preferred, it is not to say that a low collagen yield represents an unambiguous measure of accuracy. Second, carbon (wtC%) and nitrogen (wtN%) content in a sample are expressed as a percentage of the combusted collagen extract. According to van Klinken (1999), values for C in intact modern collagen normally fall around 35% and values for N between 11% and 16%. Ambrose (1990) found this to be ~47% for C in modern animal bone collagen. A more recent study (Bocherens *et al.* 2006) suggests that C values of 40% or higher and N values of 14% or higher indicate good quality collagen.

Finally, the carbon (C%) and nitrogen (N%) content of the collagen are assessed with the use of mass spectrometry. DeNiro (1985) proposed that a C:N between the range of 2.9 and 3.6 is necessary for well-preserved collagen. van Klinken (1999) suggests a somewhat narrower range of 3.1 and 3.5. Any values outside of these ranges are considered to have undergone a significant amount of diagenetic alteration. This can lead to large shifts in $\delta^{13}C$ and $\delta^{15}N$ (DeNiro 1985; van Klinken 1999).

Ageing of increments

The dentine micro-samples from first, second, and third molars were aged following the method outlined by Beaumont and Montgomery (2015), which uses the London Atlas (AlQahtani *et al.* 2010) as a standard for dental development. The Atlas provides a minimum, median, and maximum stage of achievement for chronological age stages (given as midpoints with a range). While Beaumont and Montgomery (2015) selected the earliest stage (minimum) to calculate an age for each micro-sample, this study uses the median age. The first (cusp initiation, Ci) and last stage (apex closure, Ac) of tooth development are used to calculate the formation time of the permanent molars (Table 5). While according to London Atlas the median age for the apex closure of M1 is 9.5, the age of 10.5 was selected as both the mandibular and maxillary M1 are completed (Ac) at this age.

To calculate the age of each increment Beaumont and Montgomery (2015) use the following formula: Ac – Ci = development time of the tooth / total number of increments per tooth = development time for each increment. The first increment (S-01) corresponds to the cusp initiation age of each molar and from there on the age for each increment is to be added to calculate the development of the adjacent increment. For example, a second molar, with no

Table 5. Formation time of the permanent molars according to the London Atlas (AlQahtani *et al.* 2010).

	M1	M2	M3
Cusp initiation (Ci)	0.375 years	2.5 years	8.5 years
Root apex closure (Ac)	10.5 years	16.5 years	23.5 years
Total development time	10.125 years	14 years	15 years

occlusal wear, has been sectioned into 12 increments. Ac – Ci for M2: 16.5 years (Ac age) - 2.5 years (Ci age) = 14 years of development time for the entire tooth. 14 years/12 increments = 1.166 year per slice. S-01 represents 2.5 years (Ci age); S-02 is 2.5 years + 1.166 years per slice = 3.666; S-03 is 3.666 + 1.166 = 4.832, etc. This formula is based on the assumption that the dentine growth rate is constant throughout the entire tooth (e.g. 4–5μm per day for dentine). However, research (Dean and Scandrett 1995) has shown this is not the case. Nevertheless, in a micro-sampling study that Beaumont and Montgomery (2016) conducted on the Irish poor using this particular formula, they mention that each increment will still represent an average rather than a distinct time period as a result of the sampling method (cutting through Andresen lines) and the deposition of dentine (horizontal vs. conical layers). This is conflating two factors, which have the effect of averaging the age range represented by the dentine (see Chapter 4):

1. The differences in growth rate from crown to the apex; and
2. Each increment contains a part of the adjacent slice(s) as dentine does not entirely form in horizontal layers.

These issues will be further addressed in Chapter 9. Beaumont and Montgomery (2016) further state that the error introduced by using the London Atlas would be the same for each individual analyzed. In addition, this method allows easy adjustment if an increment is sliced in 2 or 3mm, or if two increments had to be combined to provide a sufficient amount of collagen for mass spectrometry. In two instances where teeth did not fully develop as a result of the individual dying at a young age, it was impossible to measure the length of the tooth in its entirety and calculate a total development time. For this, the median age of the particular developmental stage (e.g.: R ½, root length equals crown length) was taken from the London Atlas (AlQahtani *et al.* 2010), which was then used to calculate the developmental time up until that point. The new developmental stages replace the time of apex closure (Ac).

Summary

A total of 80 molars, from 49 Cis-Baikal hunter-gatherers, are prepared for stable carbon and nitrogen isotope analysis. Sectioning of dentine follows published protocols, but an adjustment to the sodium hydroxide soak for the removal soil humates is made. The soaking time is reduced from 20 hours to six hours in order to prevent damage to extremely small and fragile prehistoric dentine samples. Molar wear is assessed for each tooth to examine the state of preservation throughout the assemblage and to determine if wear will impact the ageing of a molar's first forming increments.

Chapter 6

Dietary life-histories in the Upper Lena

This chapter presents the tooth collagen stable carbon and nitrogen isotope results from one Early Neolithic individual and 14 Early Bronze Age individuals that were buried in the Upper Lena micro-region in Cis-Baikal, Siberia, Russia. The chapter is divided into four sections. The first three sections present the results from the Upper Lena cemeteries (Manzurka, Obkhoi, and Ust'-Ilga) and the last section summarizes all results.

As previously mentioned, the Lena River is an independent fishery as it does not connect to Lake Baikal or any of its connecting rivers. The Lena River originates in the Baikal Mountains, just west of Lake Baikal and flows all the way into the Arctic Ocean. Although the Upper Lena micro-region has undergone the least amount of research by BAP, it does provide insight into past human subsistence and behaviour. The $\delta^{13}C$ (from -21.0‰ to -18.8‰) and $\delta^{15}N$ (from 10.0‰ to 14.9‰) dentine stable isotope values are considered typical for all but two of the Upper Lena individuals (Katzenberg *et al.* 2010; Weber *et al.* 2011). Furthermore, the data show that diets were more variable between and within individuals than previously thought. Twelve out of the 14 individuals show diets that result in a negative relationship for $\delta^{15}N$ and $\delta^{13}C$. For individuals with known stable isotope bone values, results demonstrate that childhood and adulthood diets did not differ significantly from one another.

General patterns in dentine stable isotope signatures

A general assessment of all micro-sampling profiles for the 49 Cis-Baikal hunter-gatherers examined in this study show that they can be grouped into five patterns. Each pattern represents a different life-history, a different dietary behaviour, and different decision making. These patterns and the stable isotope results will be discussed in greater detail in Chapter 9.

- Pattern I: Decline in $\delta^{15}N$ during infancy (weaning signature).
  The weaning period is identified by the decline of $\delta^{15}N$ in the first molar as a result of non-breastmilk proteins being introduced into the diet (Fuller *et al.* 2003; Schurr 1997, 1998; Tsutaya and Yoneda 2015). The point where the increments reach a trophic level decline (~2–3‰) and, at times, stabilize, can be seen as the complete cessation of breastfeeding. This is normally the lowest mark for $\delta^{15}N$. A trophic level decline for $\delta^{13}C$ (~1‰) is less noticeable in the Cis-Baikal hunter-gatherers and is explained in greater detail in Chapters 3 and 9.
- Pattern II: Positive relationship between $\delta^{13}C$ and $\delta^{15}N$.
  A pattern in which $\delta^{13}C$ and $\delta^{15}N$ values in micro-samples increase or decrease in tandem.
- Pattern III: Negative relationship between $\delta^{13}C$ and $\delta^{15}N$.
  A pattern in which one stable isotope signature increases while the other one decreases over time and vice versa. Often, the pattern will show a mirroring effect.
- Pattern IV: Rise in $\delta^{15}N$ toward the end of molar development.

The rise refers to an increase of 1‰ or higher over the last few dentine micro-samples of the M1, M2 or M3.

- Pattern V: Continuous oscillation of both δ^{13}C and δ^{15}N values (zigzag).
  This refers to a continuous and parallel rise and decline of both δ^{13}C and δ^{15}N values throughout a molar, creating a pattern of double zigzag line. This is also a positive relationship but of a different kind than Pattern II.

Stable isotope results for each individual are presented along with their place of birth and migrations between micro-regions (Weber and Goriunova 2013), which are based on past strontium isotope studies conducted by the BAP (Haverkort *et al.* 2008; Scharlotta and Weber 2014). The term migration, as used in the individual profiles, refers to a change in the location of one's home range for a duration long enough to result in a change to the isotopic values. This requires a minimum stay of approximately nine months (one micro-sample) within a micro-region. Any movement between micro-regions under this duration would not be visible isotopically and is not considered temporally significant enough to be labelled migration. Other obvious markers of migration are individuals with the strontium values of one micro-region but who were interred in another. The term 'place of birth' is used to refer to the area representative of the strontium isotope values in the enamel of the first permanent molars (Haverkort *et al.* 2008; Scharlotta and Weber 2014; Weber and Goriunova 2013).

The dentine patterns seen throughout an individual's molar(s) are presented, followed by infancy diet and early childhood diet (M1, up to approximately nine or 10 years), late childhood diet (from post-weaning up to the end of M2, ~16 years), and early adult diet (M3, from 12 to ~20 years). The data are presented in charts with a double y-axis for carbon (right) and nitrogen (left). The x-axis corresponds to the estimated formation age of each increment. This age was determined using the method provided by Beaumont and Montgomery (2015) and standards from the dental atlas published by AlQahtani *et al.* (2010), which are described in Chapter 5. Although the age estimates provided along the x-axis are not very precise, they are still sequential. It is also important to reiterate that each micro-sample is not equal due to differences in the timing of dentine deposition between various portions of the tooth (i.e. crown vs roots). Dentine δ^{13}C and δ^{15}N are compared with the bone δ^{13}C and δ^{15}N and presented in a scatter plot. Finally, additional observations are mentioned when necessary.

A total of 20 molars, representing 15 hunter-gatherers from the Upper Lena, produced 256 micro-samples. Stable isotope results for all samples lie within the acceptable range for % carbon, % nitrogen, and atomic C/N ratios (Appendix C). All results obtained were included owing to the quality of the collagen, although not all micro-samples provided enough collagen for analysis. In one case, two adjacent micro-samples were combined. On four other occasions, micro-samples yielded no results. Stable isotope values for all increments are also presented in Appendix C.

Manzurka

Only one Early Neolithic individual, from the Manzurka cemetery (MNZ_1974.002), has been analyzed for this study as part of a trial run. This is described in greater detail in Chapter 5 and in the first publication of this study (van der Haas *et al.* 2018). The stable isotope results of this individual are also presented here.

Individual MNZ_1974.002

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
MNZ_1974.002	U 14–19	EN	n/a	M1 (4)–18 M2 (5)–18 M3 (1)–15	−19.1	12.3	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, III, and IV.
- Infancy diet: A weaning signature is seen from ~birth (S-01) until around three years (S-05) with a decline in $\delta^{15}N$ from 13.2‰ to 10.9‰, suggesting the child was fully weaning onto solid foods around this time (Figure 9). Over the course of this weaning period, $\delta^{13}C$ increases from −20.0‰ (S-02) to −19.5‰ (S-05).
- Childhood diet: Post-weaning, the diet during early childhood fluctuates between 11.0‰ and 11.6‰ for $\delta^{15}N$ while $\delta^{13}C$ ranges between −20.0‰ and −19.1‰. In late childhood (M2), the individual shows only slightly more variation in $\delta^{15}N$ (10.8‰ to 11.7‰) than $\delta^{13}C$ (−19.8‰ to −19.1‰), yet values are similar to what is seen in the M1.
- Early adult diet: Once the individual reaches early adulthood, $\delta^{15}N$ ranges between 10.7‰ and 12.1‰, with a steady increase in aquatic protein intake visible from just before 15 years (S-07) to 22 years (S-15).
- Bone values: Bone $\delta^{13}C$ and $\delta^{15}N$ are similar to the final micro-samples during early adulthood (M3), which is not surprising as the individual died quite young (Figure 10). The M1 and M2 are roughly 1‰ to 1.5‰ lower than bone for $\delta^{15}N$.
- Other observations: The osteological analysis placed the individual between 14 and 19 years of age. Since all three molars are fully developed, this individual is most likely

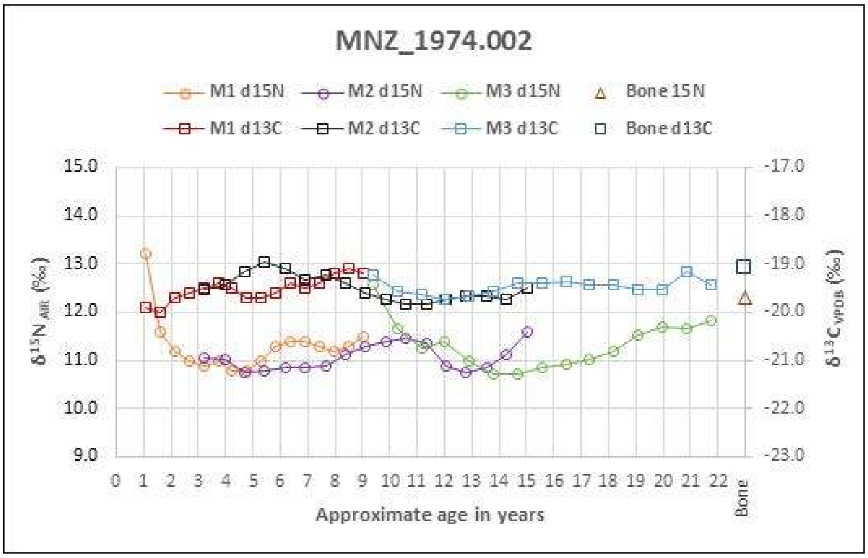


Figure 9. Multi-molar dentine profile for individual MNZ_1974.002.

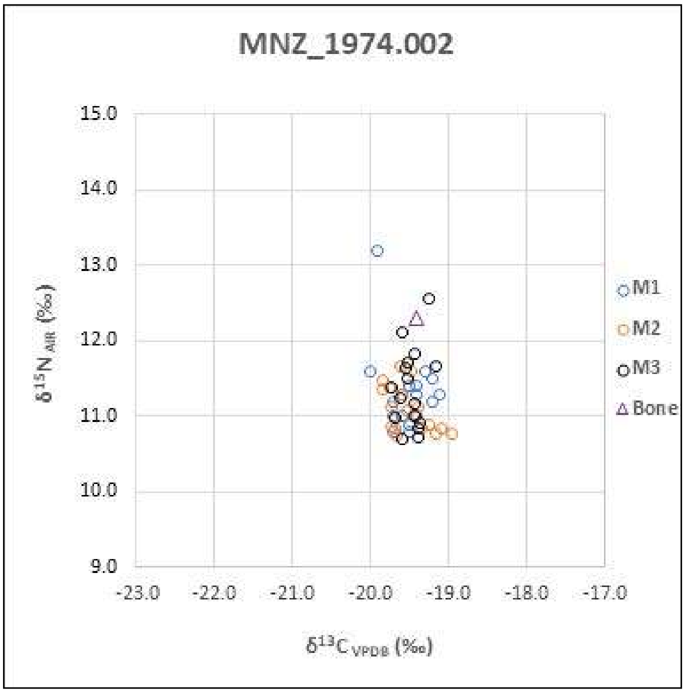


Figure 10. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values of individual MNZ_1974.002.

closer to 19 years of age. Furthermore, the first micro-sample of all three molars is 2mm thick. This is because S-01 included the small dentine horns and sectioning them into a 1mm section would not provide enough material for analysis. Therefore, they were included with the first slice which measured 2mm from the horn tips. The root tip for M1 was also kept at 2mm to ensure enough material for analysis. This also means that each 2mm section will represent a slightly longer time average. Furthermore, the S-01 of the M3 δ^{15}N (12.6‰) is roughly 1‰ above the rest and does not line up with M1 or M2. This will be further discussed in Chapter 9.

Obkhoi

Three Early Bronze Age individuals from the Obkhoi cemetery have been analyzed for this study (OBK_1971.005; OBK_1971.007; OBK_1971.013). As discussed in Chapter 2, no fieldwork reports or papers have been published on this site.

Individual 1: OBK_1971.005

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
OBK_1971.005	F 20–35	EBA	Glazkovo	M1 (7)–10 M3 (6)–11	−19.4	10.2	n/a

- Place of birth: Upper Lena valley (Scharlotta and Weber 2014).

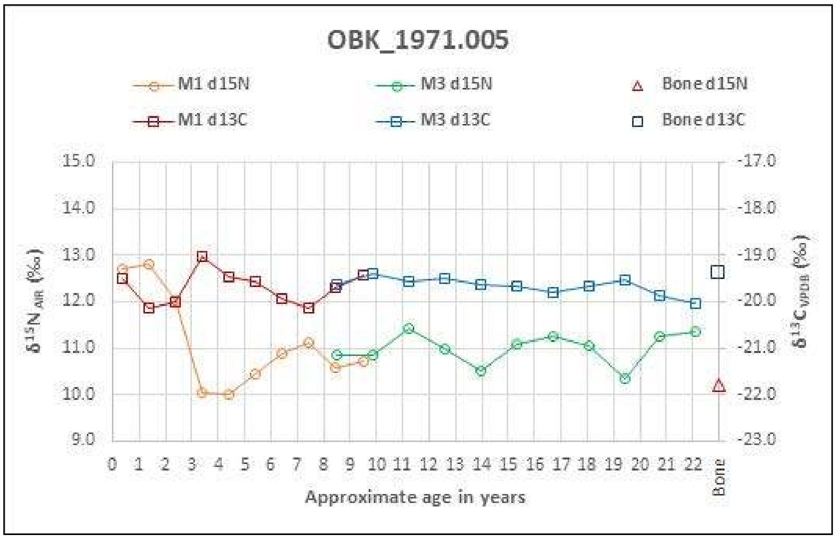


Figure 11. Multi-molar dentine profile for individual OBK_1971.005.

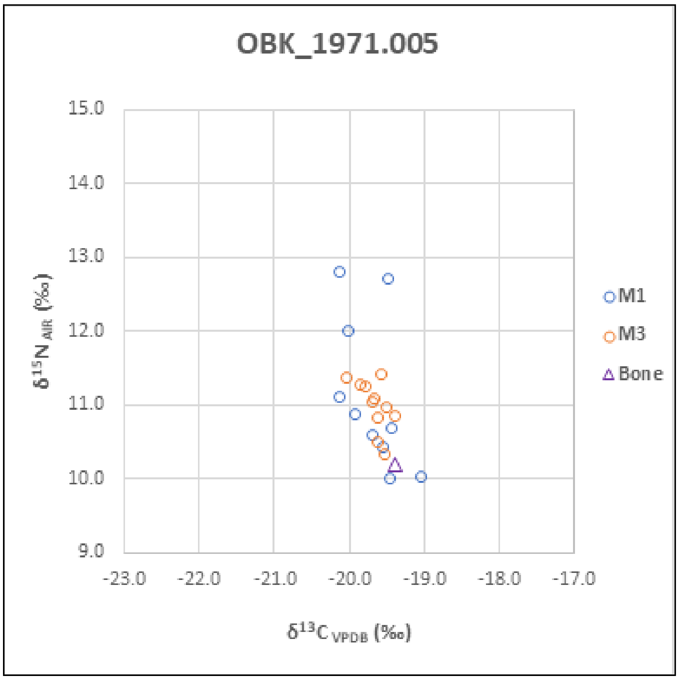


Figure 12. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values of individual OBK_1971.005.

- Migrations: Around age five the individual exhibits Sr ratios that do not match any currently recorded values for the local region, indicating a move into areas which have not yet been sampled for strontium isotope analysis (Scharlotta and Weber 2014).
- General pattern(s): I, III, and IV.
- Infancy diet: A weaning signature is seen from ~birth (S-01) with a decline in δ^{15}N from 12.8‰ to 10.0‰ around three-and-a-half years (S-04) (Figure 11). This is a 2.8‰ decline over the course of three to four years, suggesting the individual was completely

weaned off breastmilk during that time. Δ^{13}C declines from –19.5‰ to –20.1‰ (and 20.0‰) during the first approximately three years.

- Childhood diet: Post-weaning, δ^{15}N increases by 1.1‰, before slightly declining towards the end of M1 root development. Δ^{15}N and δ^{13}C exhibit a negative relationship between birth and eight-and-a-half years.
- Early adult diet: The δ^{15}N values of the M3 (10.3‰ to 11.4‰) show an increase followed by a decrease every two to three years. The δ^{13}C values are relatively steady ranging only between –20.0‰ and –19.4‰.
- Bone values: Throughout childhood, δ^{15}N is higher when compared to the adult bone values, except for the period between approximately three to four-and-a-half years of age (10.0‰) (Figure 12). Δ^{13}C is mostly lower during childhood when compared to bone.
- Other observations: Δ^{13}C and δ^{15}N of the final two micro-samples (S-09 and S-10) of the M1 match closely to S-01 and S-02 of the M3. This shows that when multi-tooth sequences align, the contemporary sections produce similar δ^{13}C and δ^{15}N values. The similarity in values also shows a good alignment regarding the age estimation.

Individual 2: OBK_1971.007

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
OBK_1971.007	U 20+	EBA	Glazkovo	M1(5)–13 M2 (4)–13	–19.0	10.8	n/a

- Place of birth: Upper Lena (Scharlotta and Weber 2014).
- Migrations: The individual appears to have lived in two micro-regions: the Upper Lena and the Little Sea. Strontium isotope analysis (Scharlotta and Weber 2014) shows a signature that is typical of the Little Sea towards the end of enamel mineralization in M1 (seven to eight years) and M2 (10–12 years). The authors state that the individual spent most of their sub-adult life within the Upper Lena, most likely close to the Manzurka Valley.
- General pattern(s): I, II, III, IV.
- Infancy diet: A weaning signature is seen from ~birth (S-01) with a decline in δ^{15}N from 12.8‰ down to the lowest values (10.0–10.1‰) in the M1 (S-09) and M2 (S-03) around four-and-a-half and six-and-a-half years (Figure 13). Δ^{13}C shows no change as values are within the margin of error.
- Childhood diet: For the remainder of the M1, δ^{15}N increases from 10.1‰ to 12.4‰ and δ^{13}C values range between –19.6‰ and –18.9‰. In late childhood (M2), essentially no change is seen in δ^{13}C. While δ^{15}N also shows little change after a 1.6‰ increase between four-and-a-half and approximately seven years, values do seem to exhibit minor oscillation between 11.2‰ and 11.9‰.
- Early adult diet: Not applicable.
- Bone values: The values lie within the range of the dentine values, albeit toward the lower end for δ^{15}N and higher end for δ^{13}C (Figure 14). Overall, adult diet does not differ significantly from childhood.

- Other observations: The molars show an offset in δ^{15}N and δ^{13}C between S-09 of the M1 and S-03 of the M2. It could be suggested that the development of the coronal part of the M2 should start slightly later (one to two years) in order to line up with the M1. Potential reasons for this offset will be discussed in Chapter 9. Despite the strontium data suggesting travel between the Little Sea and Upper Lena micro-regions, all dentine stable isotope values can be considered typical of Upper Lena EBA individuals (Katzenberg *et al.* 2010; Weber *et al.* 2011).

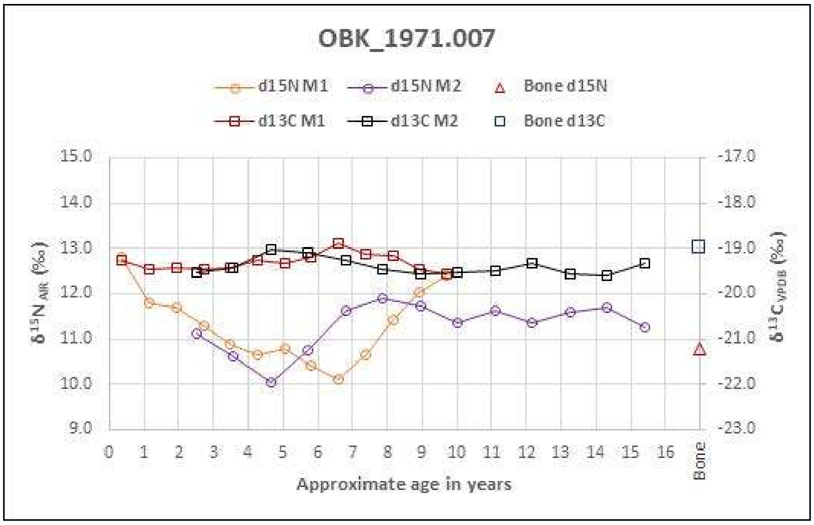


Figure 13. Multi-molar dentine profile for individual OBK_1971.007.

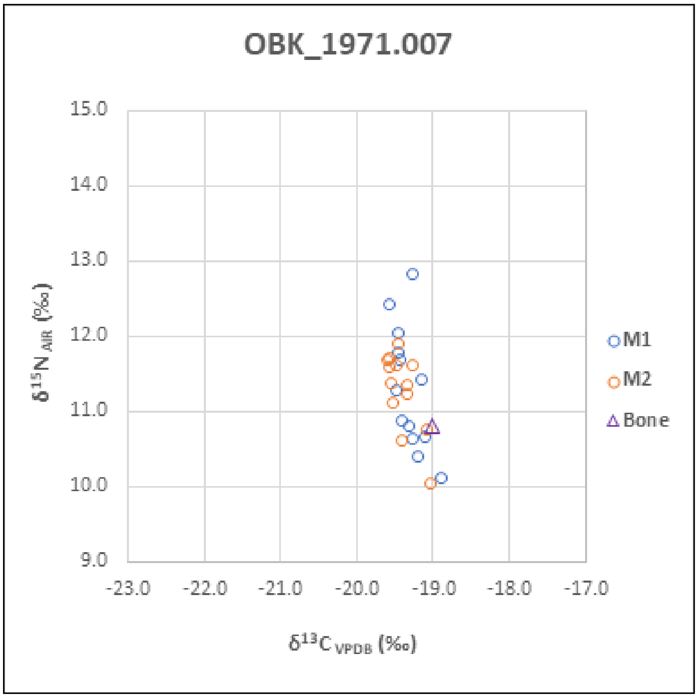


Figure 14. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values of individual OBK_1971.007.

Individual 3: OBK_1971.013

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
OBK_1971.013	U 20–25	EBA	Glazkovo	M1 (5)–11 M1 (6)–13	−19.4	11.3	n/a

- Place of birth: Upper Lena (Scharlotta and Weber 2014).
- Migrations: The individual appears to have lived close to the Kulenga River where it joins the Lena River (Scharlotta and Weber 2014). As seen in OBK_1971.005, this individual also moved into areas that have not yet been sampled for strontium isotope analysis.
- General pattern(s): I, II.
- Infancy diet: The $\delta^{15}N$ values show a weaning signature with a gradual decline from ~birth (S-01) at 13.2‰ and 13.6‰ to 11.3‰ around three-and-a-half to four years (S-05) (Figure 15). $\Delta^{13}C$ values show almost no change as they are within the margin of error.
- Childhood diet: The subsequent values show what appears to be an isotopically stable diet, with $\delta^{15}N$ slowly rising. $\Delta^{13}C$ also exhibits very little variation during development with values ranging between −19.8‰ and −19.3‰.
- Early adult diet: Not applicable.
- Bone values: The values are on the low end of the dentine values for $\delta^{15}N$ but overall similar (Figure 16).
- Other observations: The molars were initially identified as an M1 (H2000.212) and a possible M2 (H2000.213). Correct identification could not be made due to enamel having chipped off. However, stable isotope results show that the isotopic profiles of

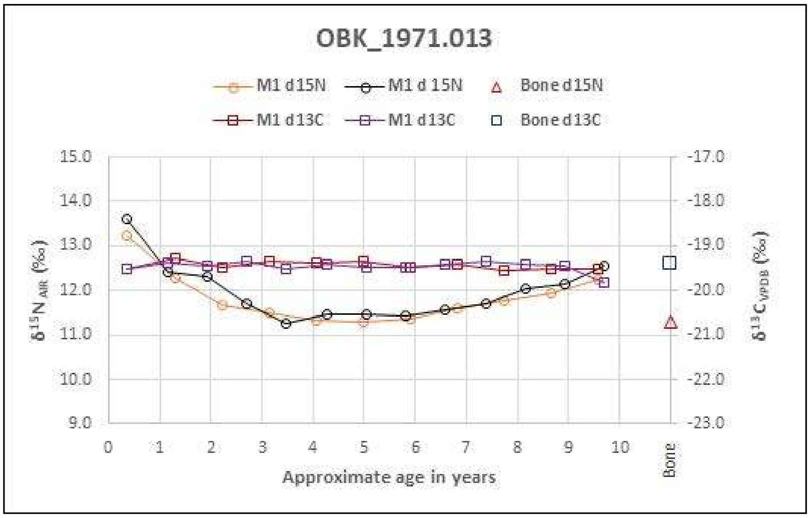


Figure 15. Multi-molar dentine profile for individual OBK_1971.013.

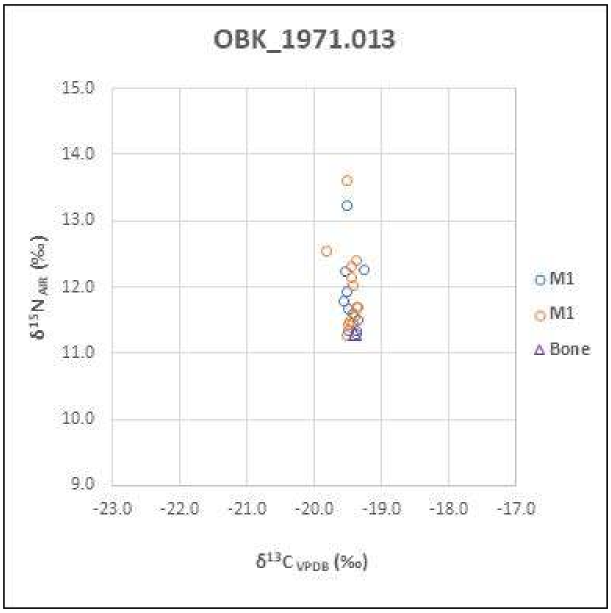


Figure 16. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values of individual OBK_1971.013.

the two teeth are essentially identical. Prior work on well-preserved modern teeth (van der Haas *et al.* 2018) indicates that the dietary information provided by a molar will depend on whether it is an M1, M2, or M3, but not on its position within the jaw. Thus, the almost identical profiles of the two teeth suggest that H2000.213 is, in fact, also an M1.

Ust'-Ilga

Childhood and early adulthood diets of 11 Early Bronze Age hunter-gatherers from the Ust'-Ilga cemetery have been examined. One molar has been micro-sampled per individual.

Individual 1: UIL_1989.001

Master ID	Sex Age in years	Period	Mortuary tradition	Teeth (Wear stage) *Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UIL_1989.001	F 25–35	EBA	Glazkovo	M2 (3)–12	−19.4	12.0	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): IV.
- Infancy diet: Not applicable.
- Childhood diet: The first few micro-samples show a decline in $\delta^{15}N$ from the age of approximately two-and-a-half years (S-01) to approximately six years (S-04), from

12.8‰ to 11.2‰ (Figure 17). This decline in δ15N values during this time may represent the last part of the weaning signal, although it remains unclear as to what weaning would have looked like during the first approximately two years. Δ13C exhibits no change as values between micro-samples are within the margin of error. Throughout the rest of the tooth's formation, δ15N increases again from 11.6‰ (S-05) at nine years to 12.5‰ at 21 years (S-12), suggesting a slight increase in aquatic protein consumption during late childhood into early adulthood. The dentine δ13C exhibits stability throughout the development of the tooth, only varying between −19.5‰ and −19.2‰.

- Early adult diet: Not applicable.

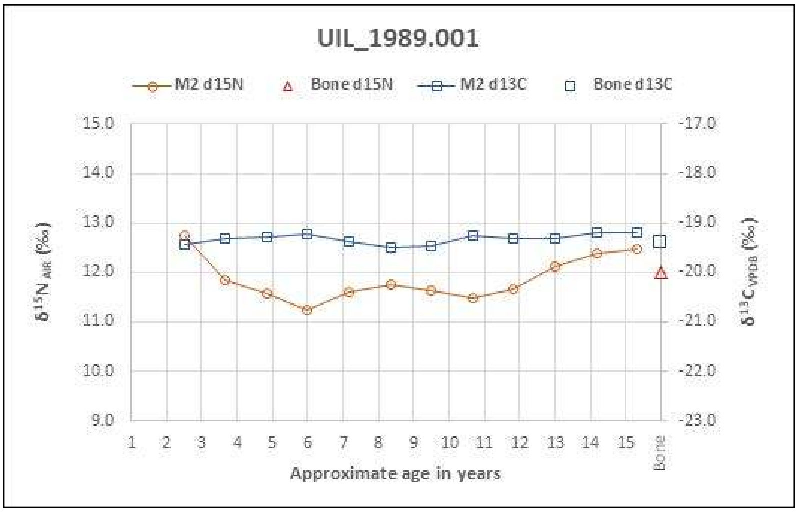


Figure 17. Single molar dentine profile for individual UIL_1989.001.

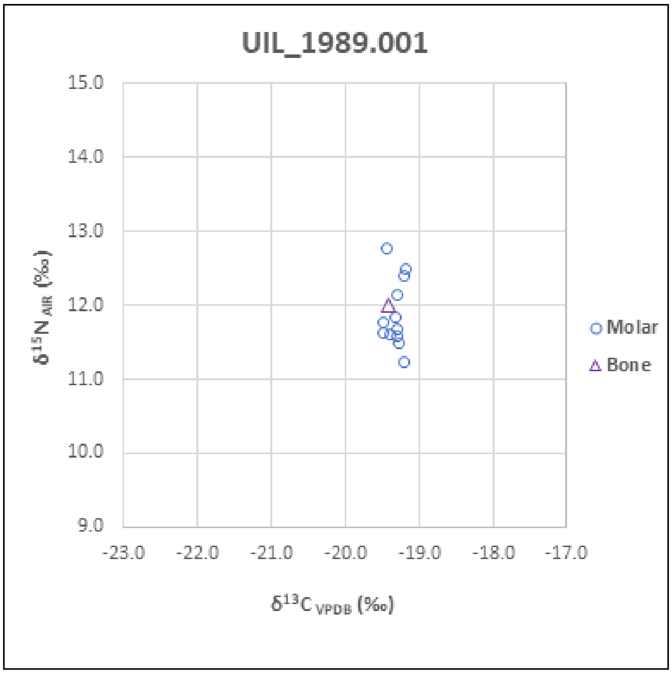


Figure 18. Scatter plot of dentine and bone δ13C and δ15N values for individual UIL_1989.001.

- Bone values: The values suggest a similar diet during childhood and adulthood (Figure 18).
- Other observations: None.

Individual 2: UIL_1989.002

Master ID	Sex Age in years	Period	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UIL_1989.002	M 40–45	EBA	Glazkovo	M2 or M3 (6)–11	n/a	n/a	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): II, III, IV.
- Infancy diet: Not applicable.
- Childhood diet: The stable isotopic data for the M2 or M3 demonstrates a negative relationship between δ^{13}C and δ^{15}N. Roughly, every one to two years the diet appears to have slightly changed. Δ^{13}C fluctuates between –20.5‰ and –19.4‰ and δ^{15}N between 11.1‰ and 12.6‰. Changes in δ^{13}C values between S-06 and S-07, and again between S-09 and S-11, fall well outside the margin of error. At the end of this individual's molar development, a change in trophic level (1‰) appears twice.
- Early adult diet: Not applicable.
- Bone values: Not applicable.
- Other observations: The tooth could not be identified with certainty and was listed as a probable M2? or M3? Therefore, it is not possible to provide age estimates for each

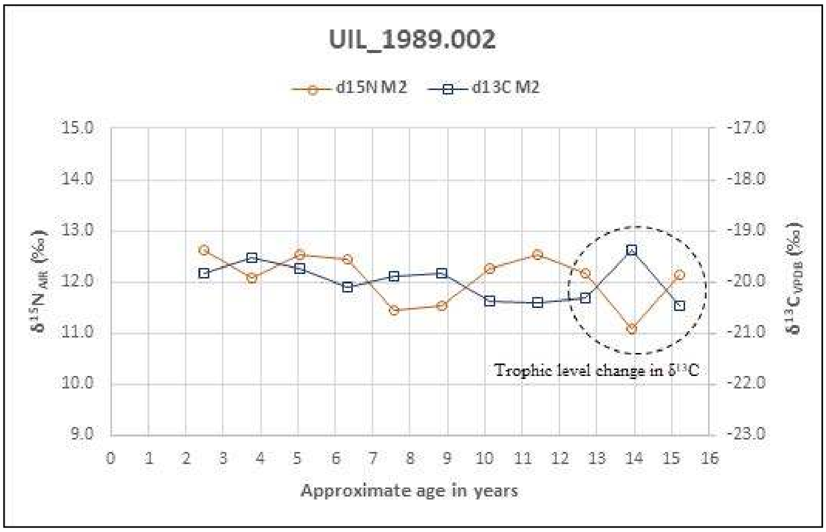


Figure 19. Single molar dentine profile for individual UIL_1989.002 as M2.

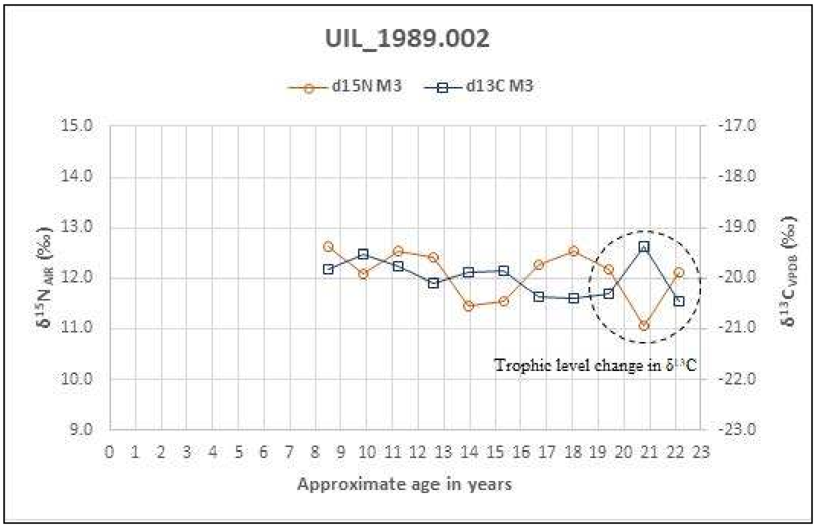


Figure 20. Single molar dentine profile for individual UIL_1989.002 as M3.

micro-sample. Nonetheless, the molar is presented in two graphs; one assuming it is an M2 (Figure 19), and one assuming it is an M3 (Figure 20).

Individual 3: UIL_1989.003

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ¹³C ‰*	*Bone δ¹⁵N ‰*	*Notes*
UIL_1989.003	M 40–45	EBA	Glazkovo	M1 (6)–12	−19.4	11.9	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, IV.
- Infancy diet: A weaning signature is seen by a steep decline in δ^{15}N from around birth at 13.1‰ (S-01) to 11.7‰ at one year (S-02) (Figure 21). Hereafter, δ^{15}N measurements continue to decline more gradually. Breastfeeding seems to have ceased just after four years. The δ^{13}C values remain almost unchanged during this process.
- Childhood diet: The δ^{15}N values increase again just before six years (S-08), suggesting another change in diet after this point. Only at the root apex, roughly between eight (S-11) and nine years (S-12), does δ^{13}C show an increase from −19.3‰ to −18.8‰.
- Early adult diet: Not applicable.
- Bone values: The values suggest a similar diet during childhood and adulthood (Figure 22).
- Other observations: None.

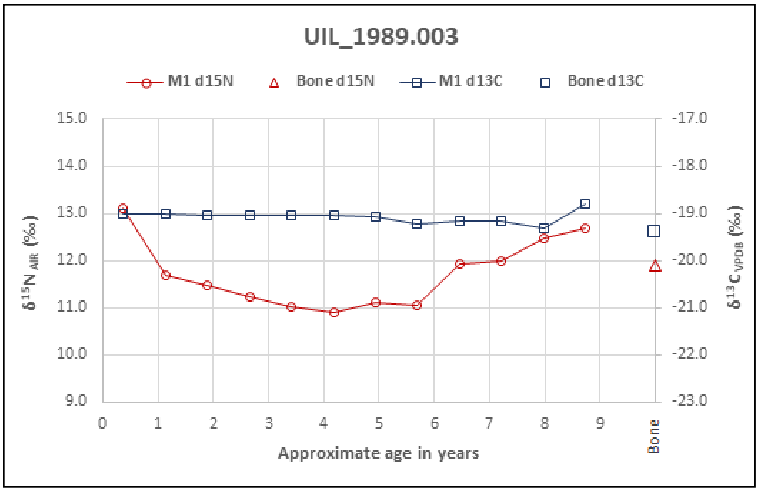


Figure 21. Single molar dentine profile for individual UIL_1989.003.

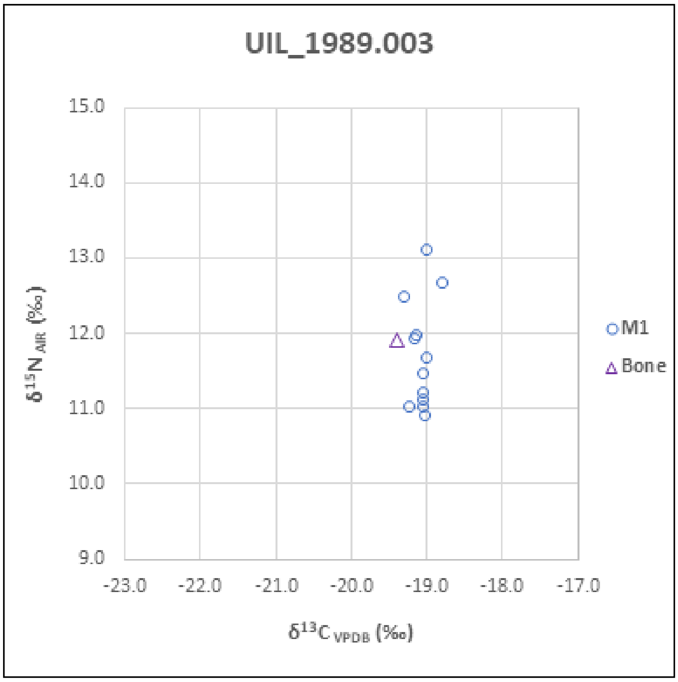


Figure 22. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UIL_1989.003.

Individual 4: UIL_1989.004.0?

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	Notes
UIL_1989.004.0?	n/a	EBA	Glazkovo	M3 (5)–10	n/a	n/a	n/a

- Place of birth: Unknown.

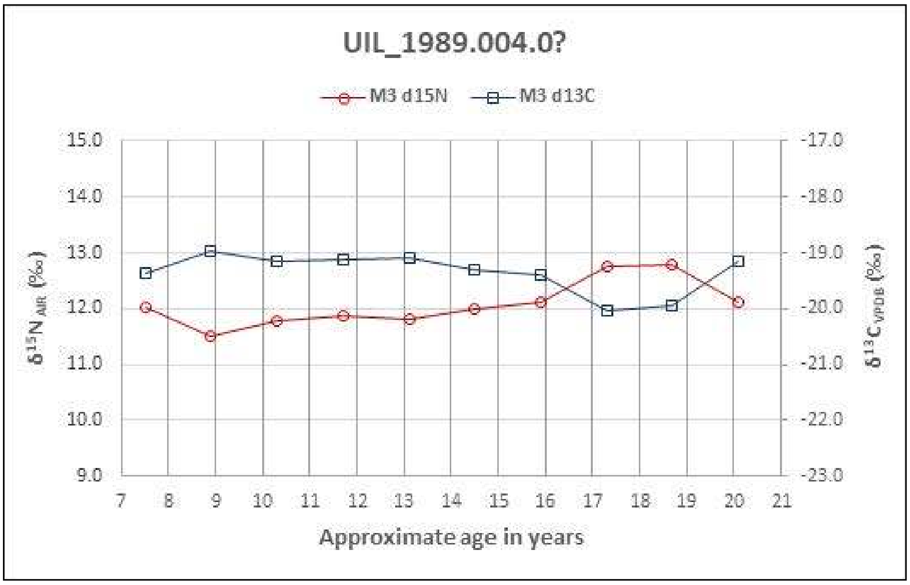


Figure 23. Single molar dentine profile for individual UIL_1989.004.0?

- Migrations: Unknown.
- General pattern(s): III.
- Infancy diet: Not applicable.
- Childhood diet: Not applicable.
- Early adult diet: As seen in UIL_1989.002, the dentine micro-samples display a negative relationship between $\delta^{13}C$ and $\delta^{15}N$ (Figure 23). From seven-and-a-half (S-01) to nine years (S-02), $\delta^{13}C$ increases from −19.4‰ to −19.0‰ and $\delta^{15}N$ decreases from 12.0‰ to 11.5‰. Subsequently (S-02 to S-07), both values show minor changes. At 16 years (S-07), $\delta^{13}C$ decreases from −19.4‰ to −20.0‰ and $\delta^{15}N$ increases from 12.1‰ to 12.8‰, suggesting a change in diet. In the root apex an elevation in $\delta^{13}C$ (from −20.0‰ to −19.2‰) and a decline in $\delta^{15}N$ (from 12.8‰ to 12.1‰) exhibit another change in diet.
- Other observations: Grave 4 contained two burials (UIL_1989.004.01 and UIL_1989.004.02). However, it is unclear which of these two burials the examined tooth belongs to. Consequently, neither the sex nor the age of the examined individual is presently known.

Individual 5: UIL_1989.005

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UIL_1989.005	M 20+	EBA	Glazkovo	M2 or M3 (n/a)–15	n/a	n/a	No results for S-14.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): III, IV.
- Infancy diet: Not applicable.

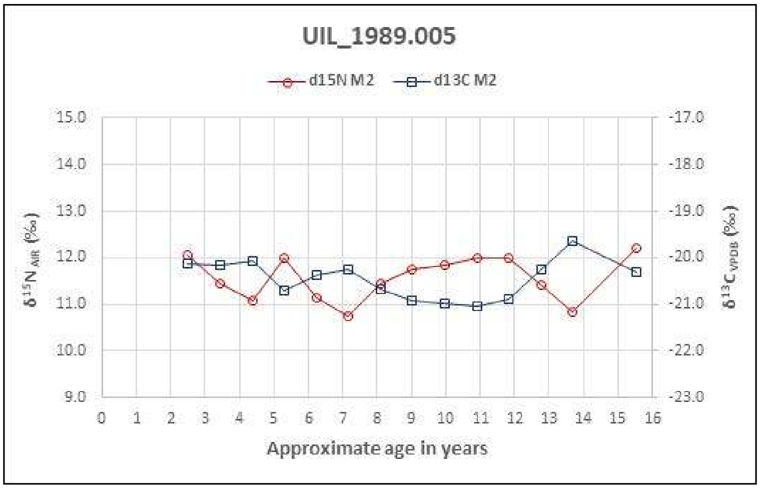


Figure 24. Single molar dentine profile for individual UIL_1989.005 as M2.

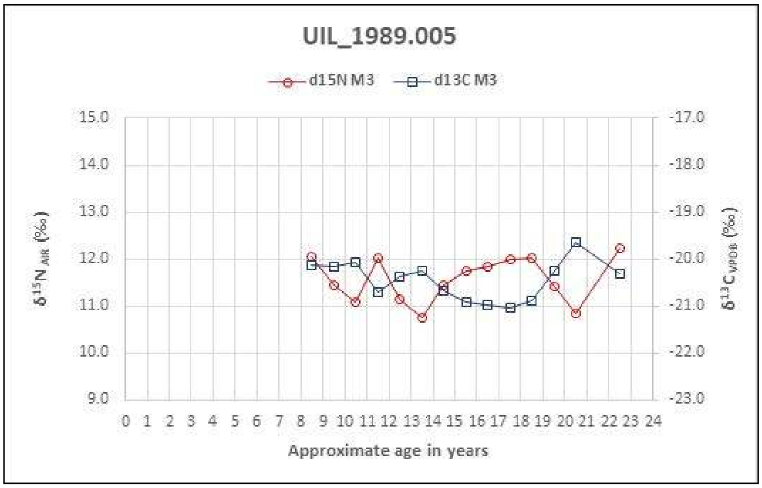


Figure 25. Single molar dentine profile for individual UIL_1989.005 as M3.

- Childhood diet: The stable isotope values exhibit a negative relationship between $\delta^{13}C$ and $\delta^{15}N$, showing a pattern that is similar to a number of the other Upper Lena individuals. The $\delta^{13}C$ values in this individual are the lowest when compared to the other individuals from the cemetery, reaching −21.0‰. The change in $\delta^{13}C$ from 12 (S-11) to 14 (S-13) years exhibits a shift in trophic level (1.2‰).
- Early adult diet: Not applicable.
- Other observations: Results are presented in two charts (Figures 24, 25). One assumes the tooth is an M2 and the other assumes the tooth is an M3. The occlusal surface of the tooth was worn as it showed a sloping angle towards the distal or mesial side of the tooth. As a result, a wear stage could not be assigned.

Individual 6: UIL_1990.009

Master ID	Sex Age in years	Period	Mortuary tradition	Teeth *(Wear stage)* *Sections*	*Bone* *$\delta^{13}C$* *‰*	*Bone* *$\delta^{15}N$* *‰*	*Notes*
UIL_1990.009	M 20–25	EBA	Glazkovo	M3 (4)–9	–20.2	12.2	No results for S-02.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): III.
- Infancy diet: Not applicable.
- Childhood diet: Not applicable.
- Early adult diet: At seven-and-a-half years (S-01), the M3 has a δ^{15}N value of 13.2‰ and a δ^{13}C value of –20.5‰ (Figure 26). By 10.5 years (S-03), δ^{15}N decreases to 12.1‰ and δ^{13}C increases to –19.9‰. Hereafter, δ^{13}C and δ^{15}N continue to display a negative relationship by moving in opposite directions. Between 17 and 20 years, the last three micro-samples (S-07, S-08, S-09) remain at δ^{15}N 12.3‰, suggesting a very stable diet for the last approximately three years of M3 development. Overall, the δ^{15}N of S-01 (13.2‰) is closer to what is typically seen in individuals living in the EBA Little Sea micro-region (Katzenberg *et al.* 2010; Weber *et al.* 2011).
- Bone values: With the exception of S-01, early adult diet and adult (bone) diet are isotopically similar (Figure 27). This is not surprising considering the individual was only 20–25 years old at death.
- Other observations: The roots of this M3 were fused together, meaning that when cutting the tooth longitudinally, the half selected for micro-sampling contained

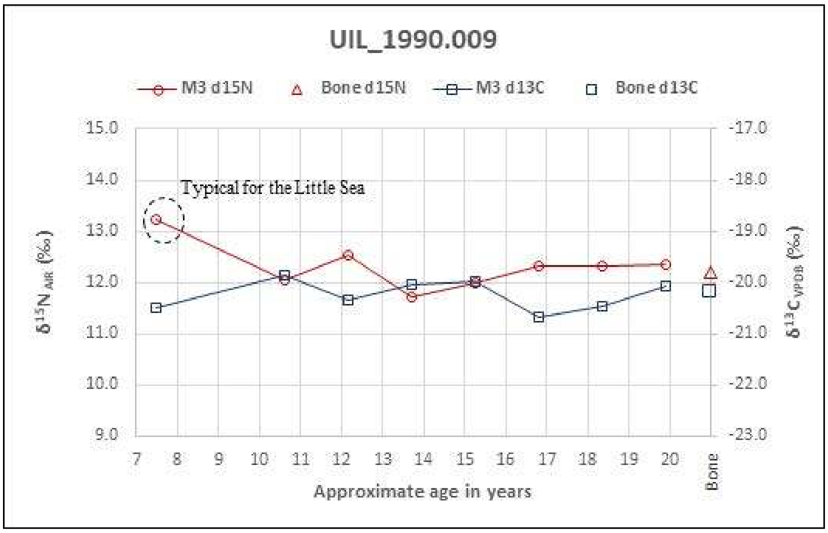


Figure 26. Single molar dentine profile for individual UIL_1990.009.

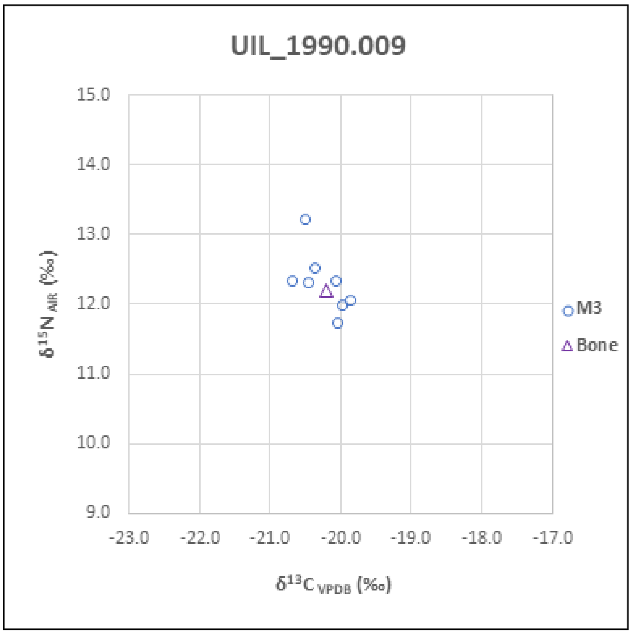


Figure 27. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UIL_1990.009.

tissue from more than one root. Therefore, the stable isotope data will contain dietary information from adjacent roots.

Individual 7: UIL_1990.010

Master ID	Sex Age in years	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UIL_1990.010	M 20+	EBA	Glazkovo	M2 (5)–12	–19.6	12.8	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): III.
- Infancy diet: Not applicable.
- Childhood diet: The M2 of this individual shows a late childhood diet that appears stable over a period of ~12 years (Figure 28). While a mirrored shift in $\delta^{13}C$ and $\delta^{15}N$ can be seen between approximately five-and-a-half and nine years, values show minimal changes in isotopic composition throughout the development of the tooth. The biggest change is from seven-and-a-half to nine-and-a-half years when $\delta^{15}N$ increases from 12.1‰ to 12.9‰. $\Delta^{13}C$ values range from –20.3 to –19.9‰.
- Early adult diet: Not applicable.
- Bone values: Dentine and bone values for $\delta^{15}N$ are very similar (Figure 29). The $\delta^{13}C$ value for bone is slightly more positive (at –19.6‰) compared to the dentine.
- Other observations: None.

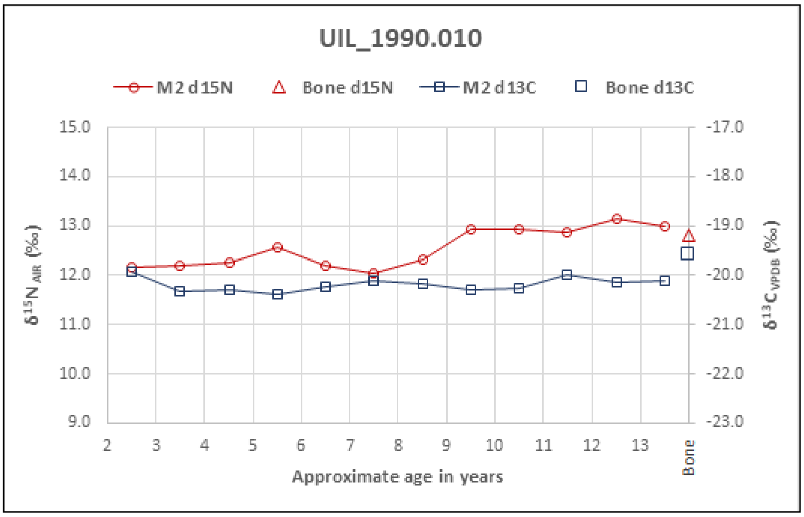


Figure 28. Single molar dentine profile for individual UIL_1990.010.

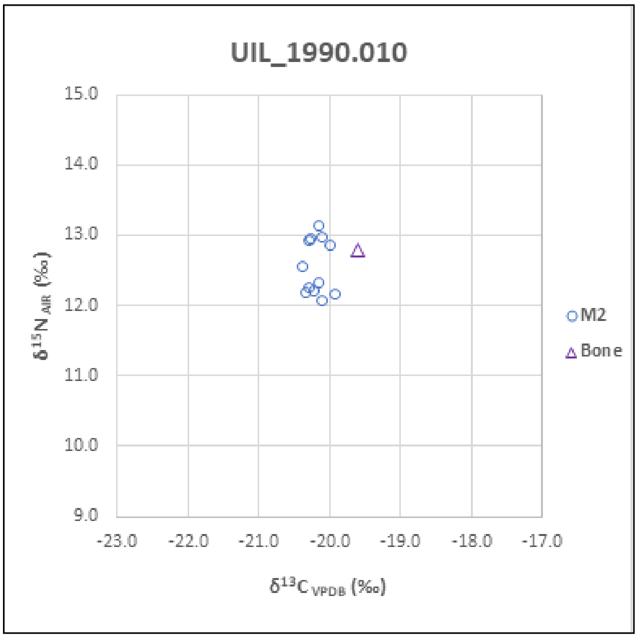


Figure 29. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UIL_1990.010.

Individual 8: UIL_1990.011

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UIL_1990.011	M 20+	EBA	Glazkovo	M1 (4)–12	n/a	n/a	n/a

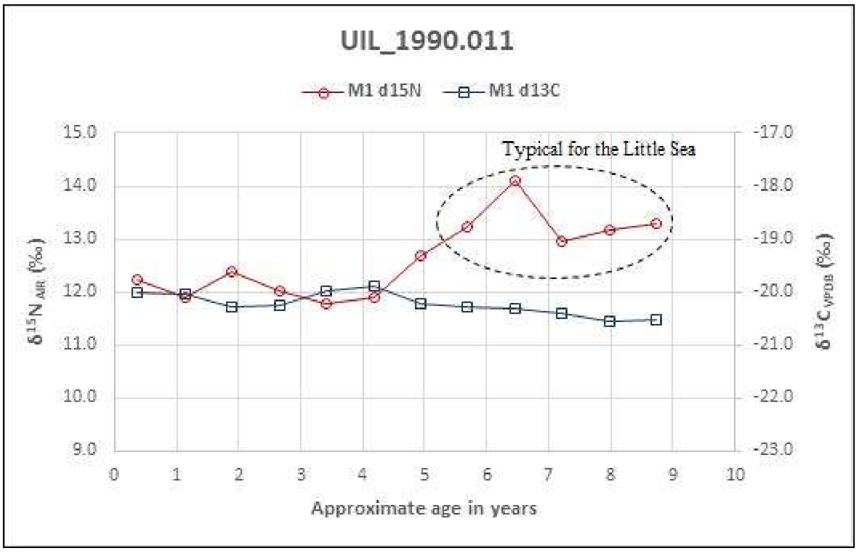


Figure 30. Single molar dentine profile for individual UIL_1990.011.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): III.
- Infancy diet: A weaning signature is not seen in the first few increments of the M1 (Figure 30). The occlusal surface of the tooth was not heavily worn, so this observation can be considered reliable.
- Childhood diet: Until just after four years (S-06), $\delta^{15}N$ and $\delta^{13}C$ exhibit little variation despite showing a negative relationship with each other. Hereafter, a steady rise of 2‰ is seen in $\delta^{15}N$ over two-and-a-half years, reaching its peak at 14.1‰ (S-09). This is higher than what is seen in the other Upper Lena individuals (Katzenberg *et al.* 2010; Weber and Goriunova 2013; Weber *et al.* 2002, 2011) and is closer to what is typically seen in EBA individuals living in the Little Sea micro-region (Katzenberg *et al.* 2010; Weber *et al.* 2011).
- Early adult diet: Not applicable.
- Bone values: Not applicable.
- Other observations: None.

Individual 9: UIL_1990.012

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UIL_1990.012	F 25–30	EBA	Glazkovo	M1 (3)-14	n/a	n/a	n/a

- Place of birth: Unknown.
- Migrations: Unknown.

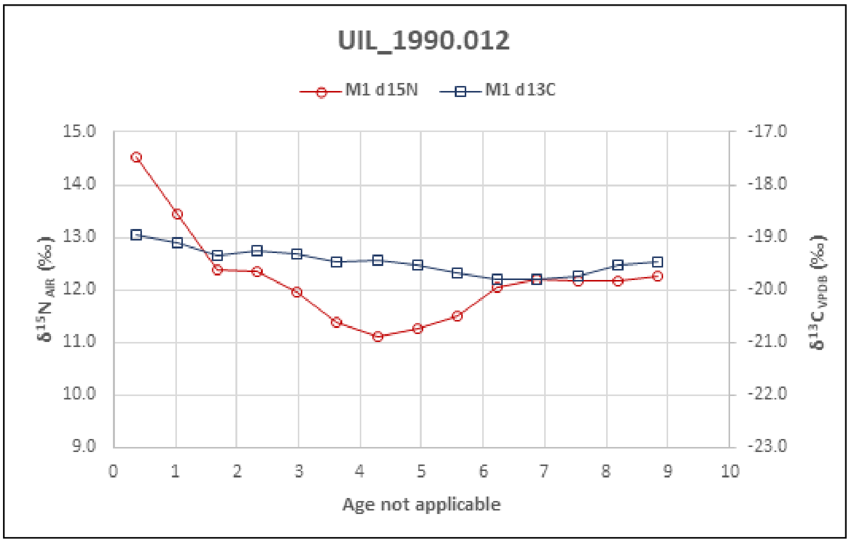


Figure 31. Single molar dentine profile for individual UIL_1990.012.

- General pattern(s): I, II.
- Infancy diet: The weaning signature is marked by a steep decline in δ^{15}N from ~birth at 14.5‰ (S-01) to 12.4‰ at one-and-a-half years (Figure 31), followed by a period of stability until ~2.3 years. Hereafter, δ^{15}N continues to decline to 11.1‰ at approximately four-and-a-half years of life (S-07), showing a total drop of 3.4‰. This change suggests that the individual was weaned just after four years.
- Childhood diet: After approximately four-and-a-half years, δ^{15}N increases again to 12.1‰ (S-10) before exhibiting dietary stability roughly between six and nine years. Throughout the development of the tooth, δ^{13}C values show little variation and range from −19.8‰ to −19.0‰.
- Early adult diet: Not applicable.
- Bone values: Not applicable.
- Other observations: None.

Individual 10: UIL_1991.013.01

Master ID	Sex Age in years	Period	Mortuary tradition	Teeth (Wear stage) Sections	Bone δ^{13}C ‰	*Bone δ^{15}N ‰*	*Notes*
UIL_1999.013.01	M 20+	EBA	Glazkovo	M1 (5)–13	n/a	n/a	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): III, IV.
- Infancy diet: The M1 does not show a clear breastfeeding signal (Figure 32). There is a slight decline in δ^{15}N from ~birth at 11.6‰ (S-01) to 10.5‰ just after three years (S-05), which is a much smaller decline (1.1‰) than what is seen in other individuals with a

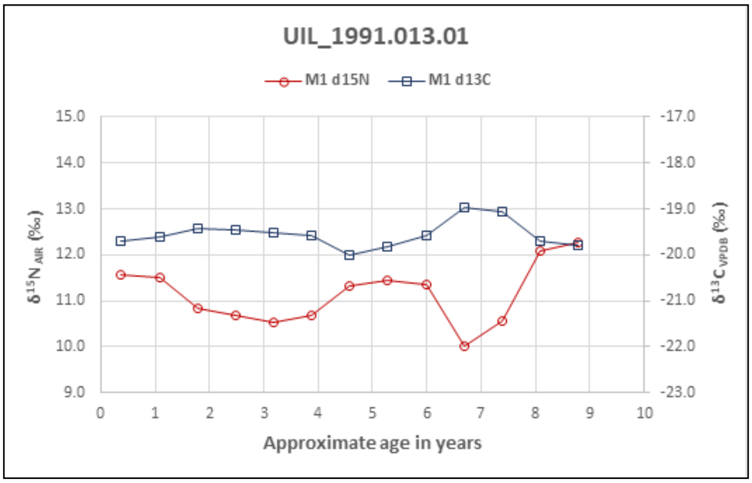


Figure 32. Single molar dentine profile for individual UIL_1991.013.01.

much clearer weaning signal. Furthermore, between birth and four-and-a-half years, $\delta^{15}N$ and $\delta^{13}C$ exhibit a minor negative relationship.
- Childhood diet: Just after five years (S-08), $\delta^{13}C$ and $\delta^{15}N$ values diverge again. The biggest changes in the M1 are seen at six years (S-09) when $\delta^{15}N$ declines from 11.4‰ to 10.0‰ (S-10) and then rises again at six-and-a-half years to 12.1‰ at eight years (S-11). Between four-and-a-half years (S-07) and almost nine years (S-13), $\delta^{13}C$ increases by 1‰ to −19.0‰, followed by a decline to −19.8‰.
- Early adult diet: Not applicable.
- Bone values: Not applicable.
- Other observations: The grave consisted of two burials with UIL_1999.013.02 discussed below.

Individual 11: UIL_1991.013.02

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UIL_1991.013.02	U 13–19	EBA	Glazkovo	M1 (2)–12	n/a	n/a	S-10 and S-11 were combined. No results for S-12.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II.
- Infancy diet: The weaning signature exhibits a decline in $\delta^{15}N$ from 14.9‰ around ~birth (S-01) to 12.8‰ at three years (S-04) (Figure 33). Hereafter, $\delta^{15}N$ remains almost unchanged until approximately six years (S-07), suggesting no change in diet. $\Delta^{13}C$ shows virtually no change.
- Childhood diet: After six years a second decline in $\delta^{15}N$, albeit rather small, is seen from 12.5‰ (S-08) to 12.1‰ (S-10 and S-11). While values are within the margin of

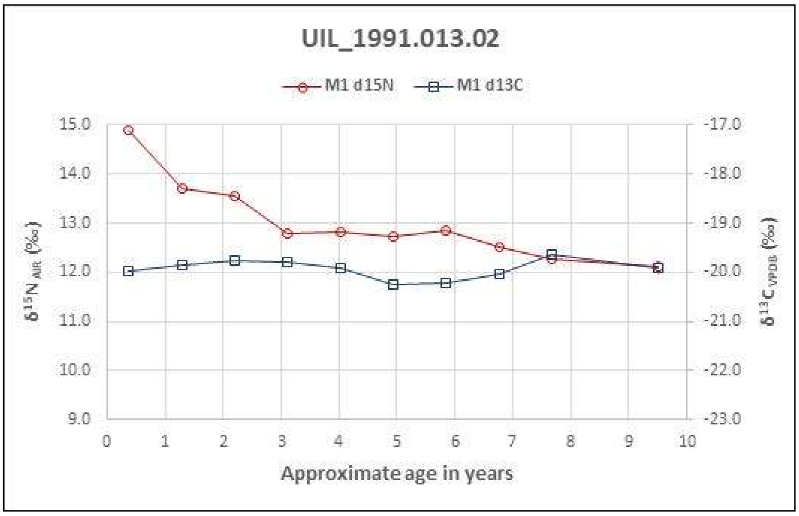


Figure 33. Single molar dentine profile for individual UIL_1991.013.02.

error, they could be considered significant as the decline is seen in the following three micro-samples. Δ^{13}C exhibits only minor changes with values ranging between −20.0‰ and −19.6‰ throughout the tooth.

- Early adult diet: Not applicable.
- Bone values: Not applicable.
- Other observations: None.

Summary

Dentine micro-samples for the Upper Lena individuals display a wide range of patterns between cemeteries and individuals. The EN Manzurka individual (MNZ_1974.002) provides stable isotope data which span life stages from weaning through childhood into early adulthood. Dentine δ^{15}N values range between 10.7‰ and 13.2‰, and δ^{13}C between −20.0‰ and −19.0‰. Results show that during childhood, the individual consumed only slightly less aquatic protein than during adulthood. However, overall, the data suggest that MNZ_1974.002 had a protein diet that was isotopically very similar during childhood and adulthood and was consuming foods from the Upper Lena micro-region.

For the EBA Obkhoi individuals, dentine δ^{15}N values range between 10.0‰ and 13.6‰, and δ^{13}C between −20.1‰ and −18.9‰. While the bone values for all three individuals cluster with the dentine values, they are consistently at the lower end of the δ^{15}N range, suggesting that they consumed slightly less aquatic protein during adulthood.

The majority of the Ust'-Ilga individuals show dentine δ^{15}N values ranging between 10.0‰ and 14.9‰ and δ^{13}C dentine between −21.0‰ and −18.8‰. Out of the 11 individuals, two (UIL_1990.009 and UIL_1990.011) exhibit δ^{15}N values that could be considered typical for the Little Sea micro-region. Furthermore, in most cases, δ^{13}C and δ^{15}N values fluctuate frequently within a single tooth, often moving in the opposite direction of one another (Pattern III).

This suggests that not only did their protein sources change frequently over time, but also more often relative to individuals from other Upper Lena cemeteries. In comparison to the adult bone values, for four of the Ust'-Ilga individuals, the dentine values are isotopically very similar.

Chapter 7

Dietary life-histories in the Angara

This chapter presents the tooth collagen stable carbon and nitrogen isotope results from individuals that were buried at the Ust’-Ida I cemetery in the Angara micro-region in Cis-Baikal, Siberia, Russia. The chapter is divided into three sections. The first two present the results of the Late Neolithic and Early Bronze Age individuals, and the third summarizes all results.

As previously mentioned, the Ust’-Ida I cemetery, situated at the confluence of the Ida and Angara rivers, yielded individuals belonging to either the Isakovo (Late Neolithic) or Glazkovo (Early Bronze Age) mortuary tradition, with one grave assigned to the Early Neolithic Kitoi (Weber *et al.* 2006). To investigate dietary differences and/or similarities between the LN and the EBA individuals at Ust’-Ida I, individuals from the two periods will be examined separately.

The $\delta^{13}C$ dentine stable isotope values range between –19.3‰ and –15.3‰ for the LN individuals and between –19.4‰ and –16.1‰ for the EBA individuals. The $\delta^{15}N$ dentine stable isotope values range between 11.2‰ and 16.1‰ for the LN Ust’-Ida I individuals and between 11.2‰ and 16.0‰ for the EBA individuals. For both groups (LN and EBA), the dentine $\delta^{13}C$ can be considered typical for the Angara micro-region (Katzenberg *et al.* 2010; Weber *et al.* 2011). The $\delta^{15}N$ values, however, are at times one trophic level higher than what has typically been observed in bone, indicating a slight difference in dietary protein between childhood and adulthood.

General patterns in dentine stable isotope signatures

The five main dentine patterns seen across all 49 hunter-gatherers are described in greater detail in Chapter 6. They are:

- Pattern I: Decline in $\delta^{15}N$ during infancy (weaning signature).
- Pattern II: Positive relationship between $\delta^{13}C$ and $\delta^{15}N$.
- Pattern III: Negative relationship between $\delta^{13}C$ and $\delta^{15}N$.
- Pattern IV: Rise in $\delta^{15}N$ toward the end of molar development.
- Pattern V: Continuous oscillation of both $\delta^{13}C$ and $\delta^{15}N$ values (zigzag).

A total number of 27 molars (20 LN, seven EBA) representing 13 hunter-gatherers (nine LN, four EBA) from the Angara produced 347 micro-samples. All results fall within the acceptable range for % carbon, % nitrogen, and atomic C/N ratios (see Appendix C). However, 10 micro-samples did not provide data either due to an instrument error or because the samples did not yield a sufficient amount of collagen.

Late Neolithic Ust'-Ida I

Individual 1: UID_1987.006

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1987.006	M 35–50	LN	Isakovo	M1 (6)–16 M3 (3)–14	-17.5	12.8	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, IV.
- Infancy diet: A weaning signature is seen in the M1 with a decline in δ^{15}N from 14.7‰ (S-01) to 13.0‰ (S-04) over the course of approximately two years (Figure 34). Between two and three-and-a-half years the values remain steady at 13.0‰, suggesting the child was weaned onto solid foods during this time.
- Childhood diet: After three-and-a-half years (S-06), δ^{15}N continues a downward trend, reaching its lowest point at 12.3‰ (S-12). Hereafter, an increase is seen in the root tips to 13.5‰ (S-16). Δ^{13}C remains stable throughout the M1, fluctuating around -18.0‰.
- Early adult diet: In the M3, δ^{13}C fluctuates between -18.0‰ and -17.1‰ and moves in sync with δ^{15}N, showing a positive relationship. Between 10.5 (S-03) and 16 years (S-08), there is an increase in δ^{15}N (1.3‰) as well as δ^{13}C (0.9‰), suggesting a change in diet. Between 16 (S-08) and 22.5 years (S-14), values change again with δ^{15}N declining to 12.7‰ and δ^{13}C to -18.0‰.
- Bone values: Bone δ^{15}N is similar to the majority of the dentine micro-samples (Figure 35). Bone δ^{13}C exhibits only a slightly more positive value compared to the M1.

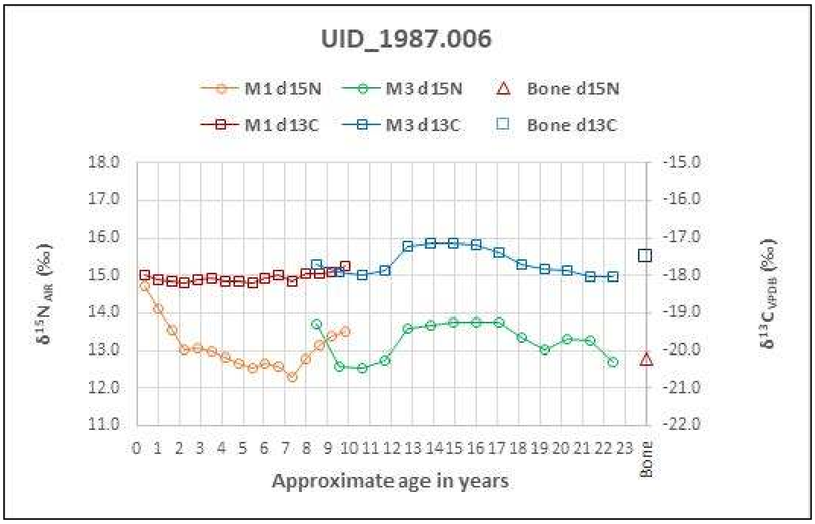


Figure 34. Multi-molar dentine profile for individual UID_1987.006.

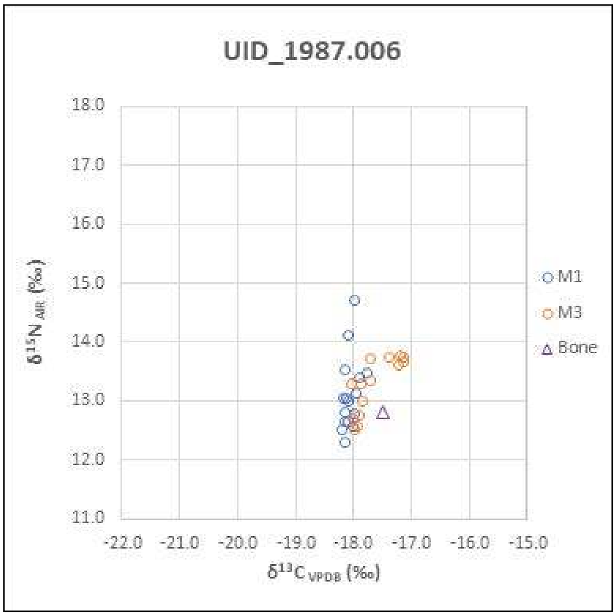


Figure 35. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1987.006.

- Other observations: S-16 of the M1 and S-01 of the M3 do not line up. This will be discussed in Chapter 9.

Individual 2: UID_1987.011

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1987.011	F 35–50	LN	Isakovo	M1 (6)–12 M2 (6)–13 M3 (4)–10	−18.2	12.3	Missing data for S-01 (M1) and S-01, 02, 03 (M2).

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, IV.
- Infancy diet: The weaning signature shows a steep decline in δ^{15}N from 14.2‰ at one year (S-02) to 12.3‰ at three years (S-04) (Figure 36). While δ^{13}C appears to move in the opposite direction with a minor increase from −18.8‰ to −18.6‰, this is within the margin of error. Between three and five years, δ^{15}N shows little variation, suggesting the child completed breastmilk consumption by this time.
- Childhood diet: M2 exhibits more variation in δ^{13}C than M1 as δ^{13}C declines from −18.6‰ at three years (S-03) to −19.4‰ at four-and-a-half years (S-05). This is the lowest δ^{13}C value of all Ust'-Ida I individuals. Between five and 10 years, δ^{15}N steadily increases from 12.3‰ (S-05) to 13.1‰ (S-10).
- Early adult diet: During the interval between 14 and 22 years (M3), δ^{15}N increases from 12.4‰ (S-05) to 13.7‰ (S-1), showing a switch to foods with slightly higher δ^{15}N. The

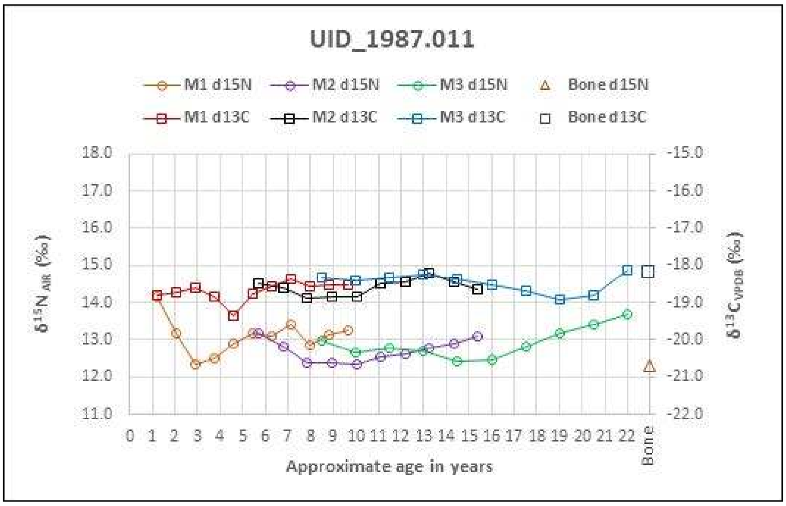


Figure 36. Multi-molar dentine profile for individual UID_1987.011.

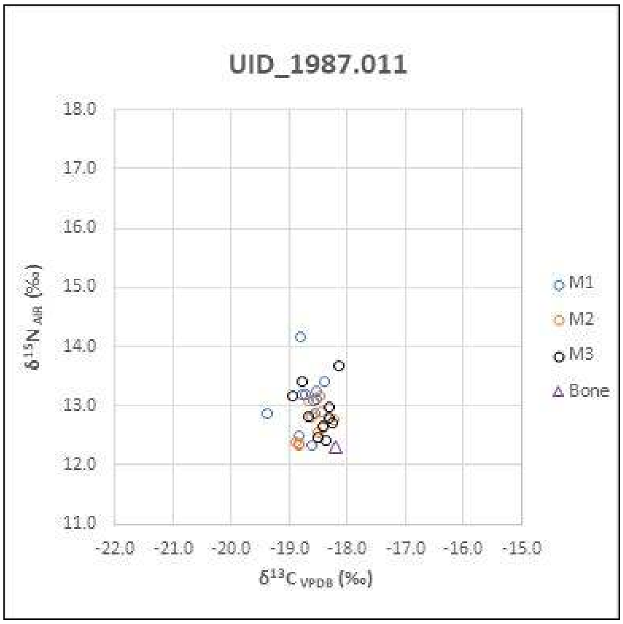


Figure 37. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1987.011.

$\delta^{13}C$ values fluctuate between −18.9‰ and −18.1‰, with the biggest change happening between 19 and 21 years.

- Bone values: The values cluster with the dentine stable isotope values, suggesting a diet that is isotopically similar during the last few years (Figure 37).
- Other observations: At times the M1 and M2 do not line up (e.g. between four and eight years for $\delta^{15}N$) even though contemporary micro-samples are expected to produce similar values. This will be discussed in Chapter 9. Samples S-01 of the M1 and the M2 did not provide any collagen. Data for samples S-02 and S-03 of the M2 were lost due to an instrumental error.

Individual 3: UID_1988.014

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1988.014	M 18–20	LN	Isakovo	M1 (4?)–12 M3 (3)–10	–18.0	12.3	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, III, IV.
- Infancy diet: The M1 exhibits a weaning signature with a decline in δ^{15}N around birth from 15.1‰ (S-01) to 12.5‰ just after five years (S-07). Hereafter, there is an approximately two–year period where δ^{15}N essentially remains unchanged, suggesting the child has been weaned off breastmilk. During weaning, the δ^{13}C in the M1 moves in the opposite direction between approximately one and four years, showing a negative relationship between both values by rising one trophic level from –18.6‰ to –17.5‰.
- Childhood diet: Post-weaning, δ^{15}N declines and reaches its lowest point at eight years with 12.3‰ (S-10) (Figure 38). Hereafter, there is an increase of 0.8‰, before δ^{15}N ends at 12.8‰ just before 10 years (S-12). Δ^{13}C continues to decline to –18.4‰ before rising again to –18.0‰ in the root tip.
- Early adult diet: During the development of the M3, there is an upward trend seen in δ^{15}N from 14 years onward from 12.8‰ to 14.1‰. Δ^{13}C shows little variation, but a minor rise (alongside δ^{15}N) from –18.0‰ to –17.7‰ is also seen towards the end of the roots (from S-08 to S-10).
- Bone values: There is a 1.8‰ difference for δ^{15}N between bone and the last dentine micro-sample of the M3 (Figure 39). Although a bone value provides an isotopic average of the last few years of life, it would be expected to be higher for δ^{15}N

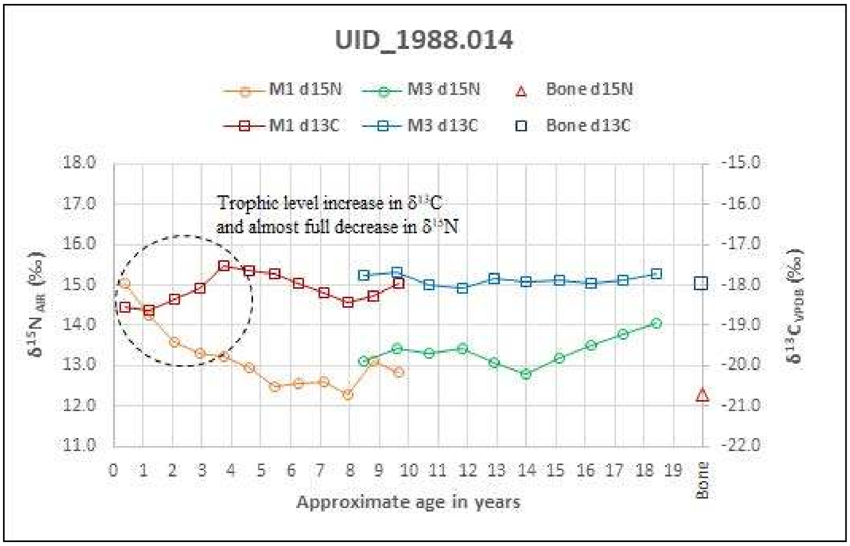


Figure 38. Multi-molar dentine profile for individual UID_1988.014.

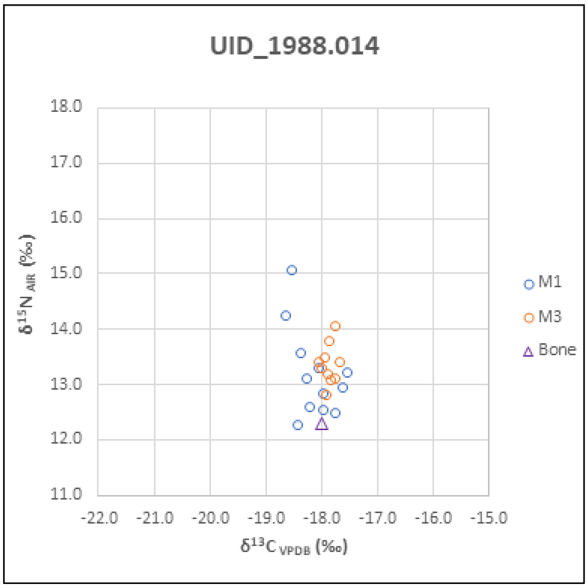


Figure 39. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1988.014.

considering the individual died when dental development had not yet been completed. A possible explanation for this is provided in Chapter 9. Overall, $\delta^{15}N$ was higher during development when compared to adulthood (bone).

- Other observations: An identification of the wear stage could not be made for M1 as most of the enamel had chipped off. The M3 was not fully developed as the root apexes were open. Based on the London Atlas (AlQahtani *et al.* 2010) this molar had reached the Rc stage (root length completed with parallel ends). The median age for this developmental stage, in both jaws, is 19.5 years. The ageing of the increments has been corrected for this as is explained in Chapter 5.

Individual 4: UID_1989.020.01

Master ID	Sex Age in years	Period	Mortuary tradition	Teeth (Wear stage) Sections	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UID_1989.020.01	M 18–24	LN	Isakovo	M1 (3)–16 M3 (3)–12	–16.8	13.5	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II.
- Infancy diet: The M1 exhibits a steep decline in $\delta^{15}N$ from ~birth (S-01) at 15.1‰ to three-and-a-half years (S-06) at 11.2‰ (Figure 40). The $\delta^{13}C$ values show a similar change to $\delta^{15}N$ with a small decline from –18.1‰ to –19.0‰. Results suggest that around three-and-a-half years the child was weaned off breastmilk.

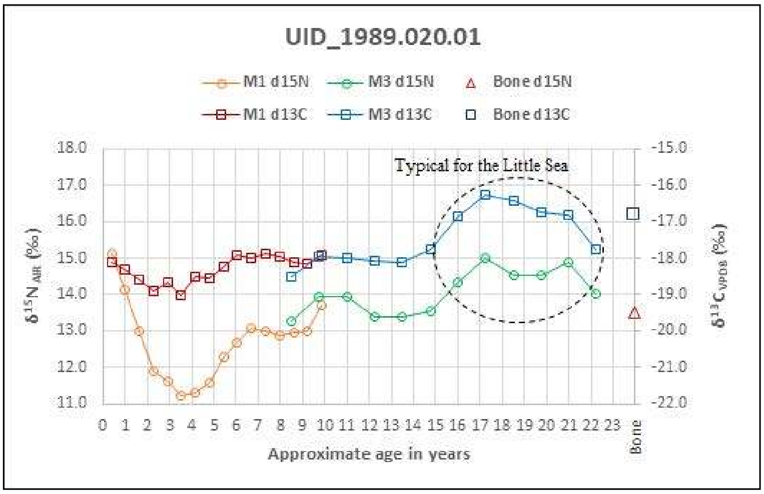


Figure 40. Multi-molar dentine profile for individual UID_1989.020.01.

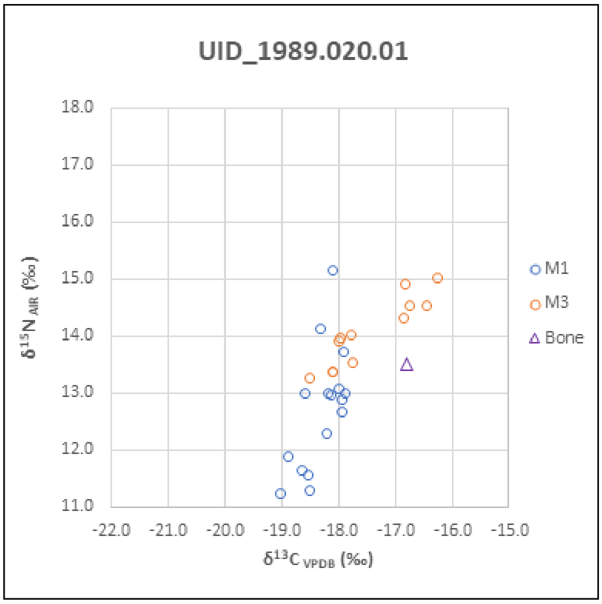


Figure 41. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1989.020.01.

- Childhood diet: Post-weaning, δ^{15}N increases from 11.2‰ to 13.7‰ at the apex, showing a change in diet. During this time δ^{13}C rises by 1‰ from −19.0‰ to −18.0‰.
- Early adult diet: In the M3, δ^{13}C and δ^{15}N exhibit a positive relationship. Between eight-and-a-half (S-01) and 17 years (S-08) there is an upward trend to δ^{15}N 15.0‰ and δ^{13}C −16.3‰. These values are typically seen in Little Sea individuals and even in Early Neolithic individuals from Southwest Baikal. After 17 years and toward the apex, δ^{15}N and δ^{13}C values decline to 14.0‰ and −17.8‰, respectively.
- Bone values: In comparison to the dentine values, bone δ^{13}C is right below a few of the M3 increments (S-07 to S-11) while δ^{15}N is higher throughout the M3 (Figure 41). Bone and M3 values are higher than in M1 (apart from values during weaning).
- Other observations: None.

Individual 5: UID_1989.020.02

Master ID	Sex Age in years	Period	Mortuary *tradition*	*Teeth (Wear stage) Sections*	*Bone δ¹³C ‰*	*Bone δ¹⁵N ‰*	*Notes*
UID_1989.020.02	F 30–40	LN	Isakovo	M1 (5)–13 M2 (5)–12 M3 (3)–10	–17.7	12.7	Missing data for S-12 of M2.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, III, IV.
- Infancy diet: The M1 exhibits a weaning signature over approximately two years from 15.8‰ (S-01) to (S-03) 13.8‰ (Figure 42). Δ^{13}C shows a 1.2‰ decrease from –17.5‰ to –18.7‰ during weaning, which is not visible in most Cis-Baikal individuals examined in this project.
- Childhood diet: Δ^{15}N and δ^{13}C display a lot of variation throughout childhood. Between two and three-and-a-half years, δ^{15}N increases before showing another steep decline from 14.3‰ to 13.0‰ at five years. Δ^{13}C rises after two years by 1.3‰. Between five and seven-and-a-half years, δ^{13}C shows almost no change. From seven to eight-and-a-half years, δ^{15}N and δ^{13}C rise to –17.5‰ and 13.9‰, respectively, in the M1 root tip. In the M2 fluctuations continue for both δ^{13}C and δ^{15}N. The δ^{15}N values range between 13.0‰ and 14.9‰ with an increase of 1.9‰ between seven-and-a-half and 14 years. Δ^{13}C values range between –18.2‰ and –17.2‰.
- Early adult diet: During M3 development, δ^{15}N and δ^{13}C show a positive relationship, apart from the small dip in δ^{13}C at S-09 to S-10. Δ^{15}N shows an upward trend in the roots of the M3, moving from 12.5‰ (S-05) to 14.0‰ (S-10).

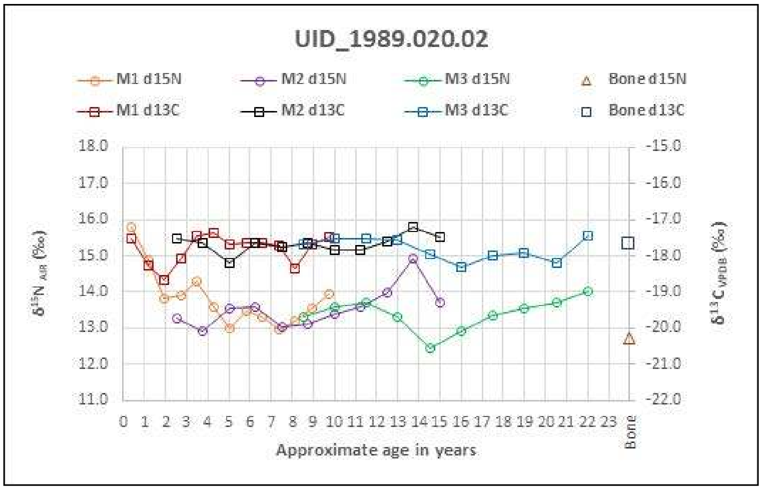


Figure 42. Multi-molar dentine profile for individual UID_1989.020.02.

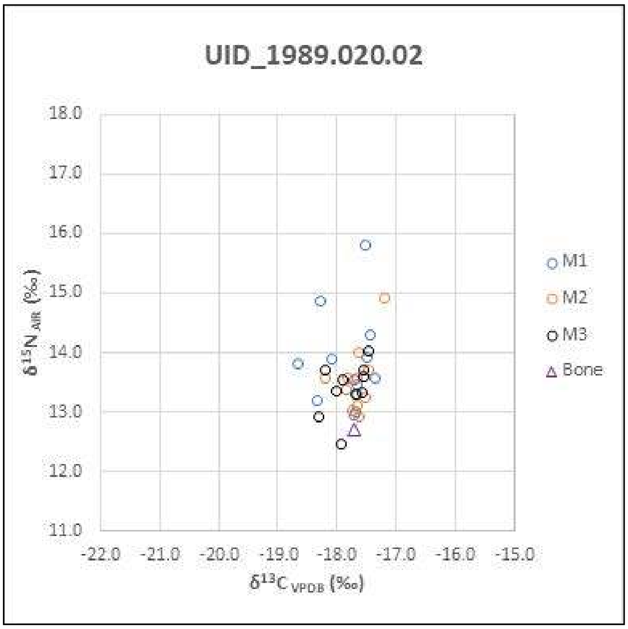


Figure 43. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.020.02.

- Bone values: The bone values are only slightly lower than most dentine micro-samples, suggesting diets were isotopically similar during dental development and the last few years of life (Figure 43).
- Other observations: This multi-molar chart displays much variation in $\delta^{13}C$ and $\delta^{15}N$. After 11.5 years, $\delta^{15}N$ in M2 and M3 move in opposite directions and display values that are greatly different. Similar patterns can be seen on a smaller scale in the $\delta^{13}C$ of M1 and M2. Possible explanations for these differences between molars will be provided in Chapter 9.

Individual 6: UID_1989.022

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UID_1989.022	F 15–20	LN	Isakovo	M1 (3)–12 M3 (3)–10	−16.0	14.4	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, IV, V.
- Infancy diet: The weaning signature in the M1 declines from $\delta^{15}N$ 16.0‰ (S-01) around birth to 12.5‰ at four-and-a-half years (S-06) (Figure 44). This is a 3.5‰ decrease, showing a change equivalent to about one entire trophic level.

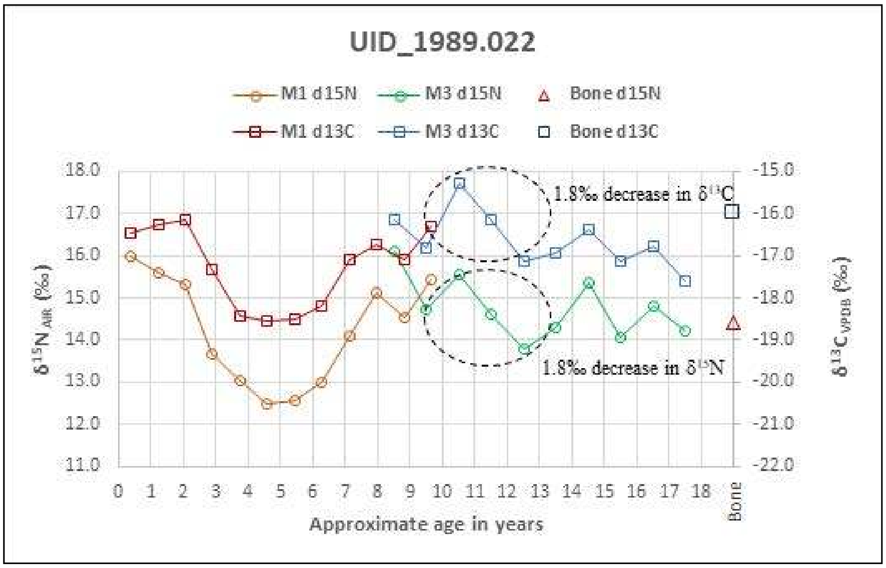


Figure 44. Multi-molar dentine profile for individual UID_1989.022.

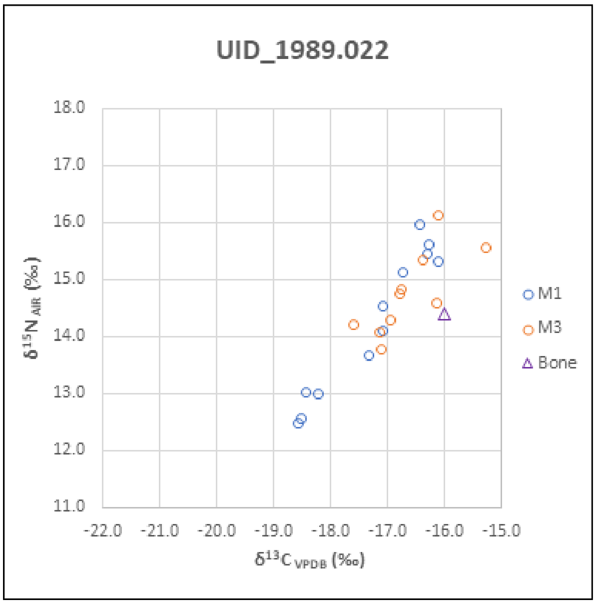


Figure 45. Scatter plot of dentine and bone δ13C and δ15N values for individual UID_1989.022.

- <u>Childhood diet</u>: Post-weaning, δ15N rises from 12.5‰ to 15.1‰, showing a full trophic level increase. Towards the end of the root, the individual exhibits a zigzag pattern, which continues into early adulthood.
- <u>Early adult diet</u>: At eight-and-a-half years (S-08) the M3 has a δ15N value of 16.1‰, which is the highest out of all Angara individuals examined in this study. This value suggests the individual was eating high trophic level foods, most likely the Baikal seal. The dentine micro-samples display a succession of increases and decreases until the end of the M3. Between eight-and-a-half and 11 years, this change appears every year. Between 11 and 14.5 years, the changes happen every two years before switching back

to once a year. Δ^{13}C exhibits a positive relationship, moving in synch with δ^{15}N. Between 10.5 and 12.5 years, there is decrease in δ^{13}C of almost two trophic levels.

- Bone values: The values are lower for δ^{13}C compared to the dentine micro-samples (Figure 45). Bone δ^{15}N is roughly in the middle (14.4‰) of a wide spread of dentine values, ranging between 12.5‰ and 16.1‰.
- Other observations: The M3 had not fully developed by the time the individual died. Based on the London Atlas (AlQahtani *et al.* 2010) the molar had reached the R3/4 stage (three-quarters of root length developed with diverge ends). The median age for this developmental stage, in both jaws, is 18.5 years. The ageing of increments has been corrected for this as explained in Chapter 5.

Individual 7: UID_1989.030

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1989.030	M 50	LN	Isakovo	M1 (5)–14 M3 (3)–12	−18.6	12.6	Missing data for S-08 and S-09 of M3.

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II.
- Infancy diet: The δ^{15}N values of the M1 show a gradual decline from 15.3‰ to the lowest point of 12.5‰ at approximately four years of age (Figure 46), which suggests the individual completed weaning by this time.
- Childhood diet: The M1 δ^{13}C reveals a positive relationship with δ^{15}N apart from the minor increase of 0.4‰ from S-03 to S-04. Both exhibit an upward trend to seven-and-a-half years before declining to 13.0‰ and −18.5‰ in the root tip.

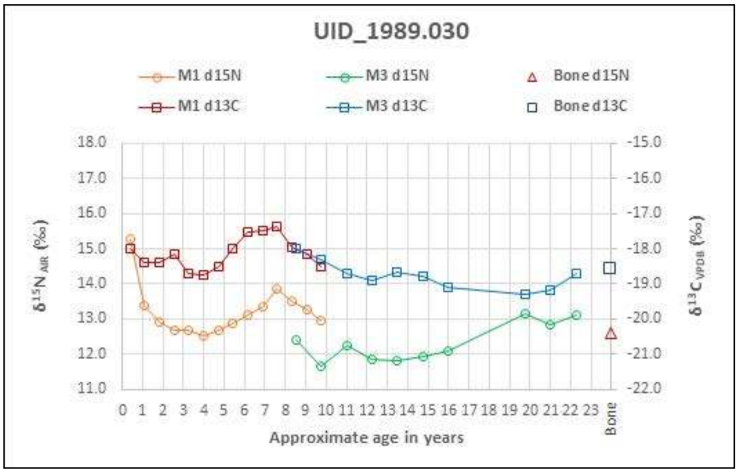


Figure 46. Multi-molar dentine profile for individual UID_1989.030.

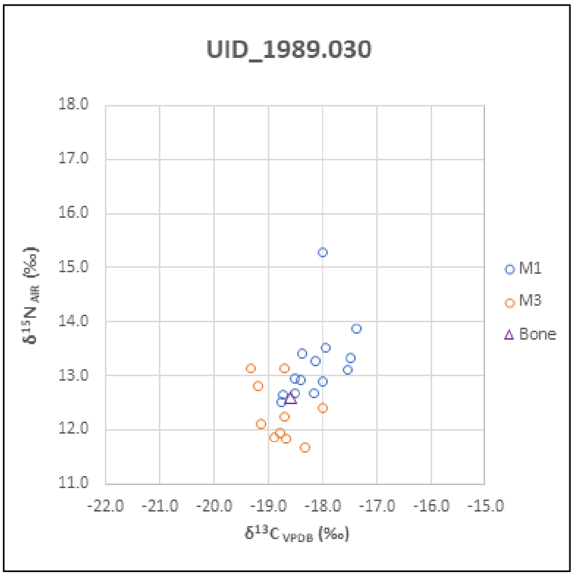


Figure 47. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1989.030.

- Early adult diet: Both values decline at the start of M3. Δ^{13}C continues to go down from −18.0‰ to −18.9‰, whereas δ^{15}N increases from 11.7‰ to 12.3‰. Between 12 (S-04) and 16 (S-07) years, there is a slight negative relationship visible between δ^{15}N and δ^{13}C. It is unknown what happens between 16 and 19.5 years for δ^{15}N as well as δ^{13}C.
- Bone values: Childhood and adulthood diet were isotopically very similar (Figure 47).
- Other observations: Interestingly, the last three increments of the M1 line up nicely with the first two increments of the M3 for δ^{13}C, which is not seen for δ^{15}N. A possible explanation as to why this might be is provided in Chapter 9.

Individual 8: UID_1991.038

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1991.038	M 45–60	LN	Isakovo	M1 (7)–10 M3 (4)–13	-18.7	12.4	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, IV.
- Infancy diet: Despite the amount of wear on the occlusal surface of the M1, a small remnant of the weaning signature is seen from δ^{15}N 14.6‰ (S-01) to 13.9‰ (S-02) (Figure 48). The duration between one-and-a-half (S-02) and three-and-a-half (S-04) years suggests little dietary change, which could mean the individual was weaned roughly somewhere from two-and-a-half to three-and-a-half years. Although the

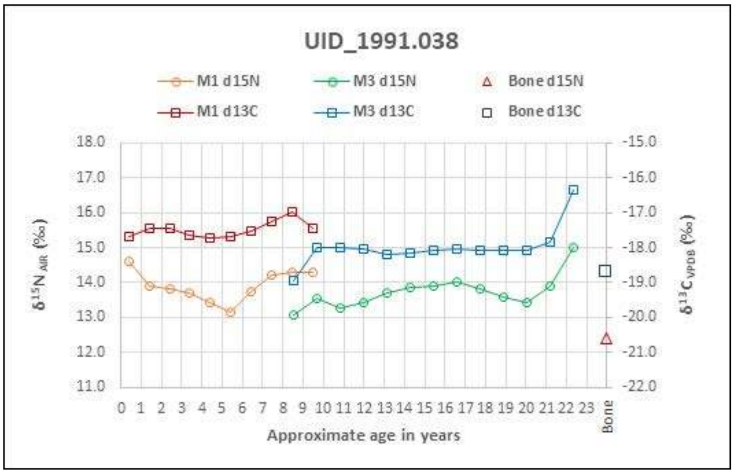


Figure 48. Multi-molar dentine profile for individual UID_1991.038.

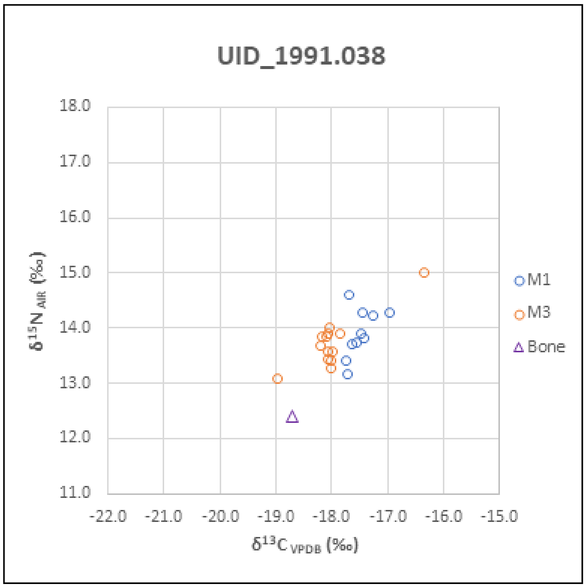


Figure 49. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1991.038.

approximate age for this event appears slightly later as a result of the wear, precisely when is unknown. Δ^{13}C exhibits essentially no change during this time.

- <u>Childhood diet</u>: Throughout the M1, δ^{13}C continues to exhibit little change between micro-samples. The δ^{13}C value slowly increases to −17.5‰ at eight years (S-09), just to decline again to −17.5‰ in the root tip. Δ^{15}N also exhibits an increase, of 1.1‰, which starts at five-and-a-half years (S-06) and continues to nine-and-a-half years, that is to the root tip.
- <u>Early adult diet</u>: During the development of the M3 there is only an increase at the start from eight-and-a-half to nine-and-a-half years (−19.0‰ to −18.0‰), and at the end of the molar from 21 to 22.5 years (−17.8‰ to −16.3‰). Only at the start and end of the M3 does δ^{13}C display a significant change of 1‰ and 1.5‰, respectively. Then, for a period of 10.5 years, δ^{13}C ranges between −18.2‰ and −18.0‰, which is within the error of measurement. During this time, δ^{15}N exhibits minor changes with the biggest

rise in the last ~24 months from 13.4‰ to 15‰. Overall, the diet appears very stable throughout the majority of M3 development.

- Bone values: Compared to the dentine micro-samples, the bone values are lower on both axes, suggesting a different diet during childhood and late adulthood (Figure 49).
- Other observations: None.

Individual 9: UID_1995.056.01

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ¹³C ‰*	*Bone δ¹⁵N ‰*	*Notes*
UID_1995.056.01	M 35–50	LN	Isakovo	M1 (?)–18 M3 (3)–13	−17.6	13.1	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, III, IV.
- Infancy diet: A weaning signature is seen in the decline in δ^{15}N at the start of M1 from 14.8‰ around birth (S-01) to 12.6‰ at three years (S-06) (Figure 50). Hereafter, values stabilize ~12.7‰ until just before four years.
- Childhood diet: Both values exhibit multiple minor fluctuations throughout the rest of the M1 micro-samples. Δ^{13}C values shift between −17.9‰ and −17.3‰ and δ^{15}N between 12.7‰ and 13.9‰. Between nine and 10 years (S-16 to S-18), δ^{15}N increases to 13.9‰.
- Early adult diet: At the start of M3, a decline in δ^{15}N is seen, reaching 12.6‰ just before 11 years (S-03). Δ^{15}N then displays an upward trend before stabilizing between 13 and 21.5 years. Δ^{13}C exhibits little change throughout the tooth apart from an increase to −17.1‰ in S-02.
- Bone values: The values cluster together with the M1 micro-samples (Figure 51). The majority of the M3 micro-samples are lower for δ^{13}C and slightly higher for δ^{15}N.

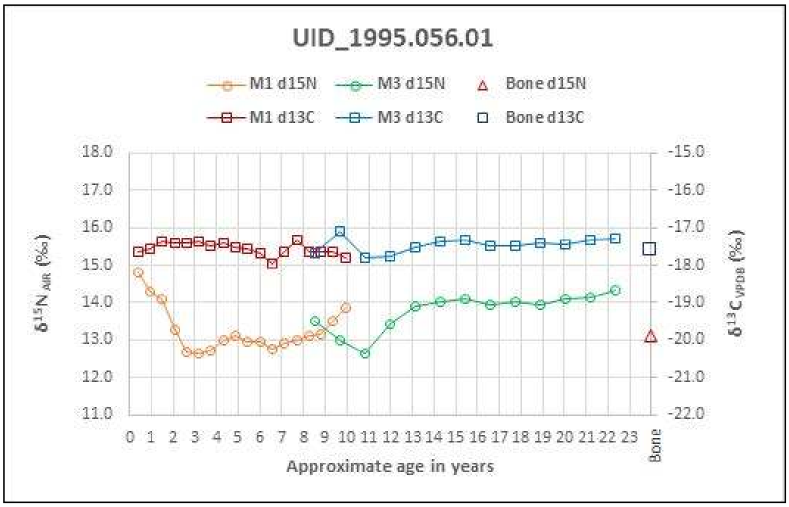


Figure 50. Multi-molar dentine profile for individual UID_1995.056.01.

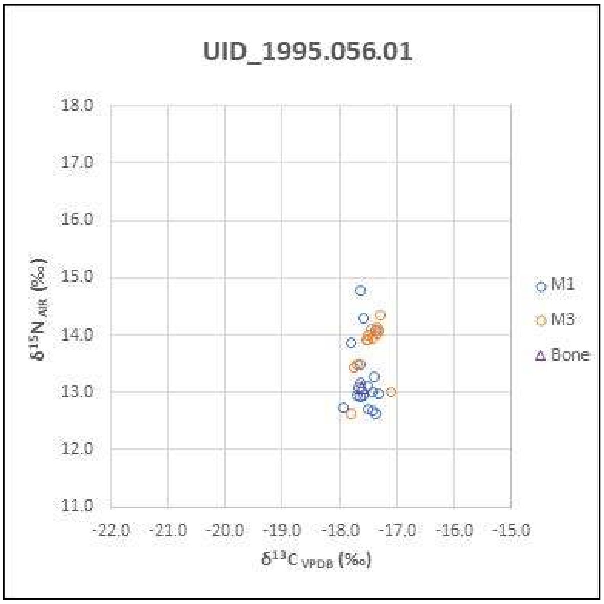


Figure 51. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1995.056.01.

- Other observations: It was not possible to assign a wear stage to the M1 as the enamel on the crown had been severely damaged by saw cut marks. The final micro-samples of the M1 overlap with the start of M3. This will be further discussed in Chapter 9.

Early Bronze Age Ust'-Ida I

Individual 10: UID_1989.019

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1989.019	M 30–35	EBA	Glazkovo	M1 (4)–12 M3 (3)–12	−18.8	12.9	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II, III, IV.
- Infancy diet: Between ~birth (S-01) and one year (S-02), a steep decline in δ^{15}N is seen from 15.8‰ to 13.8‰ (Figure 52). Δ^{15}N gradually continues to decline down to 13.0‰ at four-and-a-half years (S-06). As values between one and four-and-a-half years continue to decline gradually, it is difficult to locate the point which might indicate when the individual was weaned. Results could suggest that this happened around four-and-a-half years as the curve appears relatively stable at this point.

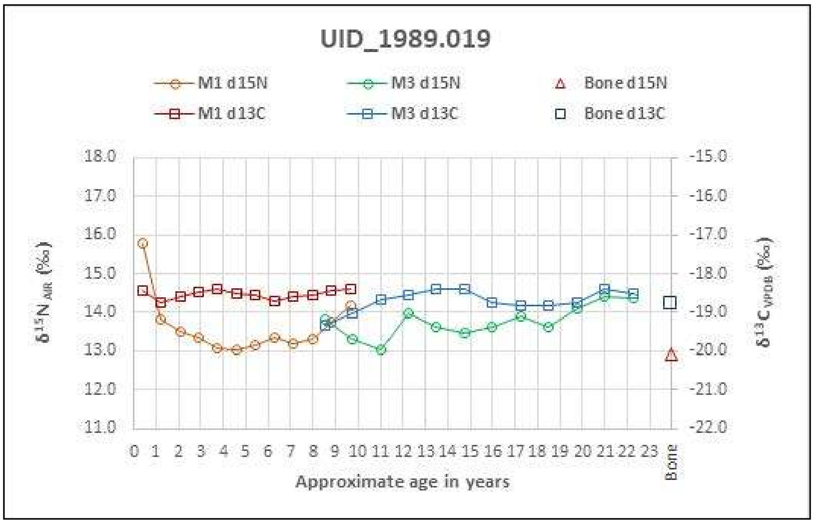


Figure 52. Multi-molar dentine profile for individual UID_1989.019.

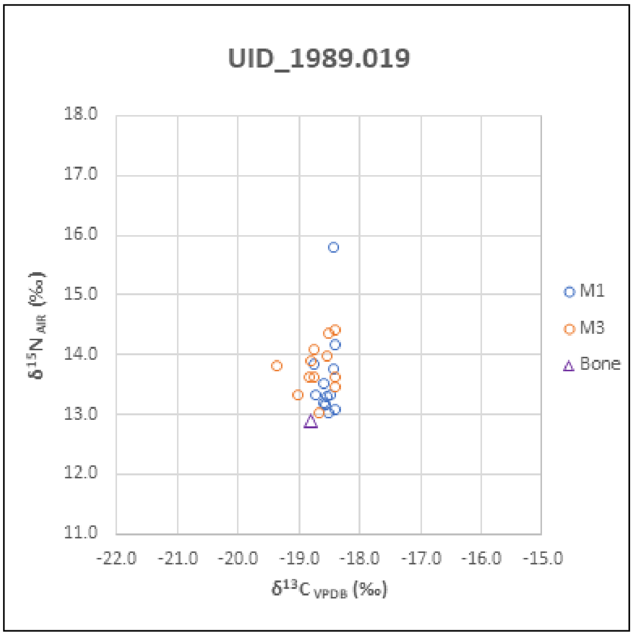


Figure 53. Scatter plot of dentine and bone δ13C and δ15N values for individual UID_1989.019.

- Childhood diet: Δ13C exhibits very little change throughout the M1 with values ranging between −18.7‰ and −18.4‰. Δ15N shows an upward trend after four-and-a-half years from 13.0‰ through to the root tip where is measures 14.2‰.
- Early adult diet: In the M3, δ13C and δ15N exhibit a negative relationship. Δ15N oscillates between increases and decreases yet showing an upward trend to 14.4‰. For δ13C, shifts between samples are still relatively small (i.e. in the range of 0.1‰ to 0.4‰), but overall an increase is seen, followed by a slight decline and another increase before reaching a value of −18.5‰ at the root tip.
- Bone values: The values fall on the low end of δ15N compared to the dentine values (Figure 53) while dentine δ13C are slightly less negative than bone.

- Other observations: As seen in a few of the other individuals, the final increment of the M1 and first increment of the M3 do not line up.

Individual 11: UID_1989.029

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ¹³C ‰*	*Bone δ¹⁵N ‰*	*Notes*
UID_1989.029	M 50	EBA	Glazkovo	M3 (3)–12	−17.4	12.1	n/a

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): II, IV, V.
- Infancy diet: Not applicable.
- Childhood diet: Not applicable.
- Early adult diet: Δ^{13}C and δ^{15}N for this individual exhibit a similar pattern that is seen in the M3 of Late Neolithic individual UID_1989.022 (Figure 54). There is a positive relationship between δ^{13}C and δ^{15}N and the dentine profiles show several increases and decreases in an almost zigzag pattern, indicating multiple changes in δ^{13}C and δ^{15}N over many years. This suggests changes in diet. There is also a gradual increase in δ^{15}N and δ^{13}C over time.
- Bone values: Bone δ^{13}C exhibits a similar value to a majority of the dentine micro-samples, while bone δ^{15}N is slightly lower than most micro-samples (Figure 55).
- Other observations: none.

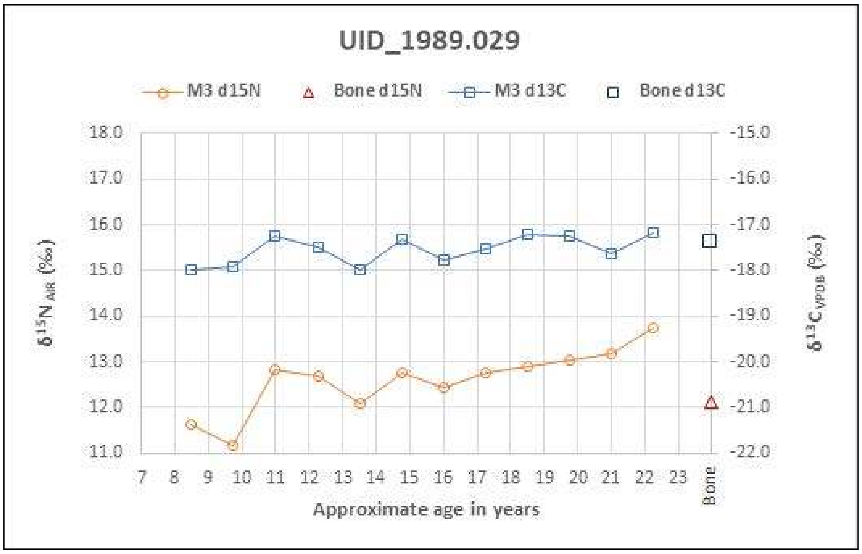


Figure 54. Single molar dentine profile for individual UID_1989.029.

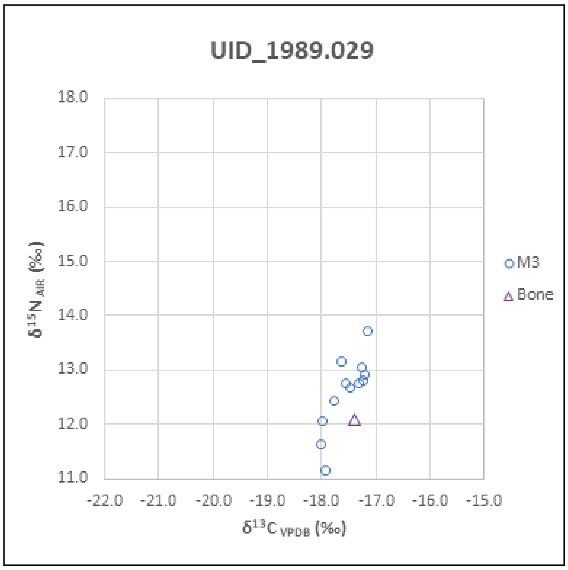


Figure 55. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual UID_1989.029.

Individual 12: UID_1993.045

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Notes*
UID_1993.045	M 22–30	EBA	Glazkovo	M1 (7)–15 M3 (4?)–14	−17.3	13.5	Missing data for S-13 (M1) and S-10 (M3).

- Place of birth: Unknown.
- Migrations: Unknown.
- General pattern(s): I, II.
- Infancy diet: The M1 exhibits a decline in $\delta^{15}N$ from 15.2‰ ~birth (S-01) to 12.3‰ at four-and-a-half years (S-07), before rising around five years (Figure 56). As seen in UID_1989.019, this individual could also have completed weaning around four-and-a-half years. Between birth and three years, $\delta^{13}C$ does not show any change and remains stable at −17.8‰.
- Childhood diet: After five years, $\delta^{15}N$ continues to increase to 14.0‰ at 10 years. $\Delta^{13}C$ exhibits minor fluctuations with the largest change from −18.0‰ at six-and-a-half years (S-10) to −17.4‰ at seven years (S-11).
- Early adult diet: Throughout the M3, $\delta^{13}C$ fluctuates between −18.0‰ and −17.1‰. $\Delta^{15}N$ shows less variation compared to the M1 with values ranging between 13.1‰ and 14.0‰.
- Bone values: The values cluster with the dentine values of the M3 (Figure 57).
- Other observations: The M3 could not be assigned a positive wear stage (4?) due to damage to the enamel removed for strontium isotope analysis. As a result, the pulp cavity was visible from the occlusal surface. The portion of the tooth that was covered and protected by enamel was micro-sampled. Furthermore, the last increment of M1

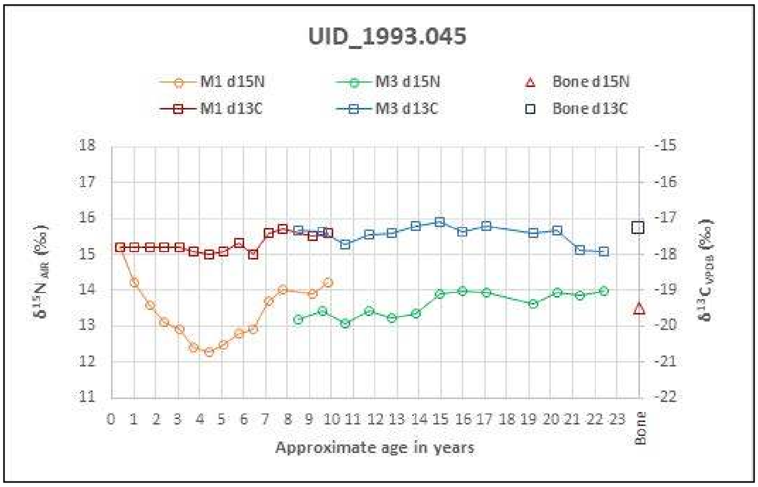


Figure 56. Multi-molar dentine profile for individual UID_1993.045.

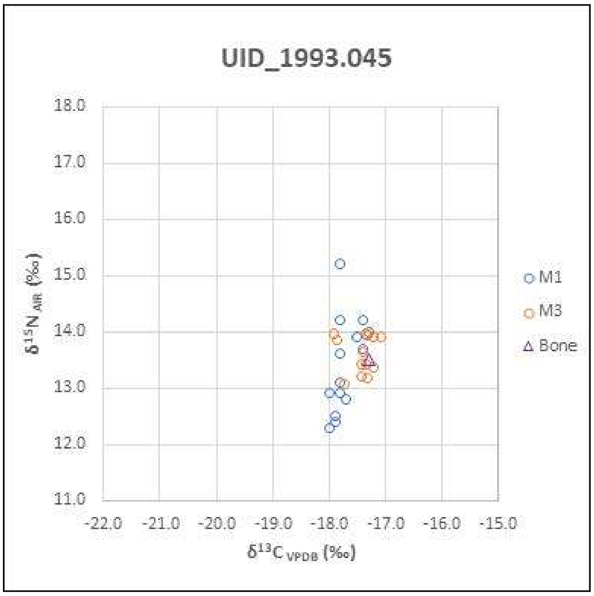


Figure 57. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1993.045.

and first increment of M3 do not line up for δ^{15}N, showing a difference of 1‰. This will be addressed in Chapter 9.

Individual 13: UID_1994.048

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Notes*
UID_1994.048	M 50	EBA	Glazkovo	M1 (5)–14 M3 (3)–16	−16.4	14.4	Missing data for S-15 (M3).

- Place of birth: Unknown.

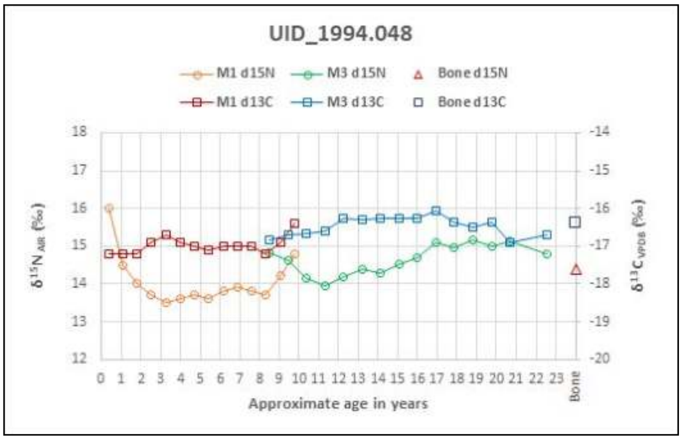


Figure 58. Multi-molar dentine profile for individual UID_1994.048.

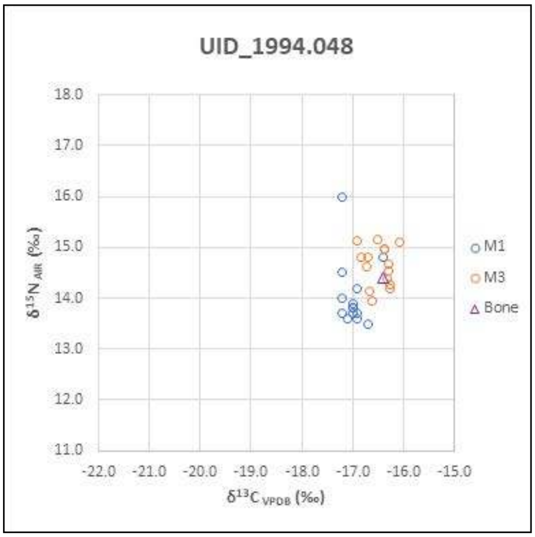


Figure 59. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual UID_1994.048.

- Migrations: Unknown.
- General pattern(s): I, II, III, IV.
- Infancy diet: Δ^{15}N values decline from ~birth at 16‰ (S-01) to 13.5‰ at three years (S-05) (Figure 58). As seen in individual UID_1993.045, the first few increments (S-01 to S-03) show no change in δ^{13}C as they remain at –17.2‰.
- Childhood diet: Post-weaning, δ^{15}N and δ^{13}C show minor changes until approximately eight-and-a-half years when both increase in the root tips to 14.8‰ and –16.4‰.
- Early adult diet: In the M3, δ^{15}N and δ^{13}C exhibit fluctuations as well, but smaller than in M1. Δ^{13}C ranges between –16.8‰ and –16.1‰ while δ^{15}N ranges between 14.0‰ and 15.2‰.
- Bone values: The values cluster with the M3 micro-samples (Figure 59), suggesting a similar diet during early adulthood and adulthood.
- Other observations: As seen in other individuals, the δ^{13}C in the last increment of the M1 and the first increment of the M3 do not line up. However, for δ^{15}N the values are the same (14.8‰).

Summary

Dentine micro-samples for the Late Neolithic Ust'-Ida I individuals show a wide range of patterns, either clustering together or exhibiting widespread variation on both axes. All nine LN individuals show a different pattern during infancy (weaning) as well as during early and late childhood when compared to one another. While micro-samples range between 11.2‰ and 16.1‰ for $\delta^{15}N$, most cluster around 13.0‰–14.0‰. Individual UID_1989.020.01 exhibits $\delta^{15}N$ values that could be considered typical for the Little Sea micro-region.

For $\delta^{13}C$, samples fall between -19.3‰ and -15.3‰, with the majority clustering between -18.0‰ and -17.0‰. Although diets during childhood and adulthood do not differ significantly for most individuals, the bone stable isotope values are on the lower end of $\delta^{15}N$, suggesting that aquatic protein played a larger role in diet during their developmental years.

In the Early Bronze Age, diets differ between the individuals as well. Stable isotope ratios of the micro-samples range between 11.2‰ and 16.0‰ for $\delta^{15}N$, and between -19.4‰ and -16.1‰ for $\delta^{13}C$. For each individual, micro-samples and bone values cluster together, showing less of a spread relative to the Late Neolithic results. There is also less difference between childhood and adult diet for the Early Bronze Age individuals. Interestingly, individuals UID_1989.022 (LN) and UID_1989.029 (EBA) show a very similar micro-sampling pattern (Pattern V, zigzag), suggesting a similar subsistence behaviour.

Chapter 8

Dietary life-histories in the Little Sea

This chapter presents the tooth collagen stable carbon and nitrogen isotope results of Early Bronze age individuals that were buried in the Little Sea micro-region of Cis-Baikal, Siberia, Russia. The chapter is divided into three sections. The first two present the results of the individuals from the Shamanskii Mys and the Khuzhir-Nuge XIV cemeteries, and the last section summarizes all results.

The Shamanskii Mys cemetery is situated on Ol'Khon Island and the Khuzhir-Nuge XIV cemetery is situated along the northwest mainland coast of Lake Baikal just across from Ol'khon Island. The Little Sea micro-region, and specifically Khuzhir-Nuge XIV, have been researched the most extensively by BAP. Stable isotope results from dentine micro-sampling add to an already existing large amount of isotope data. As mentioned in Chapter 3, two diet types have been identified within these two cemetery populations: a game-fish-seal (GFS) diet and a game-fish (GF) diet. Both diets were identified primarily on the δ^{15}N of the individuals, with GF ranging between ~10.3‰ and ~12.6‰ and GFS ranging between ~13.5‰ and ~16.5‰ (Weber and Goriunova 2013; Weber *et al.* 2011). Therefore, in this chapter, each table will include an extra column: bone diet type. Furthermore, for a number of the individuals, strontium isotope analysis provided information on their area of origin (birth). This is referred to as a local or non-local birth (Fraser-Shapiro 2012; Haverkort *et al.* 2008; Scharlotta and Weber 2014; Weber and Goriunova 2013; Weber *et al.* 2011). Local refers to the Little Sea micro-region and non-local refers to areas outside of the Little Sea micro-region.

Out of all 49 individuals, the dentine stable isotope results are the highest for the Little Sea individuals. For all Little Sea EBA individuals examined in this study, δ^{15}N values range between 10.4‰ and 20.0‰ and δ^{13}C between −19.8‰ and −16.5‰. Results demonstrate that childhood and adulthood diets differed for the majority of these individuals, with higher δ^{15}N values during childhood.

General patterns in dentine stable isotope signatures

The five main dentine patterns seen across all Cis-Baikal 49 hunter-gatherers examined in this monograph are described in greater detail in Chapter 6. They are:

- Pattern I: Decline in δ^{15}N during infancy (weaning signature).
- Pattern II: Positive relationship between δ^{13}C and δ^{15}N.
- Pattern III: Negative relationship between δ^{13}C and δ^{15}N.
- Pattern IV: Rise in δ^{15}N toward the end of molar development.
- Pattern V: Continuous oscillation of both δ^{13}C and δ^{15}N values (zigzag).

A total number of 28 molars, representing 21 EBA hunter-gatherers from the Little Sea, produced 351 micro-samples. All results fall within the acceptable range for % carbon, % nitrogen, and atomic C/N ratios (Appendix C). However, in one case, a micro-sample did not provide enough collagen for analysis. Therefore, two adjacent micro-samples were combined. On three other occasions, micro-samples yielded no results.

Shamanskii Mys

Individual 1: SHM_1975.001

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
SHM_1975.001	M 20–35	EBA	Glazkovo	M1 (6)–12	−17.3	17.6	GFS	n/a

- Place of birth: Between the Little Sea and the Upper Lena, possibly around Zhigalovo (Scharlotta and Weber 2014).
- Migrations: According to Scharlotta and Weber (2014), this individual undertook a major migration around two to two-and-a-half years. Then, between seven and eight years the strontium data exhibit values that are only found near the Little Sea micro-region. Roughly two years later the strontium levels suggest the individual migrated out of the Little Sea area. It has been postulated that this individual frequently travelled between the Little Sea and the Upper Lena micro-regions and that this resulted in an unclear provenance during the development of the M1 and M2 (Scharlotta and Weber 2014).
- General pattern(s): I, II, III, IV.
- Infancy diet: The M1 exhibits a decline in $\delta^{15}N$ from 18.1‰ at birth (S-01) to 15.1‰ at two years (S-03), as well as a decline in $\delta^{13}C$ from −16.5‰ to −17.5‰ (Figure 60). The rise in $\delta^{15}N$ after two years might suggest the individual was weaned around this time. This is younger than what is observed in most of the other Cis-Baikal individuals. However, in conjunction with the strontium data, the rise might not be the result of a post-weaning diet, but a result of the mother and child moving into the Little Sea micro-region and switching to a diet that consisted of higher trophic level foods (i.e. the seal).
- Childhood diet: From approximately three to four-and-a-half years (S-04 to S-06), $\delta^{15}N$ and $\delta^{13}C$ diverge, resulting in a negative relationship. $\Delta^{15}N$ declines to roughly the same point as it was at two years. After four-and-a-half years, $\delta^{15}N$ steadily increases to 16.9‰. During this time $\delta^{13}C$ remains around −17‰, with a minor increase to −16.8‰ around eight years.
- Early adult diet: Not applicable.
- Bone values: Bone $\delta^{15}N$ is higher than the dentine micro-samples, apart from S-01 at 18.1‰, which is due to a nursing effect (Figure 61). Bone $\delta^{13}C$ is isotopically similar to the dentine values.
- Other observations: None.

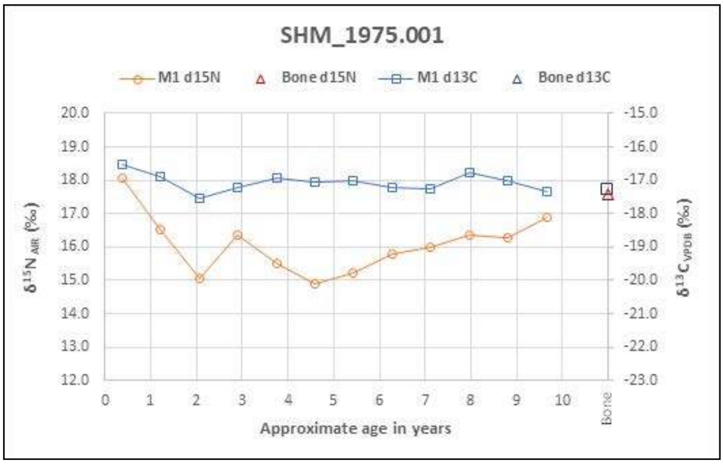


Figure 60. Single molar dentine profile for individual SHM_1975.001.

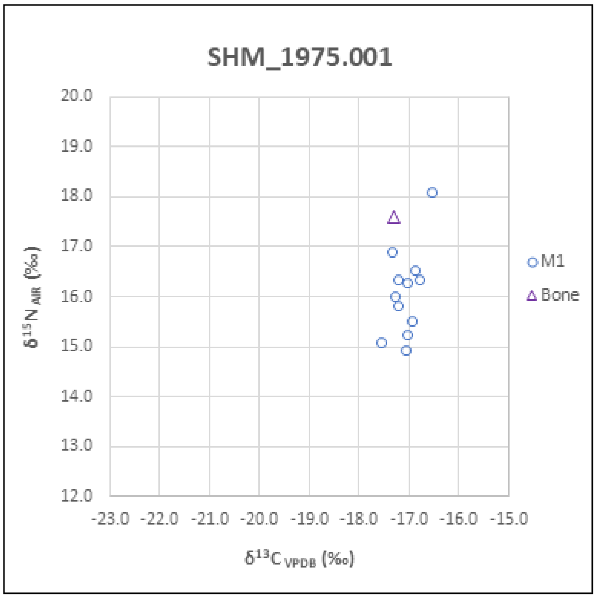


Figure 61. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual SHM_1975.001.

Individual 2: SHM_1972.002

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
SHM_1972.002	M 36–55	EBA	Glazkovo	M2 (3)–13 M3 (2)–14	−18.9	14.7	GFS	Missing data for S-11 (M2).

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: According to strontium data this individual remained within the Little Sea micro-region throughout the development of all three permanent molars (Fraser-Shapiro 2012).

- General pattern(s): II, III, IV.
- Infancy diet: Not applicable.
- Childhood diet: A positive relationship is seen between $\delta^{15}N$ and $\delta^{13}C$, albeit small, between two-and-a-half and five-and-a-half years (S-01 to S-04) in the M2 (Figure 62). On three occasions, a rise of ~1‰ is seen in $\delta^{15}N$ between two-and-a-half and four-and-a-half years (S-01 to S-03), eight-and-a-half and 10.5 years (S-07 to S-09), and 13.5 and 14.5 years (S-11 to S-12). $\Delta^{13}C$ remains stable around -19.0‰.
- Early adult diet: The M3 exhibits a decline in $\delta^{15}N$ from 14.5‰ to 13.0‰ between ~14 and 19 years (S-06 to S-10), suggesting a change in diet. Hereafter, $\delta^{15}N$ increase again to 15.2‰ towards the end of the root. Dentine micro-samples of the M3 show a good overlap with the M2 for $\delta^{13}C$, with values remaining around -19.0‰.

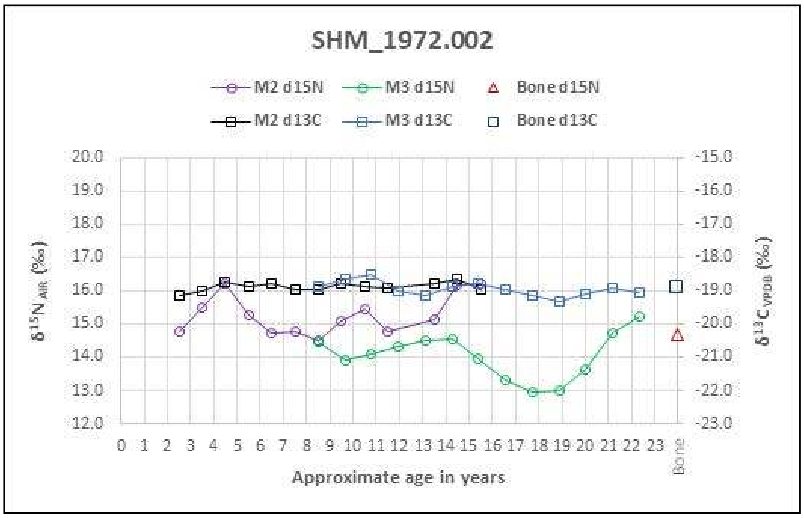


Figure 62. Multi-molar dentine profile for individual SHM_1972.002.

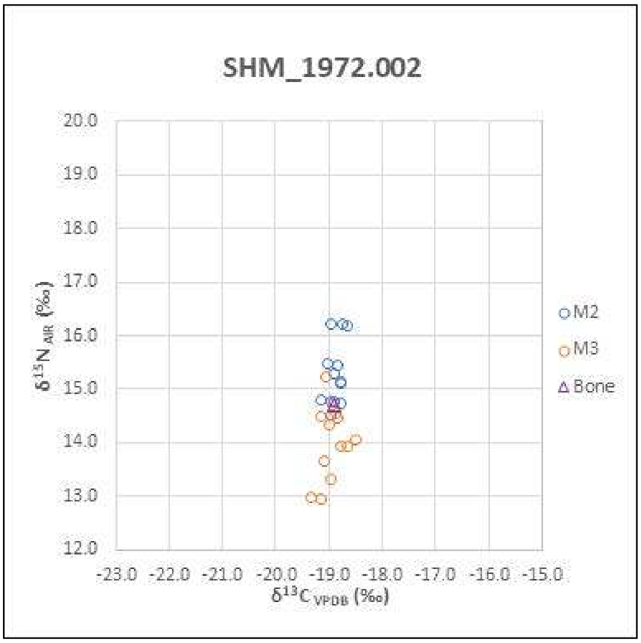


Figure 63. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual SHM_1972.002.

- Bone values: Values cluster between the M2 and M3 dentine micro-samples (Figure 63). During late childhood (M2) the individual consumed a diet higher in aquatic protein than during early adulthood (M3).
- Other observations: None.

Khuzhir-Nuge XIV

Individual 3: K14_1997.011

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1997.011	M 35–50	EBA	Glazkovo	M3 (3)–12	–18.4	15.5	GFS	n/a

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II, V.
- Infancy diet: Not applicable.
- Childhood diet: Not applicable.
- Early adult diet: Roughly between eight-and-a-half and 10 years (S-01 and S-02), $\delta^{13}C$ and $\delta^{15}N$ decrease before showing an increase toward 16 years (S-07) (Figure 64). Between 17 (S-08) and 22 (S-12) years, $\delta^{15}N$ exhibits fluctuations every one to one-and-a-half years. $\Delta^{13}C$ does not appear to have changed much during the development of the M3 with $\delta^{13}C$ values fluctuating between –18.5‰ and –17.7‰.
- Bone values: The micro-samples are higher for $\delta^{15}N$ (apart from S-02), suggesting the individual consumed a diet higher aquatic protein during M3 development (Figure 65). The $\delta^{13}C$ value for bone, –18.4‰, is at the lower end of the dentine micro-sample values.
- Other observations: None.

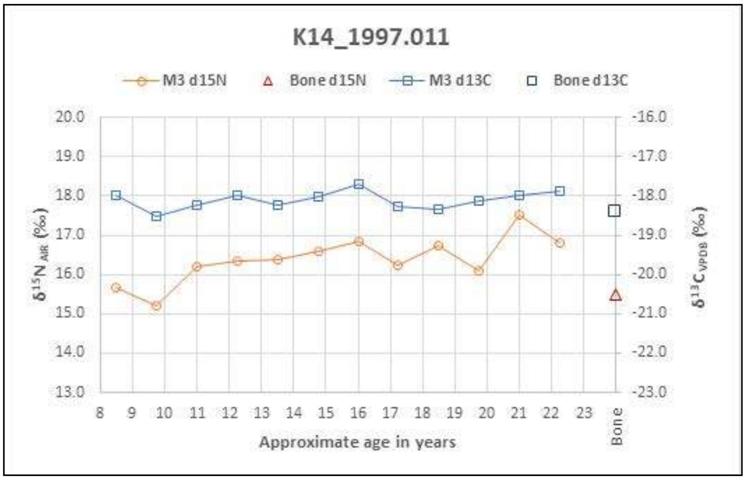


Figure 64. Single molar dentine profile for individual K14_1997.011.

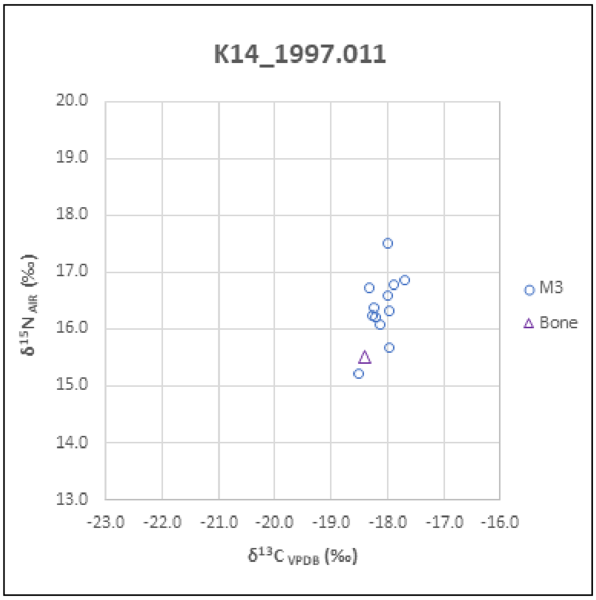


Figure 65. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.011.

Individual 4: K14_1997.012

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1997.012	U 25–35	EBA	Glazkovo	M1 (4)–14 M2 (3)–12 M3 (5)–10	−18.3	13.9	GFS	n/a

- Place of birth: Little Sea micro-region (Weber and Gorinova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, III.
- Infancy diet: The duration between birth and one year (S-01 and S-02) postulates a diet where the infant was mainly consuming breastmilk proteins (Figure 66), as $\delta^{15}N$ increases by 2.3‰. Hereafter, weaning foods are introduced to the diet and $\delta^{15}N$ declines to 13.5‰ (S-09).
- Childhood diet: Between five-and-a-half and 10 years (S-08 to S-14), the M1 exhibits minor fluctuations, suggesting perhaps frequent shifts in the types of protein consumed. For most of the development of the M2, $\delta^{15}N$ values show little change, particularly between five and nine-and-a-half years (S-06 to S-09). The $\delta^{13}C$ of the M2 mainly exhibits a slow decline with the lowest value being −18.8‰ (S-09). The highest value is −17.4‰ (S-02).
- Early adult diet: In the M3, $\delta^{13}C$ rises again while $\delta^{15}N$ shows little variation. During the interval between 14.5 and 19 years (S-05 to S-08), $\delta^{13}C$ fluctuates by rising by 0.9‰ and then declining again by 1.4‰. A similar pattern is seen in $\delta^{15}N$, albeit one-and-a-half years later.

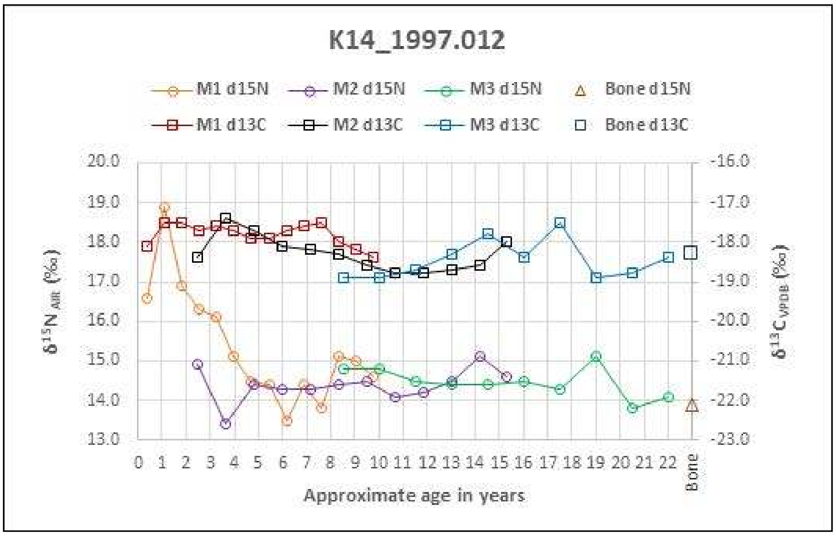


Figure 66. Multi-molar dentine profile for individual K14_1997.012.

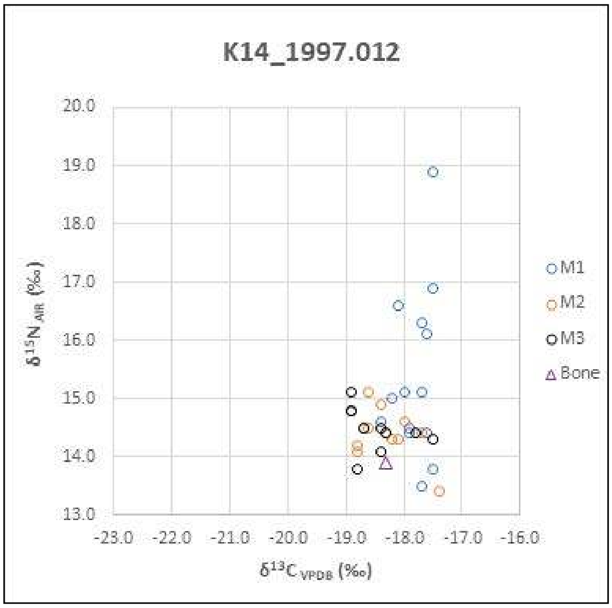


Figure 67. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.012.

- Bone values: When compared to the values of the dentine micro-samples, bone $\delta^{15}N$ is slightly on the lower end (Figure 67). M1 shows the most variability for $\delta^{15}N$, but this is also a result of breastfeeding and weaning. All $\delta^{13}C$ values are between –19‰ and –17‰. For the M2 and M3, values are isotopically similar.
- Other observations: Throughout all three molars, steep increases and decreases are shown between two micro-samples (e.g.: S-01 and S-02 of the M1 and M2). As seen in other individuals, the molar sequences do not overlap when expected. This is discussed in Chapter 9.

Individual 5: K14_1997.014

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1997.014	PM 35–50	EBA	Glazkovo	M2 (?)–10	−18.4	14.5	GFS	n/a

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II.
- Infancy diet: Not applicable.

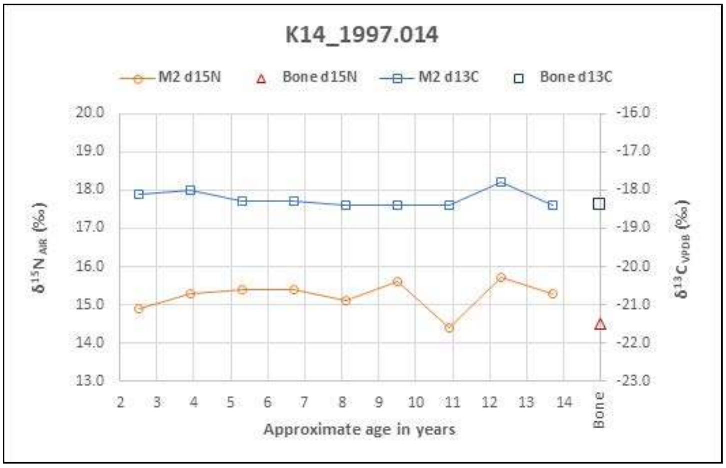


Figure 68. Single molar dentine profile for individual K14_1997.014.

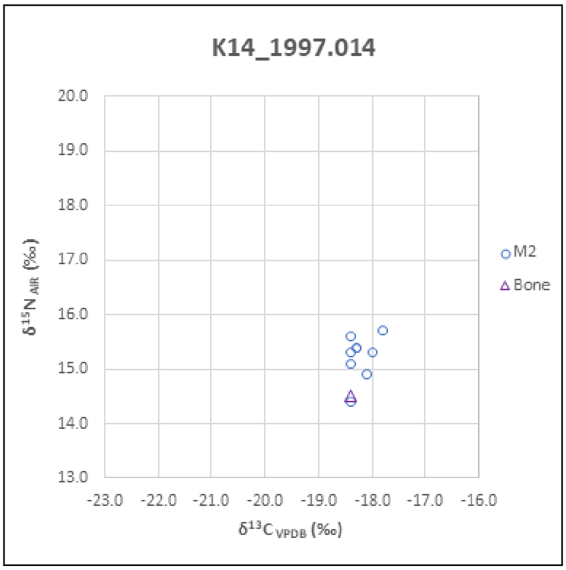


Figure 69. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.014.

- <u>Childhood diet:</u> Δ^{13}C exhibits little change between two-and-a-half and 11 years (S-01 to S-07), and δ^{15}N shows little change between two-and-a-half and eight years (S-01 to S-05) suggesting dietary stability for several years (Figure 68). Toward the end of the root (S-07), an increase of 0.6‰ in seen in δ^{13}C, before declining to −18.4‰. Between S-07 and S-09 a drop in δ^{15}N 1.2‰ is visible, which coincides with a rise in δ^{13}C.
- <u>Early adult diet:</u> Not applicable.
- <u>Bone values:</u> The bone values cluster with the micro-sample values and suggest no major change in diet between the development of M2 and the last few years of the individual's life (Figure 69).
- <u>Other observations</u>: A wear stage could not be assigned as the majority of the enamel had chipped off.

Individual 6: K14_1997.015

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_1997.015	M 25–35	EBA	Glazkovo	M2 (3)–4	−17.4	15.0	GFS	n/a

- <u>Place of birth</u>: Little Sea micro-region (Weber and Goriunova 2013).
- <u>Migrations</u>: Not applicable.
- <u>General pattern(s)</u>: II.
- <u>Infancy diet</u>: Not applicable.
- <u>Childhood diet</u>: Although age estimates cannot be given, a decline in δ^{15}N is seen from S-01 to S-04 (17.0‰ to 15.1‰), indicating the individual moved down one trophic level during the development of these dentine sections (Figure 70). Δ^{13}C drops a total of 1‰ during this time from −17.4‰ to −18.4‰.
- <u>Early adult diet</u>: Not applicable.

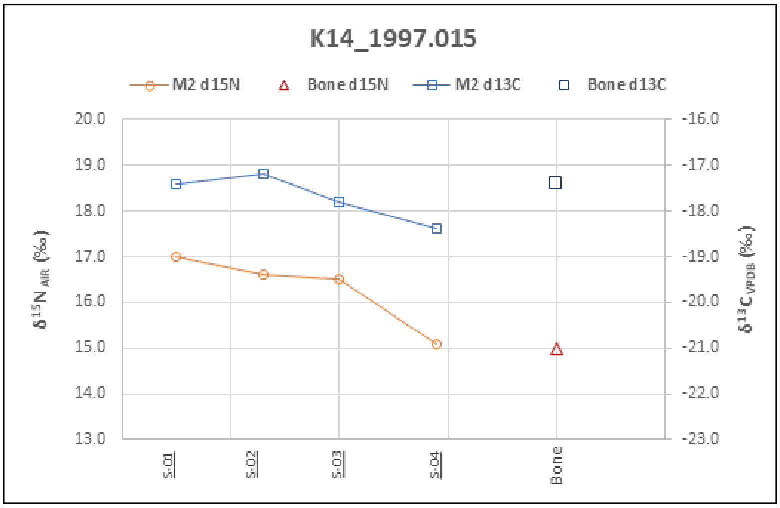


Figure 70. Single molar dentine profile for individual K14_1997.015.

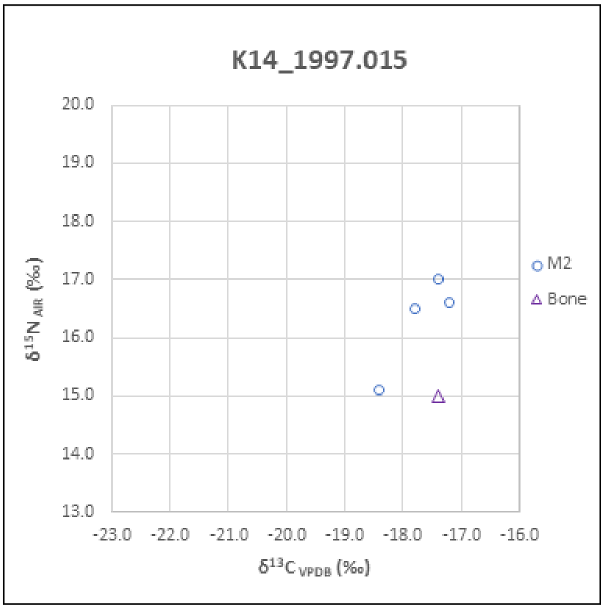


Figure 71. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1997.015.

- Bone values: The values are higher than three of the dentine micro-samples (Figure 71). S-04 and the bone values are similar in $\delta^{15}N$ but S-04 is lower in $\delta^{13}C$.
- Other observations: The remaining part of the molar could not be sectioned as the HCl treatment had turned the roots into a soft mass. As a result of the roots being lost during HCl treatment, it was not possible to calculate the number of millimetres left. Therefore, the development time of the molar cannot be provided. Along the x-axis, the approximate age in years has been removed to avoid confusion.

Individual 7: K14_1997.016

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1997.016	U 7.5–9	EBA	Glazkovo	M1 (2)–8	−17.6	16.2	GFS	S-03 is 3mm.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, III.
- Infancy diet: A breastfeeding signature is shown by an increase in $\delta^{15}N$ from 18.9‰ to 20.0‰ (S-01 to S-02) (Figure 72). The weaning signature is difficult to interpret as the 3mm thickness of S-03 masks any minor changes. The cessation of breastfeeding could have occurred at any time during this interval.
- Childhood diet: Between five-and-a-half and eight-and-a-half years (S-04 to S-07), $\delta^{15}N$ and $\delta^{13}C$ show minor changes. Overall, there is a 5‰ difference in $\delta^{15}N$ throughout the

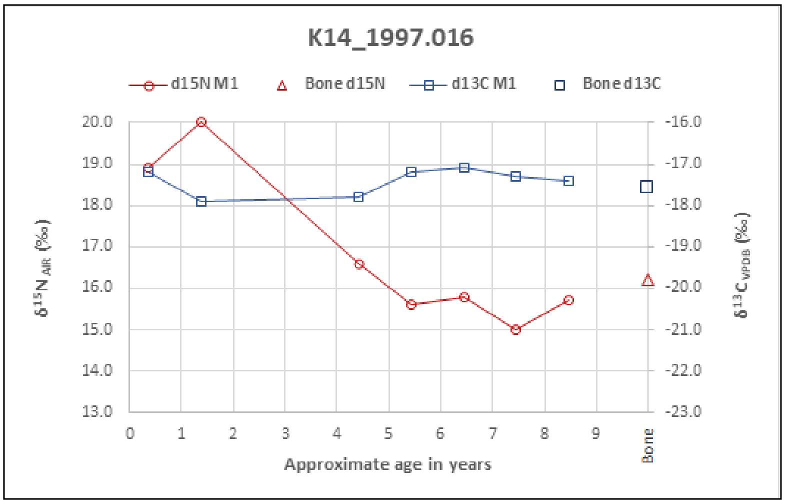


Figure 72. Single molar dentine profile for individual K14_1997.016.

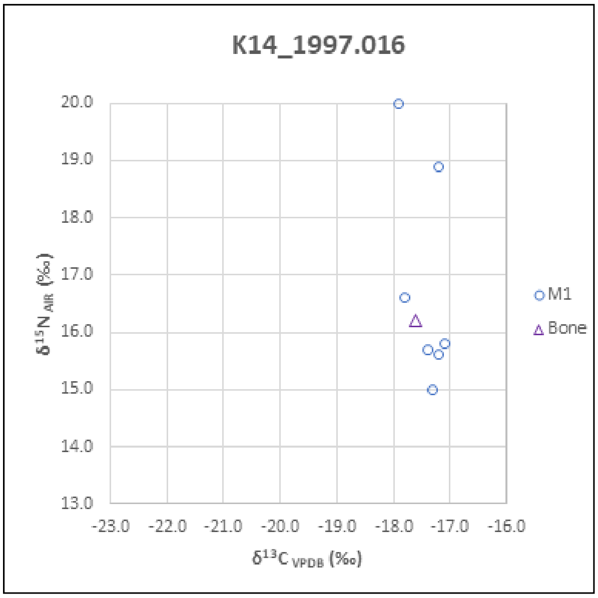


Figure 73. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_1997.016.

tooth and a 0.8‰ difference for δ^{13}C. Factors other than diet need to be considered for this change in values, such as a possible nutritional deficiency or illness. This is discussed in Chapter 9.

- Early adult diet: Not applicable.
- Bone values: The values cluster with the micro-samples (Figure 73). This is expected as the bone values represent the last few years of life and the individual died when the M1 was still developing.
- Other observations: The M1 was sectioned into eight micro-samples. The third increment is 3mm thick and will, therefore, represent a longer age estimate. Based on the London Atlas (AlQahtani *et al.* 2010) the tooth had reached the Rc stage (root length completed with parallel ends). The median age for this developmental stage, in both

jaws, is 10.5 years. Although, the developmental stage is based on one root as the other was partially broken and no longer showed the apex. The ageing of the increments has been corrected. Finally, the $\delta^{15}N$ of S-02 is the highest out of all examined individuals with a value of 20.0‰.

Individual 8: K14_1997.019

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$‰*	*Bone diet type*	*Notes*
K14_1997.019	F 35–50	EBA	Glazkovo	M2 (?)–10 M3 (6)–6	−16.7	15.7	GFS	M2: S-03 is 2mm M3: S-01, S-02 are 3mm; S-03–06 are 2mm.

- Place of birth: Outside of the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II, III.
- Infancy diet: Not applicable.
- Childhood diet: Between two-and-a-half and six years (S-01 to S-03), little change is seen in $\delta^{15}N$ and $\delta^{13}C$ (Figure 74). Hereafter, values diverge into the opposite directions with $\delta^{15}N$ increasing to 17.6‰ around 12.5 years (S-08) and $\delta^{13}C$ decreasing to −17.6‰. Between 10 and 11.5 years both values exhibit a steep rise. In the root tip (S-10) values decrease to $\delta^{15}N$ 16.8‰ and $\delta^{13}C$ −17.8‰.
- Early adult diet: Minor changes are seen in $\delta^{13}C$ and $\delta^{15}N$ throughout the development of the M3. This could be a result of larger time averages as the M3 dentine was sectioned into 2 and 3mm. $\Delta^{13}C$ values range between −17.6‰ and −17.1‰ and $\delta^{15}N$ between 16.2‰ and 16.9‰.
- Bone values: Bone values are lower for $\delta^{15}N$ and higher for $\delta^{13}C$ compared to the dentine micro-samples (Figure 75).

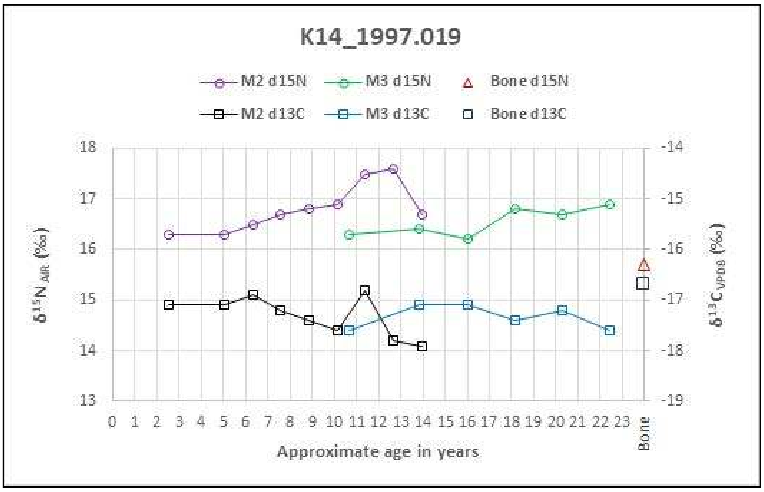


Figure 74. Multi-molar dentine profile for individual K14_1997.019.

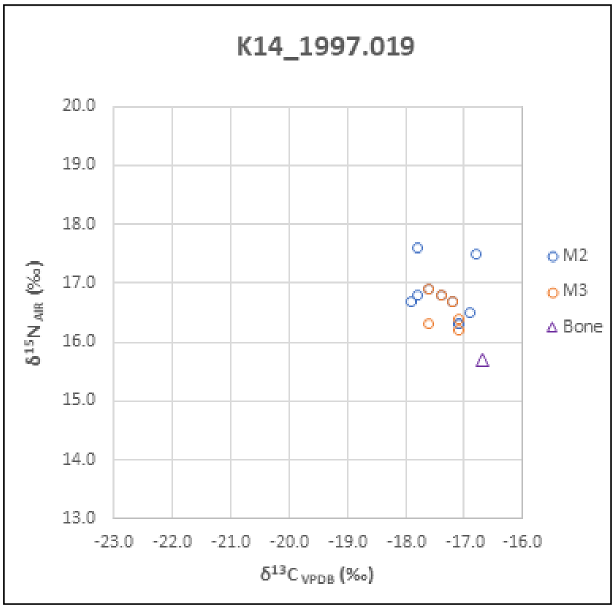


Figure 75. Scatter plot of dentine and bone $\delta^{13}C$ and δ15N values for individual K14_1997.019.

- Other observations: Accidentally, no micro photos were taken of the M2 and therefore no wear stage has been assigned.

Individual 9: K14_1998.035.02

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1998.035.02	U 8–10	EBA	Glazkovo	M2 (2)–7	−19.3	11.6	GF	S-07 is 2mm.

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II, IV.
- Infancy diet: Not applicable.
- Childhood diet: Between two-and-a-half and three-and-a-half years a steep decline is seen for $\delta^{15}N$ as it decreases by 2.4‰ from 14.2‰ (S-01) to 11.8‰ (S-02) (Figure 76). During this time, $\delta^{13}C$ decreases by 0.9‰ from −18.9‰ to −19.8‰. This could potentially exhibit the end of a weaning signature. Minor changes are seen in $\delta^{15}N$ and $\delta^{13}C$ after three-and-a-half years. Between seven-and-a-half and nine-and-a-half years (S-07 and S-08), $\delta^{15}N$ rises by 1.1‰.
- Early adult diet: Not applicable.
- Bone values: Compared to the dentine micro-samples, bone values fall on the lower end of $\delta^{15}N$, but still cluster with $\delta^{13}C$ (Figure 77).

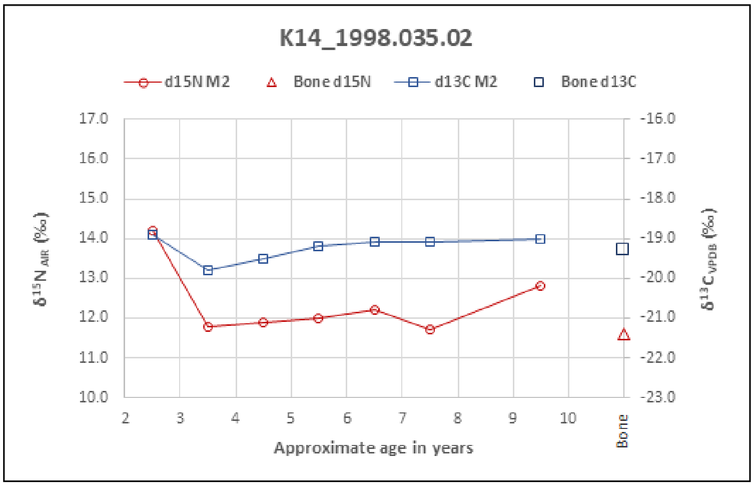


Figure 76. Single molar dentine profile for individual K14_1998.035.02.

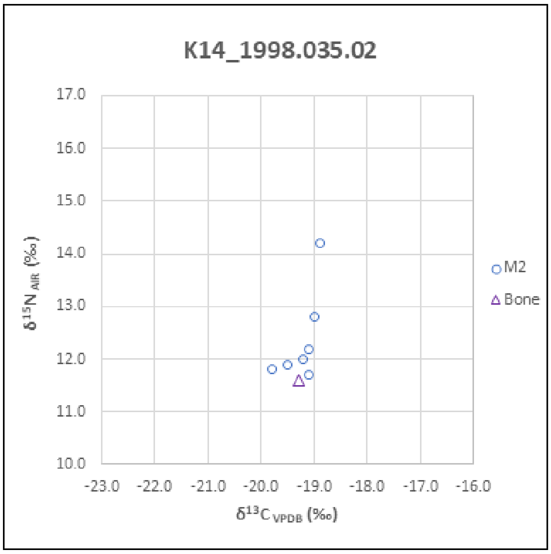


Figure 77. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_1998.035.02.

- Other observations: The M2, which was still developing at the time of death, was sectioned into seven micro-samples. Based on the London Atlas (AlQahtani *et al.* 2010), the tooth had reached the R1/2 stage (root length equals crown length). The median age for this developmental stage, in both jaws, is 10.5 years. The age of each increment has been adjusted to this. The molar received a wear stage of 2.

Individual 10: K14_1998.036.01

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_1998.036.01	U 35–50	EBA	Glazkovo	M1 (6)–11	−18.9	12.4	GF	n/a

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, IV.
- Infancy diet: Between birth and approximately one-and-a-half years (S-01 to S-02) there is a 0.6‰ increase in δ^{15}N which is likely the result of breastmilk proteins (Figure 78). Hereafter, δ^{15}N decreases to 13.4‰ and remains at this level for almost a year (S-03 and S-04), suggesting the child completed weaning around this time.
- Childhood diet: Post-weaning, δ^{15}N only exhibits minor changes before increasing to 14.0‰ between approximately seven and 10 years (S-08 to S-11). Minor fluctuations are seen in δ^{13}C between two and eight years (S-03 to S-09), followed by a rise to −18.4‰ in the root tip (S-11).
- Early adult diet: Not applicable.

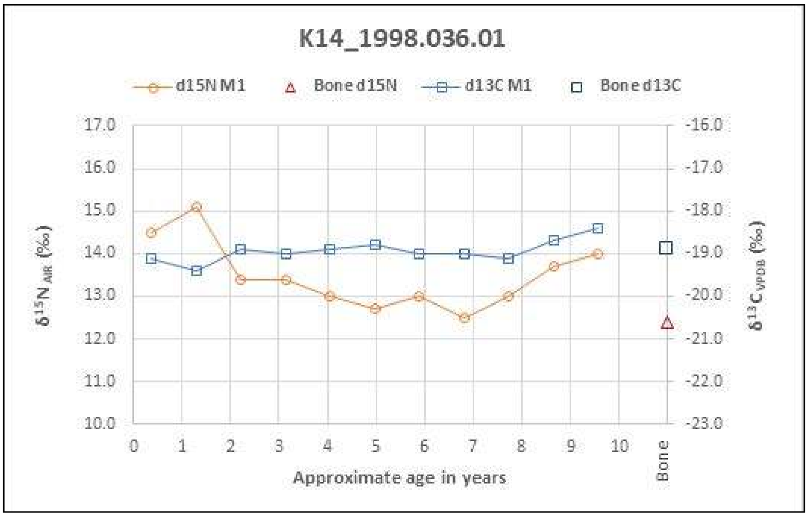


Figure 78. Single molar dentine profile for individual K14_1998.036.01.

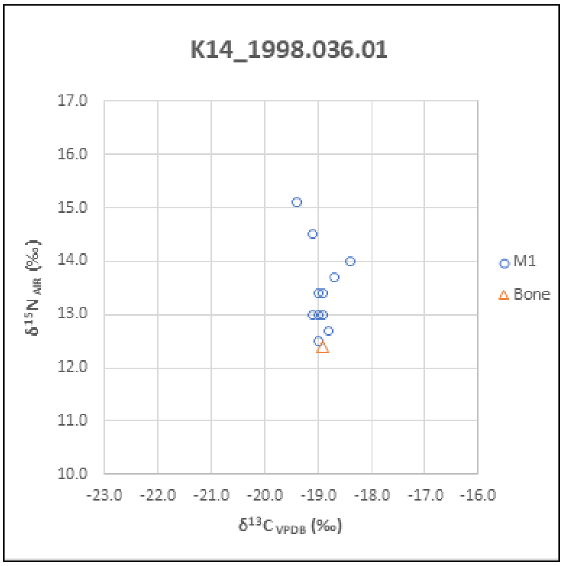


Figure 79. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_1998.036.01.

- Bone values: Compared to the dentine values, bone values are on the lower end of δ15N, but still cluster with δ13C (Figure 79).
- Other observations: None.

Individual 11: K14_1998.037.02

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ13C ‰*	*Bone δ15N ‰*	*Bone diet type*	*Notes*
K14_1998.037.02	U 14–17	EBA	Glazkovo	M1 (3)–15	−19.2	11.7	GF	n/a

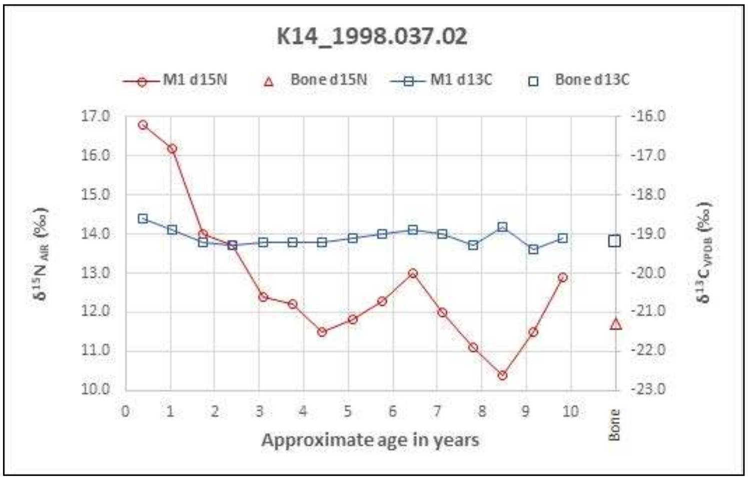


Figure 80. Single molar dentine profile for individual K14_1998.037.02.

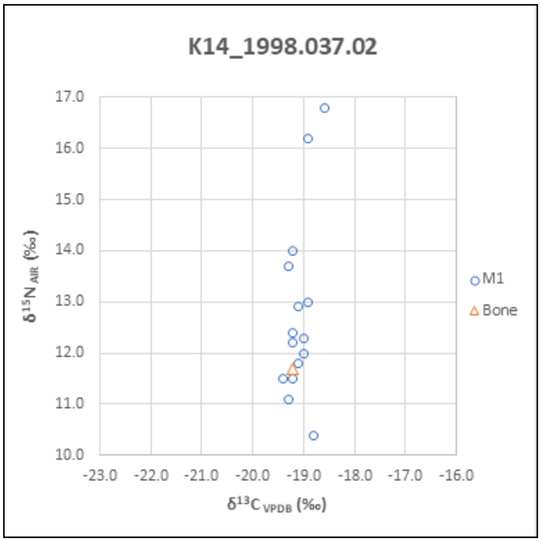


Figure 81. Scatter plot of dentine and bone δ13C and δ15N values for individual K14_1998.037.02.

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Strontium values for the M1 and M2 are typical for the upper section of the Angara (Haverkort *et al.* 2008), which is closest to Lake Baikal. The femur, however, exhibited values that fall between Angara (Haverkort *et al.* 2008) and the Upper Lena (Huh *et al.* 1994).
- General pattern(s): I, II, III, IV.
- Infancy diet: The M1 exhibits a profile with many variations in δ^{15}N (Figure 80). A weaning signature is seen as δ^{15}N declines from its highest value, 16.8‰ at birth (S-01), and continues to drop to 11.5‰ just before four-and-a-half years (S-07). This is a decline of 5.3‰. Δ^{13}C exhibits a decline of 0.7‰ between birth and two-and-a-half years (S-01 to S-03).
- Childhood diet: After four-and-a-half years, δ^{15}N increases again to 13.0‰ at six-and-a-half years (S-10). Then, between six-and-a-half and eight-and-a-half years, δ^{15}N declines to its lowest value of 10.4‰ (S-13). Hereafter, δ^{15}N rises again to 13.0‰, showing multiple shifts throughout the M1.
- Early adult diet: Not applicable.
- Bone values: The values cluster with a number of the dentine micro-samples (Figure 81). Δ^{15}N values during breastmilk consumption are high, particularly for a GF individual, causing a wide spread along the y-axis. This is discussed in Chapter 9.
- Other observations: Throughout the M1 there is a difference of 6.4‰ for δ^{15}N, which is the widest variation within a single tooth of all individuals examined for this micro-sampling study.

Individual 12: K14_1998.038

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_1998.038	M 35–50	EBA	Glazkovo	M1 (7)–7 M2 (7)–10	−18.4	13.6	GFS	4mm of root lost in M1.

- Place of birth: Outside of the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II, III, IV.
- Infancy diet: From birth (S-01) to roughly one year (S-02), a decrease of 1.1‰ is seen in δ^{15}N (Figure 82), with values stabilizing between one and three years (S-02 to S-04). This likely suggests the individual was only breastfed for a short amount of time.
- Childhood diet: Between approximately three-and-a-half and five-and-a-half years, δ^{15}N increases by one trophic level from 12.6‰ to 15‰ (S-05 to S-07). Then, in the M2, δ^{15}N increases again between five-and-a-half and ~11 years (S-03 to S-07) from 12.4‰ to 14.9‰. These increases are quite similar but are displayed at different times. This is most likely a cause of poor alignment and will be discussed in Chapter 9. Throughout the M2, δ^{13}C moves from its lowest point at −19.3‰ to its highest at −17.9‰.
- Early adult diet: Not applicable.
- Bone values: The values cluster with the dentine micro-samples (Figure 83).

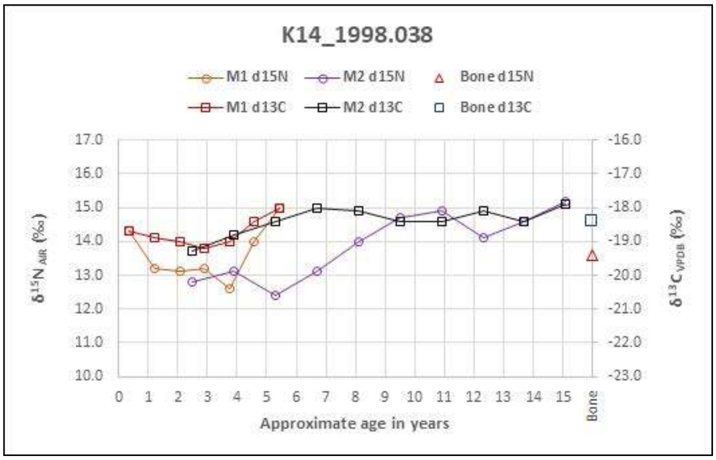


Figure 82. Multi-molar dentine profile for individual K14_1998.038.

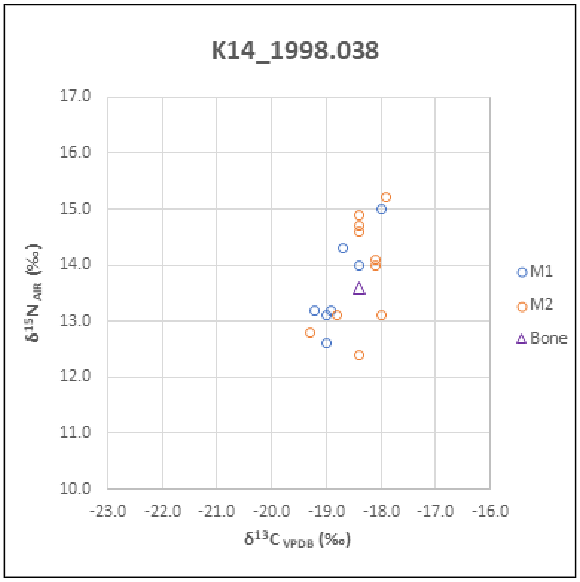


Figure 83. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.038.

- Other observations: The three roots of the M1 were enlarged, which is most likely a result of periodontitis or hypercementosis (Image 39b, Appendix A). As a result, the tooth could only be sectioned into seven slices. The remaining portion of the roots turned to a soft mass post demineralization. Approximately 4mm was lost. To provide an approximate age estimate, it is assumed the tooth was 12mm in length.

Individual 13: K14_1998.039

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1998.039	U 9–11	EBA	Glazkovo	M1 (3)–12 M2 (1)–5	−17.5	16.1	GFS	M2 not fully developed.

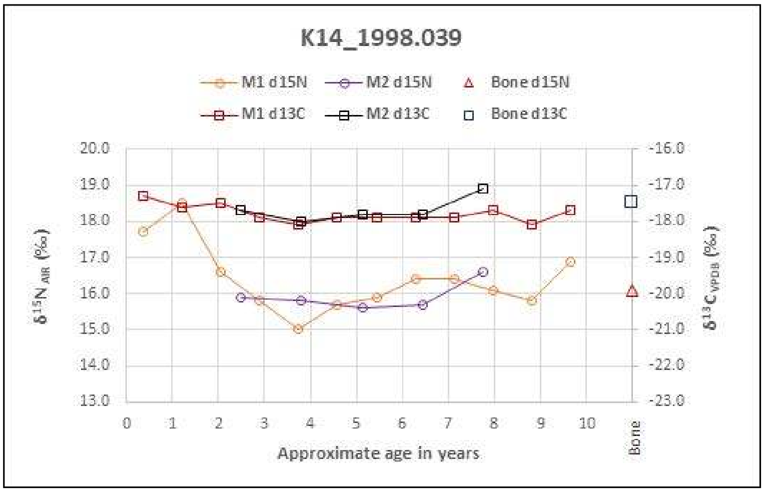


Figure 84. Multi-molar dentine profile for individual K14_1998.039.

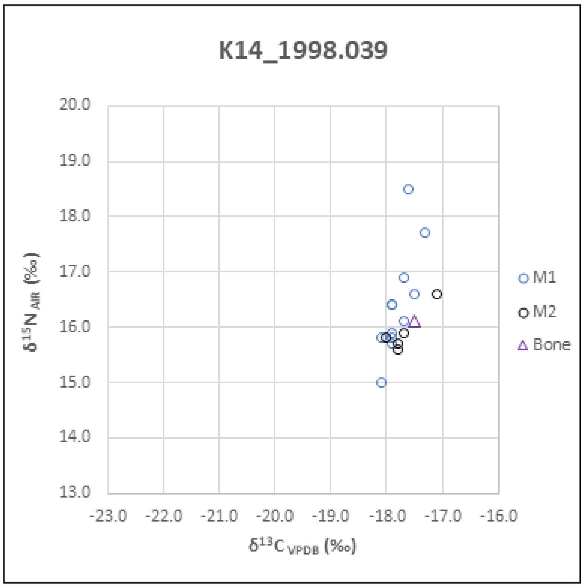


Figure 85. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1998.039.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, IV.
- Infancy diet: Between birth and just over one year, $\delta^{15}N$ increases from 17.7‰ to 18.5‰ (S-01 to S-02) (Figure 84). Hereafter, $\delta^{15}N$ decreases by 3.5‰ to 15.0‰ just before four years (S-05), suggesting weaning has been completed. $\Delta^{13}C$ declines from −17.3‰ to −18.1‰ between birth and approximately four years.
- Childhood diet: Post-weaning, $\delta^{15}N$ increases before stabilizing just after six years (S-08 and S-09). Between seven and nine years (S-08 to S-10), a minor decrease is seen before $\delta^{15}N$ increases by 0.9‰. Throughout the two molars, $\delta^{13}C$ rarely exhibits any change. Only from six-and-a-half years to around eight years (S-04 to S-05 of M2) does $\delta^{13}C$ display an increase by 0.7‰.

- Early adult diet: Not applicable.
- Bone values: M1 and M2 dentine values are isotopically similar to the bone values (Figure 85).
- Other observations: The M2 had not fully developed by the time of death. Based on the London Atlas (AlQahtani *et al.* 2010), the M2 had reached the R1/2 stage (root length equals crown length). The median age for this developmental stage, in both jaws, is 10.5 years. The ageing of the increments has been corrected. However, only the crown was sectioned as the roots did not survive demineralization. The length of the tooth was ~8mm.

Individual 14: K14_1999.044

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1999.044	M 35–50	EBA	Glazkovo	M1 (6)–16 M2 (6)–6 M3 (2)–12	−17.8	15.9	GFS	For M2: S-02 is 3mm and S-06 is 5mm.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, III, IV, V.
- Infancy diet: There is a steep decline in $\delta^{15}N$ within the first year of life (S-01 to S-02) (Figure 86). The period between one and approximately two years (S-02 and S-03) suggests the cessation of breastmilk. Between birth and approximately two years, $\delta^{13}C$ declines from −18.1‰ to −18.6‰. Hereafter, $\delta\ ^{13}C$ values remain unchanged for roughly one-and-a-half years.
- Childhood diet: Between one-and-a-half and eight years, $\delta^{15}N$ slightly increase only to display a downward trend to 13.3‰ (S-03 to S-13). A similar pattern is seen in the M2, despite S-03 representing roughly two years and S-06 roughly 3.8 years, masking any minor dietary changes. $\Delta^{13}C$ values fluctuate between −19.1‰ and −18.1‰ for early and late childhood.
- Early adult diet: In the M3, $\delta^{15}N$ is remarkably higher than during M2 development. $\Delta^{15}N$ values fluctuate between 14.6‰ and 17.0‰. $\Delta^{13}C$ follows a similar pattern with an increase from −19.3 to −17.2‰. However, the 1.6‰ increase from eight-and-a-half years (S-01) to nine-and-a-half years (S-02) does not correspond to an increase in the M2. This will be discussed in Chapter 9.
- Bone values: Values cluster with the M3 micro-samples, showing diet differed during the development of M1 and M2 (Figure 87).
- Other observations: Ageing the increments of the M2 was difficult as part of the roots were missing due to fracture. Based on the length of the tooth, it is estimated that roughly 3mm were lost. The ages were calculated assuming the molar was ~15mm in length. It was not possible to sample the entire tooth into 1mm increments as the dentine was very fragile and soft. No $\delta^{13}C$ value could be provided for S-05 in M3 due to an instrument (mass spectrometry) error. Therefore, the graph shows a disconnect between data points S-04 and S-06.

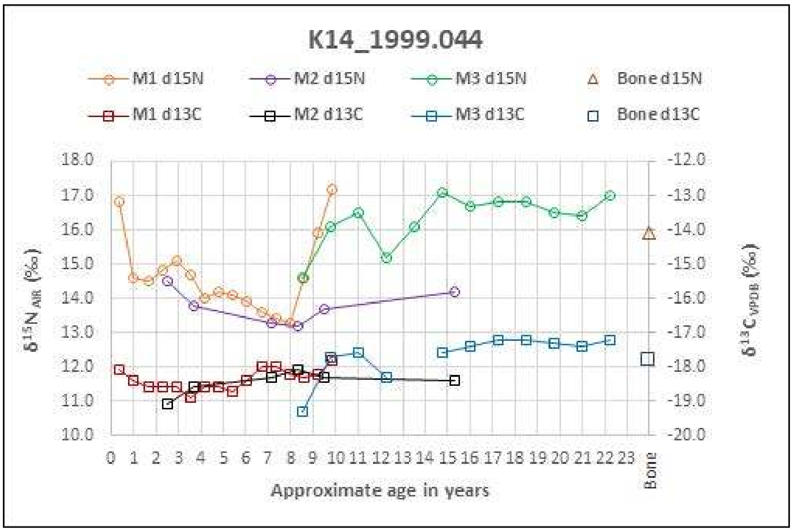


Figure 86. Multi-molar dentine profile for individual K14_1999.044.

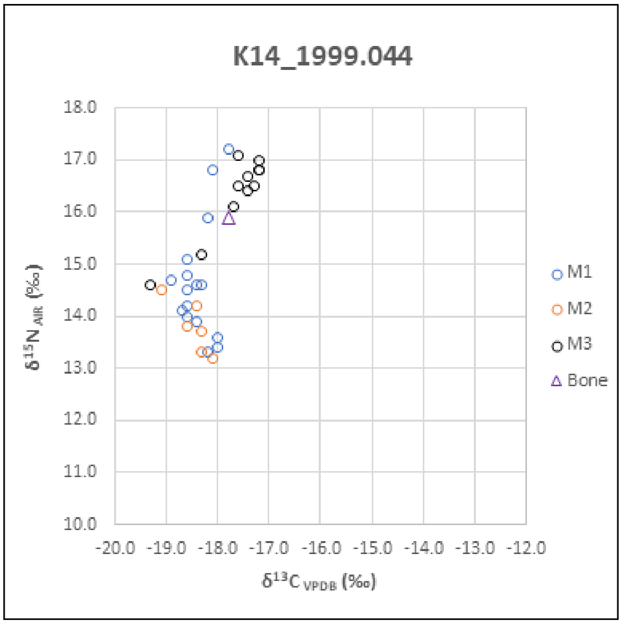


Figure 87. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_1999.044.

Individual 15: K14_1999.045

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_1999.045	U 8–10	EBA	Glazkovo	M1 (2)–14 M2 (2)–16	-17.9	14.4	GFS	M2 not fully developed.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.

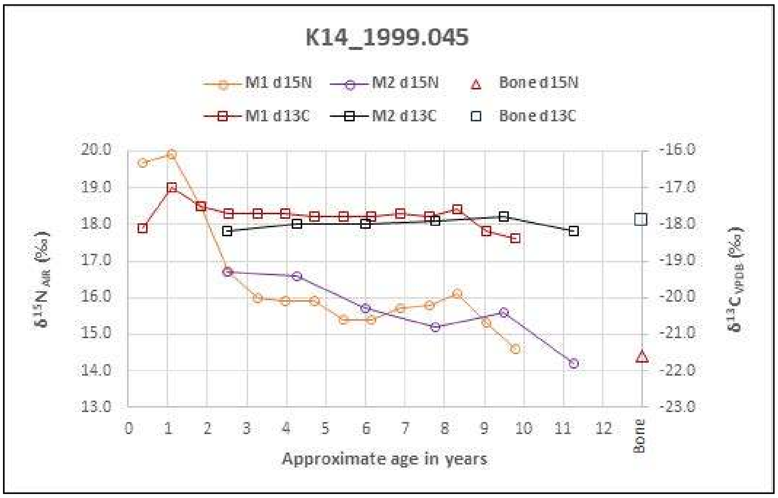


Figure 88. Multi-molar dentine profile for individual K14_1999.045.

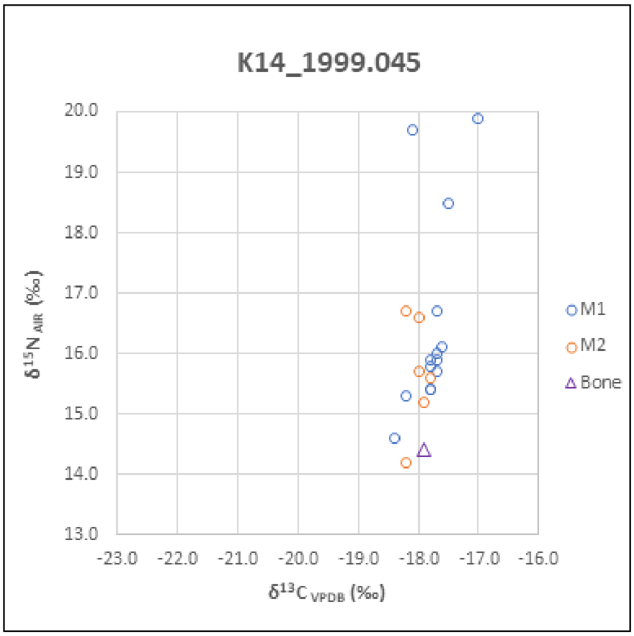


Figure 89. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.045.

- General pattern(s): I, II.
- Infancy diet: A weaning signature is visible from ~birth to just after three years with a decline from 19.7‰ (S-01) to 16.0‰ (S-05), suggesting a cessation of breastmilk around three years (Figure 88). The biggest change in $\delta^{13}C$ during this time is from birth to one year when values increase from –18.1‰ (S-01) to –17.0‰ (S-02).
- Childhood diet: Between approximately three and eight years, $\delta^{15}N$ and $\delta^{13}C$ show minor changes (S-05 to S-12). Hereafter, both values decline to a $\delta^{15}N$ of 14.6‰ and a $\delta^{13}C$ of –18.4‰. This decline is also seen in the M2 when $\delta^{15}N$ shifts from 15.6‰ to 14.2‰ and $\delta^{13}C$ from 17.8‰ to 18.2‰ (S-05 to S-06). Throughout the entire M2, $\delta^{15}N$ decreases one trophic level (2.5‰) while $\delta^{13}C$ exhibits minor changes fluctuating between –18.2‰ and –17.8‰.

- Early adult diet: Not applicable.
- Bone values: Dentine micro-samples indicate a dietary difference when compared to bone values (Figure 89). While δ^{13}C remains isotopically similar, δ^{15}N is 1–2‰ higher (not taking the breastfeeding into account).
- Other observations: The M2 had not fully developed by the time of death. Based on the London Atlas (AlQahtani *et al.* 2010), the tooth had reached the R1/2 stage (root length equals crown length). The median age for this developmental stage, in both jaws, is 10.5 years.

Individual 16: K14_1999.046

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_1999.046	M 25–35	EBA	Glazkovo	M2 (6)–6	-18.4	14.2	GFS	Root tips missing.

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II.
- Infancy diet: Not applicable.
- Childhood diet: Results show little variation within the M2 (Figure 90). Δ^{15}N fluctuates between 11.1‰ and 11.6‰ while δ^{13}C exhibits almost no change (S-01 to S-06) as values are within the margin of error. The individual was consuming a diet that is in line with the place of birth: outside the Little Sea. Furthermore, the M2 indicates no sign of a significant dietary shift.
- Early adult diet: Not applicable.

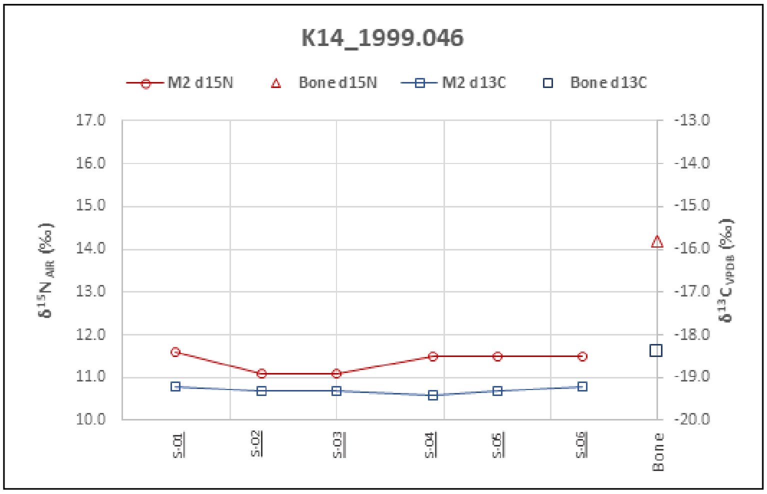


Figure 90. Single molar dentine profile for individual K14_1999.046.

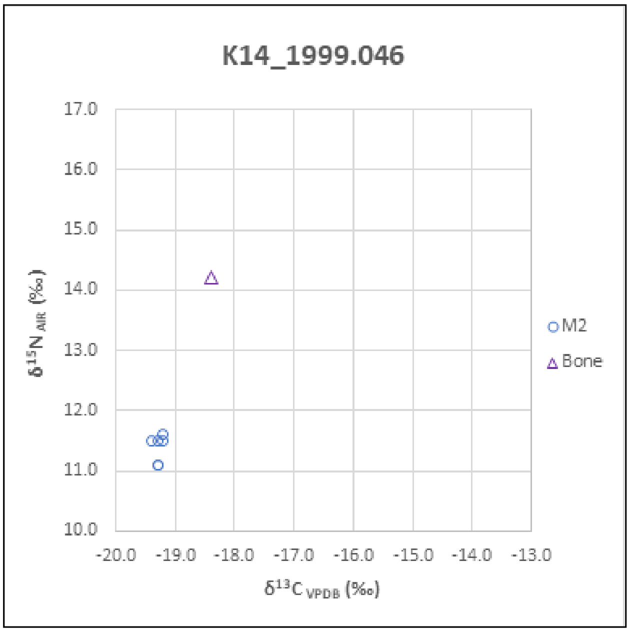


Figure 91. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.046.

- Bone values: $\Delta^{15}N$ for bone is a trophic level higher (2.6‰) than the highest micro-sample value (11.6‰ at S-01), showing a dietary difference between adulthood and childhood (Figure 91).
- Other observations: Stable isotope values for the tooth tip are missing as it did not survive demineralization. The original length of the tooth is unknown. Therefore, no approximate age can be provided.

Individual 17: K14_1999.051

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1999.051	M 18–20	EBA	Glazkovo	M1 (4)–6 M2 (3)–12	–17.6	14.8	GFS	M1: S-06 is 4mm. M2: no results for S-02, S-12 is 3mm.

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, III.
- Infancy diet: Between birth (S-01) and five years (S-05), $\delta^{15}N$ declines gradually from 17.7‰ to 16.0‰ (Figure 92), suggesting the individual was weaned around this time. $\Delta^{13}C$ mirrors $\delta^{15}N$ (Pattern III) and exhibits an increase over time from –18.8‰ to –17.7‰.
- Childhood diet: The decrease in $\delta^{15}N$ after five years (M1) is difficult to interpret as S-06 is 4mm and therefore represents an approximate age of four-and-a-half years.

In the M2 the increase from two-and-a-half to four-and-a-half years (S-01 to S-03) appears steep, which is likely a result of S-02 not yielding any result. After four-and-a-half years, changes in $\delta^{13}C$ and $\delta^{15}N$ appear small, while also exhibiting a positive relationship over time. The final micro-sample, S-12, is 3mm in length and therefore represented three years of development.

- Early adult diet: Not applicable.
- Bone values: The stable isotope values of the micro-samples are higher than the bone values, exhibiting a dietary difference between childhood and adulthood (Figure 93).
- Other observations: Roots could not be sectioned any further as they were too fragile.

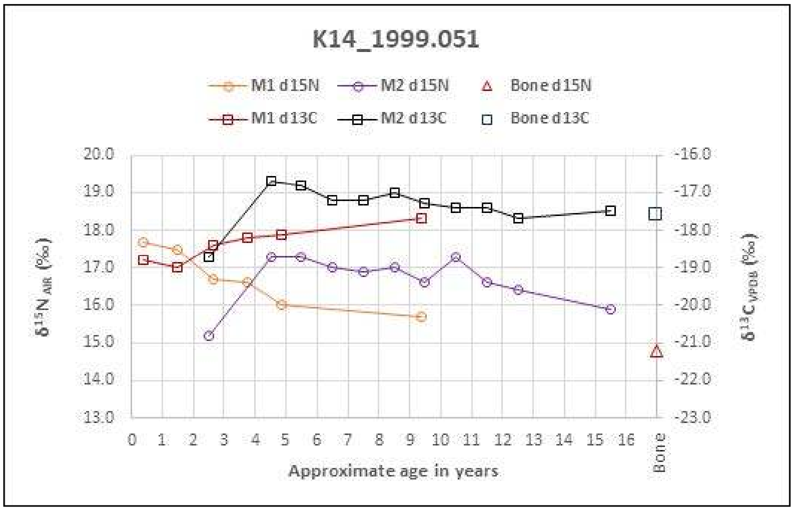


Figure 92. Multi-molar dentine profile for individual K14_1999.051.

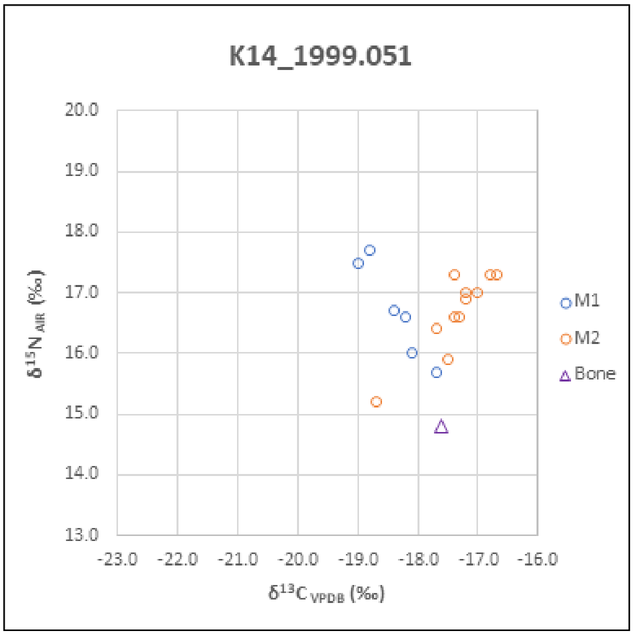


Figure 93. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.051.

Individual 18: K14_1999.057.02

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone $\delta^{13}C$ ‰*	*Bone $\delta^{15}N$ ‰*	*Bone diet type*	*Notes*
K14_1999.057.02	PM 35–50	EBA	Glazkovo	M2 (?)–10	-16.6	16.6	GFS	No wear stage.

- Place of birth: Outside the Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): II, IV.
- Infancy diet: Not applicable.
- Childhood diet: $\Delta^{15}N$ declines by 1.2‰ between two-and-a-half and four years (S-01 to S-02), followed by a 0.9‰ increase between four and seven-and-a-half years (S-02 to

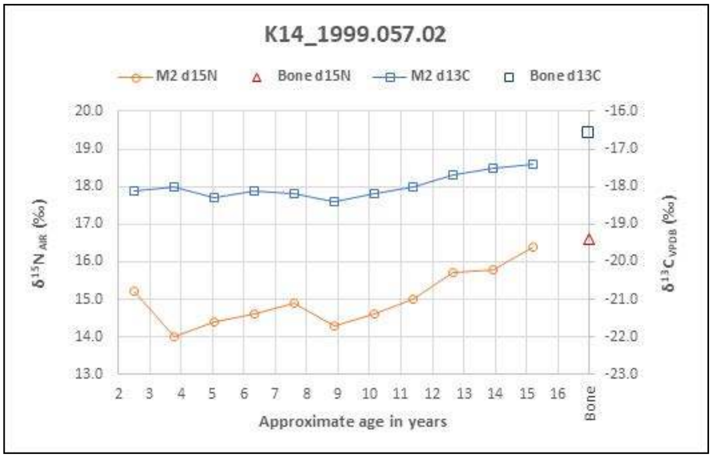


Figure 94. Single molar dentine profile for individual K14_1999.057.02.

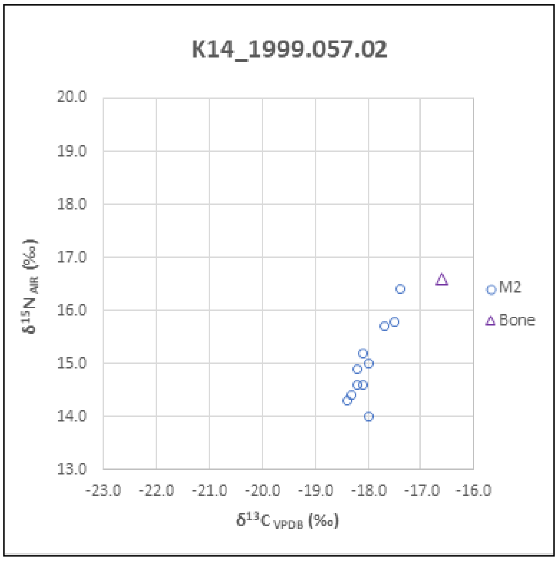


Figure 95. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_1999.057.02.

S-05) (Figure 94). This is then followed by another decline of 0.6‰ (S-06) before values increase from 14.3‰ to 16.4‰ (S-11). Between two-and-a-half and nine years (S-01 to S-06), δ^{13}C exhibits virtually no change. From nine to 15 years (S-06 to S-11), δ^{13}C values steadily increase to −17.4‰.

- Early adult diet: Not applicable.
- Bone values: The final micro-sample (S-11) of the M2 is close to the bone values. The rest of the M2 micro-samples show δ^{13}C and δ^{15}N were lower during dental development (Figure 95).
- Other observations: Most of the enamel had chipped off and therefore it was not possible to assign wear stage.

Individual 19: K14_2000.063

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_2000.063	U 16–18	EBA	Glazkovo	M1 (3)–15 M2 (2)–6	−17.1	15.6	GFS	M1: no result for S-04. M2: S-06 is 3mm.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, II, III.
- Infancy diet: A weaning signature is seen from birth (S-01) to around three years (S-04) with a decline from 18.4‰ to 14.3‰ (Figure 96). During this time δ^{13}C declines from −16.5‰ to −17.7‰. Results suggest the child was fully weaned onto solid food by three years.
- Childhood diet: Δ^{15}N continues to rise again to 16.2‰ by five years while δ^{13}C exhibits almost no change. The M2 exhibits different isotopic values than M1 between two-and-

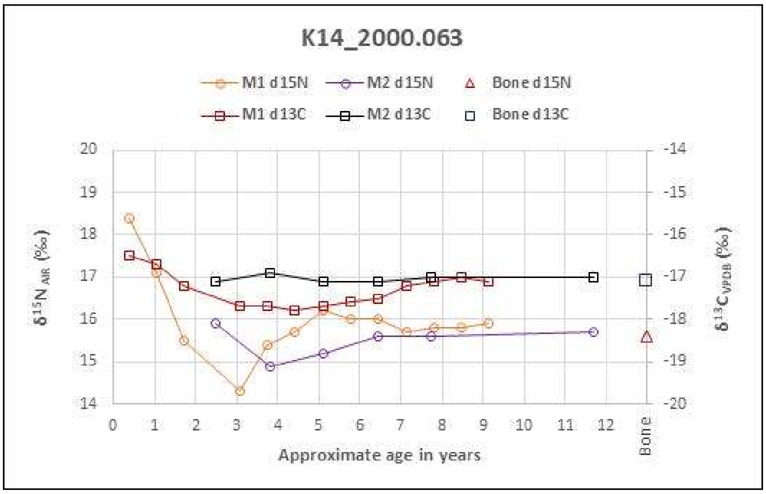


Figure 96. Multi-molar dentine profile for individual K14_2000.063.

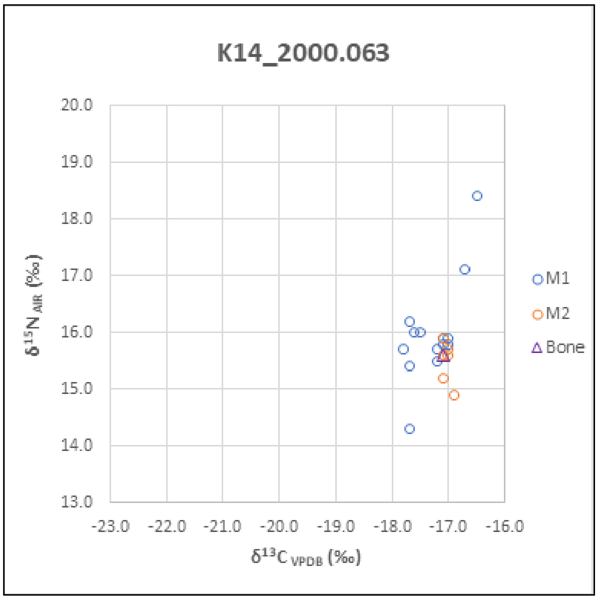


Figure 97. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_2000.063.

a-half (S-01) and six-and-a-half years (S-04). Δ^{13}C is roughly 0.5‰ higher for the M2 while δ^{15}N is roughly 1‰ lower. The root tip of the M2 provides little information as S-06 is 3mm thick in length and therefore minor changes are masked.

- Early adult diet: Not applicable.
- Bone values: The values cluster with the majority of the M3 micro-samples as well as a few M1 micro-samples (Figure 97). Outliers are a result of the nursing effect.
- Other observations: The roots of the M2 had not fully developed, which is surprising considering the individual was estimated to be 16 to 18 years of age at the time of death. Based on the London Atlas (AlQahtani *et al.* 2010), the tooth had reached the R1/2 stage (root length equals crown length). The median age for this developmental stage, in both jaws, is 10.5 years. The age of each increment has been adjusted to this.

Individual 20: K14_2000.064

Master ID	*Sex Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_2000.064	M 25–35	EBA	Glazkovo	M1 (7)–9 M3 (6)–8	–17.4	14.8	GFS	M3: S-02 and S-07 = 3mm; S-03, S-06, S-08 = 2mm, S-05 and S-06 combined.

- Place of birth: Little Sea micro-region (Weber and Goriunova 2013).
- Migrations: Not applicable.
- General pattern(s): I, III, IV.

- Infancy diet: The individual appears to have been weaned early with a δ^{15}N decline of 1.8‰ between birth (S-01) and one-and-a-half years (S-02) (Figure 98). Δ^{13}C shows a rise of 0.7‰ from −18.3‰ to −17.6‰ during this time.
- Childhood diet: Between one-and-a-half and five years, δ^{13}C and δ^{15}N show minor changes (S-02 to S-05). Hereafter, δ^{13}C increases from −18.1‰ to −17.1‰ over a span of three years. In the root tip, there is an increase in δ^{15}N from 15.5‰ to 16.5‰ (S-09).
- Early adult diet: The values of the M3 are almost one trophic level above the values of the M1. Throughout the tooth δ^{15}N and δ^{13}C exhibit only minor changes, with δ^{15}N ranging between 16.6‰ and 17.3‰ and δ^{13}C ranging between −16.8‰ and −17.7‰.
- Bone values: Values are lower for δ^{15}N in comparison to the dentine micro-samples (Figure 99). However, there is also a clear difference between M1 and M3, exhibiting three different diets throughout this person's life: one during infancy and early

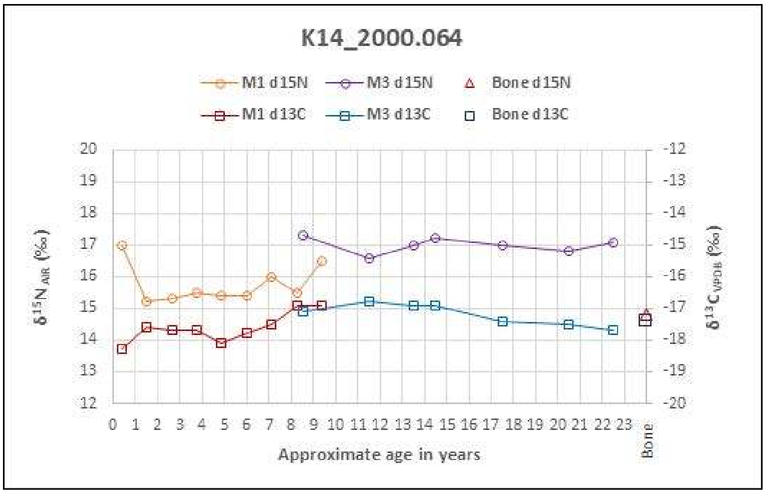


Figure 98. Multi-molar dentine profile for individual K14_2000.064.

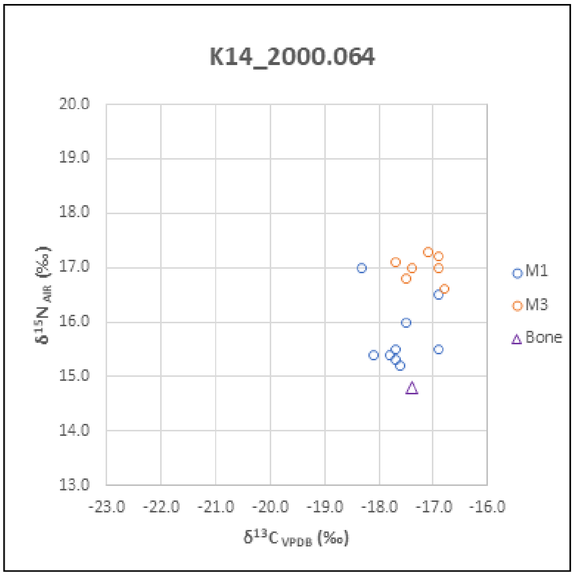


Figure 99. Scatter plot of dentine and bone δ^{13}C and δ^{15}N values for individual K14_2000.064.

childhood (M1), one during late childhood and early adulthood (M3), and one during adulthood (bone).

- Other observations: None.

Individual 21: K14_2000.077

Master ID	*Sex* *Age in years*	*Period*	*Mortuary tradition*	*Teeth (Wear stage) Sections*	*Bone δ^{13}C ‰*	*Bone δ^{15}N ‰*	*Bone diet type*	*Notes*
K14_2000.077	U 12–15	EBA	Glazkovo	M1 (3)–7	-18.7	10.5	GF	S-06 and S-07 both 3 mm.

- Place of birth: Outside of the Little Sea micro-region (Weber and Goriunova 2013). Migrations: Not applicable.
- General pattern(s): I, II.
- Infancy diet: A decrease in δ^{15}N from ~birth (S-01) until roughly four-and-a-half years (S-05) shows the weaning signature with a decline from 14.1‰ to 10.6‰ (Figure 100). Δ^{13}C remains stable throughout this weaning period at around -18.5‰.
- Childhood diet: Between four-and-a-half and 11 years (S-05 to S-07), only minor changes are seen in δ^{13}C and δ^{15}N, which is likely a result of the final two micro-samples being 3mm thick.
- Early adult diet: Not applicable.
- Bone values: The values are on the low end of δ^{15}N compared to the dentine micro-samples (Figure 101). However, the δ^{15}N values for four out of seven micro-samples are a result of the nursing effect.
- Other observations: All three roots were broken at the apex, so it is difficult to say if the tooth had fully developed. Three-quarters of the roots were present. To calculate an age per increment, the development stage of the tooth has been adjusted to R3/4

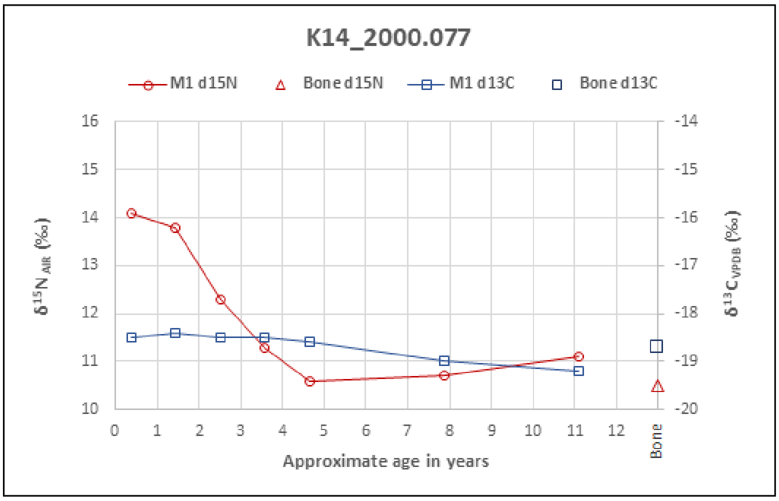


Figure 100. Single molar dentine profile for individual K14_2000.077.

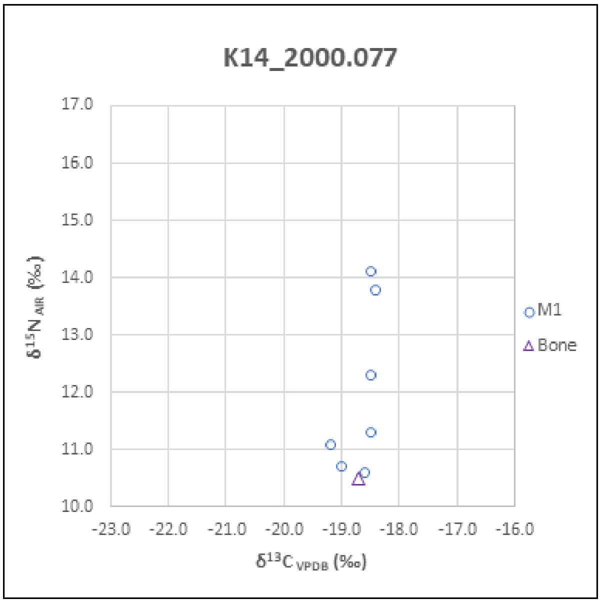


Figure 101. Scatter plot of dentine and bone $\delta^{13}C$ and $\delta^{15}N$ values for individual K14_2000.077.

(three-quarters of root length developed with diverge ends) according to the London Atlas (AlQahtani *et al.* 2010). Although the tooth developed passed this stage, adjusting the developmental age will provide a more accurate age estimate since it is unknown how much of the tooth root was lost due to fracture. The median age for R3/4 in the M1 is 7.5 years in both jaws.

Summary

The two Shamanskii Mys EBA individuals display two different diets. Individual SHM_1975.001 has high $\delta^{15}N$ values ranging between 14.9‰ and 18.1‰ and $\delta^{13}C$ values ranging between −17.5‰ and −16.5‰. The diet during adulthood (bone) has higher $\delta^{15}N$ than during childhood and early adulthood. Individual SHM_1972.002 has $\delta^{15}N$ values ranging between 13.0‰ and 16.2‰ and $\delta^{13}C$ ranging between −19.3‰ and −18.5‰. The diet during adulthood is isotopically similar to childhood.

For Khuzhir-Nuge XIV, the 19 EBA individuals have $\delta^{15}N$ values ranging between 10.4‰ and 20.0‰ and $\delta^{13}C$ ranging between −19.8‰ and −16.8‰. This is a wide range for both $\delta^{13}C$ and $\delta^{15}N$ values. However, previous data have indicated two distinct diet types (GF and GFS) at this cemetery, which corresponds to place of birth (outside vs inside the Little Sea micro-region). For most individuals with lower $\delta^{15}N$, the diet confirms the strontium data for place of birth and/or migrating outside of the Little-Sea. Three individuals, all born outside of the Little Sea micro-region, have an adult diet with higher $\delta^{15}N$ compared to childhood. For the majority of those interred at Khuzhir-Nuge XIV, the bone stable isotope values are on the lower end of $\delta^{15}N$, suggesting that aquatic protein played a bigger role in diet during childhood.

Chapter 9

Discussion

The stable isotope results confirm that the technique of dentine micro-sampling is integral to the reconstruction of individual dietary life histories in Late Neolithic and Early Bronze Age hunter-gatherers from Cis-Baikal, Siberia. The results highlight the dietary variation during childhood and early adulthood amongst the 49 individuals included in this study.

The further analysis and discussion of the results presented in Chapters 6, 7, and 8 are split here into two parts. Part 1 assesses the limitations of interpreting stable isotope data including the possible causes for isotopic outliers. The remainder of Part I describes the five general dentine patterns that are seen in all examined individuals and discusses the overall Cis-Baikal dietary and migration patterns. As stated previously in Chapter 6, the term migration refers to a change in an individual's home range that is visible in the stable isotope data. Part II further presents the archaeological interpretations, the importance of these findings, and how they lend depth to our understanding of hunter-gatherers in Cis-Baikal and beyond.

PART I

Limitations of dentine micro-sampling

Prior to discussing the general dentine micro-sampling patterns and interpreting the results, a number of limitations must first be acknowledged. These limitations help explain the patterns observed in the stable isotopic data but, more importantly, recognizing these limitations can help prevent the overanalyzing of dietary and behavioural patterns. Furthermore, discussing the current issues that micro-sampling studies face helps focus attention on the necessary constraints and considerations for future studies.

The problem with multi-molar alignment

The first limitation to be discussed is the poor alignment between multi molar micro-samples in a number of the examined individuals (e.g. MNZ_1974.002, Figure 9; UID_1987.011, Figure 36). In several instances, the root micro-samples do not align with the crown micro-samples of an adjacent molar. There are several factors that can potentially cause a poor alignment of micro-samples between teeth:

1. Reference populations vs. the Baikal hunter-gatherers.

The median age for the completion of growth stages from the London Atlas (AlQahtani *et al.* 2010) was used to age the 80 permanent molars. Based on the large dataset and its successful application to similar studies (e.g. Beaumont and Montgomery 2016; Beaumont *et al.* 2013a; Czermak *et al.* 2018; King *et al.* 2018a; van der Sluis *et al.* 2015), this atlas can be considered most suitable for calculating an approximate age per increment. Nonetheless, assigning age to dentine micro-samples remains difficult. This is in part due to the individuals and/or populations that are used to construct the age assessment models and atlases. The growth pattern of a particular reference population might not accurately reflect that of the examined Cis-Baikal hunter-gatherers. The London Atlas (AlQahtani *et al.* 2010), which examined the dentition of archaeological samples as well as living individuals of European and Bangladeshi ancestry, is quite diverse. Such diversity (e.g. cultural, genetic, age, sex) may lead to variation in timing of dental development between groups, therefore affecting the time represented by each micro-sample. While studies have suggested certain groups within the Baikal region to be genetically distinct (Mooder *et al.* 2010; Moussa *et al.* 2018), the genetic make-up currently only remains known for a small number of individuals. Therefore, it should not be assumed that each individual examined for this study belonged to the same genetic population. Furthermore, another factor which could affect the accuracy of ageing dentine increments is the variation within the London Atlas (AlQahtani *et al.* 2010) itself, and thus the accuracy of the median ages used. The application of these ages for calculating the ages of micro-samples could be a contributing factor to poor molar alignment. After all, dental atlases and charts were not designed to be used in the manner in which they are employed here. Therefore, this particular atlas alone might not accurately represent the developmental growth of all Cis-Baikal individuals. Nonetheless, while the London Atlas (AlQahtani *et al.* 2010) may currently be considered the most suitable and frequently applied age assessment model for micro-sampling studies, no current model will accurately reflect the growth patterns of all 49 examined individuals, thus in some cases leading to an under- or overestimation of age. Yet, regardless of the ageing method applied, each micro-sample is sectioned in sequential order, and thus show dietary changes over several years on an ordinal scale. As mentioned in Chapter 4, the rate of deposition of dentine varies throughout development and will affect the amount of time that is represented per micro-sample.

2. Growth in crown vs. growth in roots.

The micro-sampling method is problematic for age estimation as a result of dentinal growth. One micro-sample may contain dentine from one or more adjacent layers that were secreted earlier and/or later as a result of dentine deposition. The dentinal layers within the root tips are packed closer together as they are secreted at an angle. Thus, the microsamples from the root tips will represent the isotopic average of a larger span of time than in the crown where layers are deposited almost horizontally. This results in the poor alignment seen between the δ^{13}C and δ^{15}N of different molars in some individuals (e.g. OBK_1971.007, Figure 13; UID_1987.006, Figure 34). This also explains why micro-samples do not align between the root of one molar and the crown of another (e.g. root tip of M1 and S-01 of M2). It could be assumed this is why the majority of micro-sampling studies do not display the stable isotopic results of multiple molars in one graph.

Moreover, as a result of the dentine deposition, it is not possible to provide an exact age per micro-sample unless dentine samples are taken directly from within the incremental growth lines (Burt and Garvie-Lok 2013; Czermak *et al.* 2018) and a correct age-assessment is applied. Not only is micro-sampling between growth lines a very meticulous process, it is also highly time consuming and therefore often less feasible for large scale projects such as this. In addition, any amount of collagen extracted between the growth lines is going to be smaller than sectioning through them. Depending on the preservation of the sample, this could result in an insufficient amount of collagen for mass spectrometry. Considering that many of the micro-samples taken from the Cis-Baikal individuals provided only enough collagen for one test, sampling between growth lines would have resulted in an insufficient amount of collagen for mass spectrometry. Furthermore, in order to provide an exact age per micro-sample, the timing of dental development should be firmly established for the examined individual. This not only relies on knowledge of the genetic make-up of the Cis-Baikal hunter gatherers, but also being able to account for the difference in dentine deposition between the crown, the cervical portion, and the roots (Dean *et al.* 1993).

As a result of this issue, Scharlotta and colleagues (2018a) tried to address the poor alignment in multi-molar sequences by evaluating numerous dental age-assessment methods and various dentine growth rates. The study was conducted on Early Neolithic individuals from the Shamanka II cemetery in the Southwest Baikal micro-region of Cis-Baikal. The authors customized age-assessment methods to various dentine growth rates and found that the best sequence alignments for this particular population were AlQahtani *et al.* (2010) and Haavikko (1970). In addition, applying a different dentine growth rate to various portions of a tooth (crown, cervical, root) seemed most effective for estimating age rather than using a flat growth rate throughout the entire tooth. The authors further note that a difference of 0.5µ per day in dentine growth can produce an age offset of several months. Ultimately, this limits the possibility of establishing a specific age at which meaningful dietary changes occur (e.g. onset and cessation of weaning). The study concludes that poor multi-molar alignment is a result of population specific age-assessment models and the (regional) dental developmental differences between individuals to which these models are applied. While it is understandable that most dental age estimation models are not suitable for prehistoric Siberian hunter-gatherer populations, customizing the age-assessment methods to various dentine initiation rates does not address the issue of population-specific differences. It assumes all individuals examined are genetically similar.

The most suitable method of Scharlotta *et al.* (2018a) for EN individuals was applied to a few of the LN and EBA individuals used in this study. Results showed that it did not improve the alignment issue and led to even poorer alignment in several individuals. Moreover, the method by Scharlotta and colleagues (2018a) does not tackle the alignment issue that is partially brought on by sectioning dentine through growth layers, specifically in the roots. Therefore, regardless of the methods of dentine growth rate variants used, alignment will remain poor in a number of individuals. It could be suggested that only when the diet exhibits little to no change for the entire duration of root tip development in one molar, and during the first few increments of the following molar, will micro-samples align properly (e.g. OBK_1971.005, Figure 11), regardless of the age-assessment and dentine growth rate variants used.

3. Tooth wear.

The teeth used in this study were selected from a large sample pool. This provided the benefit of using the most well-preserved molars from the selected cemeteries. Despite this, many teeth were worn, had broken roots, and exhibited signs of poor preservation. This was most noticeable in the molars from the Khuzhir-Nuge XIV cemetery. Of the 49 individuals examined in this study, four had not yet completed dental development by time of death: K14_1997.016 (Figure 72), K14_1998.035.02 (Figure 76), UID_1988.014 (Figure 38), and UID_1989.022 (Figure 44), leading to incomplete roots. All 49 tooth crowns showed signs of wear, specifically in the M1s as they are the first to erupt, followed by M2 and M3. If crowns are worn down to the underlying dentine, then the first micro-sample does not represent the first dentine laid down. Therefore, the age assessment method will result in an incorrect age estimation for each micro-sample. Twenty-one of the 80 molars had a large surface of exposed dentine (wear stage 6 or higher), which will affect the age represented per micro-sample. However, it remains unknown how much this affects the estimated age of development as it is undetermined how much dentine was worn off.

For the same reason, Kwok (2015) developed a method to estimate the age represented by microsamples of heavily worn teeth by using the cementoenamel junction (CEJ) as a starting point. To estimate chronological age from poorly preserved teeth, two pieces of information are needed: the dentine mineralization rate and the length of each dentine section. To calculate the age of the CEJ, Kwok (2015) used the crown completion age based on the standards established by Moorrees *et al.* (1963) and modified by Smith (1991). The estimated developmental period for a given tooth was the starting point to calculate the age represented by each micro-sample in the crown portion and the root portion by calculating backwards (towards the occlusal surface from the CEJ) or forward (towards the apex from the CEJ). However, the age estimated for each section will depend on the standard that is used. While this method could be beneficial for future micro-sampling studies, it was not employed in this research. The main reason for this is when beginning this study, the most well-preserved molars were sectioned first and therefore using the CEJ as a starting point was deemed unnecessary. To age each increment according to the Kwok method (2015) and conduct inter-individual analysis of the 49 hunter-gatherers, all 930 micro-samples should have been measured by caliper. Besides, the above-mentioned issues regarding the timing of dentine deposition throughout a single tooth and sectioning through growth lines would not be accounted for, thus still leading to poor multi-molar alignments and possibly a slight age offset.

The meaning of shifts in $\delta^{13}C$ and $\delta^{15}N$

One of the more important issues to address for the examination of isotopic changes in micro-samples is the amount $\delta^{13}C$ and $\delta^{15}N$ shift in response to a change in diet (Table 6). An increase of 1.4‰ in $\delta^{15}N$ and 1.0‰ in $\delta^{13}C$ is considered to reflect a dietary or metabolic change in bulk bone collagen (DeNiro and Schoeninger 1983), yet no consensus has been reached on how much of an increase is needed for dentine micro-samples to reflect a meaningful dietary change.

One study, by Eerkens *et al.* (2016), applied the DeNiro and Schoeninger (1983) criteria to their dentine micro-sampling on prehistoric Central California hunter-gatherers. Shifts either equal to or greater than 1.4‰ in $\delta^{15}N$ and 1.0‰ in $\delta^{13}C$ across the sections of an entire molar are interpreted as a significant change in protein intake, whether this reflects a dietary shift, or a metabolic change caused by a different factor. I consider applying an average of 1.4‰ in $\delta^{15}N$ and 1.0‰ in $\delta^{13}C$ to the Baikal hunter-gatherers less straightforward due to the high variation in $\delta^{13}C$ and $\delta^{15}N$ between and within the region's aquatic species.

In several of the Cis-Baikal individuals, the shift in $\delta^{13}C$ and $\delta^{15}N$ is extremely high throughout a tooth. For instance, individual K14_1998.037.02 (Figure 80) has the largest range in $\delta^{15}N$

Table 6. Isotopic shifts in δ^{15}N and δ^{13}C across single molars for all 49 Cis-Baikal individuals. L = Left; R = Right; $M^{1, 2 \text{ or } 3}$ = Upper 1st, 2nd or 3rd molar; $M_{1, 2 \text{ or } 3}$ = Lower 1st, 2nd or 3rd molar.

No.	Cemetery	Period	Master ID	Sample ID	Molar	Max. δ^{15}N shift	Max. δ^{13}C shift
1	Khuzhir-Nuge XIV	EBA	K14_1997.011	H1997.224	R M^3	2.3‰	0.8‰
2	Khuzhir-Nuge XIV	EBA	K14_1997.012	H1997.191	L M_1	5.4‰	0.9‰
3	Khuzhir-Nuge XIV	EBA	K14_1997.012	H1997.214	L M_2	1.7‰	1.4‰
4	Khuzhir-Nuge XIV	EBA	K14_1997.012	H1997.225	L M_3	1.3‰	1.4‰
5	Khuzhir-Nuge XIV	EBA	K14_1997.014	H1997.215	L M^2	1.3‰	0.6‰
6	Khuzhir-Nuge XIV	EBA	K14_1997.015	H1997.227	L M_3	1.9‰	1.2‰
7	Khuzhir-Nuge XIV	EBA	K14_1997.016	H1997.194	L M_1	5.0‰	0.8‰
8	Khuzhir-Nuge XIV	EBA	K14_1997.019	H1997.219	L M_2	1.3‰	1.1‰
9	Khuzhir-Nuge XIV	EBA	K14_1997.019	H1997.229	L M_3	0.7‰	0.5‰
10	Khuzhir-Nuge XIV	EBA	K14_1998.035.02	H1998.359	L M_2	2.5‰	0.9‰
11	Khuzhir-Nuge XIV	EBA	K14_1998.036.01	H2003.646	R M_1	2.6‰	1.0‰
12	Khuzhir-Nuge XIV	EBA	K14_1998.037.02	H1998.372	L M_1	6.4‰	0.8‰
13	Khuzhir-Nuge XIV	EBA	K14_1998.038	H1998.376	L M^1	2.4‰	1.2‰
14	Khuzhir-Nuge XIV	EBA	K14_1998.038	H1998.377	L M_2	2.8‰	1.4‰
15	Khuzhir-Nuge XIV	EBA	K14_1998.039	H1998.379	L M_1	3.5‰	0.8‰
16	Khuzhir-Nuge XIV	EBA	K14_1998.039	H1998.380	L M_2	1.0‰	0.9‰
17	Khuzhir-Nuge XIV	EBA	K14_1999.044	H1999.163	L M_1	3.9‰	0.7‰
18	Khuzhir-Nuge XIV	EBA	K14_1999.044	H1999.164	L M_2	1.3‰	1.0‰
19	Khuzhir-Nuge XIV	EBA	K14_1999.044	H1999.165	R M^3	2.5‰	2.1‰
20	Khuzhir-Nuge XIV	EBA	K14_1999.045	H1999.156	L M_1	5.3‰	1.4‰
21	Khuzhir-Nuge XIV	EBA	K14_1999.045	H1999.157	L M_2	2.5‰	0.4‰
22	Khuzhir-Nuge XIV	EBA	K14_1999.046	H1999.130	L M_2	0.4‰	0.2‰
23	Khuzhir-Nuge XIV	EBA	K14_1999.051	H1999.134	L M_1	2.0‰	1.3‰
24	Khuzhir-Nuge XIV	EBA	K14_1999.051	H1999.135	L M_2	1.4‰	2.0‰
25	Khuzhir-Nuge XIV	EBA	K14_1999.057.02	H2001.645	L M^2	2.4‰	1.0‰
26	Khuzhir-Nuge XIV	EBA	K14_2000.063	H2000.141	L M^1	4.1‰	1.3‰
27	Khuzhir-Nuge XIV	EBA	K14_2000.063	H2000.143	L M^3	1.0‰	0.2‰
28	Khuzhir-Nuge XIV	EBA	K14_2000.064	H2000.126	L M_1	1.8‰	1.4‰
29	Khuzhir-Nuge XIV	EBA	K14_2000.064	H2000.128	L M_3	0.9‰	0.7‰
30	Khuzhir-Nuge XIV	EBA	K14_2000.077	H2000.166	L M_1	3.5‰	0.8‰
31	Manzurka	EN	MNZ_1974.002	H2000.224	R M_1	2.4‰	0.9‰
32	Manzurka	EN	MNZ_1974.002	H2000.225	R M_2	0.9‰	0.8‰
33	Manzurka	EN	MNZ_1974.002	H2000.226	R M_3	1.9‰	0.5‰
34	Obkhoi	EBA	OBK_1971.005	H2000.216	R M_1	2.7‰	1.1‰
35	Obkhoi	EBA	OBK_1971.005	H2000.218	R M_3	1.1‰	1.1‰
36	Obkhoi	EBA	OBK_1971.007	H2000.209	L or R M_1	2.7‰	0.7‰
37	Obkhoi	EBA	OBK_1971.007	H2000.210	L or R M_2	1.7‰	0.6‰
38	Obkhoi	EBA	OBK_1971.013	H2000.212	R M_1	1.9‰	0.3‰
39	Obkhoi	EBA	OBK_1971.013	H2000.213	L M_1	2.2‰	0.5‰

No.	Cemetery	Period	Master ID	Sample ID	Molar	Max. $\delta^{15}N$ shift	Max. $\delta^{13}C$ shift
40	Shamanskii Mys	EBA	SHM_1972.002	H2000.206	R M^2	2.2‰	0.8‰
41	Shamanskii Mys	EBA	SHM_1972.002	H2000.207	R M^3	1.7‰	0.5‰
42	Shamanskii Mys	EBA	SHM_1975.001	H2000.201	L M^1	3.2‰	1.0‰
43	Ust’-Ida I	LN	UID_1987.006	H2001.530	L M^3	1.3‰	0.9‰
44	Ust’-Ida I	LN	UID_1987.006	H2001.532	R M^1	2.4‰	0.4‰
45	Ust’-Ida I	LN	UID_1987.011	H2001.533	R M_3	1.2‰	0.8‰
46	Ust’-Ida I	LN	UID_1987.011	H2001.534	L M_2	0.9‰	0.7‰
47	Ust’-Ida I	LN	UID_1987.011	H2001.535	L M_1	1.9‰	1.0‰
48	Ust’-Ida I	LN	UID_1988.014	H2001.517	L M^1	2.8‰	1.1‰
49	Ust’-Ida I	LN	UID_1988.014	H2001.518	L M_3	1.3‰	0.4‰
50	Ust’-Ida I	EBA	UID_1989.019	H2001.524	R M_3	1.4‰	1.0‰
51	Ust’-Ida I	EBA	UID_1989.019	H2001.525	R M_1	2.8‰	0.3‰
52	Ust’-Ida I	LN	UID_1989.020.01	H2001.419	R M_3	1.6‰	2.2‰
53	Ust’-Ida I	LN	UID_1989.020.01	H2001.420	R M_1	3.9‰	1.1‰
54	Ust’-Ida I	LN	UID_1989.020.02	H2001.415	R M_1	2.8‰	1.3‰
55	Ust’-Ida I	LN	UID_1989.020.02	H2001.416	R M_2	2.0‰	1.0‰
56	Ust’-Ida I	LN	UID_1989.020.02	H2001.417	R M_3	1.5‰	0.8‰
57	Ust’-Ida I	LN	UID_1989.022	H2001.499	L M_3	2.3‰	2.3‰
58	Ust’-Ida I	LN	UID_1989.022	H2001.501	L M_1	3.5‰	2.5‰
59	Ust’-Ida I	EBA	UID_1989.029	H2001.488	R M_3	2.5‰	0.8‰
60	Ust'-Ida I	LN	UID_1989.030	H2001.496	R M_3	1.5‰	1.3‰
61	Ust’-Ida I	LN	UID_1989.030	H2001.498	R M_1	2.8‰	1.4‰
62	Ust’-Ida I	LN	UID_1991.038	H2001.558	L M_1	1.4‰	0.7‰
63	Ust’-Ida I	LN	UID_1991.038	H2001.560	L M_3	1.9‰	2.7‰
64	Ust’-Ida I	EBA	UID_1993.045	H2001.345	L M_1	2.9‰	0.7‰
65	Ust’-Ida I	EBA	UID_1993.045	H2001.346	L M_3	0.9‰	0.8‰
66	Ust’-Ida I	EBA	UID_1994.048	H2001.481	R M_1	2.5‰	0.8‰
67	Ust’-Ida I	EBA	UID_1994.048	H2001.483	R M_3	1.2‰	0.8‰
68	Ust’-Ida I	LN	UID_1995.056.01	H2001.456	R M_1	2.2‰	0.6‰
69	Ust’-Ida I	LN	UID_1995.056.01	H2001.458	R M_3	1.7‰	0.7‰
70	Ust’-Ilga	EBA	UIL_1989.001	H2016.015	R M^2	1.6‰	0.3‰
71	Ust’-Ilga	EBA	UIL_1989.002	H2016.018	M	1.5‰	1.1‰
72	Ust’-Ilga	EBA	UIL_1989.003	H2016.020	M	2.2‰	0.5‰
73	Ust’-Ilga	EBA	UIL_1989.004	H2016.022	M3	1.3‰	1.0‰
74	Ust’-Ilga	EBA	UIL_1989.005	H2016.014	M2 or M3	1.4‰	1.2‰
75	Ust’-Ilga	EBA	UIL_1990.009	H2016.007	M3	1.5‰	0.8‰
76	Ust’-Ilga	EBA	UIL_1990.010	H2016.028	R or L M^2	1.0‰	0.5‰
77	Ust’-Ilga	EBA	UIL_1990.011	H2016.010	L M^1	2.3‰	0.7‰
78	Ust’-Ilga	EBA	UIL_1990.012	H2016.030	L M_1	3.4‰	0.8‰
79	Ust’-Ilga	EBA	UIL_1991.013.01	H2016.032	R M^1	2.3‰	1.0‰
80	Ust’-Ilga	EBA	UIL_1991.013.02	H2016.009	L M^1	2.8‰	0.6‰

(6.4‰) across the entire tooth. The decline from S-01 to S-07 alone (~birth to four-and-a-half years) is 5.3‰. The $\delta^{13}C$ shift throughout the same molar is less than 1.0‰. For the M2 of individual K14_1998.039 (Figure 84), $\delta^{15}N$ and $\delta^{13}C$ values are below the criteria of 1.4‰ and 1.0‰ suggested by DeNiro and Schoeninger (1983), which Eerkens *et al.* (2016) would then interpret as not being a meaningful change in diet. However, the last two micro-samples, S-04 to S-05 (Figure 84), suggests the diet might be moving toward a higher trophic level. Also, the individual died between the ages of nine and 11 years, that is, before the M2 finished development. Therefore, the slight rise in $\delta^{15}N$ could also be related to illness as studies have shown $\delta^{15}N$ can increase during physiological stress (Beaumont *et al.* 2015; Fuller *et al.* 2005; Katzenberg and Lovell 1999). Nonetheless, this change toward the end of the M2 should not be considered insignificant considering the individual died very young. Perhaps the pattern of $\delta^{13}C$ and $\delta^{15}N$ in micro-samples, as discussed further below, is more important than shifts either equal to or greater than 1.4‰ and 1.0‰.

Isotopic noise

The challenge with interpreting stable isotope data from multiple samples across one tooth is in recognizing what changes are related to diet and what are related to additional factors such as instrumental error, diagenesis, or physiology (e.g. metabolism or growth). As mentioned, the instrumental error for nitrogen is ±0.2‰ and for carbon is ±0.1‰ at 1 standard deviation (SD). This means that an isotope value of a micro-sample has a 68% chance of being within 1 standard error (SE) of the point estimate and a 95% chance of being within 2 SE of the point estimate. For example, if a reported stable nitrogen isotope value of a micro-sample is 10.0‰, the actual value has a 68% chance of being within +/- 0.2‰ of that point value (9.8‰ to 10.2‰) and a 95% chance of being within +/- 0.4‰ of that point value (9.6‰ to 10.4‰). If a second micro-sample has a value of 10.2‰, the actual value has a 68% chance of being between 10.0‰ and 10.4‰ and a 95% chance of being between 9.8‰ and 9.6‰. For observations made in this research, nitrogen values need to be separated by more than 0.4‰ (68% probability range) to be considered different in statistical terms and carbon values need to be separated by more than 0.2‰. This means that very minor fluctuations, as seen in some of the individual charts, are statistically insignificant as they are within the margin of error.

On several occasions, the data exhibit high spikes or dips in $\delta^{13}C$ and $\delta^{15}N$ values (e.g. K14_1997.012, Figure 102). While some of these changes may be the result of a dietary change, they are not accompanied with a corresponding increase or decrease in the other value. This is possibly a result of measurement error. In other instances, the challenge lies in the isotopic differences between bone and dentine. For example, in individual UID_1988.014 (Figure 38), there is a difference of 1.8‰ for $\delta^{15}N$ between bone and the last micro-sample of the M3. This is rather unexpected considering the individual died quite young (18–20 years). There are three possible explanations for this:

1. The individual could have experienced some form of illness or nutritional deficiency, causing a delay in bone growth.
2. Diagenesis in either the bone or dentine could have altered the isotopic composition (Budd *et al.* 2000; Kendall *et al.* 2018). Potentially, this molar was more susceptible to diagenesis, particularly the dentine portion, as the root had not finished forming by time of death.

3. The bone represents a longer period and will therefore exhibit an average of the last few/several or more years, possibly providing a value lower in δ15N.

Regarding the first possibility, illness or malnutrition, skeletal or dental pathology would be expected. According to Lieverse (2010), who conducted osteological analysis on this individual, enamel hypoplasia is absent on the dentition as well as any indication of skeletal pathology. This could suggest that the difference in δ15N between bone and dentine was most likely not a result of long-term poor health. However, recent studies (Beaumont *et al.* 2015, 2018) indicate a possible offset between the collagen in dentine and bone, particularly during stunting. The offset ranges anywhere from 0.3 to 4.5‰ in δ15N with dentine values being higher than bone values (Beaumont *et al.* 2018). The authors (Beaumont *et al.* 2018) suggest that this might be a result of osteoblasts not producing new bone during high levels of stress. As a result, the dietary (and physiological) change will only be reflected in the δ13C and δ15N of the dentine, causing an offset between the two tissues. Nonetheless, whether the offset in δ15N for individual UID_1988.014 (Figure 38) is a result of diagenesis or perhaps even isotopic attenuation, cannot be easily explained as of yet. It could also be suggested that the offset is due to the micro-sampling method, which involves cutting through growth lines, each representing a different formation period.

In another instance, K14_1999.044 (Figure 86), the isotopic data of the M2 behave differently than the M1 and M3. Considering the roots of the M2 were missing due to fracture and the dentine appeared extremely fragile and soft post demineralization, it is possible the chemical composition of the tissue was altered due to diagenesis.

Another potential issue to cause isotopic noise may lie in secondary dentine. Even though the pulp cavity of each tooth was cleaned with a small dental burr (or sandblaster) to remove any secondary dentine, there is still the possibility that not all was removed. As secondary

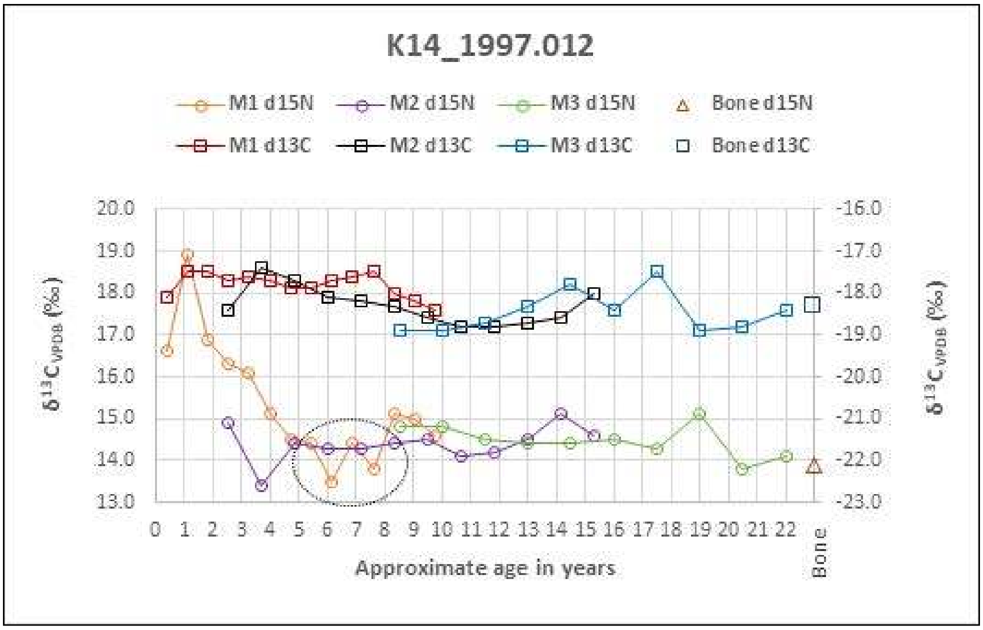


Figure 102. Potential isotopic noise seen in S-09 and S-10 δ15N (M1) of K14_1997.012.

dentine is not deposited until the roots (primary dentine) have fully formed, it will contain the isotopic signature of foods ingested after the tooth has completed development. The amount of secondary dentine varies per individual and it is not deposited evenly, particularly in molars (Nanci 2018). If a dentine micro-sample contained any secondary dentine, then this could potentially change the isotopic average of that sample and cause an increase or decrease depending on the individual's diet at that time. To what extent the isotopic average is influenced will depend on the amount of secondary dentine present in the tooth. This differs between individuals. Although secondary dentine was removed during sample preparation, it is entirely possible not all was removed as it is difficult to see with the naked eye.

Contributing factors other than diet

As outlined in Chapter 3, factors other than diet can also contribute to isotopic shifts. While it cannot be assessed with complete accuracy that certain isotopic values reflect anything other than dietary contributions, there are several instances where physiological stress appears to be reflected in the $\delta^{15}N$ values.

For instance, in individual K14_1997.016 (Figure 72), micro-samples S-01 (18.9‰) and S-02 (20.0‰) in the M1 yielded very high $\delta^{15}N$ values, even for an individual with GFS diet from the Little Sea micro-region. A decline of 5‰ ($\delta^{15}N$) is seen throughout the entire tooth. While it is not impossible that the individual (and his/her mother or wet nurse) was consuming a very high protein diet, additional factors need to be taken into consideration. Particularly concerning the young age at death (seven-and-a-half to nine years) of this individual. Previous osteological analysis showed enamel hypoplasia with at least four recorded stress events during this individual's life (Lieverse 2010). This, together with the high $\delta^{15}N$ values and the age at which the child died, seems to indicate that illness is a probable cause of death. Based on this it is possible to think of five possible scenarios:

1. The mother experienced stress during pregnancy as well as during the postpartum period. Elevated $\delta^{15}N$ in the mother would show a higher $\delta^{15}N$ elevation in the child.
2. The child suffered from illness early on and never recovered.
3. Both mother and child consumed protein poor diets that resulted in catabolism.
4. The mother was healthy and consumed a diet rich in aquatic protein, elevating the $\delta^{15}N$ of the infant even further.
5. The child died of trauma and not illness. This, however, seems the least likely scenario considering the enamel hypoplasia.

General dentine stable isotope patterns

The micro-sampling results demonstrate that the mid-Holocene Cis-Baikal hunter-gatherers exhibited substantial dietary variation during their developmental years. These dietary results are divided into five general dentine patterns. Each pattern represents a difference in dietary behavior, decision making (by the child or its mother), and protein intake. All examined individuals fit one or multiple patterns.

- Pattern I: A decline in $\delta^{15}N$ during infancy (weaning signature).

This pattern is seen during infancy and early childhood in the first few micro-samples of M1. The significance of this isotopic shift is well recognized in numerous studies (Beaumont *et al.* 2013a; Bourbou *et al.* 2013; Dettwyler and Fishman 1992; Dupras and Tocheri 2007; Fuller *et al.* 2003; Herring *et al.* 1998; Katzenberg *et al.* 1995; Richards *et al.* 2002; Schurr 1997; Tsutaya *et al.* 2014; Xia *et al.* 2018). As mentioned in Chapter 3, the decline in δ^{15}N is used to detect the duration of breastfeeding and weaning. Schurr (1997) illustrated this expected change in δ^{15}N of bone collagen (Figure 4), which affects the shape of the 'weaning curve.'

Of the 49 individuals, 34 had an M1 available for analysis. The δ^{15}N data indicate that 33 of the 34 individuals exhibit a weaning signature in their M1 with variation amongst the weaning patterns. A 'typical' (i.e. textbook) pattern, where δ^{15}N and δ^{13}C decline once solid foods are introduced to the diet, is seen in 10 individuals such as UID_1989.020.01 (Figure 103). The time between the development of S-01 and S-06 (M1) is where δ^{15}N declines one trophic level and δ^{13}C declines by 1‰ as the infant is transitioning onto a diet of solid food. The point where values stabilize between S-06 and S-07 can be seen as the time when the infant has ceased breastmilk consumption and has completely switched to a post-weaning diet. Data suggest the individual transitioned to a new diet and ceased the consumption of breastmilk between the ages of three-and-a-half and four years. The decline of δ^{15}N does not take on the shape of a curve, but rather exhibits a sharp downward trend. Potential reasons for this are discussed below.

A more gradual decline in δ^{15}N is seen in individual OBK_1971.013 (Figure 104). This pattern suggests that the replacement of breastmilk by solid foods happened gradually. The δ^{15}N data indicate that the individual was fully weaned by the age of three-and-a-half years. Interestingly, δ^{13}C does not exhibit a decline, it remains stable throughout the entire tooth. This is seen in other instances (e.g. UIL_1989.003, Figure 21; UID_1987.006, Figure 34; K14_2000.077, Figure

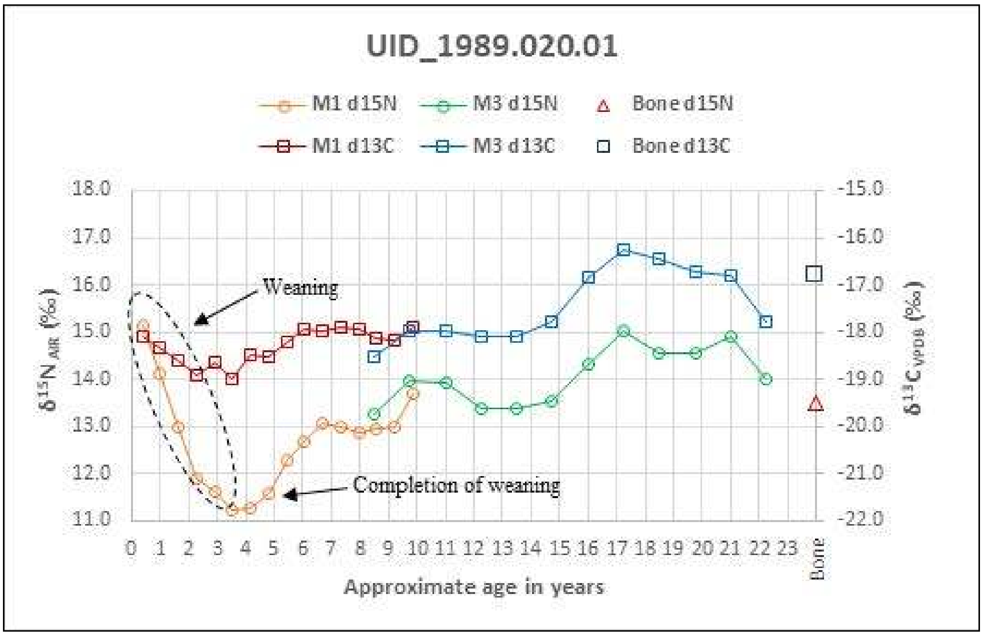


Figure 103. 'Typical' weaning pattern with a decline in δ^{15}N and δ13C in individual UID_1989.020.01.

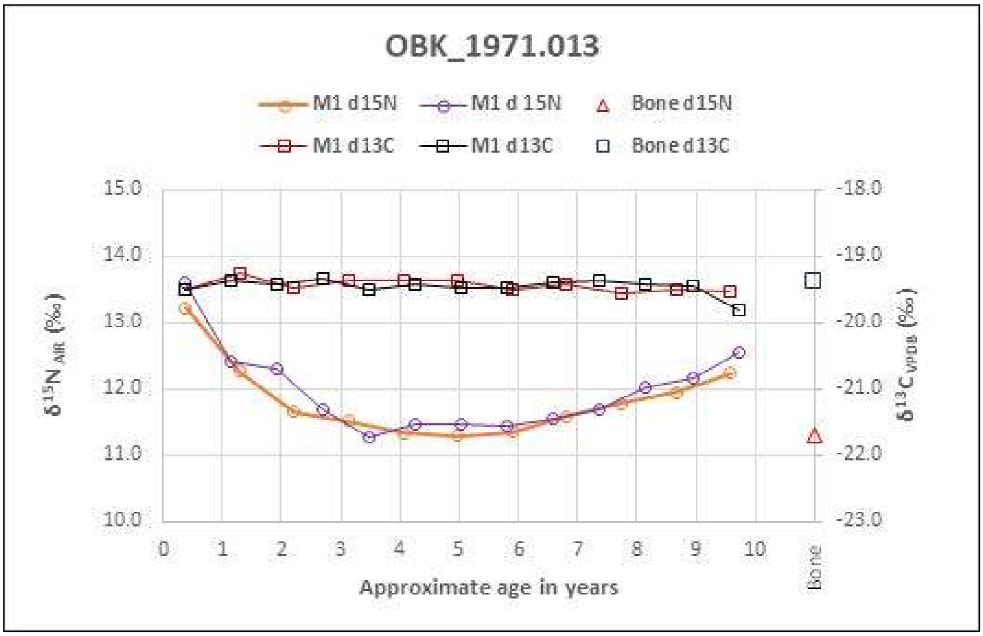


Figure 104. 'Typical' weaning pattern with a gradual decline in δ15N in individual OBK_1971.013.

100), while in other cases δ15N declines while δ13C increases (e.g. UID_1989.022, Figure 44; K14_2000.064, Figure 98). These patterns may be a result of the weaning foods that are given to the infant. If supplementary foods have a higher δ13C relative to breastmilk, then the infant's δ13C values can either increase or stabilize by 'cancelling out' the expected trophic level shift as suggested by King *et al.* (2018a: 12).

One individual (UIL_1990.011) showed no breastfeeding signal at all (Figure 105). Perhaps the mother passed away during childbirth or shortly thereafter. Despite this, the individual survived well into adulthood (age at death: 20+ years), which is rather surprising. This raises the question as to how and why the individual survived. UIL_1990.011 would have needed to receive an appropriate amount of nutrients, in subarctic conditions, from one or several members of its community. Rather than leaving the individual to succumb to starvation or commit infanticide, a decision was made to keep UIL_1990.011 alive. Therefore, this pattern also reflects the societal value these hunter-gatherers may have placed on the lives of all its members.

Another individual from Ust'-Ilga, UIL_1991.013.01 (Figure 32), exhibited a minor decline in δ15N from S-01 to S-05 (1.1‰). The same is seen in individual K14_1998.038 (Figure 82) from Khuzhir-Nuge XIV with a decline of only 1.1‰. This decline could be regarded as a non-weaning signature as it does not exhibit the typical 2–3‰ decrease in δ15N. Either the individuals were not breastfed, or the complementary solid foods were so high in δ15N that they resulted in an atypical weaning signature.

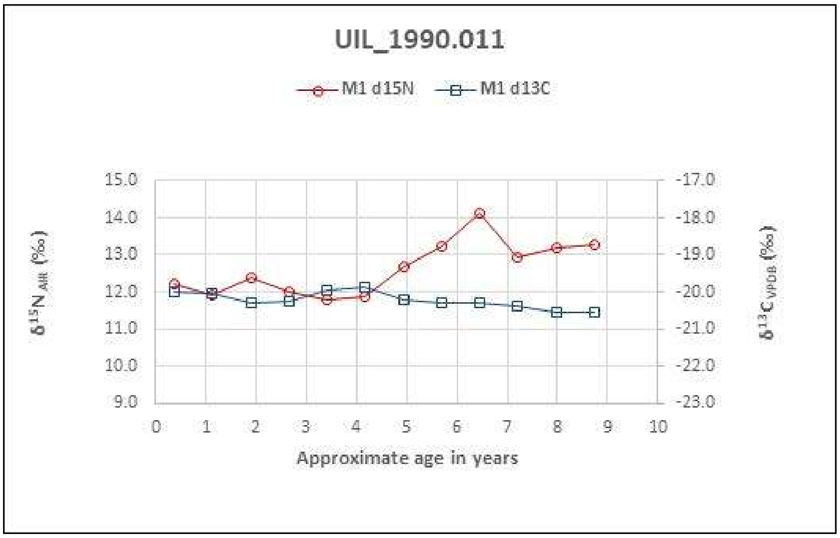


Figure 105. No weaning signature in the M1 of UIL_1990.011.

- <u>Pattern II</u>: Positive relationship between $\delta^{13}C$ and $\delta^{15}N$.

A positive relationship between $\delta^{13}C$ and $\delta^{15}N$ is present in all individuals from the Angara (n=13) and 19 out of 21 individuals from the Little Sea micro-region. Only six out of 15 Upper Lena individuals exhibit a positive relationship. A similar pattern was first mentioned in a study on weaning and childhood diet in California hunter-gatherers (Eerkens *et al.* 2011). The authors interpreted this relationship as the result of aquatic (marine) protein consumption as these foods often have high $\delta^{15}N$ and are said to be relatively high in $\delta^{13}C$.

Stable isotope analysis (Katzenberg *et al.* 2009, 2010, 2012; Lam 1994; Weber and Goriunova 2013; Weber *et al.* 2002, 2011) and faunal analysis (Losey *et al.* 2012, 2016; Nomokonova *et al.* 2015) have shown aquatic foods contributed greatly to the diet of Cis-Baikal hunter-gatherers. While the consumption of aquatic protein could have resulted in a positive relationship, it is difficult to pinpoint the extent that $\delta^{13}C$ from fish or seal contributed to this pattern as $\delta^{13}C$ shows high levels of variability within and between species (Katzenberg and Weber 1999). Furthermore, the possibility that the positive relationship is indeed the result of aquatic protein consumption is supported by the fact that it is largely seen in individuals who were buried in proximity to Lake Baikal and the Angara River, as some aquatic foods in these waters are higher in $\delta^{15}N$ (trophic level effect) and relatively high in $\delta^{13}C$ compared to the Lena River (Weber *et al.* 2011).

- <u>Pattern III</u>: Negative relationship between $\delta^{13}C$ and $\delta^{15}N$.

This pattern, which concerns both variables (decreased $\delta^{13}C$/increased $\delta^{15}N$ and increased $\delta^{13}C$/decreased $\delta^{15}N$), is present in a number of the examined Cis-Baikal individuals. The negative relationship is most frequent and prominent in the hunter-gatherers from Ust'-Ilga (Upper Lena) and Khuzhir-Nuge XIV (Little Sea). A similar pattern is seen in a study that was conducted by Beaumont and Montgomery (2016) on victims of the great Irish famine, as mentioned in Chapter 3. However, the explanation provided for this pattern, where $\delta^{15}N$ and δ^{13}C respond to a combination of nutritional stress and a switch from C3 to C4 foods, might not hold for the Cis-Baikal individuals. This is discussed further on.

In another study, on infant-feeding practices and stress in individuals interred in the Atacama Desert, Chile (King *et al.* 2018a), a negative relationship is observed in a number of the individuals. The authors state that a δ^{13}C increase (which corresponds to a decrease in δ^{15}N) during weaning could reflect a C4 dietary change, possibly to maize as it was present in the region. In a few other instances, the negative relationship (increase in δ^{15}N and decrease in δ^{13}C) happens over shorter periods and is described as most likely being the result of the body catabolising lipids (nutritional stress). This pattern is also seen in individual K14_1997.016 (Figure 72), which shows an increase in δ^{15}N and decrease in δ^{13}C between the first two increments of the M1. Nutritional stress is a plausible explanation as the rest of the skeletal remains also showed signs of stress such as enamel hypoplasia (Lieverse 2010).

Furthermore, while both oscillations (decreased δ^{13}C/increased δ^{15}N and increased δ^{13}C/decreased δ^{15}N) are present in a number of the Cis-Baikal individuals, the explanation that the increase in δ^{13}C could be a result of maize (Beaumont and Montogomery 2016; King *et al.* 2018a) does not hold for the Baikal individuals. The vegetation in the Cis-Baikal region only uses the C3 photosynthetic pathway (Katzenberg and Weber 1999; Katzenberg *et al.* 2009; Weber *et al.* 2011) and in the absence of C4 plants, Scharlotta *et al.* (2018b) suggest that Pattern III can only be the result of malnutrition. As the negative relationship is visible, in most cases, throughout the entire development of a single molar (Figure 106), it seems unlikely individuals suffered from malnutrition given the persistence in habitation and longevity of life.

In addition, the negative relationship between δ^{13}C and δ^{15}N (Pattern III) is also present in the EN individuals from Shamanka II (Scharlotta *et al.* 2018b). Here, the authors state that if individuals were indeed suffering from catabolism (nutritional stress), it should manifest as an elevation in δ^{13}C (~1‰) and δ^{15}N (~3‰) depending on the types of foods being consumed during these periods of stress. While such a manifestation is entirely possible, the authors do

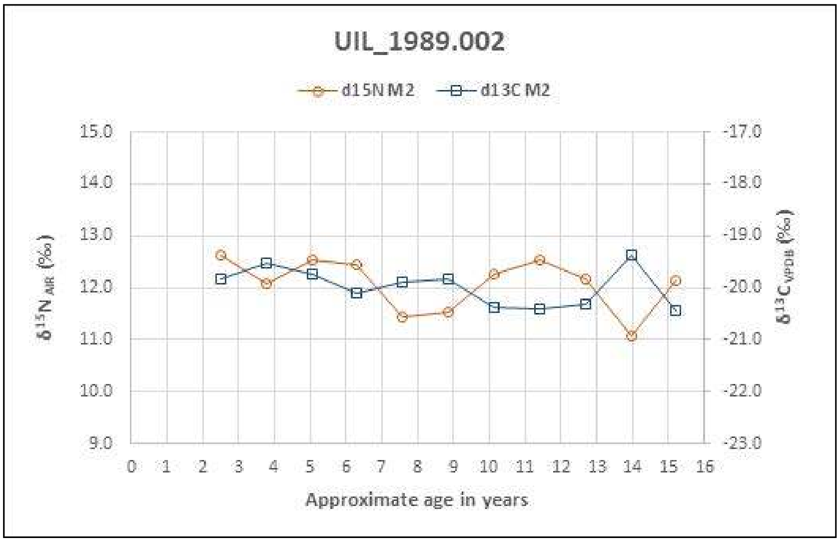


Figure 106. Negative relationship between δ^{13}C and δ^{15}N in UIL_1989.002 (M2).

not consider the complexity and variability of $\delta^{13}C$ and $\delta^{15}N$ during physiological hardship (Doi *et al.* 2017; Hatch *et al.* 2006; Mekota *et al.* 2006; Neuberger *et al.* 2013).

While Beaumont and Montgomery (2016) make a good case for malnutrition and dietary change in the Irish poor, which is further supported by historical documents, it does not necessarily apply to the individuals examined in this study. In the case of the Cis-Baikal hunter-gatherers, the negative relationship is likely a result of diet, not physiology. A combination of different foods in the region's water sources, with distinct isotopic signatures (high in $\delta^{15}N$ and low in $\delta^{13}C$), are most likely responsible for this pattern as well as the contribution of terrestrial resources such squirrel, Herring gull, or perhaps even dog (Katzenberg *et al.* 2010, 2012; Weber *et al.* 2002, 2011).

Another possible contribution could have been an aquatic mammal, the Baikal seal, which is particularly high in $\delta^{15}N$ and low in $\delta^{13}C$. Studies have shown that this animal was hunted throughout the Holocene (Losey *et al.* 2016; Nomokonova *et al.* 2010, 2013, 2015). Potentially the contribution of seal to the diet, with its distinct isotopic signature, could alter a positive relationship between $\delta^{15}N$ and $\delta^{13}C$. If this is the case, then it also raises the question as to whether seal contributed to the diet of a few Upper Lena individuals. While dentine $\delta^{15}N$ values are not as high as seen in individuals from the Little Sea, a negative relationship is visible in nine of the 15 Upper Lena individuals.

Stable isotope analysis on bone of Upper Lena individuals has suggested a migration from the Upper Lena to the Little Sea (Weber and Goriunova 2013), but thus far only very little evidence for a migration back to the Upper Lena has been found. The new data could not only imply the movement of people (or food) between the micro-regions, but also that seal was important to the diet of all Cis-Baikal hunter-gatherers and not just for those living along the coast of Lake Baikal. The other possibility is that the negative relationship is the result of higher contribution of terrestrial foods to the diet. This could explain why it is most prominent in Upper Lena individuals as previous studies postulated a heavier reliance on terrestrial food in this micro-region (Katzenberg *et al.* 2010; Weber *et al.* 2011).

- Pattern IV: Rise in $\delta^{15}N$ toward the end of molar development.

Although the increase in $\delta^{15}N$ is often below the 1.4‰ average (DeNiro and Schoeninger 1983; Eerkens *et al.* 2016), the pattern is apparent in at least 33 of the Cis-Baikal individuals. For this, I selected a $\delta^{15}N$ increase equal to or greater than 1‰ seen in the last few micro-samples of the M1, M2 or M3. For 18 individuals, the rise is seen in the M1. In a few instances the rise directly follows the weaning period, whereas in others, it does not. Either way, it could potentially signify a change in diet. In 15 of the Cis-Baikal individuals, the rise is noticeable toward the end of the M2 or M3, which raises the question as to whether a change in diet could also be related to age or socio-economic status. This is further discussed in Part II of this chapter.

- Pattern V: A continuous oscillation of both $\delta^{13}C$ and $\delta^{15}N$ values (zigzag).

The final pattern is only seen in two of the 49 individuals. Nonetheless, this pattern is important to discuss as it may imply travel rather than dietary changes alone. The pattern displays as an oscillation in $\delta^{13}C$ and $\delta^{15}N$ and is visible in the M3 of two individuals from Ust'-Ida I in the

Angara micro-region: a 15–20-year-old female, UID_1989.022 (Figure 44), dating to the LN; and a 50+ year-old male, UID_1989.029 (Figure 54), dating to the EBA (Figures 107 and 108). The oscillations occur continuously throughout the development of a single molar. Roughly every one to two years, δ¹³C and δ¹⁵N either increase or decrease in unison. In UID_1989.022 (Figure 44) the oscillations range between 13.8‰ and 16.1‰ for δ¹⁵N and between −17.6‰ and −15.3‰ for δ¹³C. In UID_1989.029 (Figure 54) the oscillations are smaller and range between 11.2‰ and 13.7‰ for δ¹⁵N, and between −18.0‰ and −17.2‰ for δ¹³C.

While the oscillation could represent a change in diet as a result of annual or bi-annual variability in resources, it does not explain the high δ¹⁵N in UID_1989.022 (Figure 44). These values imply the consumption of high trophic level fishes such as perch and pike, but also potentially Baikal seal. For the latter this would mean that the individual travelled from the Angara to the Little Sea micro-region or acquired seal through exchange or via food sharing

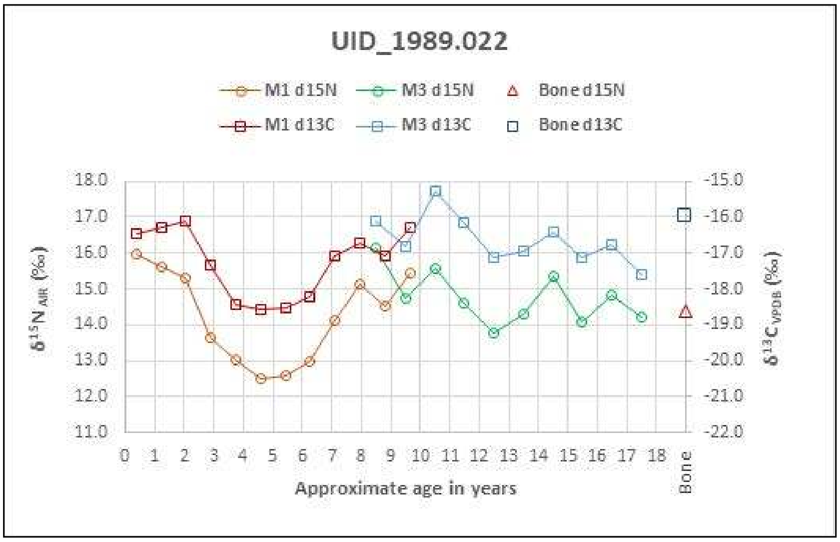


Figure 107. A continuous oscillation of both δ¹³C and δ¹⁵N in UID_1989.022 (M3).

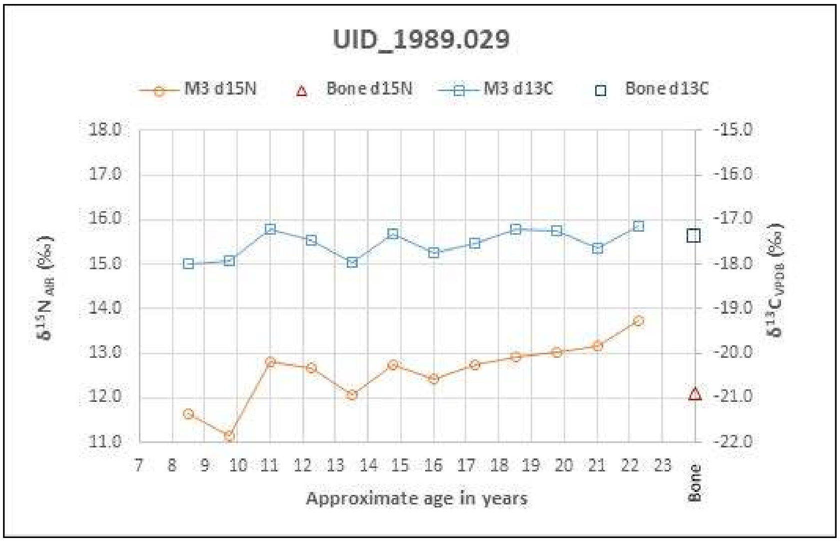


Figure 108. A continuous oscillation of both δ¹³C and δ¹⁵N in UID_1989.029 (M3).

with other members of the community. Based on the pattern of the data, continuous travel between two places seems most plausible. While $\delta^{15}N$ is lower for individual UID_1989.029 (Figure 54), an oscillation between $\delta^{13}C$ and $\delta^{15}N$ is visible. These results show that UID_1989.022 (Figure 44) and UID_1989.029 (Figure 54) had a similar subsistence pattern while separated in time by several centuries at least.

Dietary patterns in Cis-Baikal

As outlined in the introduction, the purpose of this research is to reconstruct the lifeways of the Cis-Baikal Middle Holocene hunter-gatherers. The stable isotope results on dentine micro-samples provide a large body of entirely new data on subadult diets. The two main goals, dietary patterns and migration, were divided into the three following research questions:

1. How did infant feeding practices look during the Late Neolithic and Early Bronze Age?

Infant and early childhood diet has been reconstructed for 34 hunter-gatherers (with an M1) from six mortuary sites. Of the 34, one individual belongs to the EN, nine to the LN, and 24 to the EBA. In total, 50% were completely weaned onto solid foods between four and four-and-a-half years of age (this includes the EN individual). For the LN, three out of nine individuals were weaned during that time and, for the EBA, 12 out of 24 were weaned between four and four-and-a-half years.

In the Upper Lena, the EN Manzurka individual was weaned between four and four-and-a-half years of age (Table 7). Individuals assigned to the EBA completed weaning between three and four-and-a-half years of age. The individuals at Ust'-Ida I assigned to the LN exhibit a wide range of variation in the cessation of weaning with ages ranging between three and six years. The EBA individuals interred at the same cemetery range between four and four-and-a-half years. In the Little Sea micro-region, weaning appears to have been completed between two and five years for Khuzhir-Nuge XIV and at four-and-a-half years for the one individual from Shamanskii Mys.

In a previous study on infant diet amongst Cis-Baikal hunter-gatherers (Waters-Rist *et al.* 2011), which examined stable isotope ratios in long bone, it was suggested that weaning completion occurred by three-and-a-half to four years in EN individuals and three years in LN individuals. EBA groups were not part of the study. The present research cannot confirm or deny the claim regarding infant diet of EN individuals due to the sample size (n=1). Yet, the complete cessation in the consumption of breastmilk appears later than previously suggested in the one EN individual examined here (MNZ_1974.002, Figure 9).

Regarding the Late Neolithic individuals (n=9), there is a substantial amount of variation seen at Ust'-Ida I and the individuals display a slightly wider range than suggested by Waters-Rist and colleagues (2011). Yet, it must be noted that the micro-sampling method was not applied to any of the individuals from the study conducted by Waters-Rist *et al.* (2011), which only targeted children aged between birth and 10 years. This might explain why there is a difference in weaning age between the two studies as the sample size used by Waters-Rist *et al.* (2011) was comprised only of individuals that did not make it past the first few years of life. Potentially an earlier cessation of weaning (three years) negatively affected the health of these individuals. Nonetheless, a difference in the cessation of weaning between the LN and EBA Ust'-Ida I individuals was not entirely surprising as previous studies have suggested the two groups are culturally distinct (Bazaliiskii 2010; Shepard 2012).

The variation in weaning at Khuzhir-Nuge XIV was quite surprising considering all individuals belonged to the EBA, and most were born and raised within the Little-Sea micro-region. The level of heterogeneity in infant feeding within this cemetery could represent different parental practices among smaller groups that were occupying the same micro-region. The same could be said for the Ust'-Ida I individuals in the Angara micro-region.

In addition, the variation in the age of weaning completion in the Little Sea could also have been influenced by the high number of non-locals. For instance, individual SHM_1975.001 (Figure 60) exhibits a decline in $\delta^{15}N$ of 3‰ (to 15.1‰) at the age of two, followed directly by a 1.3‰ increase and then a decrease of 1.5‰ at four-and-a-half years (to 15.2‰). While the first decline could be interpreted as a cessation of breast milk consumption, the strontium data should also be taken into consideration. As mentioned in Chapter 8, this individual was likely born outside the Little Sea micro-region and undertook major travel around the age of two to two-and-a-half years (Scharlotta and Weber 2014). If mother and child moved closer to the lake, and consumed a diet higher in aquatic protein, then their $\delta^{15}N$ values would increase. If the infant was still consuming some breastmilk, as well as different weaning foods, this migration could cause the $\delta^{15}N$ increase. Once the infant ceased to consume breastmilk, $\delta^{15}N$ values would decline once more. A weaning completion age at four-and-a-half years seems most probable as most individuals were weaned by this age.

Overall, the changes in $\delta^{15}N$ indicate variation among the 34 individuals in the timing and duration of weaning. For a number of individuals, the weaning 'curve' takes on the shape of a steep decline (e.g. OBK_1971.005, Figure 11; UID_1989.020.02, Figure 42; K14_2000.063 Figure 96). This suggests the individuals transitioned to a solid food diet quite rapidly. A possible reason for this weaning signature is that the mother was not producing a sufficient amount of milk and therefore the protein needs of the infant exceeded the supply provided by the mother's breastmilk. Potential causes for this could be that the mother suffered from malnutrition, there was a resource depletion, the mother had another infant to feed, or the mother's physiology was simply not capable of producing enough milk. Another possibility is that the mother changed her diet to foods of a lower trophic level while breastfeeding, causing her $\delta^{15}N$ to change and therefore the $\delta^{15}N$ of the infant as well. Additionally, a change in the mother's diet could be the result of consuming foods from another micro-region, either through a change in the home range, a change in foraging patch, or a change in resources in response to seasonality or climatic change.

The $\delta^{13}C$ values are less informative regarding weaning signatures than $\delta^{15}N$, yet this is not unexpected. The absence of a $\delta^{13}C$ enrichment in breastfed Cis-Baikal infants was first reported by Waters-Rist *et al.* (2011). While studies have shown $\delta^{13}C$ values of breastfed infants can also exhibit a trophic level shift by typically ~1‰ (Dupras *et al.* 2001, Fuller *et al.* 2006, Tsutaya and Yoneda 2013), the decline in $\delta^{13}C$ is not visible in most Cis-Baikal individuals. As mentioned, this is presumably the result of the $\delta^{13}C$ enrichment being smaller compared to $\delta^{15}N$ (Fuller *et al.* 2006) and potential weaning foods that could have masked the $\delta^{13}C$ breastfeeding signal.

Possible weaning foods given to the Cis-Baikal hunter-gatherer infants will be discussed further on in Part II of this chapter.

Finally, factors contributing to differences in the weaning patterns may range from the micro-region in which the infant was raised, to the protein intake of the mother, to the overall

Table 7. Weaning ages of the Cis-Baikal individuals.

No.	Master ID	Micro-region and period	Cessation of weaning in years
1	MNZ_1974.002	Upper Lena EN	4.5
2	OBK_1971.005	Upper Lena EBA	4
3	OBK_1971.007	Upper Lena EBA	4.5
4	OBK_1971.013	Upper Lena EBA	4
5	UIL_1989.003	Upper Lena EBA	4
6	UIL_1990.011	Upper Lena EBA	Not breastfed
7	UIL_1990.012	Upper Lena EBA	4.5
8	UIL_1991.013.01	Upper Lena EBA	3.5
9	UIL_1991.013.02	Upper Lena EBA	3.5
10	UID_1987.006	Angara LN	3
11	UID_1987.011	Angara LN	4
12	UID_1988.014	Angara LN	6
13	UID_1989.020.01	Angara LN	4
14	UID_1989.020.02	Angara LN	3
15	UID_1989.022	Angara LN	5
16	UID_1989.030	Angara LN	4
17	UID_1991.038	Angara LN	5.5
18	UID_1995.056.01	Angara LN	3.5
19	UID_1989.019	Angara EBA	4.5
20	UID_1993.045	Angara EBA	4.5
21	UID_1994.048	Angara EBA	4
22	SHM_1975.001	Little Sea EBA	4.5
23	K14_1997.012	Little Sea EBA	5
24	K14_1997.016	Little Sea EBA	Unclear
25	K14_1998.036.01	Little Sea EBA	3
26	K14_1998.037.02	Little Sea EBA	4.5
27	K14_1998.038	Little Sea EBA	2
28	K14_1998.039	Little Sea EBA	4
29	K14_1999.044	Little Sea EBA	2
30	K14_1999.045	Little Sea EBA	4
31	K14_1999.051	Little Sea EBA	2.5
32	K14_2000.063	Little Sea EBA	3.5
33	K14_2000.064	Little Sea EBA	2
34	K14_2000.077	Little Sea EBA	4.5

health of the mother and infant. Although it is impossible to make a valid argument regarding weaning of infants of different sexes, due to a small sample size of females with an M1 (n=3), there appears to be no significant difference between males and females. aDNA studies that are currently in progress will hopefully shed light on this matter, allowing for a comparison between males and females. Differences in the duration and completion of weaning could have affected population growth, mortality, and the health of the infant and mother.

2. Was childhood diet similar to adult diet in Late Neolithic and Early Bronze Age hunter-gatherers?

The post-weaning diets vary between and within the cemeteries. The majority of the EBA individuals from the Upper Lena have diets that are isotopically similar to the adult bone values, suggesting children had access to resources that were available to the adults. This will be further discussed in Part II. Only at Obkhoi does it appear that $\delta^{15}N$ was slightly higher during childhood. Here, the isotopic data suggest individuals were either consuming foods from a higher trophic level during childhood, or they were consuming a higher quantity of the same foods during childhood.

The Ust'-Ida I individuals were separated into two units (LN and EBA) for the purposes of comparison. As mentioned, both groups have previously often been pooled together, mainly because the Late Neolithic is not well represented in the BAP dataset.

Overall, both groups fall within the same range for $\delta^{15}N$ and $\delta^{13}C$. Differences become more apparent when the data are examined intra-individually. Starting with the LN, five of the nine individuals' $\delta^{15}N$ are on the lower end of the scatter plots, suggesting that diet during late childhood and adulthood did not differ substantially. Individual UID_1991.038 (Figure 48) exhibits the largest difference in $\delta^{15}N$ between dentine and bone. For four individuals (UID_1987.011, Figure 36; UID_1988.014, Figure 38; UID_1989.020.02, Figure 42; and UID_1989.030, Figure 46), the M3 displays a $\delta^{15}N$ rise (Pattern IV) of 1‰ or more, around 14 years. Although the sample size is too small to draw any definitive conclusions, it might imply that individuals altered their diet around this age as aquatic protein started to play a larger role. Perhaps this is due to a socio-economic change. However, a rise in $\delta^{15}N$ in also seen in the last three micro-samples of individual UID_1991.038 (Figure 48), which does not happen until the age of ~20 years. Interestingly, the increase in $\delta^{15}N$ is seen in males as well as females, showing a similar dietary behaviour between the sexes.

Additionally, two of the Late Neolithic individuals that are examined here, UID_1989.020.01 and UID_1989.020.02, were buried together (Figure 109). The individuals have been radiocarbon dated to 4584±71 and 4655±75 BP (Weber *et al.* 2016), respectively. The genetic relationship between them is currently unknown. In the first individual (Male, 18–24 years old, UID_1989.020.01), the dentine stable isotope values show a wide range on both axes with $\delta^{15}N$ ranging between 11.2‰ and 15.1‰ and $\delta^{13}C$ between −19.0‰ and −16.3‰. Breastfeeding and weaning are in part responsible for this variability. If $\delta^{15}N$ results for the first six micro-samples are not considered (weaning), values still exhibit a wide range between 11.3‰ and 15.0‰. Data reveal a change between childhood and early adulthood to a diet that is heavier in $\delta^{15}N$ and $\delta^{13}C$. $\Delta^{15}N$ values rise to 15.0‰ suggesting the contribution of aquatic dietary protein from Lake Baikal. In the second individual (Female, 30–40 years old, UID_1989.020.02), values suggest little change between childhood and adulthood diet. Not considering the first three

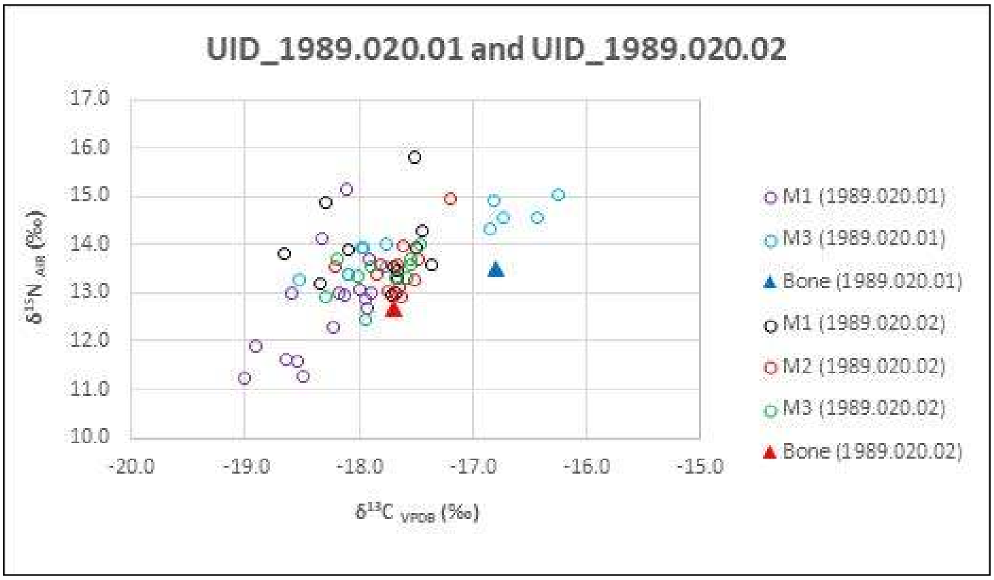


Figure 109. Stable isotope results for UID_1989.020.01 and UID_1989.020.02.

micro-samples in the M1 (weaning), δ^{15}N ranges between 12.5‰ and 14.9‰, and δ^{13}C between −18.7‰ and −17.2‰ across all three molars and bone. Despite being interred together, and possibly living contemporaneously, the individuals exhibit different diets, yet both high in δ^{15}N.

Dietary variation between childhood and adulthood is most apparent in the Little-Sea micro-region. At Shamanskii Mys the two individuals show a difference in diet between childhood and adulthood, as well as between one another. SHM_1975.001 has higher δ^{15}N in bone (apart from S-01 of the M1 due to weaning) than dentine. When both individuals are placed alongside each other in a scatter plot (Figure 110), the dietary difference becomes most noticeable. Interestingly, SHM_ 1972.002 was defined as a seal hunter by Okladnikov and Konopatskii (1975: 304; after McKenzie 2006: 239). This was based on the grave goods and seal remains surrounding the grave. While the dietary data does suggest the possible incorporation of seal protein, the other individual (SHM_1975.001) has even higher δ^{15}N, along with higher δ^{13}C. The latter may imply this individual's diet consisted of more Baikal fishes from the Little Sea (e.g. whitefish, grayling, perch, pike, and omul') than the diet of SHM_1972.002 (Katzenberg *et al.* 2012; Weber *et al.* 2011). There was no mention by Okladnikov and Konopatski whether this individual was perhaps also a seal hunter.

The majority of the Khuzhir-Nuge XIV individuals exhibit a childhood diet that is similar to adulthood diet, only with slightly higher δ^{15}N during the developmental years. Three of the Little Sea individuals (SHM_1975.001, Figure 60; K14_1999.046, Figure 90; K14_1999.057.02 Figure 94) have higher δ^{15}N in bone than in dentine. This is the opposite of what is seen in individuals from the other micro-regions. The commonality these three Little Sea individuals share (apart from higher bone δ^{15}N than dentine) is that all were born probably outside of the Little Sea micro-region. This suggests a difference in resource acquisition during adulthood when compared to individuals born in the Little Sea. For other individuals that were born outside of the Little Sea but buried at Khuzhir-Nuge XIV, bone and dentine values either

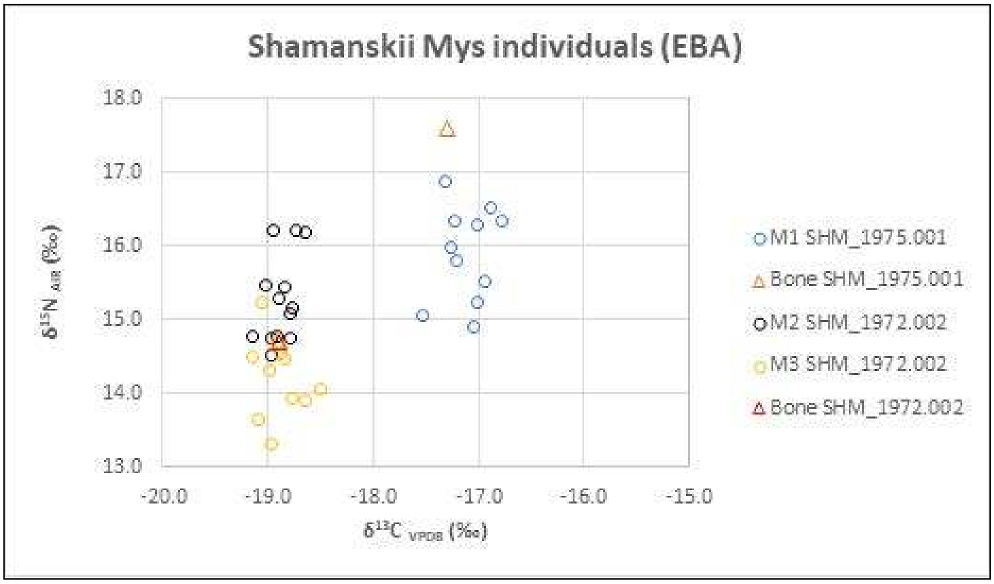


Figure 110. Stable isotope results for SHM_1975.001 and SHM_1972.002.

cluster together (K14_1998.037.02, Figure 80; K14_1998.038, Figure 82) or δ^{15}N is lower in bone (K14_1997.019, Figure 74; K14_1998.035.02, Figure 76; K14_1998.036.01, Figure 78; K14_1999.051, Figure 92; K14_2000.077, Figure 100).

Finally, in some individuals, the δ^{13}C values exhibit a wider range (1‰ to 2.5‰) than what is seen in most individuals (0.1‰ to 1.0‰). For example, individuals MNZ_1974.002 (Figure 9), UID_1987.011 (Figure 36), K14_1999.051 (Figure 92), and K14_2000.064 (Figure 98) display variation in δ^{13}C of 1‰ or higher throughout a molar. Individual UID_1989.022 (Figure 44) displays the widest range in δ^{13}C in the M3 (2.5‰). As δ^{13}C records any changes in the carbon source of dietary protein, the variation seen in these individuals is a result of changes in aquatic protein consumption, and possibly terrestrial protein as well. Although the latter is masked due to the high variation of carbon in and between the aquatic species as a result of bathymetry, particularly in Lake Baikal (Katzenberg and Weber 1999; Katzenberg *et al.* 2010).

Migratory patterns in Cis-Baikal

Although ^{87}Sr/^{86}Sr isotope analysis is typically used as a geochemical marker of locality (Haverkort *et al.* 2010), this study investigates whether migration-related dietary inferences can be drawn based on carbon and nitrogen isotope data alone. Several individuals were subjected to strontium analysis in the past (Haverkort *et al.* 2008, 2010; Scharlotta and Weber 2014; Weber and Goriunova 2013) and serve as a control for current observations. As mentioned at the beginning of Chapter 6, migration is defined here as a change in an individual's home range that is visible in the stable carbon and nitrogen isotope data, as well as individuals with the strontium values of one micro-region but who were interred in another.

Prior to discussing migration based on δ^{13}C and δ^{15}N, two points need to be discussed in regard to the strontium isotope analysis. First, while the strontium values from the Cis-Baikal region do exhibit different geological zones, they cover large areas and, at times, overlap. Haverkort *et al.* (2008) state that the main geological zones happen to overlap within three of the four micro-regions: The Lake Baikal basin (including Ol'khon), the upper and middle section of the Angara River, and the Upper Lena basin. This becomes problematic when trying to pinpoint a specific birthplace as well as track travel within a micro-region along with inferences on subsistence ranges. As a result of this overlap, most individuals are listed as 'born outside the Little Sea' as more specific information is currently unavailable. Certain areas within the Cis-Baikal are yet to be sampled for strontium analysis.

Second, the isotopic signature of bone will represent a much longer time frame than enamel as a result of bone turnover, thus providing an average of resources consumed over a period of ~10 years or more, depending on what type of bone is used for analysis. As a result, frequent travel between micro-regions during bone turnover could have been averaged out and masked. This also includes the strontium values of (terrestrial) foods being consumed outside of a person's micro-region. To what extent this affects the strontium signature of the individual will depend on strontium's contribution to the diet. This is where $\delta^{13}C$ and $\delta^{15}N$ can potentially aid in providing additional information on the size of a person's home range and migration.

3. What inferences can be made on migration based on dietary reconstruction alone?

Migration refers to a change in home range, which is signified by the specific isotopic values of food sources in an area (e.g. micro-region). The $\delta^{13}C$ and $\delta^{15}N$ of some individuals suggest high levels of travel between micro-regions. For instance, the dentine micro-sampling Pattern V (zigzag) in UID_1989.022 (Figure 44) and UID_1989.029 (Figure 54) suggests travel between at least two locales: $\delta^{13}C$ and $\delta^{15}N$ display an annual or bi-annual shift. Based on this data alone, it could be assumed the individuals were travelling back and forth between at least two micro-regions (the Angara and Little Sea), and possibly three (Southwest Baikal). These inferences are based on the isotopic baselines of the micro-regions' flora and fauna. This means that if hypotheses are to be drawn from just carbon and nitrogen isotope analysis, clear baselines need to be established and micro-regional isotopic signatures need to be distinct enough to discern any differences.

Although the carbon and nitrogen data of two Ust'-Ida I individuals, UID_1989.022 (Figure 44) and UID_1989.029 (Figure 54) suggest frequent travel, this cannot be confirmed or denied by strontium data as of this moment. Another Ust'-Ida I individual (UID_1989.020.01, Figure 40) showed dentine values that suggest the consumption of aquatic foods from Lake Baikal. Strontium isotope analysis has not yet been conducted on this individual either. If the carbon and nitrogen data are correct in suggesting place of residence, then the data suggest that UID_1989.020.01 moved out of the Angara micro-region and into the Little Sea area during early childhood as values continuously increase toward those characterizing the GFS diet.

In another individual, K14_1999.046 (Figure 90), there are no clear signs of a migration (such as Pattern V), but carbon and nitrogen data indicate a more specific birth locale. This person was born outside of the Little Sea area and previously listed as 'non-local' (Weber and Goriunova 2013). Despite the significant overlap and wide ranges of biologically available strontium, the data exhibit values of the Upper Angara area for the M1 and M2, but values of the Upper Lena for M3 (Haverkort *et al.* 2008). The dentine $\delta^{15}N$ values (between 11.1‰ and 11.6‰) of the M2 are much lower than bone (14.2‰). Based on the latter, Weber and Goriunova (2013) assigned this individual a GFS diet type. The dentine $\delta^{15}N$ values suggest a diet that is not considered to be typical of the Little Sea micro-region, which is confirmed by the strontium data. The new (dentine) $\delta^{13}C$ and $\delta^{15}N$ values are similar to Bronze Age individuals from Ust'-Belaia along the Angara (Katzenberg *et al.* 2010; Weber *et al.* 2002), suggesting this location as the individual's specific birth locale.

Individual K14_1999.051 (Figure 92), also said to be born outside of the Little Sea, shows a diet throughout all three molars that is considered to be typical of the Little Sea (GFS). There is also no indication of travel from another micro-region (at least not through diet). The data imply the individual always consumed a GFS diet. If this individual was indeed born outside of the Little Sea, as previous studies have suggested (Katzenberg *et al.* 2009; Weber and Goriunova 2013), then, considering the individual's diet, there should have been frequent travel or contact with the Little Sea.

Although the Upper Lena individuals are yet to be analyzed for strontium, two Ust'-Ilga individuals, UIL_1990.009 (Figure 26) and UIL_1990.011 (Figure 30), exhibited $\delta^{15}N$ values that are more typical of the Little Sea micro-region (13.2‰ and 14.0‰, respectively). If these hunter-gatherers did in fact consume foods in the Little Sea, this would be one of the very few instances where there is evidence of contact with the Little Sea while being interred in an Upper Lena cemetery, indicating a move back. Up until now, only one individual from an EBA cemetery (Makrushino) in the Upper Lena showed a clear GFS diet (Dr Andrzej Weber, personal communication, September 15, 2019). Future isotope studies will hopefully provide even more insight.

PART II

The second part of this discussion briefly touches upon the life history approach and its significance to hunter-gatherer research, as well as the theoretical and methodological approaches to studying human behaviour before discussing the data through a critical archaeological lens. Past studies on hunter-gatherer subsistence behaviour, as well as studies on child foragers, provide the necessary framework for interpreting the data and reconstructing foraging behaviours. The stable isotope analysis was carried out to further improve our understanding of hunter-gatherers in Cis-Baikal and beyond.

The importance of studying hunter-gatherer life histories

The individual life-history approach enables us to study human behavioural change. In the case of Baikal Middle Holocene hunter-gatherers, life-history focuses on the examination of dietary variation between and within cemetery populations, as well as the timing of specific events such as weaning and the dietary transition from childhood to adulthood. If changes are observed, these can potentially be tied to climatic changes, subsistence changes, socio-political changes, and/or technological changes. Examination of dietary variation, migration, and how diet changed throughout the Cis-Baikal Middle Holocene, enables researchers to investigate micro and macro-regional connections in Siberia, Russia (Shepard *et al.* 2015). Hunter-gatherers use the landscape in various ways and the relationship between an individual and the environment will not always reflect that of the entire group. While travel will largely be dependent on the distribution of resources within the environment as well as the seasonality of food, it may also be tied to exchange partnerships or other social events (e.g. ceremonies).

Furthermore, examining infant and childhood diet through dentine micro-sampling will also aid in bridging the gap in the understanding of hunter-gatherer children. Apart from a child's need for physical development, their cultural development is equally important. The latter being learnt through observation and interaction processes. The information that is passed down to younger generations, through whatever means possible, allows for the continuation, equilibrium, and even the discontinuity of a culture. According to Hewlett and Lamb (2005b: 3, 4), more than 40% of hunter-gatherer populations are represented by children, yet they are rarely described ethnographically or theoretically in hunter-gatherer literature. The study of hunter-gatherer children is valuable to understand the behaviour of all members within a society. Fortunately, studies on children amongst prehistoric groups are growing, particularly from the social perspective rather than just a biological perspective (e.g. Baxter 2005; Halcrow and Tayles 2008; Hewlett and Lamb 2005a; Sofaer 2006).

The remainder of this chapter presents the theoretical interpretations of the results shown in Chapters 6, 7, and 8. While dietary change and migration during childhood are the overarching goals of this research, both are rooted in a deeper goal of understanding variation and change in past populations. How BAP gains insight into the processes of change is facilitated through a research model known as the 'life history approach' (also referred to as life history theory). While Chapter 4 briefly touched upon the definition of life-history theory, and how the dentition has become valuable for examining important life events, I will further discuss here how this theoretical approach explores the behavioural choices individuals make. Mithen and Mithen (1990: 5) draw attention to the importance of shifting the focus from populations to individuals: '...it becomes immediately apparent that even the most egalitarian hunter-gatherer society is immensely heterogeneous.' Focusing attention on the individual and the dietary decisions he or she made, can provide not only a better understanding of the individual but also how the individuals operate as a group. However, when discussing the decision-making abilities of particular individuals, the biological forces that drive these processes need to be discussed as well.

Growing up in Baikal

The previous stable isotope data on bone samples and the new data on tooth dentine micro-samples both confirm that aquatic resources were an important part of the diet for all individuals within the Cis-Baikal, regardless of age, sex, period, or place of burial. However, some individuals either consumed a higher quantity of aquatic resources or resources of a higher trophic level than others. The $\delta^{13}C$ and $\delta^{15}N$ values of dentine micro-samples of the permanent molars also provide insight into feeding practices and childhood diet, and allow for the comparison between bulk bone and dentine samples. As a result of the dentine micro-sampling conducted in this study, the dietary life history during the first ~20 years of the life of the Cis-Baikal hunter-gatherers is illuminated. Before discussing the behavioural variation seen in individuals during their developmental years, the difficulty of defining childhood must first be addressed.

The pitfalls of defining childhood

For this research, tooth eruption is used as the criterion for assigning age categories (infancy, early childhood, late childhood, and early adulthood). As outlined in Chapter 3, a person's biological age does not correspond one-to-one with chronological age, and also the terminology used to describe certain life periods or events differs between studies. The terminology used in this monograph was created to link observed dietary changes to life events. Nonetheless, the terminology does cause issues as this study deals with skeletal material and not a living population.

The age categories selected will have implications for data interpretation (Halcrow and Tayles 2008), particularly when short-term intervals (e.g. micro-samples) are applied to interpret weaning age, health, or social changes related to diet. Kamp (2001: 3) raises an important point that although 'biological changes occur as an individual matures, the cultural meaning imposed on these changes is, to a large extent, arbitrary.' Yet, in order to make inferences regarding a change in individuals and populations, we must rely on biological interpretations. Apart from the issue regarding the correct age terminology and categories, we should also consider the biological and social changes that occur at the intra-individual level.

While individuals might follow the same social trajectory, visible changes related to this would not necessarily appear at the same point in time. For example, a person may alter their diet as a result of a change in the way they contribute to the subsistence economy (i.e. because they are perhaps no longer perceived as being a child). For one individual, these changes might be visible in the isotope data around eight years, while for another, it might be at 10 years. The problem then lies in identifying at which point in time this dietary (and social) change occurs. Prehistoric hunter-gatherers would not have kept track of age in the way that is customary in modern societies (the yearly anniversary of birth). The age or status of an individual would be mostly related to biological change such as the development of certain sexual characteristics (e.g. onset of menarche, breast development, appearance of pubic hair) or changes related to skills such as self-sufficiency in fishing or foraging, or even a cultural change as seen in the Nayaka (Bird-David 2005: 98) who are not considered an adult until they become a parent. This complicates the ability to observe the occurrence of certain patterns within or between populations.

So, how should researchers tackle these issues when investigating past childhood, especially when the term childhood varies between groups? It has been suggested that when conducting bioarchaeological research, social age categories should be applied as well (Halcrow and Tayles 2008; Kamp 2001; Perry 2005). Kamp (2001: 4) emphasizes that the age categories will differ based on the society being examined and that when examining a prehistoric population (where this solution is notably less straightforward), the best possibility is 'a determination of significant cultural age categories and their basic characteristics.' However, the problem with this is that there is no way of knowing what such social categories among Cis-Baikal hunter-gatherers might have been. Imposing different categories on these individuals would likely be imprecise, causing additional complications. Perry (2005) further notes that a description of age categories that are culturally appropriate can assist the (bio)archaeologist when examining past childhood. As previously mentioned, several age categories have been applied to the Cis-Baikal individuals that do not always match one another. For example, some individuals were listed as an adolescent in one database and listed as an adult in another, albeit the age in years was always provided when possible. Differences between categories are a result of discrepancies between Russian and North American researchers. While this is currently being rectified by some of the project's osteologists by re-examination of the skeletal collections in Siberia, this topic should be critically examined among the BAP archaeologists and bio-anthropologists in the near future. Outlining the biological and social age categories will benefit collaboration between the project's researchers as well as communication with the rest of the scientific community.

Infant feeding practices

Weaning

The stable isotope data presented in Part I of this chapter (general dentine Pattern I) provide insight into the timing and duration of weaning. The $\delta^{15}N$ data reveal variation in the 34 individuals (with an M1) examined. The time during which children were no longer solely dependent on breastmilk (the weaning period) might offer some indication as to what type of foods were provided. Suggestions concerning supplementary foods were first put forward in a study by Waters-Rist *et al.* (2011). Here, the authors suggested premasticated foods (terrestrial and/or aquatic). This is in part based on an ethnographic study of an Eastern Siberian hunter-gatherer population, the Koryak (Jochelson 1908), whose infants were given premasticated foods as well as seal fat to chew and suck on. A similar observation was made in another hunter-gatherer population from Northern Japan and Sakhalin, Russia: the Ainu. This population provided soft foods such as seal fat, premasticated salmon, and bear rib to the infants (Ohnuki-Tierney 1974). Soft fish flesh is easy to consume. In a micro-sampling study conducted on EN individuals from Shamanka II (Scharlotta *et al.* 2018b), fish gruels were suggested as a probable weaning food, keeping in mind the shortage of plant foods in Cis-Baikal.

The Baikal seal would have been an excellent source of fat, particularly for the individuals that lived within the vicinity of the lake (Khuzhir-Nuge XIV, Shamanskii Mys). If premasticated foods and pieces of seal fat were being consumed by Cis-Baikal infants, it would most likely have caused their $\delta^{13}C$ to become more negative as lipids, which are present in fats, are depleted in $\delta^{13}C$ relative to carbohydrates and proteins (DeNiro and Epstein 1977; Tieszen *et al.* 1983). Although the $\delta^{13}C$ values are difficult to interpret due to the wide variation of stable carbon isotopes in the region's aquatic food sources, a number of individuals from such cemeteries as Ust'-Ida I, Shamanskii Mys, and Khuzhir-Nuge XIV do exhibit a ~1‰ decline during the first few dentine increments. Nonetheless, this could be a result of a general shift in trophic level during weaning (Fuller *et al.* 2006).

After seal, lenok or grayling would have been the best sources for fatty fishes (Waters-Rist *et al.* 2011). Individuals with slightly less negative $\delta^{13}C$ might have been consuming fishes that were not as fatty such as perch and pike. Individuals living and interred at Obkhoi, Ust'-Ilga and Manzurka may have targeted other sources of fat than seal, such as terrestrial game or fishes from the Lena River.

Of the 32 individuals with a weaning signature, 21 show little to no change in $\delta^{13}C$ for the first few micro-samples of the M1. For the Upper Lena, seven of eight individuals exhibit little to no change in $\delta^{13}C$, (MNZ_1974.002, Figure 9; OBK_1971.007, Figure 13; OBK_1971.013, Figure 15; UIL_1989.003, Figure 21; UIL_1990.012, Figure 31; UIL_1991.013.01, Figure 32; UIL_1991.013.02, Figure 33), in the Angara eight out of 12 (UID_1987.006, Figure 34; UID_1987.011, Figure 36; UID_1988.014, Figure 38; UID_1989.022, Figure 44; UID_1991.038, Figure 48; UID_1995.056.01, Figure 50; UID_1993.045, Figure 56; UID_1994.048, Figure 58), and in the Little Sea six out of 13 (K14_1997.012, Figure 66; K14_1998.038, Figure 82; K14_1998.039, Figure 84; K14_1999.051, Figure 92; K14_2000.063, Figure 96; K14_2000.077, Figure 100). In some instances, $\delta^{13}C$ does not reflect a weaning signature (decline) in conjunction with $\delta^{15}N$ until the second micro-sample as the first micro-sample exhibits either no change or a minor increase. For example, while $\delta^{13}C$ for S-01 of K14_1997.012 (Figure 66) displays an increase of 0.6‰, $\delta^{15}N$ exhibits an increase of 2.3‰, suggesting S-01 is still representing a sole breastmilk protein diet. Hereafter, $\delta^{13}C$ remains at −17.5‰ for S-02 and S-03. This particular isotopic display of $\delta^{13}C$ is seen across cemeteries, micro-regions and periods.

While the wide range of $\delta^{13}C$ values between and within the aquatic Baikal species hinders the ability to signify what foods were given during the weaning period, there appears to be some level of homogeneity in infant feeding practices, despite differences in the duration of weaning. As mentioned in Part I of this chapter, the stagnation of $\delta^{13}C$ values during the onset of weaning could represent the contribution of foods that are higher in $\delta^{13}C$ relative to breastmilk and therefore mask a trophic shift. Fishes that have relatively low $\delta^{15}N$ and high $\delta^{13}C$ are lenok and grayling (Katzenberg *et al.* 2010, 2012; Weber *et al.* 2011). Nonetheless, the isotopic variability between and within species needs to be considered. These fish species are found in the lake as well as the region's main waterways.

Ten of the 32 individuals exhibit a decline in $\delta^{13}C$, which likely corresponds to a trophic level shift as a result of complementary foods that are lower in $\delta^{13}C$ relative to the mother's diet. This could represent a higher contribution of terrestrial sources or different types of fish compared to those that show little to no change. However, in some instances, the decline is less than the expected 1‰ and, on occasion, barely represents any increase or decrease (e.g. <0.3‰).

In the Upper Lena, only OBK_1971.005 (Figure 11) exhibits a decline (0.6‰) as the $\delta^{13}C$ weaning signature of all other individuals are represented by little to no change. On the Angara, four individuals exhibit a decline of about 1‰, two of which were buried together: UID_1989.020.01 (0.8‰, Figure 40) and UID_1989.020.02 (1.2‰, Figure 42); UID_1989.030 (0.4‰, Figure 46); UID_1989.019 (0.3‰, Figure 52). In the Little Sea, one individual from Shamanski Mys (SHM_1975.001, 1‰, Figure 60) and four from Khuzhir-Nuge XIV show decline in $\delta^{13}C$ by about 1‰: K14_1997.016 (0.7‰, Figure 72); K14_1998.035.02 (0.9‰, Figure 76); K14_1998.036.01 (0.3‰, Figure 78); K14_1998.037.02 (0.6‰, Figure 80).

Only for individual K14_2000.064 does $\delta^{13}C$ increase at the start of the M1 (Figure 98). However, individual UID_1988.014 (Figure 38) also shows a $\delta^{13}C$ increase starting at the second micro-sample. This suggests the contribution of complementary foods that had $\delta^{13}C$ higher than the mother's milk. Perhaps a higher contribution of foods such as grayling, lenok, and pike was given to this infant. Other studies that showed an increase in $\delta^{13}C$ during the onset of weaning

(King *et al.* 2018a; Sandberg *et al.* 2014; Wright and Schwarcz 1998) suggest the increase is related to the isotopic content of supplementary C4 foods such as maize or even goat and sheep milk (Sandberg *et al.* 2014). However, the rise in δ^{13}C in this Cis-Baikal individual cannot be linked to C4 foods as they are not present within the region. Additionally, animal husbandry and access to animal milk are not present in the Baikal region until around *3400* cal BP (Losey *et al.* 2013) in the Late Bronze Age.

Overall, while the supplementary foods would also have been dependent on resource availability, seasonality, and home range, a specific weaning diet causing δ^{13}C to stagnate was provided. There is the possibility that food sources which have not yet been analyzed were part of the weaning (and overall) diet. Examples of such food sources are eggs, along with certain bird and plant species in the region. As of yet, it is not possible to say whether infant feeding practices changed through time. For this, additional data are necessary and a comparison with the EN individuals needs to be made.

Atypical weaning

K14_1998.036.01 (Figure 78) is an example of atypical weaning which exhibits a rise at the start of the M1. While δ^{13}C drops by 0.3‰ between S-01 and S-02, δ^{15}N rises by 0.6‰. If the rise in δ^{15}N was still representing the contribution of milk proteins, we would expect to see a positive relationship with δ^{13}C. Once δ^{15}N declines, δ^{13}C increases again by 0.5‰ from S-02 to S-03. This could perhaps represent the aforementioned negative co-variance between both variables as a result of nutritional stress. Additional osteological evidence does not provide insight into nutritional stress as the individual died between the age of 35 and 50 years. At this age, bone turnover would have eliminated any signs of malnutrition during infancy and the deciduous dentition is no longer present.

Individuals K14_1999.044 (Figure 86), K14_1999.051 (Figure 92), and K14_2000.064 (Figure 98), who were weaned at an early age (approximately two years), show a minor decline in δ^{15}N and could have ceased breastmilk consumption for a number of reasons. It is most likely that this is a result of the mother not being capable of producing enough breastmilk. Either a resource depletion led to insufficient amounts of milk production or the mother had another mouth to feed. Ohnuki-Thierney (1974) mentions that amongst the Ainu, if a sibling is born before the other has completed weaning, the mother will nurse both children. The birth of another infant could cause the mother to wean the firstborn at a quicker rate than initially intended. The two individuals that show a minor decline in δ^{15}N could have not been breastfed or weaned onto foods that were high enough in δ^{15}N (e.g. seal) to mask the trophic level shift.

Children as foragers

Multiple studies (Bird and Bliege Bird 2000, 2002; Bliege Bird and Bird 2002; Hawkes *et al.* 1995; Kelly 2013; Tucker and Young 2005) have shown most children forage on their own and select different types of foods than adults. Teaching how to forage efficiently or perform certain tasks would be time-consuming for the parent or caretaker. How long it takes to acquire these skills will depend on when the child begins learning from others, the physical and cognitive abilities of the child, as well as time spent learning and environmental conditions. For example, Hadza children over five years of age already foraged in small groups, while often accompanied by mothers and grandmothers (Hawkes *et al.* 2001). Meriam children growing up in the Torres Strait typically start to accompany adults and learn how to forage on the reef around the age of five or six and become fairly efficient foragers in a short amount of time (Bliege Bird and Bird 2002). Hereafter, the children will forage alongside the older children where they learn about prey choice and the processing of resources. As a result, children spend a relatively short amount of their time learning from the adults, thus leaving them with more time to forage for high ranked prey. Bliege Bird and Bird (2002) also note that once children start foraging, they are less constrained by intellect than by size, which causes them to cover smaller distances than adults.

The degree of child foraging also varies between populations, with some groups showing no evidence of children foragers such as the !Kung in Africa (Blurton Jones *et al.* 1994). The reason given for this is that the environment of the !Kung would require children to cover long distances to acquire a sufficient amount of food, thereby running the risk of getting lost when unsupervised by adults. Therefore, children would instead help their mothers carry and crack nuts.

Hunter-gatherer children that do forage often tend to consume their food on the spot. In Hadza children, boys typically consume what they collect (plants and small game), and girls return their collected food to camp (Hawkes *et al.* 1995). On Sulawesi, Indonesia, the Butonese people fish with the use of traps while children accompany the adult trap-fishers and learn through observation (Lancy 2015). By eight years of age, the children can trap independently, although learning how to make the traps requires additional observation and learning by trial and error. Nonetheless, these examples come from places where winter is either mild or nonexistent.

Furthermore, children could potentially be searching for food as ‘play’ or out of boredom. Recognizing their contribution to their diet and perhaps even the diet of others is crucial for understanding the role of each individual and the role of children in prehistoric Cis-Baikal. Bird and Bliege Bird (2000) note that despite advances, the analyses of children’s activities and how they could potentially shape archaeological patterns (Hammond and Hammond 1981) are almost absent from the discussion about site formation processes. Furthermore, children aren’t discussed amongst the Cis-Baikal literature as they are underrepresented at many of the Baikal cemeteries. The dietary profiles seen in the permanent molars can hopefully shed some light on this issue and provide room for discussion on children in the Cis-Baikal region.

Diet in early and late childhood

Three cemeteries in the Upper Lena will first be presented in relation to diet in early and late childhood. At Ust’-Ilga, the dentine $\delta^{13}C$ and $\delta^{15}N$ are similar to the adult bone values of four individuals. There are no $\delta^{13}C$ and $\delta^{15}N$ bone values available for the remaining seven individuals as of yet. During early and late childhood, the EN individual from Manzurka appears to have consumed a slightly lower-valued aquatic protein diet (~1‰) than during adulthood. However, the overall diet is considered to be similar as the difference is less than a trophic level. Such isotopic expression has also been observed in some of the region’s EN individuals interred at Shamanka II (Scharlotta *et al.* 2018a). The authors suggest that children had access to the same resources the adults were consuming (post-weaning) and that no agegraded differences were observed. Considering the Lena River is smaller than the Angara River, is not connected to Lake Baikal, and the aquatic resources are less abundant, it would seem only plausible that children would have been given access to the same foods as the adults. Until other EN individuals from the Upper Lena are also sampled, not much can be said for their foraging behaviour during childhood.

At Obkhoi, the δ^{13}C and δ^{15}N values of the dentine micro-samples cluster with the adult bone values, but the latter are on the lower end of the δ^{15}N range. At this cemetery, the individuals also appear to have consumed slightly less aquatic protein during adulthood than childhood, but the difference is still less than one trophic level. These results could mean the Upper Lena children foraged on their own and targeted slightly different foods. Another possibility is that they were given different types of fish by adults. Either of these scenarios is implied by the isotopic data of individual OBK_1971.007 (Figure 13), who exhibits a rise in δ^{15}N of 1.9 to 2.4‰ (Pattern IV) of the M1, directly following the weaning period. This suggests an increase in aquatic protein consumption as soon as the individuals are no longer dependant on breastmilk proteins.

In the Angara micro-region, diet during childhood for most LN Ust'-Ida I individuals only slightly differs from the adult values. The bone δ^{15}N value is on the lower end of the dentine range, suggesting that aquatic protein played a slightly larger role in diet during their developmental years but, overall, the diets are quite similar. Here, distinct dietary changes (increase or decrease in trophic level) appear after childhood, which is discussed further on in this chapter. During the EBA at Ust'-Ida I, there is even less of a difference between childhood and adulthood diet, suggesting children had access to the same foods as adults. However, the inter-individual comparison does show different diets for all four of the EBA individuals, suggesting a difference in the types and quantity of the micro-regional food sources. This variation could lie within subsistence differences between smaller groups. This is also discussed further on.

In the Little Sea, there is even more inter-individual variability than in the Upper Lena and Angara micro-regions. Starting with Shamanskii Mys, the diet of SHM_1975.001 (Figure 60) during childhood has a lower δ^{15}N value than during adulthood. This implies that lower trophic level foods were consumed during the developmental years. For the second individual from Shamanskii Mys, SHM_1972.002 (Figure 62), the diet during adulthood is isotopically similar to childhood, suggesting the individual had access to the same foods the adults were consuming. Apart from a difference in dietary behaviour, SHM_1975.001 is also said to have been born outside of the Little Sea area (Scharlotta and Weber 2014).

At Khuzhir-Nuge XIV, the majority of the individuals exhibit bone stable isotope values that are on the lower end of the δ^{15}N dentine micro-samples, implying aquatic protein played a larger role during development. In three individuals, K14_1999.044 (Figure 86), K14_1999.046 (Figure 90) and K14_1999.057.02 (Figure 94), dietary behaviour shows the opposite, as aquatic protein appears to have played a larger role during adulthood. Both K14_1999.046 and K14_1999.057.02 are listed as non-locals (Weber and Goriunova 2013). For the remainder of individuals interred at Khuzhir-Nuge XIV, bone and dentine values are very similar, suggesting a similar diet during childhood and adulthood.

Foraging

Overall, the majority of the children appear to have been provided with or foraged for foods that were isotopically similar to what adults were consuming. Those that show a meaningful dietary difference (at least one trophic level) between childhood and adulthood are the three individuals that were interred in the Little Sea. However, this dietary difference appears to be a result of a residential move into the Little Sea. Concerning child foraging, Scharlotta *et al.* (2018a) make an interesting point by stating that resources in Cis-Baikal would have been difficult for children to obtain, particularly pertaining to foods that have a significant nutritional value. This is especially true for those living in the Upper Lena micro-region, which is known to lack food resources compared to the other micro-regions (Weber *et al.* 2016).

Scharlotta and colleagues (2018a) go on to say that low-ranked resources (e.g. small reptiles, berries, mushrooms) could have been harvested during the warmer periods of the year, but these are characterized by low $\delta^{13}C$ and $\delta^{15}N$ values (Katzenberg *et al.* 2012; Weber *et al.* 2011) which are not visible in the EN Shamanka II individuals they examined. The same can be said for the LN and EBA individuals in this particular study. Here, a number of the individuals exhibit an increase in $\delta^{15}N$ (Pattern IV) of the M1 either right after the weaning period (e.g. OBK_1971.007, Figure 13) or a bit later on in early childhood (e.g. UIL_1989.003, Figure 21). This rise is visible in the M1 of 18 individuals across five cemeteries (excluding the EN individual from Manzurka). If children were foraging on their own, they appear to have been targeting foods that are characterized by high $\delta^{15}N$ values, not low. These would most likely have been high trophic level fish such as perch, pike and sturgeon (Katzenberg *et al.* 2012; Weber *et al.* 2011). Another high trophic level food source is the Baikal seal, albeit it seems highly unlikely children would have been able to target this mammal. Another possibility are eggs, although it is currently unknown what these values would have been for the avian species in Cis-Baikal.

Furthermore, while Scharlotta and colleagues (2018a) raise an important point by assuming children would most likely only have been able to forage actively in Cis-Baikal during spring and summer, it is doubtful whether these dietary contributions would be visible in the dentine micro-samples unless they contributed a sufficient amount of the necessary nutrients. Since each 1mm micro-sample represents roughly nine to 12 months of developmental life (Beaumont *et al.* 2013a), their foraging period could easily be masked. Also, children would not have been solely dependent on resources they obtained themselves. Dietary staples would have come from foods collected by adults, which would most likely have been higher ranked food sources. Children appeared to have targeted (or been given) higher trophic level foods than the adults as $\delta^{15}N$ bone values are typically lower than the dentine values. This is particularly true in the Angara and the Little Sea micro-regions. A similar pattern to these individuals is seen in hunter-gatherers from a site in Central California (Eerkens *et al.* 2011), in which the authors provide three possible scenarios for a $\delta^{15}N$ increase post-weaning:

1. It is the result of parental investment, where adults feed children protein-rich foods.
2. It is the result of a residential move.
3. It is the result of children foraging on their own and targeting higher trophic level foods.

Examples given for possible foods targeted are fish, small reptiles, and amphibians (Eerkens *et al.* 2011). This, however, contradicts what Scharlotta and colleagues (2018a: 594) stated as these types of foods 'are known or anticipated to have depleted δ^{13}C and δ^{15}N values.' However, the authors do not provide any stable isotope values in support of this suggestion. For the Little Sea individuals, strontium data show whether individuals were born inside or outside of the micro-region. Therefore, it is known that an increase in δ^{15}N, for most individuals interred at Shamanskii Mys or Khuzhir-Nuge XIV, is not a result of a residential move. While children could have been targeting higher trophic level fishes like perch and sturgeon (Katzenberg *et al.* 2012; Weber *et al.* 2011), it does seem unlikely they would have targeted seal as this would involve a different and more advanced skill set. Fish would have been caught in the shallow parts of the lake. Here, fish typically have higher δ^{13}C which I would then expect to see in the isotopic data during childhood. However, this is only observed in K14_1997.019 (Figure 74) and K14_1999.051 (Figure 92). Cis-Baikal children could have been processing foods rather than foraging as observed in the !Kung children (Blurton Jones *et al.* 1994), while only a small amount of foraging occurred in the company of adults. Foods could then have been consumed while processing fish (and seal) and terrestrial meat. When the children reached a certain age, their economic task would probably have switched from processing to engaging in hunting or fishing.

Children could also have been provisioned by adults so more time could have been spent on acquiring certain skills. Becoming an efficient hunter-gatherer takes time as skills such as tracking (i.e. understanding animal behaviour), killing, and processing animals are all part of a long learning process (Gurven *et al.* 2006). Several studies have shown that for hunting, the most successful period for men lies anywhere between 35 and 50 years of age (Blurton Jones and Marlowe 2002; Gurven *et al.* 2006; Walker *et al.* 2002), while for fishing, success can be seen at a much earlier age. Merian children, for instance, learn to spearfish as efficiently as adults by 10 to 14 years of age (Bird and Bliege Bird 2002). Similar behaviour in learning how to hunt and gather could hold for several of the individuals in Cis-Baikal. There, stable isotope data suggest a greater dependency on aquatic resources during the formative years of the permanent molars (~20 years) and possibly a greater dependency on terrestrial resources in adulthood, which is signified by a decline in trophic level. Changes in foraging proficiency could have been predominantly age-related.

Regardless of whether the Cis-Baikal children were foraging on their own or being fed by adults, the micro-sampling data suggest that the foods targeted were specific to the micro-region in which the individual grew up. Children in the Upper Lena show little difference between childhood and adulthood diet, whereas those along the lake appeared to have consumed foods of a higher trophic level. This implies that foraging is tied to resource availability or that groups differed in childrearing practices.

From child to adult

As defined for this particular study, late childhood ends with the development of the M2 and early adulthood starts with the development of the M3. The stable isotope results of these molars highlight an interesting pattern (Pattern IV) in 15 of the 49 individuals. An increase of 1‰ is seen in δ^{15}N toward the root tip of the molar. As mentioned in Part I, this suggests that some were moving to a diet that consisted of higher trophic level foods or consuming more of the same foods. This dietary change likely relates to a change in the individual's productivity. While fishing could easily have been part of their foraging ways, it could now also be part of their socio-economic responsibilities. Furthermore, fishing for one type of fish might differ from fishing for another. Some species could have been easier to catch due to their proximity to the coast or riverbanks, or their abundance provided more opportunity for getting caught. Catching other species might have required the use of a different skill set that is not learnt until later in life.

The rise in $\delta^{15}N$ of 1‰ is seen in 15 individuals across all three micro-regions. For five Ust'-Ida I individuals with a sectioned M2 or M3 (UID_1987.011, Figure 36; UID_1988.014, Figure 38; UID_1989.020.02, Figure 42; UID_1989.029, Figure 54; UID_1991.038, Figure 48), the molars display a rise of 1‰ or more in $\delta^{15}N$. For Shamanskii Mys, one of the two individuals had an M2 sectioned (SHM_1975.001, Figure 60), which also shows a rise in $\delta^{15}N$ toward the end of its development. At Khuzir-Nuge XIV, three out of 15 individuals display Pattern IV: K14_1998.035.02 (Figure 76); K14_1998.038 (Figure 82); K14_1997.057.02 (Figure 94). Out of eight Upper Lena individuals with a sectioned M2 or M3, five individuals exhibit Pattern IV: MNZ_1974.002 (Figure 9), OBK_1971.005 (Figure 11), UIL_1989.001 (Figure 17), UIL_1989.002 (Figures 19 and 20), and UIL_1989.005 (Figures 24 and 25). Interestingly, the cemetery with the largest sample size (Khuzhir-Nuge XIV) represents the lowest number of individuals with this particular pattern. Furthermore, the three individuals interred at Khuzhir-Nuge XIV that exhibit Pattern IV were all born outside of the Little Sea (non-local) (Weber and Goriunova 2013).

Although the sample sizes from the remaining five cemeteries are small, this could indicate a micro-regional difference in age-related dietary changes. For all but one of the individuals from the Upper Lena, $\delta^{15}N$ starts to rise at age 14, moving toward a different diet. The remaining individual (OBK_1971.005, Figure 11) does not display this rise until 19.5 years. However, $\delta^{15}N$ oscillates throughout the molar between peaks and valleys (zigzag), indicating a dietary change every few years, therefore obscuring the pattern. In the Little Sea and Angara region, the ages at which this increase occurs are more variable. At Ust'-Ida I, two individuals display the increase around 14 years (UID_1988.014, Figure 38; UID_1989.020.02, Figure 42), two at 16 years (UID_1987.011, Figure 36; UID_1989.029, Figure 54), and one at 20 years (UID_1991.038, Figure 48). At Shamanskii Mys, SHM_1972.002 (Figure 62) exhibits two rises. One at 11.5 years (M2) and one at 19 years (M3). At Khuzhir-Nuge XIV, one individual shows a rise at seven-and-a-half years (UID_1998.035.02, Figure 76). Albeit, this tooth was not fully developed at the time of death. The remaining two individuals increase in $\delta^{15}N$ at nine years (K14_1999.057.02, Figure 94) and 12.5 years (K14_1998.038, Figure 82). The dietary changes displayed as Pattern IV, which seem to be occurring toward the end of late childhood and the start of early adulthood, could be related to an age-specific dietary change (e.g. change in foraging or hunting) which, in turn, is dependent on their place of residence. Additional insight may lie in the mortuary treatment of the individuals.

Variation in dietary and mortuary practices

Although burial information on most Upper Lena cemeteries is, as of yet, unavailable in English, the cemeteries in the Angara and the Little Sea have been researched more extensively. This produced multiple publications in Russian as well as English. Khuzhir-Nuge

XIV has especially received a great deal of attention, with osteological and archaeological materials having been examined to a very detailed degree. Now that the dietary life histories of a number of individuals interred at this cemetery have been reconstructed, examining their diet in association with their mortuary context can generate new insights. While a comparison between the dietary and archaeological data generated from the cemeteries is currently beyond the scope of this monograph, I briefly summarize some important findings from Khuzhir-Nuge XIV here.

Of the 88 EBA (Glazkovo) individuals interred at Khuzhir-Nuge XIV, five are female and 27 are male, while the sex of the remaining 56 could not be determined (Lieverse 2007; McKenzie *et al.* 2008). Lieverse (2007) further notes that of the 56 individuals who could not be sexed, 18 are children and another seven individuals could not be aged. In addition, no sex determinations for individuals younger than 15 years were made, as sex-specific features do not develop until the onset of puberty (Thomson 1899). As a result, individuals are grouped into broad age categories (adults, adolescents, children, infants), causing individuals to be categorized based on biological definitions rather than social definitions. To complicate matters even further, the demographic profile of the cemetery is difficult to reconstruct as infants (younger than three years) were not interred at Khuzhir-Nuge XIV (Lieverse 2007).

The mortuary data of each individual were recorded and published in two large monographs (Weber *et al.* 2007a, 2008a). The archaeological materials (Weber *et al.* 2008a) provide insight into the features and artifacts of the Khuzhir-Nuge XIV burials. Overall, each individual was interred with a number of artifacts. The type and abundance of artifacts were dependent on age and possibly social status. McKenzie *et al.* (2008) note that adults between the ages of 20 and 35 years were interred with a larger number of artifacts than adults aged 50 years and older. It has been postulated that this is an indication of social roles. Furthermore, the authors mention that the mortuary treatment of adolescents (12–20 years) resembled that of younger children but in turn also resembled the mortuary treatment of adults. In other words, the burial treatment of those categorized as adolescents appears to exhibit a transitionary phase between children and adults. Those aged 15 years or older were interred with implements (e.g. tools) in addition to ornaments (e.g. beads) (McKenzie *et al.* 2008). If the authors are correct in identifying a different pattern in mortuary treatment between children and adults (with the shift occurring around the age of 15 years), then this corroborates the findings in the dietary data. This implies that during early adulthood, individuals were not only transitioning to a different diet, but the change was accompanied by a change in socio-economic status.

Furthermore, many of the individuals typically have slightly lower $\delta^{15}N$ values during adulthood, which could imply terrestrial hunting was an age-related activity. Perhaps fishing and seal hunting were more physically strenuous, therefore causing a change in the procurement of resources once the individual aged. Another possibility is that terrestrial food was more of a luxury food item that was tied to social changes, or the higher trophic level foods were reserved for the developing children and young adults who started to contribute to society. This could explain why individuals aged 50 years and older were interred with a smaller number of artifacts than younger adults.

Considering the intra and inter-individual variability within and between cemeteries, food may not have been shared extensively beyond the immediate kin group. A similar behaviour was suggested for Late Holocene hunter-gatherers interred in Central California (Eerkens *et al.* 2016). There, individuals were within 10 to 15 kilometres from a marsh that provided brackish-water foods as well as terrestrial hunting grounds, but the isotopic data reveal that not all individuals foraged there. A similar pattern is seen within the Cis-Baikal cemeteries. First, the timing of weaning shows substantial heterogeneity between cemeteries within the same micro-region as well as within the cemeteries. Second, the diets during childhood and early adulthood also show substantial variation. While the dentine stable isotope results indicate Cis-Baikal individuals consumed aquatic resources, differences between one another lie in the quantity and species. This is in part a result of their catchment area, but also their access to foods within those catchment areas. The most notable differences in dietary patterns are the EBA individuals at Ust'-Ida I and Khuzhir-Nuge XIV. Here, it could be postulated that groups utilized the same resources, but to varying degrees. In the Upper Lena, differences are small but still show variable diets. Individuals at Ust'-Ilga most likely exploited different foods than those at Obkhoi and Manzurka, as evidenced by a negative relationship between carbon and nitrogen. One of the Ust'-Ilga individuals even has $\delta^{13}C$ and $\delta^{15}N$ values that suggest the consumption of fish from the Little Sea, or perhaps even the Baikal seal. This will be discussed in greater detail later in this chapter.

Finally, dietary changes, big or small, appear to have been quite frequent. Some dietary patterns are marked by cyclical events (e.g. UID_1989.022, Figure 44) while others show substantial variability over the course of several years (e.g. K14_1999.044, Figure 86). Only the occasional individual exhibits little change suggesting dietary stability (e.g. OBK_1971.013, Figure 15).

While changes in diet could very well have been the result of socio-economic and physiological changes such as learning how to hunt or pregnancy, annual climatic fluctuations must also be considered. Resources could have been affected on a more frequent scale, leading to changes in diet depending on access to foods. Afterall, Cis-Baikal is a region with drastic changes in temperature between seasons. Unfortunately, the effect of climatic conditions on foraging behaviour is understudied in Arctic and sub-Arctic hunter-gatherers as the majority of studies are primarily focused on those occupying warmer regions. Thus, while providing beneficial information on foraging behaviour, these studies do not provide an adequate comparison with those inhabiting colder regions. While hunter-gatherers occupying cold climates are said to rely more heavily on stored foods than those living in warmer regions (Kelly 2013), no evidence for storage has been found in Cis-Baikal thus far. Yet, it is possible that stored food did not leave an archaeological trace. The drying, fermenting, or freezing of foods does not necessarily require the construction of containers of some kind. These activities could have been carried out without leaving an archaeological trace.

An ethnographic study on the Lake Yessei Yakuts (Argounova-Low 2009), a small ethnic group living around Lake Yessei in Siberia, examined the subsistence and diet of this particular population. The Lake Yessei Yakuts were considered to be nomadic and semi-nomadic before settling into village life in the late 1920s. While hunting and fishing were important modes of subsistence, the former was preferred, particularly wild reindeer. Fishing, which included preparing the fish for storage, was said to have been busiest in summer and autumn. However, fishing would still be done in winter. Preserving the fish was done by drying or smoking.

Dried or smoked fish was considered a popular snack that would even be used for exchanging foods or goods with people who lived beyond Yessei. Fish that were caught in winter could easily be frozen and kept. A similar scenario could have been possible for the Cis-Baikal hunter-gatherers. Certain foods could then have been consumed year-round, which could have been the case for the individuals that exhibit dietary stability for a number of years (e.g. OBK_1971.013, Figure 15; UID_1991.038, Figure 48; UID_1989.019, Figure 52). Nevertheless, this was not the case for all interred in Cis-Baikal as some exhibit frequent dietary changes throughout life, including annual or bi-annual changes in diet.

Furthermore, a commonly used fallback food for the Yessei Yakuts in the past was the inner bark of pine and larch trees (Argounova-Low 2009). Evidence for consuming this food has also been seen in the historical Sami people of Scandinavia, just north of the Arctic Circle (Bergman *et al.* 2004). While such foods have yet to be analyzed for Cis-Baikal, bark was used in the burial treatment of a number of Khuzhir-Nuge XIV individuals (Weber *et al.* 2008b) and could also have been a source of food.

Hunter-gatherer migration

Micro-regional scale

The stable carbon and nitrogen isotope analysis of dentine, at times in conjunction with the strontium data, provides new insight into the travel of hunter-gatherers across the Cis-Baikal landscape. Migration can be tied to a change in residence (long-term), seasonal rounds related to hunting (short-term) or venturing into other areas for social reasons. Starting in the Upper Lena micro-region (the area from which several individuals interred at Khuzhir-Nuge XIV came) the dentine isotope data show that for two of the Ust'-Ilga individuals (UIL_1990.009 and UIL_1990.011), the δ^{15}N is at times closer to what is typically seen in individuals living in the EBA Angara and Little Sea micro-regions (Katzenberg *et al.* 2010; Weber *et al.* 2011). The mirroring of δ^{13}C and δ^{15}N (five shifts over ~14 years) in UIL_1990.009 could indicate travel between the Upper Lena and Little Sea (or Angara) every few years. Another possible analysis of this individual's isotopic values is that foods from other foraging ranges were being consumed. This would either have involved the transportation of food by hunting parties that ventured into neighbouring micro-regions or through an exchange. For this, the Little Sea is a good possibility considering its particularly wide range in δ^{13}C (−30.5 ± 2.2‰ to −10.9 ± 2.4‰) of aquatic foods as well as the high δ^{15}N values of some of these foods. Contact with this micro-region seems most plausible for several reasons: it is in closer proximity to the area in which the individuals were interred (assuming they lived close to where they were buried), aquatic food sources are more abundant in Lake Baikal than in the Lena River, and previous studies have confirmed the migration of individuals from the Upper Lena to the Little Sea (Weber and Goriunova 2013). Individual UIL_1990.011 (Figure 30) reaches a δ^{15}N value of 14.1‰ (at around six-and-a-half years), also suggesting the consumption of higher trophic level fish. If this individual did in fact move closer to the lake during his or her lifetime, this also provides evidence for moving back to the Upper Lena later in life. Micro-sampling the M2 or M3 of this individual could provide additional insight into migration. Ultimately, strontium isotope analysis might provide the best understanding of this individual's travel.

A change in home range could be the result of environmental pressures on a micro-regional scale or the depletion of resources by a group. It could also be the result of relocating for a marital purpose (matrilocal/patrilocal) as well as a response to irregular sex ratios within a group. Regardless of their reason for a change in residence, diet did not always change as a result. For this, two possible reasons are suggested. First, it is possible that individuals only exploited the resources they were most familiar with in their previous environment. Learning a new skill and/or how to hunt a different kind of animal, in a new environment, would most likely result in minimizing benefits. This reason could have caused them to not target higher trophic level foods such as the seal and possibly continue to incorporate terrestrial foods into their diet to a higher degree than 'locals.' Along these lines, some individuals from the Upper Lena might have been applying their skillset (e.g. terrestrial mammal hunting) in the Little Sea when living amongst new groups. Therefore, diets could have been related to seasonal movement. Second, it is possible that foods were not widely shared between 'locals' and 'non-locals.' Evidence for a certain degree of separation may lie in the mortuary data as the area of a person's origin (birth locale) is tied to the place of internment within the Khuzhir-Nuge XIV cemetery (McKenzie 2006; Weber and Goriunova 2013). However, this does not explain why a number of non-locals did change their diet to the consumption of higher trophic level fish and possibly seal while others did not. Perhaps the blending of kin groups caused some individuals to switch diet, but this cannot be confirmed.

Of the eight Khuzhir-Nuge XIV individuals that are listed as non-locals (Weber and Goriunova 2013), only two exhibit a change in diet that could be tied to a move into the Little Sea micro-region (K14_1998.035.02 and K14_1998.036.01). In K14_1998.035.02 (Figure 76) and K14_1998.036.01 (Figure 78), an increase in $\delta^{15}N$ toward 12.8‰ and 14.0‰ is seen at the start of seven-and-a-half and seven years, respectively. However, both individuals were assigned a GF diet based on stable isotope bone values (Weber and Goriunova 2013). Individuals K14_1997.019 (Figure 74), K14_1998.038 (Figure 82), and K14_1999.051 (Figure 92) exhibit a GFS diet since infancy despite being born 'outside of the Little Sea.' Individual K14_1999.057.02 (Figure 94) also shows a GFS diet type, but this is in the M2. Potentially, the individual moved into the region shortly after birth, resulting in a GFS diet from early childhood. For the remaining two individuals, K14_1999.046 (Figure 90) would have switched to a Little Sea (GFS) diet after the formation of the M2 as this molar only exhibits a typical GF (Upper Lena) diet. Individual K14_1998.037.02 (Figure 80) showed high $\delta^{15}N$ values (up to 16.8‰ in the M1), but that is likely related to factors other than diet as discussed earlier in this chapter.

Diet types

It should be noted that the above-mentioned diets highlight a possible issue with the application of terms such as GFS and GF diet. It implies that individuals can be placed into one of two categories (a game-fish-seal diet or mainly a game-fish diet) when the degree of seal consumption more likely operated on a spectrum. The use of these arbitrary definitions raises a valid concern as a GFS isotopic signature is potentially possible to obtain without the consumption of seal. While seal consumption seems likely considering the amount of uncovered seal remains, its dietary value, and the ethnographic work that shows the economic importance of the seal, we cannot assume that every individual with relatively high $\delta^{15}N$ (13.5‰ or higher) was, in fact, consuming this aquatic mammal. Especially when some fishes (e.g. pike and perch) in Lake Baikal can be found within the same trophic level as the seal and produce equally high nitrogen levels (Weber and Goriunova 2013), even though the seal is the one aquatic food in Lake Baikal that consistently produces δ^{15}N values around 13–15‰ (Katzenberg and Weber 1999; Katzenberg *et al.* 2009, 2010, 2012; Weber *et al.* 2002, 2011).

Although individual K14_1999.057.02 (Figure 94) was interred in the Little Sea micro-region, this individual is said to have been born outside of this micro-region (Weber and Goriunova 2013). However, the dietary data of the M2 imply residence in the Little Sea from two to 15 years if we were to base this assessment on the high δ^{15}N values and, in turn, the assumed GFS diet type. It is possible that the individual relocated to the Little Sea during infancy, causing the data to exhibit a GFS diet since approximately two years of age. Another possibility is the child always consumed a diet high in aquatic protein (including seal). For this, any part of the Baikal coast would be the most likely option as a place of birth before relocating to the Little Sea micro-region at some point. A third possibility is that the infant consumed high trophic level fish producing a high δ^{15}N value that is assumed to represent a GFS diet. Since the individual was interred in the Little Sea micro-region the individual likely consumed seal from a young age. However, assumptions on GF vs GFS diet cannot be made based on the isotopic results alone as there are food items which can cause a similar isotopic signature to GFS even when seal is not consumed.

If we are to assume that high (13.5‰ or higher) δ^{15}N are indicative of seal consumption, than individual UIL_1990.009 (Figure 26), for instance, would have spent time in the Little Sea (with a GFS diet) before moving back to the Upper Lena before death. In addition, all individuals interred in Ust'-Ida I in the Angara micro-region exhibit δ^{15}N values higher than 13.5‰ during childhood and early adulthood with the bone values of some individuals showing a nitrogen value of 13.5‰ or higher up until death. This would suggest that these individuals spent most of their life on a GFS diet (some right until death) yet they were interred at Ust'-Ida I (~200km away from Lake Baikal). There are three major possibilities: the individuals consumed a GFS diet while living near the shore of Lake Baikal before moving to the Angara micro-region close to death (there is currently no evidence of movement in this direction), the individuals traded for seal meat, or there were other high trophic level foods in the environment (possibly piscivore fish).

Another individual, K14_1998.037.02 (Figure 80), who is said to have been born outside the Little Sea micro-region (Weber and Goriunova 2013), showed strontium values (in the M1) suggesting the individual is from the Angara (Haverkort *et al.* 2008). However, the stable isotopic δ^{15}N values during breastfeeding and weaning (M1) are high, even when a 3‰ nursing effect is subtracted. The maternal diet would have been around δ^{15}N 14‰, which is normally seen in Little Sea individuals and would be indicative of a GFS diet according to Weber and Goriunova (2013). It is possible the mother consumed a high protein diet during pregnancy and breastfeeding. However, this then raises the question as to whether she was consuming aquatic foods from Lake Baikal, including seal. If so, the mother and infant either would have been living in the Little Sea or seal consumption would have somehow been made possible while residing in the Angara, perhaps through food sharing and/or exchange. Another possibility is that the mother was suffering from nutritional stress during pregnancy, resulting in higher δ^{15}N values for her and the infant. Then, around eight-and-a-half years, the δ^{13}C and δ^{15}N of K14_1998.037.02 (Figure 80) are considered typical for an Upper Lena diet. Yet, the femoral strontium data are said to exhibit values of the Upper Angara (Haverkort *et al.* 2008).

However, these values could also be considered indicative of the Upper Lena (Huh *et al.* 1994) due to isotopic overlap, suggesting frequent movement for this individual. The diet during the last few years of K14_1998.037.02's life is said to have been GF (Weber and Goriunova 2013). Based on the femoral strontium values, this could have been the preferred diet while living in the Angara. Moving into the Little Sea did not cause the individual to change diet, or at least not fast enough to make it visible in $\delta^{13}C$ and $\delta^{15}N$.

Dietary independence

Two individuals from Ust'-Ida I, UID_1989.022 (Figure 44) and UID_1989.029 (Figure 54), display $\delta^{13}C$ and $\delta^{15}N$ values that clearly suggest travel between micro-regions. The oscillation of carbon and nitrogen (Pattern V) occurs throughout a molar over several years. As one individual is assigned to the LN (4543±71 cal BP) and the other to the EBA (3822±71 cal BP), they were not living contemporaneously. The similarity in diet (as well as travel) might indicate that these two individuals interred at Ust'-Ida I followed a very similar, almost identical, mode of subsistence. Thus far, no other individuals at Ust'-Ida I, or elsewhere in Cis-Baikal, display this unique dietary pattern. This could indicate that food sharing did not extend beyond the kin group. Additional micro-sampling and aDNA studies on Cis-Baikal individuals can help explore this notion even further.

Furthermore, at the Ust'-Ida I cemetery, all four EBA individuals exhibit a different diet (Chapter 7), and the same is seen between the two individuals at Shamanskii Mys (Figure 109). A similar observation regarding dietary differences was made in South African hunter-gatherers that occupied and exploited the Greater Cape Floristic Region in the Later Stone Age (Pfeiffer and Harrington 2019). One group is characterized by having consumed higher trophic marine protein than neighbouring groups just 14 kilometres away. The same could have been the case for various Cis-Baikal groups occupying the same micro-region and buried within the same cemetery. Sealy (2006) argued that dietary difference, in which protein consumption differed significantly, is representative of territories while Kelly (2013) mentions that hunter-gatherers share land to varying degrees.

In the Fort Irwin area of the Mojave Desert, ethnographic and archaeological evidence suggests various hunter-gatherer groups, all coming from different directions, jointly managed and made use of the land (Eerkens 1999). In Evenki groups, living in Central Siberia, land ownership was absent, yet there was an understanding of territories that were considered their own and those that were viewed as alien (Turov 2010). As a result, annual migrations and hunting routes occurred within the community's boundaries. In Cis-Baikal, travel happened between micro-regions as strontium data have shown (Haverkort *et al.* 2008, 2010; Scharlotta and Weber 2014), indicating that a frequent relocation was an integral part of their foraging lifeway. The new data presented here also hint at the sharing and moving of resources across micro-regions.

Sharing foods and material goods are considered an integral part of the hunter-gatherer economy, with some referring to this as 'generalized reciprocity' (Sahlins 1972), where favour or repayment is not expected. It is an altruistic motive to ensure exchange, enhance the status and foster relationships between groups through the sharing of food and material goods. Kelly (2013: 138) states that sharing 'varies along a continuum' in foraging societies as the right to food and land ownership differs between groups. In some groups, sharing is an essential part of the hunter-gatherer lifeway, whereas in others, sharing rarely occurs. Nonetheless, the sharing of foods and goods is not always entirely altruistic. Providing food for the welfare of another may, in turn, be beneficial for the gift-giver in the near future (Hawkes *et al.* 2001). It can help reduce the risk of food shortage during a poor hunt or when resources start to become scarce. Furthermore, sharing is at times a necessity in any society, such as ensuring the survival of infants and young children as they are not yet capable of sustaining themselves. Sharing can also extend beyond the family unit as well as the community, albeit this is usually considered exchange or trade, where one product is traded for another.

Exchange and food sharing in Cis-Baikal

Shepard (2012) studied changes in political strategies among the Middle Holocene Cis-Baikal hunter-gatherers by examining burial treatments. His findings imply a connection between funerary treatment and political life through the display of grave goods. This is partially based after Hayden (2009), who suggested funerals could offer a view of changing political economies, causing agents to engage in the transformation of social structures. Shepard (2012) examined the archaeological data of LN and EBA burials within the Little Sea area by paying attention to burial treatment between the individuals and cemeteries, as well as the difference in grave goods. He concluded that during the start of the EBA, there was a greater focus on what he refers to as 'individualistic funeral aesthetic,' where more emphasis was placed on the wealth and status of the individual interred.

Shepard (2012) also notes that grave goods made from white nephrite appear in graves during the EBA. This material's source is located in the Vitim River Basin, east of Lake Baikal. To acquire the nephrite, either long-distance travel or exchange with groups closer to the source would have been necessary. Shepard (2012) suggested the EBA groups might have been involved in a supra-regional exchange with those from the Vitim River Basin. This also raises an interesting possibility concerning trade with groups in the East (or Trans-Baikal), possibly in winter when the Lake is entirely frozen. If this were the case, then goods such as food could have been exchanged as well. Dried or smoked fish would have been a possibility, as was seen among the Lake Yessei Yakuts (Argounova-Low 2009). The hunter-gatherer groups within Cis-Baikal who were closest to the Vitim River Basin, would have been those living in the Upper Lena micro-region. Although little research has been done in this part of Baikal, it would be interesting to further examine possible contact and exchange (goods, food, partnerships) between the two regions. Furthermore, Shephard (2012) points out that we do not yet fully understand the social distinction between the individuals buried at EBA cemeteries, only that grave goods played a role in these distinctions. Future aDNA analysis of the individuals might help shed some light on this issue, providing not only a better understanding of the sex ratios at cemeteries but also differences in male and female interments. Such analysis will also shed light on dietary differences and/or similarities between the sexes.

Finally, the stable isotope data from the dentine micro-samples display dietary variation (beyond the measurement errors) between individuals, suggesting a certain level of dietary independence. This is seen in the results presented in Chapters 6–8. Although it is currently not yet possible to say with certainty to what level of analysis dietary independence applies (e.g. individual, family, community), it appears to have operated at the level of the individual.

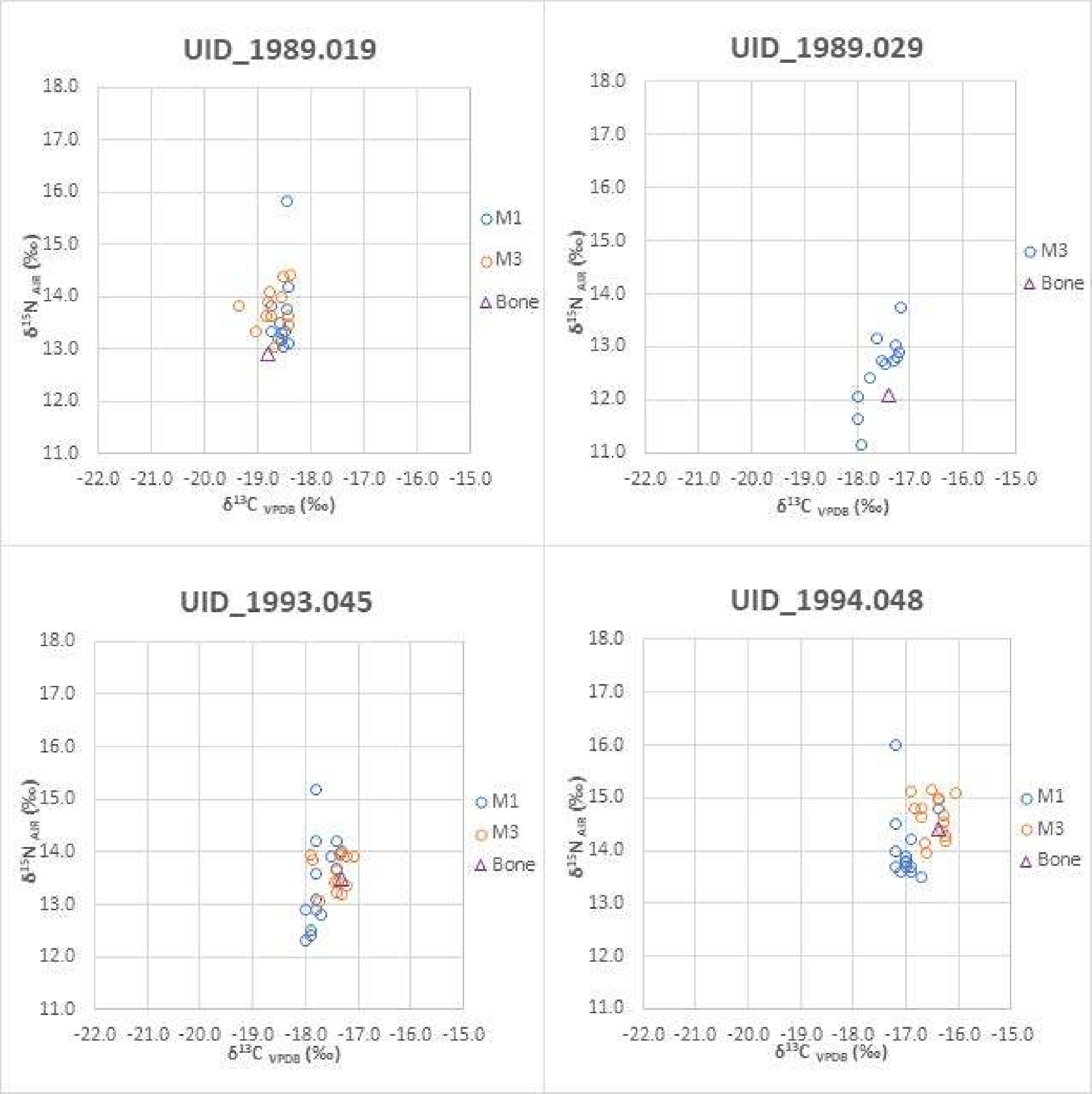


Figure 111. Stable isotope results for the EBA Ust'-Ida I individuals: UID_1989.019; UID_1989.029; UID_1993.045; UID_1994.048.

For example, dietary variation is seen between various micro-regional groups (e.g. Little Sea vs. Upper Lena), within the cemeteries (e.g. two EBA individuals from Shamanskii Mys, Figure 110; the EBA individuals from Ust'-Ida I, Figure 111), and between individuals that are interred together (e.g. LN individuals UID_1989.020.01 and UID_1989.020.02, Figure 109).

At Khuzhir-Nuge XIV dietary variation is also apparent (Figure 112). This has previously been observed in the stable isotope values of bone collagen (Weber and Goriunova 2013). The variation is also a result of individuals having migrated from other micro-regions and maintaining a diet that likely did not include seal, or very little.

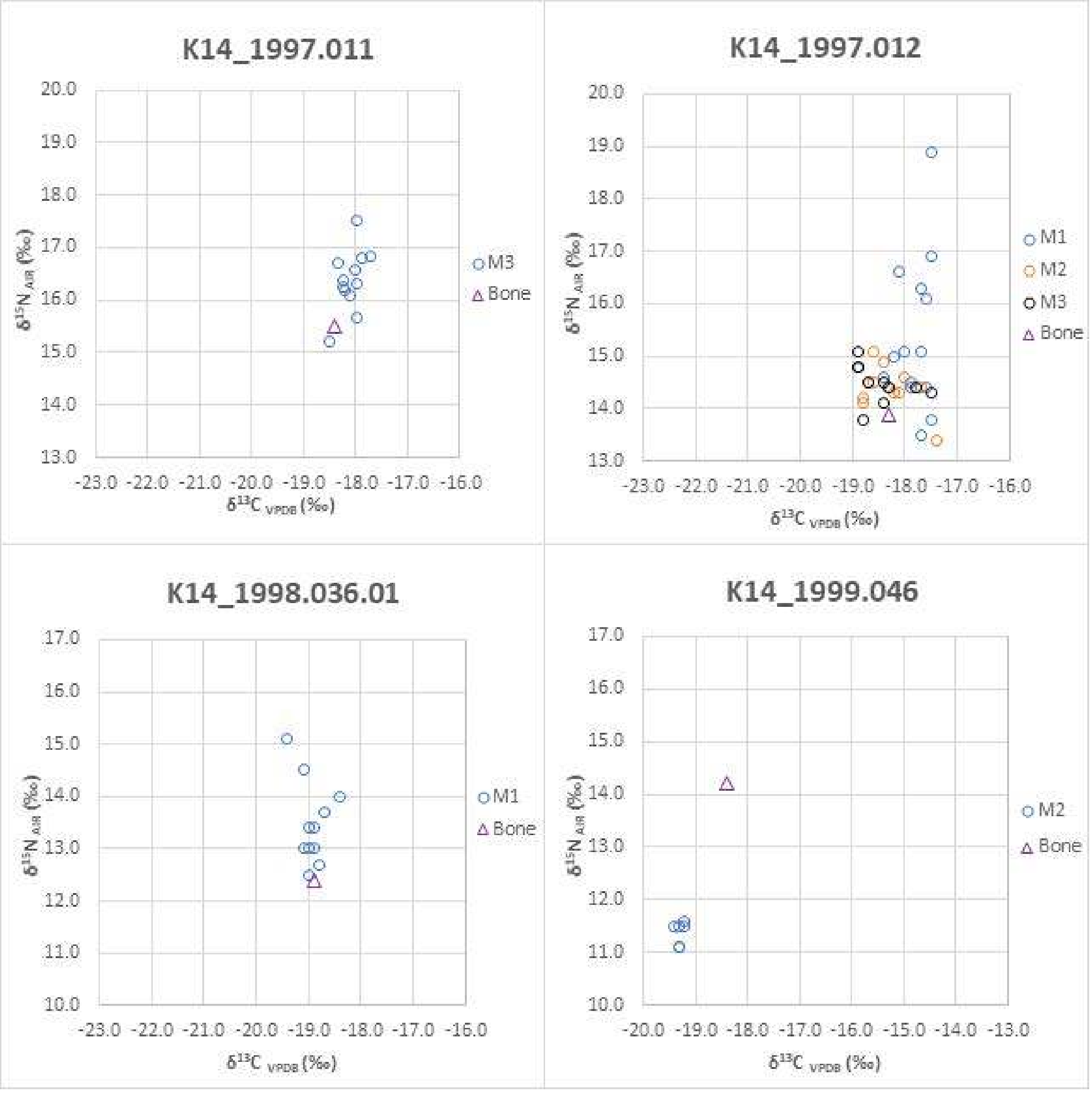


Figure 112. Stable isotope results for the EBA Khuzhir-Nuge XIV individuals: K14_1997.011; K14_1997.012; K14_1998.036.01; K14_1999.046.

Those that come closest to being similar in terms of dietary behaviour are the two individuals from Ust'-Ida I (UID_1989.022 and UID_1989.029). Both individuals display a positive zigzag relationship (Pattern V) between $\delta^{13}C$ and $\delta^{15}N$ (Figures 44 and 54). As LN and EBA individuals exhibit similar isotopic values, the dietary differences appear to lie mainly between the micro-regions and not necessarily between periods.

Summary

This discussion chapter was divided into two parts. The first part provided an explanation of the limitations of dentine micro-sampling. While the method is a powerful tool for examining the infant and childhood diet of individuals that lived into adulthood, there are a number of factors that can affect our analysis of the stable isotope results. It is important these are discussed in this study, and elsewhere, to improve our understanding of dietary analysis when applying this technique. Issues pertaining to poor multi-molar alignment, the meaning of isotopic shifts throughout a single tooth, isotopic noise (e.g. diagenesis), as well as physiological factors have all been discussed. However, despite its shortcomings, micro-sampling allows for dietary reconstruction at a much higher temporal resolution than bone. The final section of Part I discussed the general analysis of the five main dietary patterns as well as migration patterns.

Results showed that diets vary between and within the cemeteries. Individuals that were buried along the coast of Lake Baikal generally have higher $\delta^{13}C$ and $\delta^{15}N$ than those interred further away from the lake. During infancy and early childhood, the age at which individuals completed the consumption of breastmilk shows substantial variability, ranging between two and six years. In childhood and early adulthood, the diet consisted of higher trophic level protein for the majority of individuals. Only in the Angara are diets isotopically similar throughout life. The data also occasionally highlight movement between micro-regions, lending further credence to previous BAP studies stating that the Cis-Baikal hunter-gatherers moved into surrounding regions as well as leading to changes in diet catchments.

The second part of this chapter focused on the interpretation of the results presented in Chapters 6, 7, and 8 and how they provide additional information and understanding of prehistoric hunter-gatherers. Past (dietary) lifeways are discussed further by reviewing anthropological literature. Migration, economic, funerary treatment, and political organization are analyzed. More importantly, this research adds new information on the lives of Cis-Baikal children. Until now, infants and children were rarely discussed amongst the Cis-Baikal literature as they are underrepresented at many of the Baikal cemeteries. Micro-sampling of dentine has allowed for the examination of, and discussion on, the lives of the region's younger individuals.

Chapter 10

Conclusions

During the past three decades, the Baikal Archaeology Project (BAP) has done much work in the Cis-Baikal region of Siberia, Russia (e.g. Bazaliiskii 2010; Haverkort *et al.* 2008; Katzenberg *et al.* 2009, 2010, 2012; Lieverse 2007, 2010; Losey *et al.* 2012, 2016; McKenzie 2006; Mooder *et al.* 2006, 2010; Moussa *et al.* 2018; Scharlotta *et al.* 2018a, 2018b; Scharlotta and Weber 2014; Shepard 2012; Tarasov *et al.* 2007, 2017; Waters-Rist *et al.* 2011; Weber 1995; Weber and Bettinger 2010; Weber and Goriunova 2013; Weber *et al.* 2002, 2011, 2016; White and Bush 2010). The project aims to understand the variation, cultural changes, and adaptability of the region's Middle Holocene hunter-gatherers (*c. 8200–3700* cal BP). The majority of the work relies on the examination of skeletal remains from Baikal's extensive mortuary record. Through the reconstruction of individual hunter-gatherer life histories (age, health, sex, diet, migration), the project seeks to better understand the processes of cultural change as well as past people's relationship with the environment. The research presented in this monograph provides new insights into the life history of some of these hunter-gatherers at a much finer temporal scale. This work presents the stable carbon and nitrogen isotopic profiles for 49 individuals dating back to the Early Neolithic (*c. 7500–7000* cal BP), Late Neolithic (*c. 5500–4500* cal BP), and Early Bronze Age (*c. 4500–3700* cal BP). For this, a total of 80 permanent molars were used, which produced 930 dentine micro-samples for stable isotope analysis. This study addressed two main research goals: understanding the dietary and the migratory patterns of mid-Holocene hunter-gatherers from Cis-Baikal. These two goals were subdivided into the three following research questions:

1. How did infant feeding practices look during the Late Neolithic and Early Bronze Age?
2. Was childhood diet similar to adult diet in Late Neolithic and Early Bronze Age hunter-gatherers?
3. What inferences can be made on migration based on dietary reconstruction alone?

The work presented here is of importance to the study of prehistoric hunter-gatherers, specifically those occupying territories within the subarctic region, for a number of reasons. First, most micro-sampling studies have focused on dietary change within agrarian populations. This work, together with the micro-sampling study on Early Neolithic individuals (Scharlotta *et al.* 2018a, 2018b), are currently the only studies to have been conducted on hunter-gatherers from the Baikal region and two of the few micro-sampling studies conducted on prehistoric people, as the body of literature which utilizes the micro-sampling technique grows. Second, this research has expanded the resolution of the Cis-Baikal hunter-gatherer lifeways, highlighting unique dietary and migratory patterns that could previously not be observed. The work presented here helps us to better understand the choices made and changes experienced by the Cis-Baikal hunter-gatherers, which ultimately contributes to our overall understanding of past human life and hunter-gatherer societies. This chapter is divided into four sections focusing on diet, migration, future directions, and final remarks.

Early life dietary patterns in Cis-Baikal

The results presented in this monograph show that dentine micro-sampling allows for the examination of short-term (nine to 12 months) dietary events that occurred during the first ~20 years of life amongst the region's hunter-gatherers. This new study not only extends the life-history of these prehistoric people, but as a result of expanding the resolution, also highlights unique dietary patterns that could not be seen in bone collagen. The 930 micro-samples add very promising results as they allow, for the first time, insight into weaning behaviour, maternal investment, and childhood diet in Cis-Baikal individuals that survived into adulthood.

Furthermore, the method has proved to be successful in that it yields a sufficient amount of collagen for stable isotope analysis from the Cis-Baikal materials, opening up new avenues for future studies. Despite the need for methodological improvements to fine-tune the temporal resolution, the intra-individual analysis provides new insight into the lives of these prehistoric peoples, allowing for a better understanding of prehistoric hunter-gatherers occupying circumpolar regions.

First, the dentine micro-sample data corroborate previous carbon and nitrogen stable isotope studies (Katzenberg and Weber 1999; Katzenberg *et al.* 2009, 2010, 2012; Weber and Bettinger 2010, Weber and Goriunova 2013; Weber *et al.* 2002, 2011) by confirming that the diets of Cis-Baikal hunter-gatherers consisted of aquatic foods. Second, it identifies dietary changes over time, some as short as nine months. The diets studied amongst the individuals were similar in the sense that regional and, particularly, micro-regional resources were targeted. This showcases that while people may have had the same subsistence strategy, it resulted in dietary differences. Through the micro-sampling research, we now also see that these differences lie mainly within micro-regional dietary variation, which is greater than the temporal variation. Third, it highlights the migration of individuals between micro-regions, sometimes occurring every few years, which is of paramount importance as data from bone collagen was limited. These results add to the discussion on hunter-gatherer movement, subsistence patterns, and individual as well as population behaviour.

Overall, the highest dentine $\delta^{15}N$ values are found in individuals from the cemeteries in the Little Sea micro-region (Khuzhir-Nuge XIV and Shamanskii Mys), and the lowest are found in individuals from the Upper Lena micro-region (Obkhoi, Ust'-Ilga, Manzurka), which further corroborates the previous findings of isotopic studies on bulk bone collagen. This is a result of the animal protein available in the micro-regions. It is possible that individuals in the Upper Lena had a higher dependency on terrestrial animals and plants (lower $\delta^{15}N$). The $\delta^{15}N$ stable isotope data of the Ust'-Ida I individuals in the Angara micro-region fall in between the values of the Little Sea and the Upper Lena. While the $\delta^{15}N$ results indicate consumption of riverine fish during childhood and early adulthood, a few individuals exhibit values that suggest the consumption of fish of a higher trophic level, and possibly even the consumption of Baikal seal. The latter would have involved foraging or exchanging resources with the Little Sea micro-region. Although differences are quite small, the lowest $\delta^{13}C$ values are seen amongst the individuals interred in the Upper Lena micro-region and the highest in the Angara micro-region.

Particularly interesting are the five general dentine isotope patterns that are prevalent in the molars of the examined individuals. Each individual exhibits at least one or more of the following patterns:

- Pattern I: Decline in $\delta^{15}N$ during infancy (weaning signature).
- Pattern II: Positive relationship between $\delta^{13}C$ and $\delta^{15}N$.
- Pattern III: Negative relationship between $\delta^{13}C$ and $\delta^{15}N$.
- Pattern IV: Rise in $\delta^{15}N$ toward the end of molar development.
- Pattern V: Continuous oscillation of both $\delta^{13}C$ and $\delta^{15}N$ values (zigzag).

The five general dentine isotope patterns provide important insight into human behaviour and subsistence in Cis-Baikal hunter-gatherers. Dietary variation is seen between as well as within the cemetery populations. This suggests that while subsistence strategies were similar, dietary independence appears to have existed among various hunter-gatherer groups. The new micro-sampling results create room for discussion on whether individuals acted on their own or on behalf of a group, and how these decisions ultimately affected foraging lifeways.

Starting with infancy and Pattern I, it is now possible to examine breastfeeding and weaning of individuals that survived into adulthood. This is one of the many benefits of micro-sampling dentine as it allows for the reconstruction of early life diet in individuals that did not succumb to disease or trauma. As a result, this method is not restricted by the age distributions at which children died.

The new results show that there was variation in the weaning process: spatially and temporally. Stable carbon and nitrogen isotope analysis on the first molars of 34 individuals shows that all but one was weaned from breastmilk onto solid foods and that 50% were fully weaned around the same time, between four and four-and-a-half years. The $\delta^{15}N$ values primarily indicate the duration and cessation of weaning while $\delta^{13}C$ provides some insight into the supplementary foods given. The majority of the individuals exhibit little to no change in $\delta^{13}C$ during breastfeeding and weaning, which could represent that infant feeding practices involved the dietary contribution of foods that were higher in $\delta^{13}C$ relative to breastmilk and therefore masked a trophic shift. Despite differences in the duration of weaning, it appears that most caretakers preferred to provide infants with weaning foods that were relatively high in $\delta^{13}C$ compared to the mother's milk, leading to a stagnation of the values in tooth micro-samples. In some cases, for this to happen, fishes such as perch and pike could have been a preferred weaning food. They are slightly less negative in $\delta^{13}C$ compared to fatty fishes such as lenok or grayling. In other instances, such as in the Upper Lena micro-region where fish have low $\delta^{13}C$ values, (premasticated) terrestrial resources could have been the preferred weaning food. While it remains unknown what those foods were, the results imply a difference in weaning behaviour between different EBA groups.

The remaining four general dentine patterns further display high levels of variation in dietary protein between and within individuals during the post-weaning stage and into late childhood/early adulthood.

A positive relationship between $\delta^{13}C$ and $\delta^{15}N$ suggest diets typically consisted of aquatic protein with a fairly small amount of terrestrial protein. On the other hand, what a negative relationship signifies remains less certain. However, this might not be related to nutritional stress, as has been stated in other micro-sampling studies, but rather the result of a diet with more terrestrial protein. Another possibility is the addition of seal to the diet, which is known to be high in $\delta^{15}N$ and low in $\delta^{13}C$, which could also be responsible for the negative relationship. If this is true, then the aquatic mammal was important to individuals not just in the Little Sea, but also living outside of it. This means contact between micro-regions would have been more prevalent than previously thought. Prior to this micro-sampling research, seal consumption by individuals outside of the Little Sea had not been suggested by the stable isotope data (Katzenberg *et al.* 2010; Lam 1994; Weber and Goriunova 2013; Weber *et al.* 2002, 2011), as long-term averages from bone samples mask such variation. These findings are important as they can help understand Cis-Baikal hunter-gatherer adaptive strategies.

Considering the high variation in diets of the Cis-Baikal individuals, it is clear that different foods were targeted as opposed to focussing on one main resource. A similar pattern was observed in the Early Neolithic hunter-gatherers from Shamanka II in Southwest Baikal (Scharlotta *et al.* 2018b). This represents a similar subsistence strategy throughout the Baikal region in the sense that hunter-gatherers were targeting fish, terrestrial animals, and seal.

The inter-individual dietary differences might suggest that Cis-Baikal hunter-gatherer groups were independent from one another in terms of diet. The sharing and exchange of food would likely have occurred to a certain degree, while (kin) groups maintained their own diet. At Ust'-Ilga for instance, the diets display a different pattern than individuals from Obkhoi and Manzurka. There are also differences in protein intake between individuals interred at the same cemetery. At Ust'-Ida I, the Early Bronze Age individuals exhibit four different patterns despite subsisting on the same micro-regional resources. In the Little Sea, patterns are even more variable, which is also due to the larger sample size and the inclusion of individuals born in neighbouring micro-regions. Lastly, the data suggest that some individuals were more mobile between various micro-regions than previously thought. Frequent movement and the dependency on foods from different aquatic environments resulted in dietary shifts on an annual or bi-annual basis.

Migration patterns in Cis-Baikal

While it is possible to make inferences regarding the birth locale and the home range of an individual at different stages of life based on $\delta^{13}C$ and $\delta^{15}N$ in dentine micro-samples, this is only possible if clear micro-regional stable isotopic baselines have been established. Fortunately, this is the case for several areas within the Cis-Baikal region. Therefore, carbon and nitrogen aid in the examination of hunter-gatherer migration in conjunction with strontium isotope analysis. In addition, carbon and nitrogen values can also be particularly useful in a region such as Cis-Baikal where the spatial distribution of the biologically available strontium isotope ratios has not yet been fully mapped. Based on the currently available strontium data, Cis-Baikal can be divided into three major geological zones, which are known to have similar bedrock, causing considerable overlap in Sr isotope ratios (Haverkort *et al.* 2008). Naturally, this complicates the ability to assess travel in hunter-gatherers. Furthermore, the behaviour of the individual being examined also plays a large role in identifying a place of residence at a certain point in time. High levels of travel between two isotopic landscapes can potentially cause attenuation in $\delta^{13}C$ and $\delta^{15}N$ as well as $^{87}Sr/^{86}Sr$. Nonetheless, combining the current biochemical data with previously examined biochemical data (Haverkort *et al.* 2008, 2010; Scharlotta and Weber 2014), lends credence to the movement of certain individuals. Two individuals from Ust'-Ida I show substantial evidence for a change in the home range between micro-regions. Future strontium isotope analysis of these individuals would help confirm these claims. Past research shows that the two individuals were not contemporaneous and that there is a difference in sex as well as age. Nonetheless, the dentine pattern is almost identical, suggesting a similar subsistence strategy. This could lend further credence to the idea that migration and diet differed between small groups and remain unchanged over time.

Two individuals from the Ust'-Ilga cemetery exhibit stable isotope values that are normally seen in individuals around the Little Sea area. These dietary changes, which imply movement between various micro-regions, were not noticeable prior to the micro-sampling method. This information can also help target which Baikal individuals, out of hundreds, need to be analyzed for strontium.

For the individuals that were interred at Khuzhir-Nuge XIV and listed as 'non-locals' (n=8), two showed a dietary change to a GFS diet type which could be related to moving into the Little Sea micro-region. None of the individuals exhibited a solely GF diet throughout their life, and most individuals showed a GFS diet since birth despite their birth locale being outside of the Little Sea. This raises a concern with the application of terms such as GF and GFS diets. It also suggests that high trophic level fish, and possibly even seal, were being consumed by individuals inhabiting all three micro-regions at least on a short-term basis which would explain why such an isotopic signal is not visible in their bone measurements. This implies either that hunting parties ventured into neighbouring regions and/or exchanged goods such as seal and fish, either dried, smoked, or fermented.

Future directions

This research is the first of its kind on Late Neolithic and Early Bronze Age individuals from Cis-Baikal. The dentine micro-sampling method has proven to be applicable and effective for investigating childhood diet in these Siberian hunter-gatherers. Most micro-sample studies on prehistoric individuals have focused on much smaller sample sizes (e.g. Eerkens and Bartelink 2013; Eerkens *et al.* 2011; Greenwald *et al.* 2016; Scharlotta *et al.* 2018a), making this work unique, and allowing for inter-individual comparison to a much greater extent. Although, because of the large sample size, this work also becomes more challenging in terms of data analysis and making sense of the results in behavioural terms. The past isotopic research conducted on the same individuals used in this study (Haverkort *et al.* 2008, 2010; Scharlotta and Weber 2014; Waters-Rist *et al.* 2011; Weber and Goriunova 2013) was very beneficial since it produced a dietary framework to build upon. Additional work in the Baikal region and further micro-sampling studies to refine and complement future research on archaeological materials is suggested.

A lack of information regarding the sex of several of the examined hunter-gatherers makes it difficult to determine whether infant-feeding practices and overall childhood diet varied between males and females and, if so, to what extent. Known sex estimations can also offer insight into a population's parental investment and reveal potential temporal and micro-regional differences. Obtaining such information would be beneficial as it would add to the understanding of past social behaviour. Applying ancient DNA sequencing for sex identification is one possibility. However, this process is costly, often time-consuming, and usually not applicable if skeletal samples are poorly preserved which is, unfortunately, the case for many of the region's individuals. A cheaper and less invasive option is via amelogenin, an enamel-forming protein, whose genes are found on X and Y chromosomes (Parker *et al.* 2019; Stewart *et al.* 2017). Minor differences in the amino acid sequences (peptides) between the two chromosomes allow for sex determination in an individual. Considering the project obtained a large number of teeth, and they generally preserve better than bone, this is a good alternative to aDNA.

Equally important, the project would also benefit from additional genetic research to determine population origins. While genetic studies (Mooder *et al.* 2006, 2010; Moussa *et al.* 2018) have been conducted, sample sizes were small and thus only offer a glimpse into the genetic landscape of Cis-Baikal. Not only can new research provide additional insight into population structure, but it also may reveal information on shared affinities with other prehistoric groups in Siberia (matrilineal and patrilineal lineages) which, in turn, can advance our understanding of cultural change in Cis-Baikal.

Although micro-sampling dentine for stable isotope analyses provides better insight into the onset and duration of weaning compared to bulk bone samples, it should not be considered a replacement for bulk bone stable isotope analysis. King and colleagues (2018b) mention that focusing on the individual can increase the risk of over-emphasizing idiosyncratic weaning behaviour when infant-feeding could be a result of factors such as temporal variation, resource availability, or cultural practices. The comparison of bulk bone and dentine micro-sample stable isotope values expands the dietary life history of the Cis-Baikal hunter-gatherers. Yet, certain issues pertaining to the micro-sampling method do require further attention.

While some studies have begun focussing on sampling between dentine growth lines in human and animal teeth (Burt and Garvie Lok 2013; Czermak *et al.* 2018; Guiry *et al.* 2016a) in order to improve temporal resolution, there is currently no solution for sectioning between growth lines of poorly preserved teeth. Several micro-sampling sections were 2mm thick (or more) as it was impossible to keep the dentine from disintegrating had they been sectioned any thinner. There is also no guarantee sufficient collagen would have been extracted. In certain instances, sectioning through growth lines remains the only suitable option. Exploring avenues that could circumvent this should be encouraged. At the same time, refining the age represented per tooth section is needed for more accurate dietary life history reconstructions. Furthermore, Scharlotta and colleagues (2018b) question the application of dentine growth rate models and age-assessment models to archaeological populations as these models are based on modern or late historical populations and are much removed genetically from the prehistoric groups. It is necessary to create additional reference populations that are more genetically diverse and are based on healthy individuals.

In light of improving the micro-sampling temporal resolution, the dietary studies may also benefit from obtaining more information on the contributions of consumed protein, specifically when focused on areas with complex food webs, such as Baikal. This lies in the application of compound-specific stable isotope analysis by targeting individuals' amino acids, which are the smallest sub-units of proteins, and provide insight on the contributions of terrestrial and aquatic resources (e.g. Fogel and Tuross 2003; Webb *et al.* 2015). Investigation of the contribution and routing of potential food groups to the diet of Cis-Baikal individuals is currently underway (Chaput – forthcoming). This involves using a Bayesian isotopic mixing model known as FRUITS (Food Reconstruction Using Isotopic Transferred Signals) that allows for the consideration of sources of uncertainty by using prior information (Fernandes *et al.* 2014b). The application of such a tool can increase the precision of food intake (macronutrients) estimates and ultimately provide a different perspective on past diet.

Furthermore, interpretation of the meaning of stable isotope values in micro-samples, other than diet and malnutrition, has received little attention. Eerkens *et al.* (2016) were the first to apply a minimum shift of 1.0‰ for $\delta^{13}C$ and 1.4‰ for $\delta^{15}N$ (DeNiro and Schoeninger 1983) across sections of a molar for interpreting meaningful changes in diet. Ideally, studies further exploring shifts across molars as well as between single micro-samples will add interesting and necessary discussions on the importance of interpreting dietary values. This may be helpful to refrain from over-interpreting results. As presented in this monograph, multiple factors can influence the fractionation of stable isotopes and possibly lead to misinterpretation. Moreover, I worry that terms such as malnutrition, nutritional stress, or starvation are too prominent and swiftly applied when isotopic values cannot be easily explained through diet. As mentioned previously, Beaumont and Montgomery (2016) shed light on this through the examination of survivors of the Great Irish Famine, which is supported by historical documents on the social, environmental, and political conditions. Clinical studies on eating disorders (Hatch *et al.* 2006; Mekota *et al.* 2006) provide additional insight into the expression of carbon and nitrogen isotopes during low protein intake. While these studies lend credence to recognizing physiological stress in micro-samples, whether it be dentine or hair, they were applied to unwell individuals. Conducting a micro-sampling study on the (deciduous) dentition of modern people can serve as a potential reference for the analysis of stable isotopes in micro-samples. For example, in many modern societies, individuals have a record of infant-feeding practices, medical visits, dietary information (e.g. food restrictions/allergies), and possibly even a record of stress (e.g. developmental delay, trauma). It would be beneficial to reconstruct the diet of these individuals and detect whether particular patterns appear as was the case for the Cis-Baikal hunter-gatherers. Analyzing the isotopic data in conjunction with the additional written (and possibly spoken) information, might eliminate some uncertainty regarding the analysis of the dentine micro-samples.

Finally, additional fieldwork and human osteological analysis, which started during the spring of 2019, will hopefully fill in some gaps regarding individual background data. For instance, it is currently unknown to what extent osteological analysis has been conducted on the Ust'-Ilga individuals from the Upper Lena. Examining these human skeletal remains for pathology (e.g. enamel hypoplasia, Harris lines, cribra orbitalia, stature) could aid in confirming if the negative relationship between $\delta^{13}C$ and $\delta^{15}N$ is, in fact, diet-related or if it could be a result of nutritional stress after all. Linking changes in tooth micro-sample isotopic composition to linear enamel hypoplasia, as seen in a study by Dori *et al.* (2019), will also be of value for future studies on diet and health in past populations. Lastly, a lack of information regarding strontium data further complicates the ability to make inferences regarding movement and dietary changes.

Final remarks

This research demonstrates the successful applicability of dentine micro-sampling to mid-Holocene hunter-gatherers from the Cis-Baikal region in Siberia, Russia. Emerging from this doctoral research is not only an expansion of the project's stable isotope dataset but also a more comprehensive view of the dynamic lives these hunter-gatherers led. Their knowledge of the Cis-Baikal's resources, including those within the various micro-regions they moved through, provided them with the ability to thrive for such a long period of time.

Yet, despite this study and the substantial amount of research that has been conducted by the BAP, there is ample room for further investigation. New questions have arisen including issues pertaining to the sampling method such as slicing through incremental lines. Suggestions on how to potentially tackle these have been highlighted in this work. The BAP continues working towards revealing the cultural dynamics of these hunter-gatherers and has already made substantial progress. This micro-sampling study, together with that of Scharlotta *et al.* (2018b), provides an important dietary framework for future interpretations. The findings have revealed interesting patterns and opened new avenues for more general studies on dietary reconstructions based on the stable isotope data of tooth dentine. Moreover, the studies add to the necessary exploration of prehistoric hunter-gatherers occupying northern regions. Archaeological research that is continuing in the Cis-Baikal region next summer (2020) will hopefully aid in closing some of the gaps in our current understanding. I look forward to seeing this work continued in the near future.

Appendix A

Images of the molar occlusal surfaces

Upper Lena micro-region

Manzurka

Image 1a. MNZ_1974.002 M1 (H2000.224)

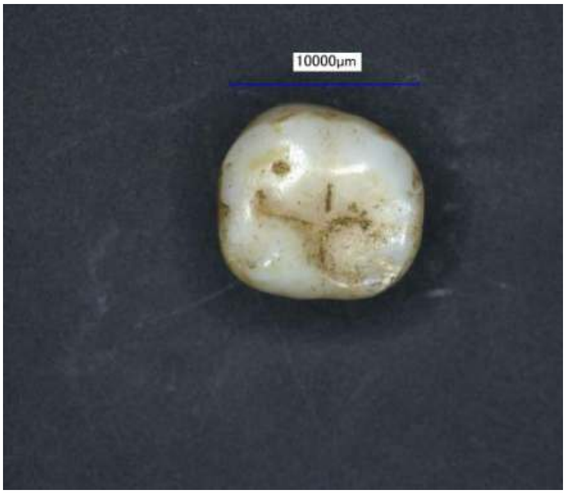


Image 1b. MNZ_1974.002 M2 (H2000.225)

Image 1c. MNZ_1974.002 M3 (H2000.226)

Obkhoi

Image 2a. OBK_1971.005 M1 (H2000.216)

Image 2b. OBK_1971.005 M2 (H2000.218)

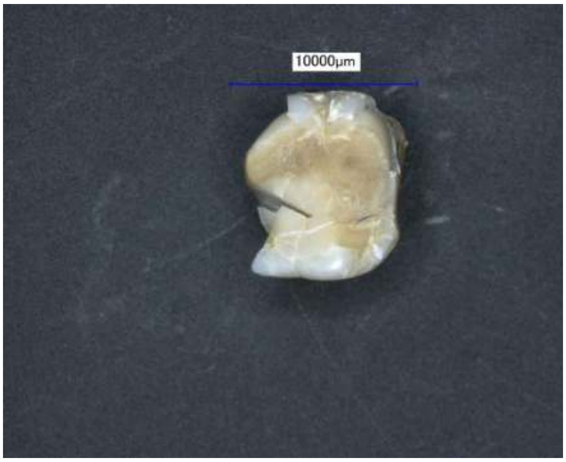


Image 3a. OBK_1971.007 M1 (H2000.209)

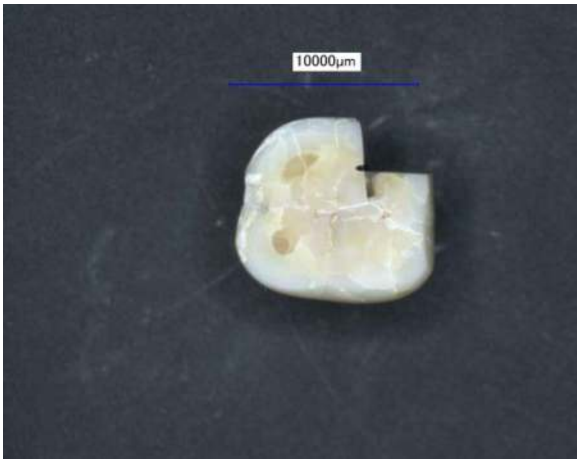


Image 3b. OBK_1971.007 M2 (H2000.210)

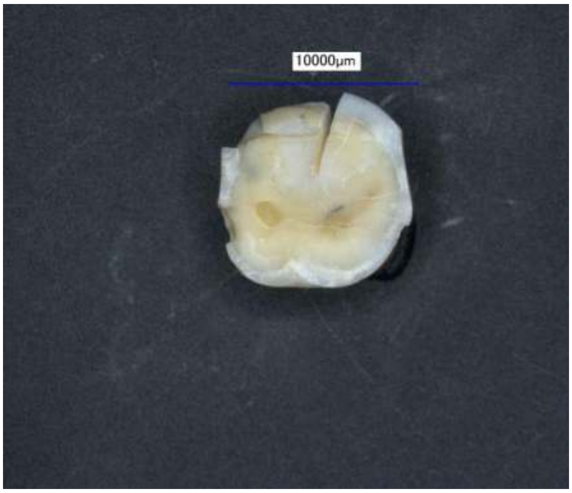


Image 4a. OBK_1971.013 M1 (H2000.212)

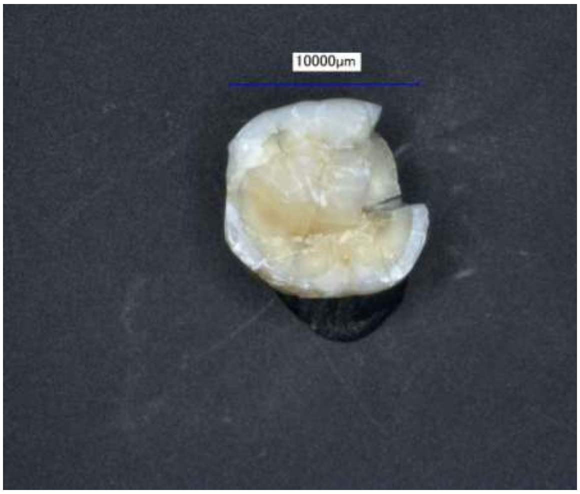


Image 4b. OBK_1971.013 M1 (H2000.213)

Ust'-Ilga

Image 5. UIL_1989.001 M2 (H2016.015)

Image 6. UIL_1989.002 M (H2016.018)

Image 7. UIL_1989.003 M (H2016.020)

Image 8. UIL_1989.004 M3 (H2016.022)

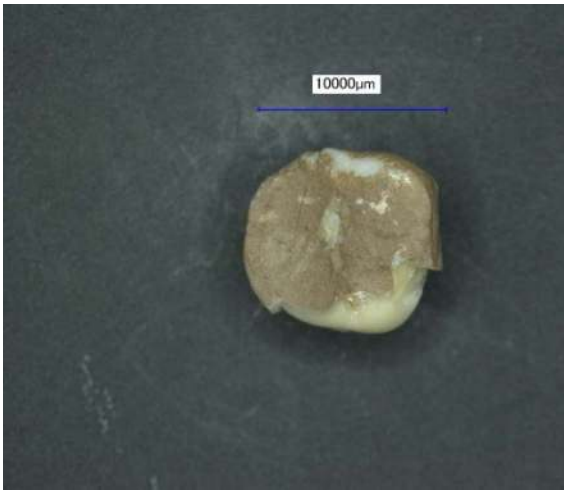


Image 9. UIL_1989.005 M2 or M3 (H2016.014)

Image 10. UIL_1990.009 M3 (H2016.007)

Image 11. UIL_1990.010 M2 (H2016.028)

Image 12. UIL_1990.011 M1 (H2016.010)

Image 13. UIL_1990.012 M1 (H2016.030)

Image 14. UIL_1991.013.01 M1 (H2016.032)

Image 15. UIL_1991.013.02 M1 (H2016.009)

Angara micro-region

Ust'-Ida I Late Neolithic

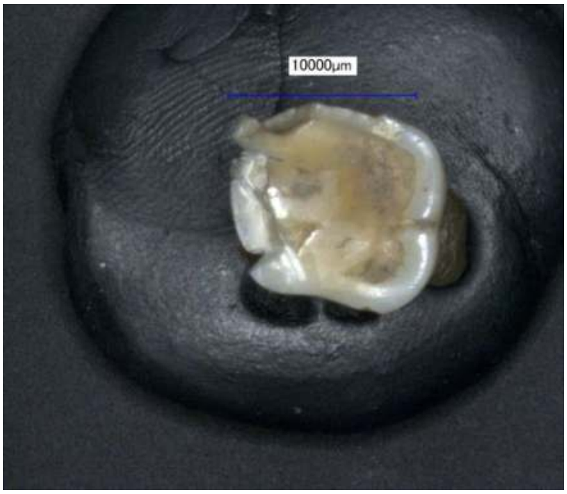


Image 16a. UID_1987.006 M1 (H2001.532)

Image 16b. UID_1987.006 M3 (H2001.530)

Image 17a. UID_1987.011 M1 (H2001.535)

Image 17b. UID_1987.011 M2 (H2001.534)

Image 17c. UID_1987.011 M3 (H2001.533)

Image 18a. UID_1988.014 M1 (H2001.517)

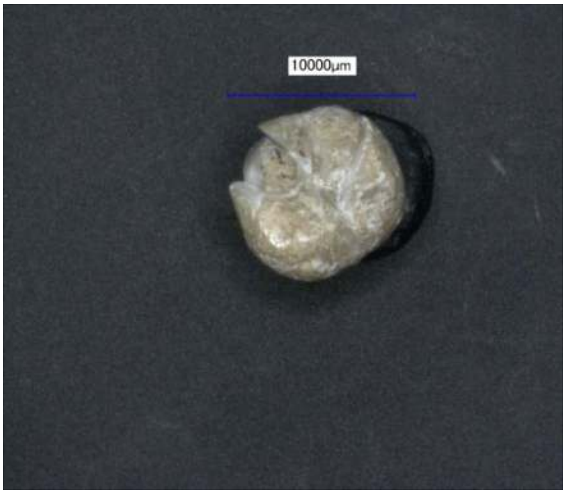


Image 18b. UID_1988.014 M3 (H2001.518)

Image 19a. UID_1989.020.01 M1 (H2001.420)

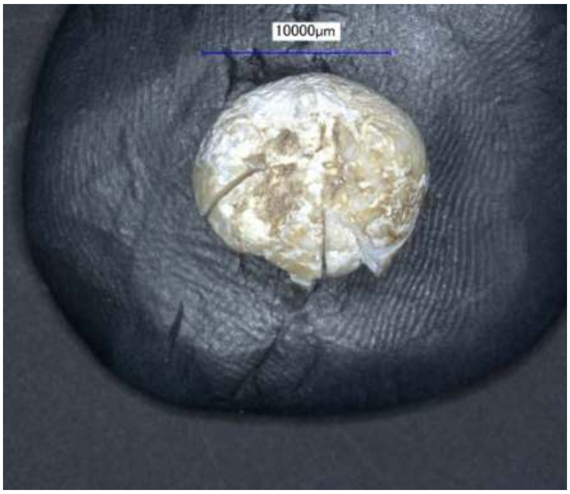


Image 19b. UID_1989.020.01 M3 (H2001.419)

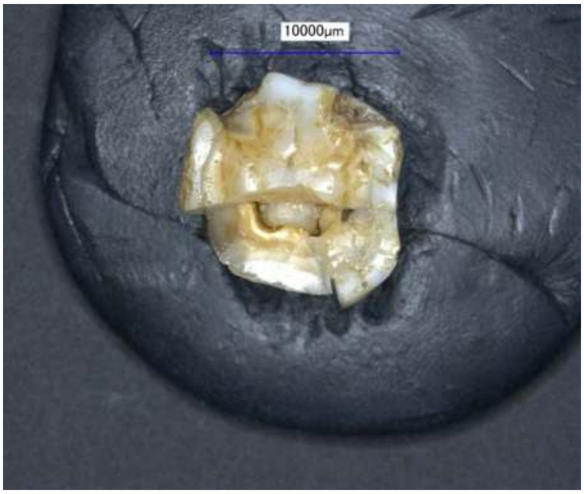


Image 20a. UID_1989.020.02 M1 (H2001.415)

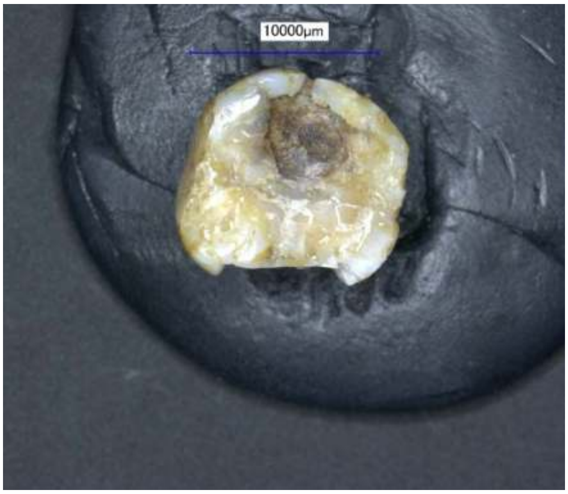


Image 20b. UID_1989.020.02 M2 (H2001.416)

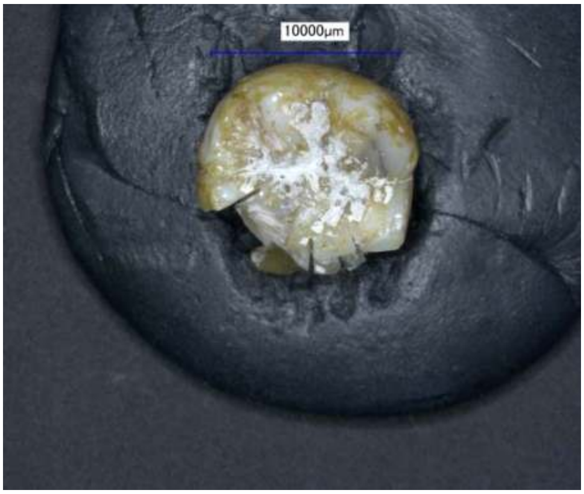


Image 20c. UID_1989.020.02 M3 (H2001.417)

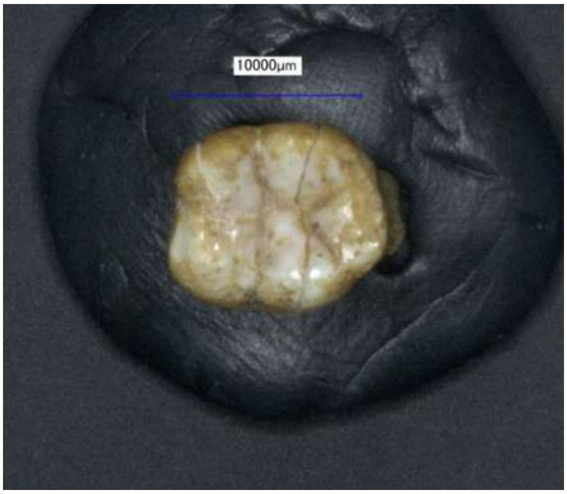


Image 21a. UID_1989.022 M1 (H2001.501)

Image 21b. UID_1989.022 M3 (H2001.499)

Image 22a. UID_1989.030 M1 (H2001.498)

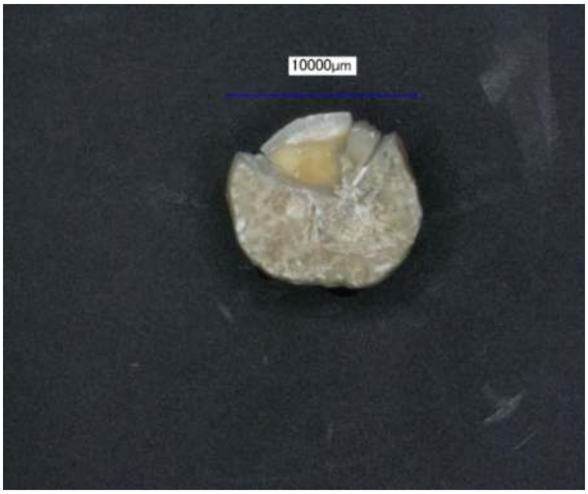


Image 22b. UID_1989.030 M3 (H2001.496)

Image 23a. UID_1991.038 M1 (H2001.558)

Image 23b. UID_1991.038 M3 (H2001.560)

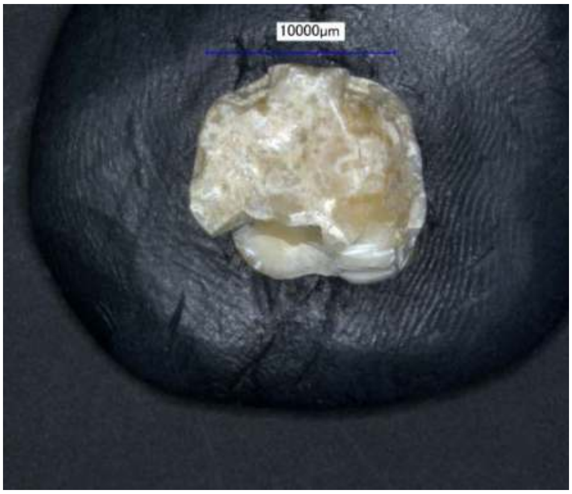


Image 24a. UID_1995.056.01 M1 (H2001.456)

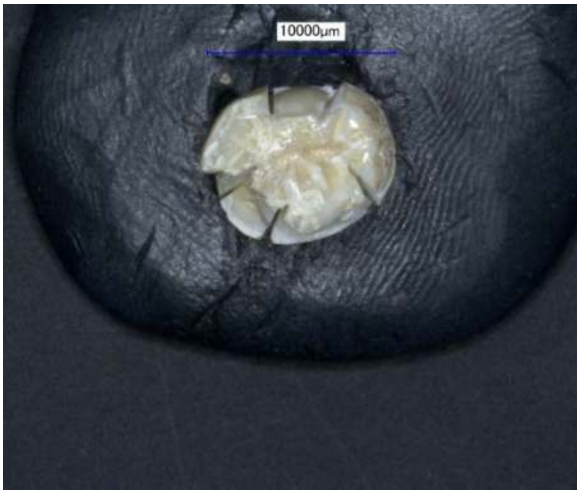


Image 24b. UID_1995.056.01 M3 (H2001.458)

Ust'-Ida I Early Bronze Age

Image 25a. UID_1989.019 M1 (H2001.525)

Image 25b. UID_1989.019 M3 (H2001.524)

Image 26. UID_1989.029 M3 (H2001.488)

Image 27a. UID_1993.045 M1 (H2001.345)

Image 27b. M3 (H2001.346)

Image 28a. UID_1994.048 M1 (H2001.481)

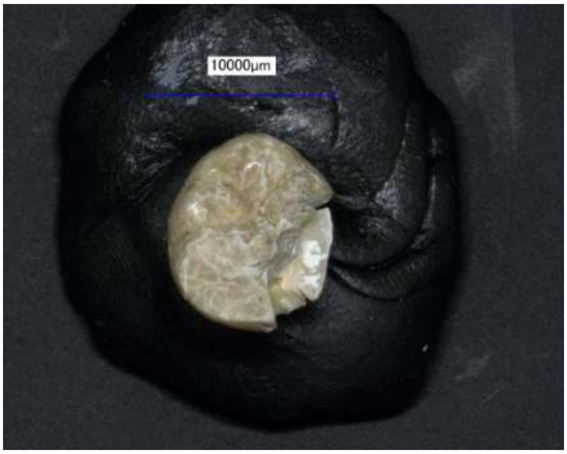


Image 28b. UID_1994.048 M3 (H2001.483)

Little Sea micro-region

Shamanskii Mys

Image 29a. SHM_1972.002 M2 (H2000.206)

Image 29b. SHM_1972.002 M3 (H2000.207)

Image 30. SHM_1975.001 M1 (H2000.201)

Khuzhir-Nuge XIV

Image 31. K14_1997.011 M3 (H1997.224)

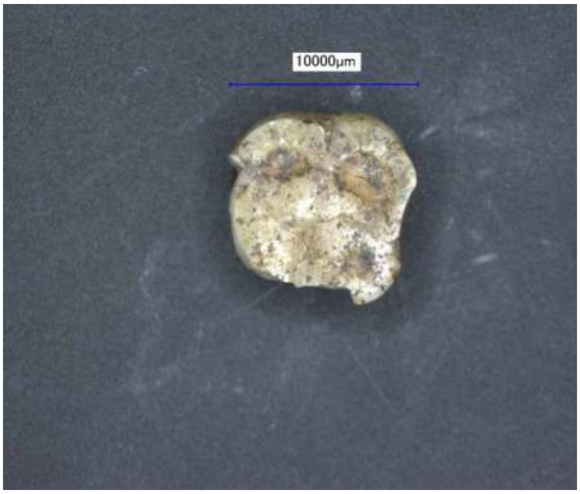


Image 32a. K14_1997.012 M1 (H1997.191)

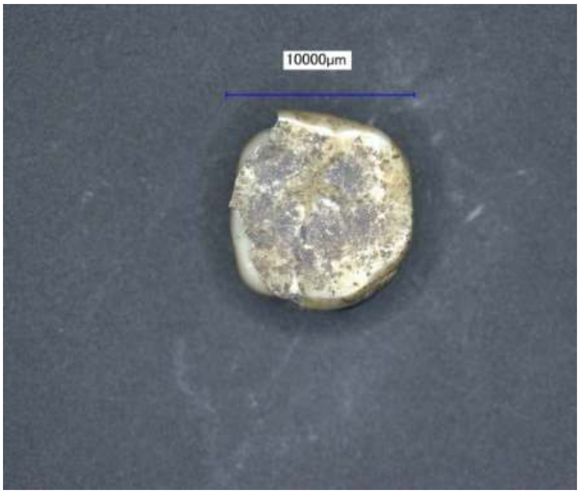


Image 32b. K14_1997.012 M2 (H1996.214)

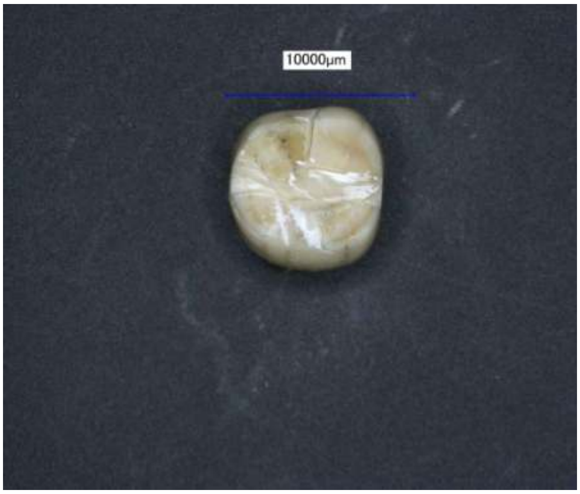


Image 32c. K14_1997.012 M3 (H1997.225)

Image 33. K14_1997.014 M2 (H1997.215)

Image 34. K14_1997.015 M3 (H1997.227)

Image 35. K14_1997.016 M1 (H1997.194)

Individual K14_1997.019

The molars of this individual did not get photographed under the microscope as they were accidentally skipped.

Image 36. K14_1998.035.02 M2 (H1998.359)

Image 37. K14_1998.036.01 M1 (H2003.646)

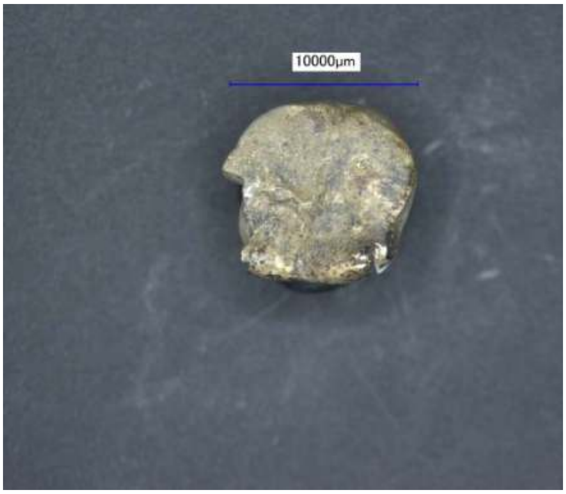


Image 38. K14_1997.037.02 M1 (H1998.372)

Image 39a. K14_1998.038 M1 (H1998.376)

Image 39b. K14_1998.038 M1 (H1998.376) side-view

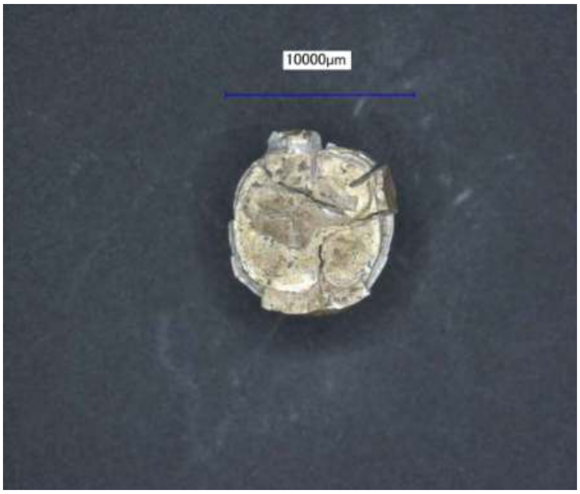


Image 39c. K14_1998.038 M2 (H1998.377)

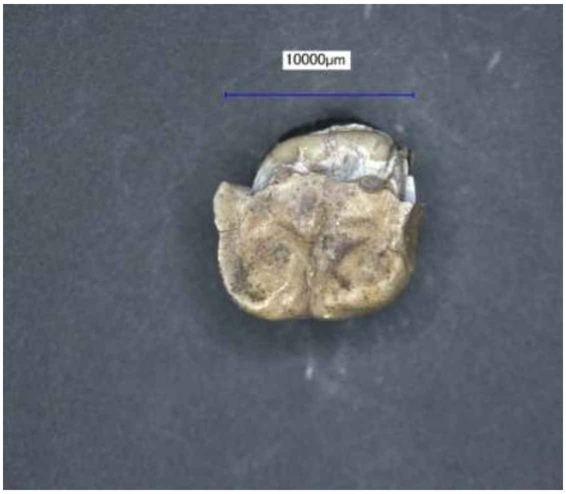


Image 40a. K14_1998.039 M1 (H1998.379)

Image 40b. K14_1998.039 M2 (H1998.380)

Image 41a. K14_1999.044 M1 (H1999.163)

Image 41b. K14_1999.044 M2 (H1999.164)

Image 41c. K14_1999.044 M3 (H1999.165)

Image 42a. K14_1999.045 M1 (H1999.156)

Image 42b. K14_1999.045 M2 (H1999.157)

Image 43. K14_1999.046 M2 (H1999.130)

Image 44a. K14_1999.051 M1 (H1999.134)

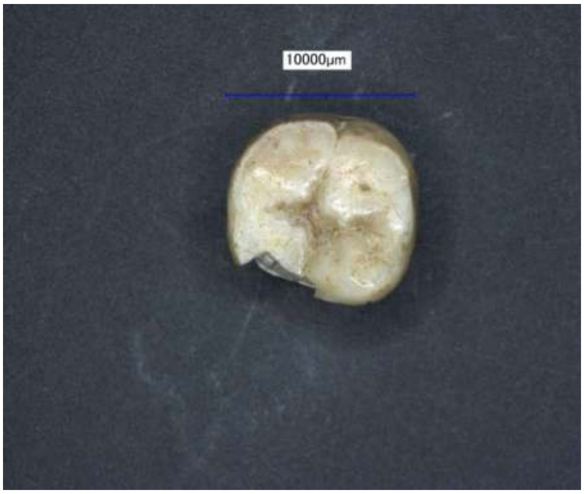


Image 44b. K14_1999.051 M2 (H1999.135)

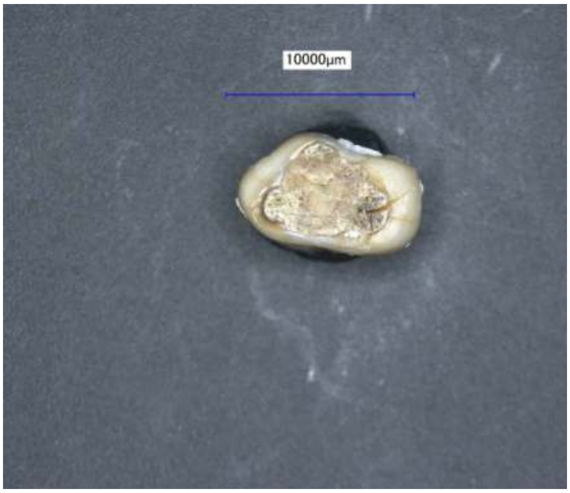


Image 45. K14_1999.057.02 M2 (H2001.645)

Image 46a. K14_2000.063 M1 (H2000.141)

Image 46b. K14_2000.063 M3 (H2000.143)

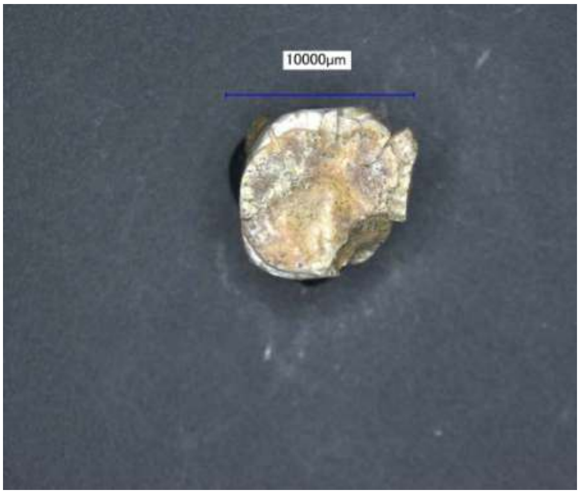


Image 47a. K14_2000.064 M1 (H2000.126)

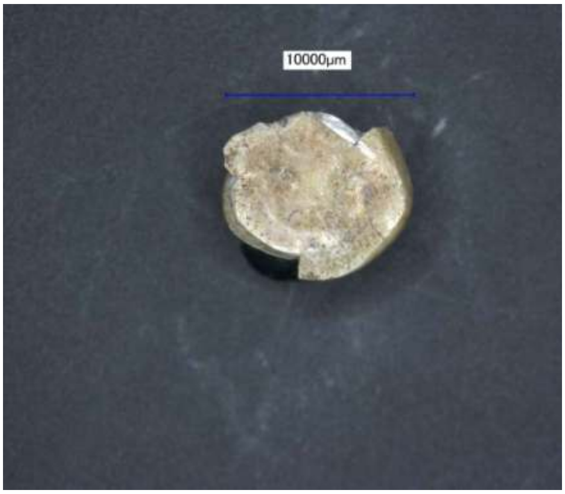


Image 47b. K14_2000.064 M3 (H2000.128)

Image 48. K14_2000.077 M1 (2000.166)

Appendix B

Molar wear assessment of all 49 Cis-Baikal individuals

Upper Lena individuals

Master_ID	Sample_ID	Molar	Wear stage
MNZ_1974.002	H2000.224	R Man. M1	3
MNZ_1974.002	H2000.225	R Man. M2	2
MNZ_1974.002	H2000.226	R Man. M3	2
OBK_1971.005	H2000.216	L Man. M1	7
OBK_1971.005	H2000.218	R Man. M3	6
OBK_1971.007	H2000.209	L or R Man. M1	5
OBK_1971.007	H2000.210	L or R Man. M2	4
OBK_1971.013	H2000.212	R Man. M1	7
OBK_1971.013	H2000.213	L Man. M1	6
UIL_1989.001	H2016.015	R Max. M2	3
UIL_1989.002	H2016.018	Molar	6
UIL_1989.003	H2016.021	Molar	6
UIL_1989.004	H2016.022	M3	5
UIL_1989.005	H2016.014	M2 or M3	n/a
UIL_1990.009	H2016.007	M3	4
UIL_1990.010	H2016.028	R or L Max. M2	5
UIL_1990.011	H2016.010	L Max. M1	4
UIL_1990.012	H2016.030	L Man. M1	3
UIL_1991.013.01	H2016.032	R Max. M1	5
UIL_1991.013.02	H2016.009	L Max. M1	2?

Tooth H2016.014 could not be scored as a result of dirt and calculus.

Angara individuals

Master_ID	Sample_ID	Molar	Wear stage
UID_1987.006	H2001.530	L. Max. M3	*3
UID_1987.006	H2001.532	R. Max. M1	*6
UID_1987.011	H2001.533	R. Man. M3	*4
UID_1987.011	H2001.534	L. Man. M2	*6
UID_1987.011	H2001.535	L. Man. M1	*6
UID_1988.014	H2001.517	L. Max. M1	*4
UID_1988.014	H2001.518	L. Man. M3	*3
UID_1989.019	H2001.524	R. Man. M3	*3
UID_1989.019	H2001.525	R. Man M1	*4
UID_1989.020.01	H2001.419	R. Man. M3	*3
UID_1989.020.01	H2001.420	R. Man. M1	*3
UID_1989.020.02	H2001.415	R. Man. M1	*5
UID_1989.020.02	H2001.416	R. Man. M2	*5
UID_1989.020.02	H2001.417	R. Man. M3	*3
UID_1989.022	H2001.499	L. Man. M3	*3
UID_1989.022	H2001.501	L. Man. M1	*3
UID_1989.029	H2001.488	R. Man. M3	*3
UID_1989.030	H2001.496	R. Man. M3	*3
UID_1989.030	H2001.498	R. Man. M1	*5
UID_1991.038	H2001.558	L. Man. M1	*7
UID_1991.038	H2001.560	L. Man. M3	*4
UID_1993.045	H2001.345	L. Man. M1	*7
UID_1993.045	H2001.346	L. Man. M3	*4
UID_1994.048	H2001.481	R. Man. M1	*5
UID_1994.048	H2001.483	R. Man. M3	*3
UID_1995.056.01	H2001.456	R. Man. M1	n/a
UID_1995.056.01	H2001.458	R. Man. M3	*3

*Removal or chipping of enamel post burial

Little Sea individuals

Master_ID	Sample_ID	Molar	Wear stage
SHM_1972.002	H2000.206	R Max. M2	3
SHM_1972.002	H2000.207	R Max. M3	*2
SHM_1975.001	H2000.201	L Man. M1	*6
K14_1997.011	H1997.224	R Max. M3	*3
K14_1997.012	H1997.191	L Man. M1	*4
K14_1997.012	H1997.214	L Man. M2	*3
K14_1997.012	H1997.225	L Man. M3	*5
K14_1997.014	H1997.215	L Max. M2	*n/a
K14_1997.015	H1997.227	L Man. M3	*3
K14_1997.016	H1997.194	L Man. M1	2
K14_1997.019	H1997.219	L Man. M2	No photos
K14_1997.019	H1997.229	L Man. M3	*6
K14_1998.035.02	H1998.359	L Man. M2	*2
K14_1998.036.01	H2003.646	R Man. M1	6
K14_1998.037.02	H1998.372	L Man. M1	*3
K14_1998.038	H1998.376	L Max. M1	7
K14_1998.038	H1998.377	L Man. M2	*7
K14_1998.039	H1998.379	L Man. M1	*3
K14_1998.039	H1998.380	L Man. M2	*1
K14_1999.044	H1999.163	L Man. M1	*6
K14_1999.044	H1999.164	L Man. M2	*6
K14_1999.044	H1999.165	R. Max. M3	2
K14_1999.045	H1999.156	L Man. M1	*2
K14_1999.045	H1999.157	L Man. M2	*2
K14_1999.046	H1999.130	L Man. M2	*6
K14_1999.051	H1999.134	L Man. M1	*4
K14_1999.051	H1999.135	L Man. M2	*3
K14_1999.057.02	H2001.645	L Max. M2	*n/a
K14_2000.063	H2000.141	L Max. M1	*3
K14_2000.063	H2000.143	L Max. M3	*2
K14_2000.064	H2000.126	L Man. M1	*7
K14_2000.064	H2000.128	L Man. M3	*6
K14_2000.077	H2000.166	L Man. M1	*3?

*Removal or chipping of enamel post burial

Appendix C

Stable carbon (^{13}C) and nitrogen (^{15}N) isotope values for all micro-samples, carbon (C%) and nitrogen (N%) percentage, and carbon/nitrogen ratio (C:N)

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-01	-18.0	15.7	41.5	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-02	-18.5	15.2	41.4	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-03	-18.2	16.2	41.3	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-04	-18.0	16.3	41.5	15.0	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-05	-18.2	16.4	41.1	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-06	-18.0	16.6	41.1	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-07	-17.7	16.9	40.7	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-08	-18.3	16.2	40.8	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-09	-18.3	16.7	45.2	16.2	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-10	-18.1	16.1	34.2	12.2	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-11	-18.0	17.5	37.9	13.4	3.3
Khuzhir-Nuge XIV	K14_1997.011	H1997.224 S-12	-17.9	16.8	74.0	26.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-01	-18.1	16.6	21.2	7.2	3.4
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-02	-17.5	18.9	41.4	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-03	-17.5	16.9	41.3	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-04	-17.7	16.3	41.9	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-05	-17.6	16.1	42.1	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-06	-17.7	15.1	41.9	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-07	-17.9	14.5	41.6	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-08	-17.9	14.4	41.4	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-09	-17.7	13.5	41.7	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-10	-17.6	14.4	42.0	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-11	-17.5	13.8	41.5	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-12	-18.0	15.1	42.1	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-13	-18.2	15.0	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.191 S-14	-18.4	14.6	41.3	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-01	-18.4	14.9	42.6	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-02	-17.4	13.4	42.5	15.4	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-03	-17.7	14.4	42.8	15.4	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-04	-18.1	14.3	42.8	15.4	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-05	-18.2	14.3	42.8	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-06	-18.3	14.4	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-07	-18.6	14.5	42.6	15.3	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-08	-18.8	14.1	42.3	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-09	-18.8	14.2	42.5	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-10	-18.7	14.5	42.7	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-11	-18.6	15.1	42.1	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.214 S-12	-18.0	14.6	42.6	14.9	3.4
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-01	-18.9	14.8	41.9	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-02	-18.9	14.8	42.5	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-03	-18.7	14.5	43.0	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-04	-18.3	14.4	42.9	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-05	-17.8	14.4	42.4	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-06	-18.4	14.5	42.6	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-07	-17.5	14.3	40.2	14.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-08	-18.9	15.1	42.1	15.0	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-09	-18.8	13.8	42.1	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.225 S-10	-18.4	14.1	42.3	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.227 S-01	-17.4	17.0	42.4	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.227 S-02	-17.2	16.6	43.4	15.5	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.227 S-03	-17.8	16.5	43.3	15.5	3.3
Khuzhir-Nuge XIV	K14_1997.012	H1997.227 S-04	-18.4	15.1	43.4	15.6	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-01	-18.1	14.9	41.5	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-02	-18.0	15.3	41.8	15.0	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-03	-18.3	15.4	41.0	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-04	-18.3	15.4	41.4	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-05	-18.4	15.1	40.3	14.4	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-06	-18.4	15.6	39.2	13.9	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-07	-18.4	14.4	38.4	13.6	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-09	-17.8	15.7	39.5	14.0	3.3
Khuzhir-Nuge XIV	K14_1997.014	H1997.215 S-10	-18.4	15.3	41.6	14.6	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-01	-17.2	18.9	41.9	14.9	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-02	-17.9	20.0	42.6	15.1	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-03	-17.8	16.6	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-04	-17.2	15.6	39.8	14.0	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-06	-17.1	15.8	37.4	13.4	3.3
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-07	-17.3	15.0	34.2	11.9	3.4
Khuzhir-Nuge XIV	K14_1997.016	H1997.194 S-08	-17.4	15.7	34.9	12.5	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-01	-17.1	16.3	43.3	15.6	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-02	-17.1	16.3	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-03	-16.9	16.5	42.9	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-04	-17.2	16.7	42.2	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-05	-17.4	16.8	40.8	14.6	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-06	-17.6	16.9	41.8	14.8	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-07	-16.8	17.5	41.1	14.8	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-08	-17.8	17.6	41.4	14.7	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-09	-17.9	16.7	43.0	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.219 S-10	-17.8	16.8	41.2	14.3	3.4
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-01	-17.6	16.3	43.5	15.2	3.4
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-02	-17.1	16.4	42.3	15.0	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-03	-17.1	16.2	40.8	14.6	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-04	-17.4	16.8	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-05	-17.2	16.7	40.8	14.5	3.3
Khuzhir-Nuge XIV	K14_1997.019	H1997.229 S-06	-17.6	16.9	41.9	14.6	3.4
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-01	-18.9	14.2	43.2	15.6	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-02	-19.8	11.8	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-03	-19.5	11.9	43.3	15.5	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-04	-19.2	12.0	44.0	15.8	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-05	-19.1	12.2	43.6	15.7	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-06	-19.1	11.7	43.2	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.035.02	H1998.359 S-07	-19.0	12.8	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-01	-19.1	14.5	47.3	17.0	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-02	-19.4	15.1	47.1	16.9	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-03	-18.9	13.4	46.9	16.8	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-04	-19.0	13.4	47.5	17.0	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-05	-18.9	13.0	47.4	16.9	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-06	-18.8	12.7	46.5	16.6	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-07	-19.0	13.0	45.7	16.3	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-08	-19.0	12.5	43.3	15.5	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-09	-19.1	13.0	46.4	16.6	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-10	-18.7	13.7	46.9	16.9	3.3
Khuzhir-Nuge XIV	K14_1998.036.01	H2003.646 S-11	-18.4	14.0	43.5	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-01	-18.6	16.8	42.8	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-02	-18.9	16.2	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-03	-19.2	14.0	42.8	15.3	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-04	-19.3	13.7	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-05	-19.2	12.4	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-06	-19.2	12.2	42.7	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-07	-19.2	11.5	42.2	15.1	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-08	-19.1	11.8	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-09	-19.0	12.3	42.8	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-10	-18.9	13.0	42.8	15.3	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-11	-19.0	12.0	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-12	-19.3	11.1	42.2	14.9	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-13	-18.8	10.4	42.9	15.3	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-14	-19.4	11.5	43.0	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.037.02	H1998.372 S-15	-19.1	12.9	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-01	-18.7	14.3	40.1	13.7	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-02	-18.9	13.2	39.4	13.7	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-03	-19.0	13.1	38.8	13.5	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-04	-19.2	13.2	38.5	13.5	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-05	-19.0	12.6	38.8	13.8	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-06	-18.4	14.0	40.6	14.4	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.376 S-07	-18.0	15.0	41.6	14.6	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-01	-19.3	12.8	42.5	15.0	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-02	-18.8	13.1	42.4	15.0	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-03	-18.4	12.4	43.1	15.1	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-04	-18.0	13.1	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-05	-18.1	14.0	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-06	-18.4	14.7	42.6	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-07	-18.4	14.9	43.0	15.3	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-08	-18.1	14.1	42.7	15.3	3.3
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-09	-18.4	14.6	42.5	14.9	3.4
Khuzhir-Nuge XIV	K14_1998.038	H1998.377 S-10	-17.9	15.2	42.2	14.9	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-01	-17.3	17.7	46.1	16.4	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-02	-17.6	18.5	47.6	17.0	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-03	-17.5	16.6	47.5	17.0	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-04	-17.9	15.8	46.9	16.8	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-05	-18.1	15.0	47.5	17.1	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-06	-17.9	15.7	46.1	16.7	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-07	-17.9	15.9	45.8	16.2	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-08	-17.9	16.4	45.8	16.2	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-09	-17.9	16.4	43.3	15.2	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-10	-17.7	16.1	41.7	14.9	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-11	-18.1	15.8	43.9	15.7	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.379 S-12	-17.7	16.9	43.0	15.0	3.4
Khuzhir-Nuge XIV	K14_1998.039	H1998.380 S-01	-17.7	15.9	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.380 S-02	-18.0	15.8	42.4	15.1	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.380 S-03	-17.8	15.6	42.2	15.1	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.380 S-04	-17.8	15.7	42.3	15.0	3.3
Khuzhir-Nuge XIV	K14_1998.039	H1998.380 S-05	-17.1	16.6	42.5	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-01	-18.1	16.8	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-02	-18.4	14.6	42.7	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-03	-18.6	14.5	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-04	-18.6	14.8	43.2	15.5	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-05	-18.6	15.1	43.2	15.4	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-06	-18.9	14.7	43.3	15.6	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-07	-18.6	14.0	42.4	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-08	-18.6	14.2	42.4	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-09	-18.7	14.1	42.1	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-10	-18.4	13.9	42.0	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-11	-18.0	13.6	41.9	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-12	-18.0	13.4	42.8	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-13	-18.2	13.3	42.5	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-14	-18.3	14.6	42.7	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-15	-18.2	15.9	42.9	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.163 S-16	-17.8	17.2	43.0	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-01	-19.1	14.5	43.5	15.6	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-02	-18.6	13.8	43.3	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-03	-18.3	13.3	42.8	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-04	-18.1	13.2	42.1	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-05	-18.3	13.7	41.3	14.8	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.164 S-06	-18.4	14.2	38.5	13.7	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-01	-19.3	14.6	43.0	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-02	-17.7	16.1	42.7	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-03	-17.6	16.5	43.1	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-04	-18.3	15.2	42.9	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-05	Error	16.1	42.8	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-06	-17.6	17.1	42.0	14.7	3.4
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-07	-17.4	16.7	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-08	-17.2	16.8	41.7	14.8	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-09	-17.2	16.8	41.8	14.8	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-10	-17.3	16.5	39.9	14.2	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-11	-17.4	16.4	41.0	14.5	3.3
Khuzhir-Nuge XIV	K14_1999.044	H1999.165 S-12	-17.2	17.0	41.0	14.4	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-01	-18.1	19.7	41.6	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-02	-17.0	19.9	42.8	15.3	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-03	-17.5	18.5	42.5	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-04	-17.7	16.7	42.4	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-05	-17.7	16.0	42.4	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-06	-17.7	15.9	41.5	14.8	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-07	-17.8	15.9	41.8	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-08	-17.8	15.4	41.6	14.8	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-09	-17.8	15.4	42.3	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-10	-17.7	15.7	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-11	-17.8	15.8	42.5	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-12	-17.6	16.1	42.3	15.1	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-13	-18.2	15.3	42.2	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.156 S-14	-18.4	14.6	42.3	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-01	-18.2	16.7	40.3	14.5	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-02	-18.0	16.6	41.6	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-03	-18.0	15.7	41.6	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-04	-17.9	15.2	41.7	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-05	-17.8	15.6	41.7	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.045	H1999.157 S-06	-18.2	14.2	41.2	14.7	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-01	-19.2	11.6	43.3	15.5	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-02	-19.3	11.1	43.2	15.5	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-03	-19.3	11.1	42.8	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-04	-19.4	11.5	43.5	15.6	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-05	-19.3	11.5	43.5	15.6	3.3
Khuzhir-Nuge XIV	K14_1999.046	H1999.130 S-06	-19.2	11.5	43.0	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-01	-18.8	17.7	43.4	15.6	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-02	-19.0	17.5	43.4	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-03	-18.4	16.7	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-04	-18.2	16.6	42.7	15.2	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-05	-18.1	16.0	42.5	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.134 S-06	-17.7	15.7	39.1	13.9	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-01	-18.7	15.2	41.5	14.7	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-03	-16.7	17.3	42.2	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-04	-16.8	17.3	41.9	14.9	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-05	-17.2	17.0	41.0	14.2	3.4
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-06	-17.2	16.9	39.8	13.9	3.4
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-07	-17.0	17.0	32.3	11.6	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-08	-17.3	16.6	38.6	13.4	3.4
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-09	-17.4	17.3	41.5	14.6	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-10	-17.4	16.6	40.7	14.4	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-11	-17.7	16.4	41.4	14.7	3.3
Khuzhir-Nuge XIV	K14_1999.051	H1999.135 S-12	-17.5	15.9	41.8	14.7	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-01	-18.1	15.2	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-02	-18.0	14.0	43.0	15.5	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-03	-18.3	14.4	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-04	-18.1	14.6	43.1	15.5	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-05	-18.2	14.9	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-06	-18.4	14.3	42.4	15.1	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-07	-18.2	14.6	42.3	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-08	-18.0	15.0	42.3	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-09	-17.7	15.7	42.0	15.0	3.3
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-10	-17.5	15.8	41.4	14.7	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_1999.057.02	H2001.645 S-11	-17.4	16.4	40.8	14.5	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-01	-16.5	18.4	42.3	14.9	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-02	-16.7	17.1	42.9	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-03	-17.2	15.5	42.6	15.2	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-05	-17.7	14.3	40.5	14.3	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-06	-17.7	15.4	41.7	14.9	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-07	-17.8	15.7	41.3	14.6	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-08	-17.7	16.2	42.4	15.2	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-09	-17.6	16.0	42.3	15.1	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-10	-17.5	16.0	42.6	15.2	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-11	-17.2	15.7	42.9	15.2	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-12	-17.1	15.8	43.2	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-13	-17.0	15.8	42.8	15.1	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-14	-17.1	15.9	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.141 S-15	-17.0	15.9	43.0	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-01	-17.1	15.9	42.8	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-02	-16.9	14.9	43.7	15.7	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-03	-17.1	15.2	44.0	15.8	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-04	-17.1	15.6	44.0	15.8	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-05	-17.0	15.6	43.4	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.063	H2000.143 S-06	-17.0	15.7	43.9	15.7	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-01	-18.3	17.0	42.1	14.8	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-02	-17.6	15.2	42.4	14.9	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-03	-17.7	15.3	42.0	15.0	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-04	-17.7	15.5	40.7	14.3	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-05	-18.1	15.4	39.9	14.2	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-06	-17.8	15.4	39.7	13.9	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-07	-17.5	16.0	38.7	13.3	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-08	-16.9	15.5	38.6	13.2	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.126 S-09	-16.9	16.5	40.6	13.9	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-01	-17.1	17.3	42.0	15.1	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-02	-16.8	16.6	41.6	14.9	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-03	-16.9	17.0	39.9	14.0	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-04	-16.9	17.2	38.2	13.5	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-05+S-06	-17.4	17.0	37.6	13.2	3.3
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-07	-17.5	16.8	38.2	13.4	3.4
Khuzhir-Nuge XIV	K14_2000.064	H2000.128 S-08	-17.7	17.1	38.8	13.3	3.4
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-01	-18.5	14.1	43.1	15.4	3.3
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-02	-18.4	13.8	42.7	15.3	3.3
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-03	-18.5	12.3	43.9	15.7	3.3
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-04	-18.5	11.3	43.7	15.7	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-05	-18.6	10.6	43.1	15.5	3.3
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-06	-19.0	10.7	44.8	16.1	3.3
Khuzhir-Nuge XIV	K14_2000.077	H2000.166 S-07	-19.2	11.1	43.8	15.5	3.3
Manzurka	MNZ_1974.002	H2000.224 S-01	-19.9	13.2	44.0	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-02	-20.0	11.6	43.6	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-03	-19.7	11.2	43.9	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-04	-19.6	11.0	44.1	15.5	3.3
Manzurka	MNZ_1974.002	H2000.224 S-05	-19.5	10.9	44.3	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-06	-19.4	11.0	44.4	15.6	3.4
Manzurka	MNZ_1974.002	H2000.224 S-07	-19.5	10.8	45.1	15.5	3.4
Manzurka	MNZ_1974.002	H2000.224 S-08	-19.7	10.8	49.1	17.2	3.4
Manzurka	MNZ_1974.002	H2000.224 S-09	-19.7	11.0	42.9	14.7	3.4
Manzurka	MNZ_1974.002	H2000.224 S-10	-19.6	11.3	43.4	15.4	3.3
Manzurka	MNZ_1974.002	H2000.224 S-11	-19.4	11.4	43.5	15.5	3.3
Manzurka	MNZ_1974.002	H2000.224 S-12	-19.5	11.4	44.2	15.7	3.3
Manzurka	MNZ_1974.002	H2000.224 S-13	-19.4	11.3	44.1	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-14	-19.2	11.2	44.3	15.7	3.3
Manzurka	MNZ_1974.002	H2000.224 S-15	-19.1	11.3	44.1	15.6	3.3
Manzurka	MNZ_1974.002	H2000.224 S-16	-19.2	11.5	43.8	15.5	3.3
Manzurka	MNZ_1974.002	H2000.224 S-17	-19.3	11.6	42.8	15.1	3.3
Manzurka	MNZ_1974.002	H2000.225 S-01	-19.5	11.1	44.8	15.9	3.3
Manzurka	MNZ_1974.002	H2000.225 S-02	-19.4	11.0	45.4	16.3	3.3
Manzurka	MNZ_1974.002	H2000.225 S-03	-19.2	10.8	45.6	16.3	3.3
Manzurka	MNZ_1974.002	H2000.225 S-04	-19.0	10.8	45.5	16.3	3.3
Manzurka	MNZ_1974.002	H2000.225 S-05	-19.1	10.8	46.0	16.4	3.3
Manzurka	MNZ_1974.002	H2000.225 S-06	-19.3	10.9	45.7	16.0	3.4
Manzurka	MNZ_1974.002	H2000.225 S-07	-19.2	10.9	45.9	16.2	3.3
Manzurka	MNZ_1974.002	H2000.225 S-08	-19.4	11.1	46.2	16.4	3.3
Manzurka	MNZ_1974.002	H2000.225 S-09	-19.6	11.3	46.1	16.5	3.3
Manzurka	MNZ_1974.002	H2000.225 S-10	-19.7	11.4	45.9	16.5	3.3
Manzurka	MNZ_1974.002	H2000.225 S-11	-19.8	11.5	46.0	16.4	3.3
Manzurka	MNZ_1974.002	H2000.225 S-12	-19.8	11.4	45.6	16.2	3.3
Manzurka	MNZ_1974.002	H2000.225 S-13	-19.7	10.9	45.4	16.2	3.3
Manzurka	MNZ_1974.002	H2000.225 S-14	-19.7	10.8	45.7	16.2	3.3
Manzurka	MNZ_1974.002	H2000.225 S-15	-19.7	10.8	48.4	17.4	3.3
Manzurka	MNZ_1974.002	H2000.225 S-16	-19.7	11.1	45.5	16.1	3.3
Manzurka	MNZ_1974.002	H2000.225 S-17	-19.5	11.6	45.6	16.3	3.3
Manzurka	MNZ_1974.002	H2000.225 S-18	-19.6	11.7	45.4	16.1	3.3
Manzurka	MNZ_1974.002	H2000.226 S-01	-19.2	12.6	45.5	16.0	3.3
Manzurka	MNZ_1974.002	H2000.226 S-02	-19.6	11.7	45.9	16.3	3.3
Manzurka	MNZ_1974.002	H2000.226 S-03	-19.6	11.3	46.3	16.3	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Manzurka	MNZ_1974.002	H2000.226 S-04	-19.7	11.4	46.4	16.5	3.3
Manzurka	MNZ_1974.002	H2000.226 S-05	-19.7	11.0	45.9	16.3	3.3
Manzurka	MNZ_1974.002	H2000.226 S-06	-19.6	10.7	46.5	16.4	3.3
Manzurka	MNZ_1974.002	H2000.226 S-07	-19.4	10.7	46.2	16.4	3.3
Manzurka	MNZ_1974.002	H2000.226 S-08	-19.4	10.8	45.4	16.4	3.3
Manzurka	MNZ_1974.002	H2000.226 S-09	-19.4	10.9	46.1	16.6	3.3
Manzurka	MNZ_1974.002	H2000.226 S-10	-19.4	11.0	46.2	16.5	3.3
Manzurka	MNZ_1974.002	H2000.226 S-11	-19.4	11.2	46.1	16.5	3.3
Manzurka	MNZ_1974.002	H2000.226 S-12	-19.5	11.5	45.8	16.4	3.3
Manzurka	MNZ_1974.002	H2000.226 S-13	-19.5	11.7	46.1	16.5	3.3
Manzurka	MNZ_1974.002	H2000.226 S-14	-19.2	11.7	46.2	16.5	3.3
Manzurka	MNZ_1974.002	H2000.226 S-15	-19.4	11.8	45.9	16.4	3.3
Manzurka	MNZ_1974.002	H2000.226 S-16	-19.6	12.1	45.0	16.1	3.3
Obkhoi	OBK_1971.005	H2000.216 S-01	-19.5	12.7	46.2	16.8	3.3
Obkhoi	OBK_1971.005	H2000.216 S-02	-20.1	12.8	46.9	16.6	3.3
Obkhoi	OBK_1971.005	H2000.216 S-03	-20.0	12.0	45.0	16.3	3.3
Obkhoi	OBK_1971.005	H2000.216 S-04	-19.0	10.0	45.7	16.5	3.3
Obkhoi	OBK_1971.005	H2000.216 S-05	-19.5	10.0	45.9	16.5	3.3
Obkhoi	OBK_1971.005	H2000.216 S-06	-19.6	10.4	46.9	17.0	3.3
Obkhoi	OBK_1971.005	H2000.216 S-07	-19.9	10.9	47.0	16.9	3.3
Obkhoi	OBK_1971.005	H2000.216 S-08	-20.1	11.1	46.5	16.7	3.3
Obkhoi	OBK_1971.005	H2000.216 S-09	-19.7	10.6	46.6	16.9	3.3
Obkhoi	OBK_1971.005	H2000.216 S-10	-19.4	10.7	45.8	16.5	3.3
Obkhoi	OBK_1971.005	H2000.218 S-01	-19.6	10.8	46.1	16.7	3.3
Obkhoi	OBK_1971.005	H2000.218 S-02	-19.4	10.9	46.2	16.7	3.3
Obkhoi	OBK_1971.005	H2000.218 S-03	-19.6	11.4	46.5	16.8	3.3
Obkhoi	OBK_1971.005	H2000.218 S-04	-19.5	11.0	46.1	16.8	3.2
Obkhoi	OBK_1971.005	H2000.218 S-05	-19.6	10.5	46.7	17.3	3.2
Obkhoi	OBK_1971.005	H2000.218 S-06	-19.7	11.1	46.9	17.3	3.2
Obkhoi	OBK_1971.005	H2000.218 S-07	-19.8	11.3	46.5	17.0	3.2
Obkhoi	OBK_1971.005	H2000.218 S-08	-19.7	11.0	45.6	16.6	3.2
Obkhoi	OBK_1971.005	H2000.218 S-09	-19.5	10.3	46.1	16.9	3.2
Obkhoi	OBK_1971.005	H2000.218 S-10	-19.9	11.3	45.6	16.6	3.3
Obkhoi	OBK_1971.005	H2000.218 S-11	-20.0	11.4	45.1	16.4	3.3
Obkhoi	OBK_1971.007	H2000.209 S-01	-19.3	12.8	44.5	15.8	3.3
Obkhoi	OBK_1971.007	H2000.209 S-02	-19.5	11.8	45.9	16.3	3.3
Obkhoi	OBK_1971.007	H2000.209 S-03	-19.4	11.7	46.2	16.6	3.3
Obkhoi	OBK_1971.007	H2000.209 S-04	-19.5	11.3	46.0	16.4	3.3
Obkhoi	OBK_1971.007	H2000.209 S-05	-19.4	10.9	47.8	17.1	3.3
Obkhoi	OBK_1971.007	H2000.209 S-06	-19.3	10.7	47.0	16.7	3.3
Obkhoi	OBK_1971.007	H2000.209 S-07	-19.3	10.8	46.1	16.4	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Obkhoi	OBK_1971.007	H2000.209 S-08	-19.2	10.4	45.9	16.2	3.3
Obkhoi	OBK_1971.007	H2000.209 S-09	-18.9	10.1	45.9	16.7	3.2
Obkhoi	OBK_1971.007	H2000.209 S-10	-19.1	10.7	45.9	16.6	3.3
Obkhoi	OBK_1971.007	H2000.209 S-11	-19.2	11.4	46.6	16.9	3.3
Obkhoi	OBK_1971.007	H2000.209 S-12	-19.5	12.0	46.4	16.8	3.3
Obkhoi	OBK_1971.007	H2000.209 S-13	-19.6	12.4	46.4	16.5	3.3
Obkhoi	OBK_1971.013	H2000.212 S-01	-19.5	13.2	46.5	16.8	3.3
Obkhoi	OBK_1971.013	H2000.212 S-02	-19.3	12.3	45.7	16.6	3.3
Obkhoi	OBK_1971.013	H2000.212 S-03	-19.5	11.7	46.5	16.7	3.3
Obkhoi	OBK_1971.013	H2000.212 S-04	-19.4	11.5	46.2	16.8	3.3
Obkhoi	OBK_1971.013	H2000.212 S-05	-19.4	11.3	46.1	16.7	3.3
Obkhoi	OBK_1971.013	H2000.212 S-06	-19.4	11.3	46.2	16.7	3.3
Obkhoi	OBK_1971.013	H2000.212 S-07	-19.5	11.4	45.8	16.5	3.3
Obkhoi	OBK_1971.013	H2000.212 S-08	-19.4	11.6	46.3	16.8	3.3
Obkhoi	OBK_1971.013	H2000.212 S-09	-19.6	11.8	45.7	16.4	3.3
Obkhoi	OBK_1971.013	H2000.212 S-10	-19.5	11.9	46.2	16.7	3.3
Obkhoi	OBK_1971.013	H2000.212 S-11	-19.5	12.2	46.1	16.6	3.3
Obkhoi	OBK_1971.013	H2000.213 S-01	-19.5	13.6	45.3	16.4	3.3
Obkhoi	OBK_1971.013	H2000.213 S-02	-19.4	12.4	45.7	16.6	3.3
Obkhoi	OBK_1971.013	H2000.213 S-03	-19.4	12.3	*71.9	*27.6	3.1
Obkhoi	OBK_1971.013	H2000.213 S-04	-19.3	11.7	46.2	16.7	3.3
Obkhoi	OBK_1971.013	H2000.213 S-05	-19.5	11.3	46.5	16.7	3.3
Obkhoi	OBK_1971.013	H2000.213 S-06	-19.4	11.5	46.5	16.7	3.3
Obkhoi	OBK_1971.013	H2000.213 S-07	-19.5	11.5	46.5	16.8	3.3
Obkhoi	OBK_1971.013	H2000.213 S-08	-19.5	11.4	46.3	16.7	3.3
Obkhoi	OBK_1971.013	H2000.213 S-09	-19.4	11.6	45.9	16.7	3.2
Obkhoi	OBK_1971.013	H2000.213 S-10	-19.4	11.7	46.0	16.6	3.3
Obkhoi	OBK_1971.013	H2000.213 S-11	-19.4	12.0	46.0	16.6	3.3
Obkhoi	OBK_1971.013	H2000.213 S-12	-19.4	12.2	46.4	16.7	3.3
Obkhoi	OBK_1971.013	H2000.213 S-13	-19.8	12.6	46.7	16.8	3.3
Okbhoi	OBK_1971.007	H2000.210 S-01	-19.5	11.1	45.7	16.6	3.3
Okbhoi	OBK_1971.007	H2000.210 S-02	-19.4	10.6	46.1	16.8	3.2
Okbhoi	OBK_1971.007	H2000.210 S-03	-19.0	10.0	45.6	16.7	3.2
Okbhoi	OBK_1971.007	H2000.210 S-04	-19.1	10.8	45.6	16.5	3.3
Okbhoi	OBK_1971.007	H2000.210 S-05	-19.3	11.6	46.2	16.8	3.3
Okbhoi	OBK_1971.007	H2000.210 S-06	-19.5	11.9	45.9	16.5	3.3
Okbhoi	OBK_1971.007	H2000.210 S-07	-19.6	11.7	45.7	16.6	3.3
Okbhoi	OBK_1971.007	H2000.210 S-08	-19.5	11.4	46.2	16.8	3.3
Okbhoi	OBK_1971.007	H2000.210 S-09	-19.5	11.6	46.7	16.9	3.3
Okbhoi	OBK_1971.007	H2000.210 S-10	-19.3	11.3	44.5	16.1	3.3
Okbhoi	OBK_1971.007	H2000.210 S-11	-19.6	11.6	45.9	16.6	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Okbhoi	OBK_1971.007	H2000.210 S-12	-19.6	11.7	46.0	16.5	3.3
Okbhoi	OBK_1971.007	H2000.210 S-13	-19.3	11.2	46.1	16.4	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-01	-18.5	14.1	43.8	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-02	-18.6	13.9	45.9	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-03	-15.6	14.1	46.4	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-03	-18.5	14.1	43.8	15.8	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-04	-19.0	14.3	46.6	16.8	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-05	-19.2	14.5	46.3	16.6	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-06	-18.9	14.5	46.5	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-07	-18.8	13.9	46.4	16.6	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-08	-19.0	13.3	46.2	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-09	-19.1	13.0	46.4	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-10	-19.3	13.0	46.0	16.3	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-11	-19.1	13.5	45.8	16.4	3.4
Shamanskii Mys	SHM_1972.002	H2000.206 S-12	-18.9	14.7	46.9	16.4	3.3
Shamanskii Mys	SHM_1972.002	H2000.206 S-13	-19.1	15.2	45.9	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-01	-19.1	14.8	46.2	16.6	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-02	-19.0	15.5	46.1	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-03	-18.7	16.2	45.7	16.5	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-04	-18.9	15.3	46.8	16.8	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-05	-18.8	14.7	46.6	16.9	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-06	-19.0	14.8	46.5	16.6	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-07	-19.0	14.5	46.4	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-08	-18.8	15.1	46.6	16.8	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-09	-18.9	15.4	46.4	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-10	-18.9	14.8	46.6	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-12	-18.8	15.2	46.7	16.7	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-13	-18.6	16.2	47.0	16.9	3.3
Shamanskii Mys	SHM_1972.002	H2000.207 S-14	-19.0	16.2	46.3	16.6	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-01	-16.5	18.1	47.0	16.9	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-02	-16.9	16.5	46.9	16.8	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-03	-17.5	15.1	46.8	16.9	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-04	-17.2	16.4	46.9	16.8	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-05	-16.9	15.5	46.5	16.7	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-06	-17.1	14.9	46.3	16.6	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-07	-17.0	15.2	46.6	16.7	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-08	-17.2	15.8	46.8	16.8	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-09	-17.3	16.0	46.6	16.7	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-10	-16.8	16.4	46.7	16.8	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-11	-17.0	16.3	51.3	18.5	3.3
Shamanskii Mys	SHM_1975.001	H2000.201 S-12	-17.3	16.9	45.8	16.3	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1987.006	H2001.530 S-01	-17.7	13.7	46.6	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-02	-17.9	12.6	46.4	16.4	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-03	-18.0	12.5	46.2	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-04	-17.9	12.8	46.8	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-05	-17.2	13.6	47.0	16.8	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-06	-17.1	13.7	46.9	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-07	-17.1	13.8	46.7	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-08	-17.2	13.8	46.2	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-09	-17.4	13.7	47.3	16.9	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-10	-17.7	13.3	46.4	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-11	-17.8	13.0	46.6	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-12	-17.9	13.3	46.9	16.8	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-13	-18.0	13.3	45.7	16.2	3.3
Ust'-Ida I	UID_1987.006	H2001.530 S-14	-18.0	12.7	45.7	16.1	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-01	-18.0	14.7	45.8	16.3	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-02	-18.1	14.1	45.9	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-03	-18.1	13.5	46.0	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-04	-18.2	13.0	46.1	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-05	-18.1	13.1	45.9	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-06	-18.1	13.0	46.1	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-07	-18.1	12.8	46.4	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-08	-18.2	12.6	46.5	16.8	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-09	-18.2	12.5	46.2	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-10	-18.1	12.7	46.4	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-11	-18.0	12.6	46.2	16.5	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-12	-18.1	12.3	45.5	16.3	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-13	-18.0	12.8	46.2	16.7	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-14	-18.0	13.1	46.0	16.6	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-15	-17.9	13.4	45.5	16.4	3.3
Ust'-Ida I	UID_1987.006	H2001.532 S-16	-17.8	13.5	45.9	15.6	3.4
Ust'-Ida I	UID_1987.011	H2001.533 S-01	-18.3	13.0	46.8	16.8	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-02	-18.4	12.7	46.8	16.6	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-03	-18.3	12.8	47.2	16.7	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-04	-18.3	12.7	46.9	16.8	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-05	-18.4	12.4	46.9	16.7	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-06	-18.5	12.5	46.9	16.9	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-07	-18.7	12.8	46.5	16.5	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-08	-18.9	13.2	46.8	16.7	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-09	-18.8	13.4	46.7	16.7	3.3
Ust'-Ida I	UID_1987.011	H2001.533 S-10	-18.1	13.7	46.5	16.7	3.3
Ust'-Ida I	UID_1987.011	H2001.534 S-02	Error	Error	x	x	x

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust’-Ida I	UID_1987.011	H2001.534 S-03	Error	Error	x	x	x
Ust’-Ida I	UID_1987.011	H2001.534 S-04	-18.5	13.2	46.5	16.6	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-05	-18.6	12.8	46.7	16.6	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-06	-18.9	12.4	46.9	16.6	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-07	-18.8	12.4	46.5	16.4	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-08	-18.8	12.3	46.9	16.5	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-09	-18.5	12.6	46.9	16.6	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-10	-18.4	12.6	46.6	16.7	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-11	-18.2	12.8	46.2	16.5	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-12	-18.5	12.9	46.5	16.6	3.3
Ust’-Ida I	UID_1987.011	H2001.534 S-13	-18.7	13.1	46.9	16.5	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-02	-18.8	14.2	46.3	16.4	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-03	-18.7	13.2	47.4	16.7	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-04	-18.6	12.3	47.0	16.2	3.4
Ust’-Ida I	UID_1987.011	H2001.535 S-05	-18.8	12.5	47.2	16.3	3.4
Ust’-Ida I	UID_1987.011	H2001.535 S-06	-19.4	12.9	48.4	16.4	3.5
Ust’-Ida I	UID_1987.011	H2001.535 S-07	-18.8	13.2	46.2	16.5	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-08	-18.6	13.1	45.3	16.2	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-09	-18.4	13.4	45.7	16.3	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-10	-18.6	12.9	46.0	16.5	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-11	-18.5	13.1	45.4	16	3.3
Ust’-Ida I	UID_1987.011	H2001.535 S-12	-18.5	13.2	45.3	15.7	3.4
Ust’-Ida I	UID_1988.014	H2001.517 S-01	-18.5	15.1	46.2	16.5	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-02	-18.6	14.2	46.7	16.8	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-03	-18.4	13.6	47.0	16.9	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-04	-18.1	13.3	46.8	16.8	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-05	-17.5	13.2	46.7	16.8	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-06	-17.6	13.0	46.8	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-07	-17.7	12.5	46.4	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-08	-18.0	12.6	46.1	16.6	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-09	-18.2	12.6	47.2	16.9	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-10	-18.4	12.3	46.9	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-11	-18.3	13.1	46.7	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.517 S-12	-18.0	12.8	46.4	16.5	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-01	-17.8	13.1	45.9	16.4	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-02	-17.7	13.4	45.9	16.5	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-03	-18.0	13.3	46.5	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-04	-18.1	13.4	46.1	16.6	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-05	-17.8	13.1	46.7	16.8	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-06	-17.9	12.8	46.4	16.7	3.3
Ust’-Ida I	UID_1988.014	H2001.518 S-07	-17.9	13.2	46.4	16.7	3.3

Cemetery	**Master_ID**	**Sample_ID and sample number**	**^{13}C (‰)**	**^{15}N (‰)**	**C%**	**N%**	**C:N**
Ust'-Ida I	UID_1988.014	H2001.518 S-08	-18.0	13.5	46.1	16.5	3.3
Ust'-Ida I	UID_1988.014	H2001.518 S-09	-17.9	13.8	45.3	16.3	3.3
Ust'-Ida I	UID_1988.014	H2001.518 S-10	-17.7	14.1	44.9	15.9	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-01	-19.4	13.8	45.5	16.3	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-02	-19.0	13.3	46.8	16.8	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-03	-18.7	13.0	46.7	16.8	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-04	-18.5	14.0	46.2	16.5	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-05	-18.4	13.6	45.7	16.5	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-06	-18.4	13.5	46.1	16.5	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-07	-18.7	13.6	45.6	16.4	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-08	-18.8	13.9	46.0	16.5	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-09	-18.8	13.6	46.1	16.6	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-10	-18.8	14.1	45.9	16.2	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-11	-18.4	14.4	45.1	16.1	3.3
Ust'-Ida I	UID_1989.019	H2001.524 S-12	-18.5	14.4	46.0	16.4	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-01	-18.4	15.8	46.7	16.6	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-02	-18.7	13.8	45.9	16.3	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-03	-18.6	13.5	46.5	16.7	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-04	-18.5	13.3	46.3	16.4	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-05	-18.4	13.1	46.1	16.3	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-06	-18.5	13.0	45.9	16.4	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-07	-18.6	13.2	47.1	16.9	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-08	-18.7	13.3	46.0	16.3	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-09	-18.6	13.2	46.0	16.4	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-10	-18.5	13.3	45.0	16.1	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-11	-18.4	13.8	45.1	16.0	3.3
Ust'-Ida I	UID_1989.019	H2001.525 S-12	-18.4	14.2	46.9	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-01	-18.5	13.3	45.9	16.4	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-02	-18.0	14.0	46.5	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-03	-18.0	13.9	46.4	16.7	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-04	-18.1	13.4	46.7	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-05	-18.1	13.4	46.6	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-06	-17.8	13.5	46.5	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-07	-16.9	14.3	46.3	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-08	-16.3	15.0	46.6	16.5	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-09	-16.4	14.5	46.4	16.5	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-10	-16.7	14.5	46.0	16.2	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-11	-16.8	14.9	46.2	16.1	3.3
Ust'-Ida I	UID_1989.020.01	H2001.419 S-12	-17.8	14.0	45.6	15.6	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-01	-18.1	15.1	43.6	15.3	3.3
Ust'-Ida I	UID_1989.020.01	H2001.420 S-02	-18.3	14.1	46.0	16.1	3.4

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1989.020.01	H2001.420 S-03	-18.6	13.0	46.9	16.0	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-04	-18.9	11.9	48.0	16.0	3.5
Ust'-Ida I	UID_1989.020.01	H2001.420 S-05	-18.7	11.6	47.5	16.1	3.5
Ust'-Ida I	UID_1989.020.01	H2001.420 S-06	-19.0	11.2	47.7	15.9	3.5
Ust'-Ida I	UID_1989.020.01	H2001.420 S-07	-18.5	11.3	46.8	16.1	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-08	-18.5	11.6	46.9	16.0	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-09	-18.2	12.3	47.1	16.3	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-10	-17.9	12.7	46.8	16.4	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-11	-18.0	13.1	46.4	16.0	3.4
Ust'-Ida I	UID_1989.020.01	H2001.420 S-12	-17.9	13.0	46.3	16.3	3.3
Ust'-Ida I	UID_1989.020.01	H2001.420 S-13	-18.0	12.9	46.0	16.4	3.3
Ust'-Ida I	UID_1989.020.01	H2001.420 S-14	-18.1	13.0	46.3	16.3	3.3
Ust'-Ida I	UID_1989.020.01	H2001.420 S-15	-18.2	13.0	46.4	16.6	3.3
Ust'-Ida I	UID_1989.020.01	H2001.420 S-16	-17.9	13.7	45.3	15.9	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-01	-17.5	15.8	46.7	16.8	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-02	-18.3	14.9	44.4	16.0	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-03	-18.7	13.8	47.8	17.2	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-04	-18.1	13.9	46.7	16.8	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-05	-17.5	14.3	47.5	17.2	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-06	-17.4	13.6	47.2	16.9	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-07	-17.7	13.0	48.3	17.2	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-08	-17.7	13.5	46.6	16.6	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-09	-17.7	13.3	47.4	17.1	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-10	-17.7	13.0	52.6	18.7	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-11	-18.3	13.2	48.7	16.6	3.4
Ust'-Ida I	UID_1989.020.02	H2001.415 S-12	-17.7	13.5	48.1	17.0	3.3
Ust'-Ida I	UID_1989.020.02	H2001.415 S-13	-17.5	13.9	47.1	16.8	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-01	-17.5	13.3	46.3	16.6	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-02	-17.6	12.9	46.5	16.7	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-03	-18.2	13.6	47.7	16.1	3.5
Ust'-Ida I	UID_1989.020.02	H2001.416 S-04	-17.7	13.6	47.2	16.7	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-05	-17.8	13.0	49.0	17.2	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-06	-17.7	13.1	46.8	16.5	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-07	-17.9	13.4	46.6	16.5	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-08	-17.8	13.6	47.2	16.7	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-09	-17.6	14.0	46.5	16.6	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-10	-17.2	14.9	45.9	16.4	3.3
Ust'-Ida I	UID_1989.020.02	H2001.416 S-11	-17.5	13.7	45.9	16.4	3.3
Ust'-Ida I	UID_1989.020.02	H2001.417 S-01	-17.7	13.3	46.3	16.2	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-02	-17.5	13.6	47.0	16.1	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-03	-17.5	13.7	47.0	15.9	3.5

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1989.020.02	H2001.417 S-04	-17.6	13.3	46.5	16.3	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-05	-17.9	12.5	46.7	16.4	3.3
Ust'-Ida I	UID_1989.020.02	H2001.417 S-06	-18.3	12.9	46.4	15.9	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-07	-18.0	13.3	46.4	16.3	3.3
Ust'-Ida I	UID_1989.020.02	H2001.417 S-08	-17.9	13.6	46.3	16.2	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-09	-18.2	13.7	43.4	15.1	3.4
Ust'-Ida I	UID_1989.020.02	H2001.417 S-10	-17.5	14.0	45.8	16.1	3.5
Ust'-Ida I	UID_1989.022	H2001.499 S-01	-16.1	16.1	45.6	16.5	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-02	-16.8	14.7	46.2	16.7	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-03	-15.3	15.6	45.3	16.4	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-04	-16.1	14.6	46.4	16.8	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-05	-17.1	13.8	46.2	16.6	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-06	-17.0	14.3	46.4	16.8	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-07	-16.4	15.3	45.6	16.4	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-08	-17.1	14.1	46.6	16.6	3.3
Ust'-Ida I	UID_1989.022	H2001.499 S-09	-16.8	14.8	46.8	16.4	3.4
Ust'-Ida I	UID_1989.022	H2001.499 S-10	-17.6	14.2	46.1	16.2	3.3
Ust'-Ida I	UID_1989.022	H2001.501 S-01	-16.5	16.0	46.1	16.1	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-02	-16.3	15.6	47.2	16.2	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-03	-16.1	15.3	46.7	16.5	3.3
Ust'-Ida I	UID_1989.022	H2001.501 S-04	-17.3	13.7	46.6	16.3	3.3
Ust'-Ida I	UID_1989.022	H2001.501 S-05	-18.4	13.0	47.3	16.1	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-06	-18.6	12.5	46.8	16.4	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-07	-18.5	12.6	47.3	16.5	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-08	-18.2	13.0	47.2	16.3	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-09	-17.1	14.1	46.9	16.4	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-10	-16.7	15.1	47.1	16.2	3.4
Ust'-Ida I	UID_1989.022	H2001.501 S-11	-17.1	14.5	46.2	16.3	3.3
Ust'-Ida I	UID_1989.022	H2001.501 S-12	-16.3	15.5	45.6	16.0	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-01	-18.0	11.6	46.3	17.0	3.2
Ust'-Ida I	UID_1989.029	H2001.488 S-02	-17.9	11.2	46.3	16.9	3.2
Ust'-Ida I	UID_1989.029	H2001.488 S-03	-17.2	12.8	46.1	16.7	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-04	-17.5	12.7	46.8	17.0	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-05	-18.0	12.1	47.0	16.8	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-06	-17.3	12.8	46.4	16.7	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-07	-17.8	12.4	46.9	16.6	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-08	-17.5	12.8	47.7	17.2	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-09	-17.2	12.9	45.9	16.6	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-10	-17.3	13.0	46.2	16.8	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-11	-17.6	13.2	46.0	16.7	3.3
Ust'-Ida I	UID_1989.029	H2001.488 S-12	-17.2	13.7	46.2	16.8	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1989.030	H2001.496 S-01	-18.0	12.4	45.6	16.3	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-02	-18.3	11.7	45.5	16.5	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-03	-18.7	12.3	45.4	16.3	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-04	-18.9	11.9	44.7	15.9	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-05	-18.7	11.8	46.3	16.6	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-06	-18.8	11.9	45.9	16.4	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-07	-19.1	12.1	46.1	16.3	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-10	-19.3	13.2	45.5	16.2	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-11	-19.2	12.8	45.4	16.1	3.3
Ust'-Ida I	UID_1989.030	H2001.496 S-12	-18.7	13.1	44.7	15.9	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-01	-18.0	15.3	45.4	16.2	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-02	-18.4	13.4	45.4	16.1	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-03	-18.4	12.9	46.8	16.4	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-04	-18.2	12.7	46.6	16.4	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-05	-18.7	12.7	47.0	16.4	3.4
Ust'-Ida I	UID_1989.030	H2001.498 S-06	-18.8	12.5	47.3	16.3	3.4
Ust'-Ida I	UID_1989.030	H2001.498 S-07	-18.5	12.7	46.6	16.1	3.4
Ust'-Ida I	UID_1989.030	H2001.498 S-08	-18.0	12.9	46.8	16.4	3.4
Ust'-Ida I	UID_1989.030	H2001.498 S-09	-17.5	13.1	45.9	16.3	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-10	-17.5	13.3	45.8	16.3	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-11	-17.4	13.9	45.5	16.2	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-12	-18.0	13.5	45.4	16.1	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-13	-18.1	13.3	45.3	16.1	3.3
Ust'-Ida I	UID_1989.030	H2001.498 S-14	-18.5	13.0	44.8	15.2	3.4
Ust'-Ida I	UID_1991.038	H2001.558 S-01	-17.7	14.6	46.7	16.5	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-02	-17.5	13.9	46.9	16.6	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-03	-17.4	13.8	46.5	16.6	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-04	-17.6	13.7	46.7	16.6	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-05	-17.7	13.4	46.8	16.3	3.4
Ust'-Ida I	UID_1991.038	H2001.558 S-06	-17.7	13.2	46.7	16.6	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-07	-17.5	13.7	46.5	16.5	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-08	-17.3	14.2	46.2	16.3	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-09	-17.0	14.3	45.8	16.2	3.3
Ust'-Ida I	UID_1991.038	H2001.558 S-10	-17.5	14.3	45.4	16.1	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-01	-19.0	13.1	45.6	16.2	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-02	-18.0	13.6	47.1	16.9	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-03	-18.0	13.3	47.4	16.9	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-04	-18.0	13.4	47.2	16.8	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-05	-18.2	13.7	46.9	16.7	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-06	-18.2	13.9	46.6	16.5	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-07	-18.1	13.9	46.5	16.5	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1991.038	H2001.560 S-08	-18.0	14.0	46.3	16.5	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-09	-18.1	13.8	46.7	16.5	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-10	-18.1	13.6	46.0	16.3	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-11	-18.1	13.4	45.8	16.2	3.3
Ust'-Ida I	UID_1991.038	H2001.560 S-12	-17.8	13.9	43.2	14.8	3.4
Ust'-Ida I	UID_1991.038	H2001.560 S-13	-16.3	15.0	45.6	15.9	3.4
Ust'-Ida I	UID_1993.045	H2001.345 S-01	-17.8	15.2	46.1	16.3	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-02	-17.8	14.2	48.1	17.1	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-03	-17.8	13.6	47.9	17.0	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-04	-17.8	13.1	47.1	16.8	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-05	-17.8	12.9	47.2	16.8	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-06	-17.9	12.4	48.1	17.2	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-07	-18.0	12.3	48.0	17.1	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-08	-17.9	12.5	47.7	16.8	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-09	-17.7	12.8	47.0	16.7	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-10	-18.0	12.9	47.1	16.7	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-11	-17.4	13.7	47.6	16.8	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-12	-17.3	14.0	47.2	16.7	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-14	-17.5	13.9	47.6	16.8	3.3
Ust'-Ida I	UID_1993.045	H2001.345 S-15	-17.4	14.2	45.4	16.0	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-01	-17.3	13.2	45.3	16.3	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-02	-17.4	13.4	46.0	16.5	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-03	-17.7	13.1	45.5	16.2	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-04	-17.4	13.4	45.5	16.3	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-05	-17.4	13.2	45.6	16.3	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-06	-17.2	13.4	46.2	16.6	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-07	-17.1	13.9	46.5	16.6	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-08	-17.4	14.0	45.8	16.4	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-09	-17.2	13.9	46.3	16.5	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-11	-17.4	13.6	45.1	16.2	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-12	-17.3	13.9	44.9	16.0	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-13	-17.9	13.9	45.0	16.0	3.3
Ust'-Ida I	UID_1993.045	H2001.346 S-14	-17.9	14.0	43.4	14.8	3.4
Ust'-Ida I	UID_1994.048	H2001.481 S-01	-17.2	16.0	46.0	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-02	-17.2	14.5	46.3	16.6	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-03	-17.2	14.0	46.1	16.4	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-04	-16.9	13.7	46.2	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-05	-16.7	13.5	46.0	16.4	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-06	-16.9	13.6	46.3	16.6	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-07	-17.0	13.7	46.2	16.6	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-08	-17.1	13.6	46.0	16.2	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1994.048	H2001.481 S-09	-17.0	13.8	45.9	16.4	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-10	-17.0	13.9	45.9	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-11	-17.0	13.8	45.7	16.4	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-12	-17.2	13.7	45.3	16.2	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-13	-16.9	14.2	45.2	16.1	3.3
Ust'-Ida I	UID_1994.048	H2001.481 S-14	-16.4	14.8	44.2	15.7	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-01	-16.8	14.8	45.4	16.3	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-02	-16.7	14.6	45.1	16.3	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-03	-16.7	14.1	46.1	16.6	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-04	-16.6	14.0	45.9	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-05	-16.3	14.2	46.3	16.6	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-06	-16.3	14.4	46.0	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-07	-16.3	14.3	45.9	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-08	-16.3	14.5	46.1	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-09	-16.3	14.7	46.2	16.7	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-10	-16.1	15.1	45.3	16.3	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-11	-16.4	15.0	46.0	16.4	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-12	-16.5	15.2	45.8	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-13	-16.4	15.0	45.8	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-14	-16.9	15.1	45.9	16.5	3.3
Ust'-Ida I	UID_1994.048	H2001.483 S-16	-16.7	14.8	43.3	15.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-01	-17.6	14.8	45.7	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-02	-17.6	14.3	45.8	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-03	-17.4	14.1	46.1	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-04	-17.4	13.3	46.2	16.6	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-05	-17.4	12.7	46.1	16.5	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-06	-17.4	12.6	46.0	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-07	-17.5	12.7	46.2	16.5	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-08	-17.4	13.0	46.3	16.6	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-09	-17.5	13.1	46.0	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-10	-17.6	13.0	45.9	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-11	-17.7	13.0	46.0	16.2	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-12	-17.9	12.8	45.4	16.2	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-13	-17.7	12.9	46.0	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-14	-17.3	13.0	45.9	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-15	-17.7	13.1	45.8	16.2	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-16	-17.6	13.2	46.1	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-17	-17.7	13.5	46.0	16.2	3.3
Ust'-Ida I	UID_1995.056.01	H2001.456 S-18	-17.8	13.9	45.5	15.9	3.4
Ust'-Ida I	UID_1995.056.01	H2001.458 S-01	-17.7	13.5	44.8	16.1	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-02	-17.1	13.0	43.1	15.4	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ida I	UID_1995.056.01	H2001.458 S-03	-17.8	12.6	45.6	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-04	-17.8	13.4	45.7	16.5	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-05	-17.5	13.9	45.9	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-06	-17.4	14.0	46.1	16.5	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-07	-17.3	14.1	45.5	16.3	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-08	-17.5	13.9	46.3	16.5	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-09	-17.5	14.0	45.8	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-10	-17.4	14.0	46.2	16.6	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-11	-17.4	14.1	45.7	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-12	-17.3	14.1	45.9	16.4	3.3
Ust'-Ida I	UID_1995.056.01	H2001.458 S-13	-17.3	14.3	46.2	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-01	-19.4	12.8	45.7	16.2	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-02	-19.3	11.8	45.4	16.2	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-03	-19.3	11.6	46.1	16.5	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-04	-19.2	11.2	46.0	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-05	-19.4	11.6	46.2	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-06	-19.5	11.8	46.1	16.5	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-07	-19.5	11.6	46.0	16.5	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-08	-19.3	11.5	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-09	-19.3	11.7	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-10	-19.3	12.1	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-11	-19.2	12.4	45.1	16.1	3.3
Ust'-Ilga	UIL_1989.001	H2016.015 S-12	-19.2	12.5	45.6	16.3	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-01	-19.8	12.6	46.0	16.5	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-02	-19.5	12.1	45.8	16.5	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-03	-19.8	12.5	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-04	-20.1	12.4	46.0	16.5	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-05	-19.9	11.4	46.1	16.5	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-06	-19.8	11.5	46.0	16.4	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-07	-20.4	12.3	45.9	16.4	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-08	-20.4	12.5	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-09	-20.3	12.2	45.6	16.3	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-10	-19.4	11.1	45.6	16.3	3.3
Ust'-Ilga	UIL_1989.002	H2016.018 S-11	-20.5	12.1	45.2	15.8	3.4
Ust'-Ilga	UIL_1989.003	H2016.020 S-01	-19.0	13.1	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-02	-19.0	11.7	45.8	16.2	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-03	-19.1	11.5	46.0	16.5	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-04	-19.1	11.2	44.9	15.9	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-05	-19.1	11.0	45.9	16.5	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-06	-19.0	10.9	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-07	-19.1	11.1	46.3	16.4	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ilga	UIL_1989.003	H2016.020 S-08	-19.2	11.0	46.0	16.4	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-09	-19.2	11.9	46.0	16.4	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-10	-19.2	12.0	45.7	16.2	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-11	-19.3	12.5	45.5	16.2	3.3
Ust'-Ilga	UIL_1989.003	H2016.020 S-12	-18.8	12.7	45.2	16.0	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-01	-19.4	12.0	46.0	16.6	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-02	-19.0	11.5	46.1	16.6	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-03	-19.1	11.8	45.8	16.3	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-04	-19.1	11.9	46.7	16.8	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-05	-19.1	11.8	46.1	16.4	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-06	-19.3	12.0	46.6	16.7	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-07	-19.4	12.1	46.8	16.6	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-08	-20.0	12.8	45.6	16.2	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-09	-20.0	12.8	45.8	16.4	3.3
Ust'-Ilga	UIL_1989.004	H2016.022 S-10	-19.2	12.1	45.2	16.0	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-01	-20.1	12.1	46.1	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-02	-20.2	11.5	46.2	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-03	-20.1	11.1	46.5	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-04	-20.7	12.0	46.3	16.5	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-05	-20.4	11.2	46.4	16.5	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-06	-20.2	10.8	46.6	16.5	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-07	-20.7	11.5	46.8	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-08	-20.9	11.7	46.5	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-09	-21.0	11.8	46.5	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-10	-21.0	12.0	46.3	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-11	-20.9	12.0	46.2	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-12	-20.3	11.4	46.3	16.4	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-13	-19.7	10.8	45.6	16.0	3.3
Ust'-Ilga	UIL_1989.005	H2016.014 S-15	-20.3	12.2	45.2	15.9	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-01	-20.5	13.2	45.3	16.3	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-03	-19.9	12.1	45.7	16.5	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-04	-20.4	12.5	45.8	16.6	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-05	-20.0	11.7	45.9	16.6	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-06	-20.0	12.0	46.0	16.5	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-07	-20.7	12.3	45.8	16.5	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-08	-20.5	12.3	45.5	16.3	3.3
Ust'-Ilga	UIL_1990.009	H2016.007 S-09	-20.1	12.3	45.4	16.1	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-01	-19.9	12.2	45.6	16.3	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-02	-20.3	12.2	46.3	16.4	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-03	-20.3	12.3	46.7	16.4	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-04	-20.4	12.6	46.3	16.5	3.3

Cemetery	Master_ID	Sample_ID and sample number	^{13}C (‰)	^{15}N (‰)	C%	N%	C:N
Ust'-Ilga	UIL_1990.010	H2016.028 S-05	-20.2	12.2	46.4	16.4	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-06	-20.1	12.1	46.8	16.6	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-07	-20.2	12.3	46.3	16.4	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-08	-20.3	12.9	46.4	16.3	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-09	-20.3	12.9	46.7	16.4	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-10	-20.0	12.9	46.3	16.3	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-11	-20.1	13.1	46.0	16.3	3.3
Ust'-Ilga	UIL_1990.010	H2016.028 S-12	-20.1	13.0	45.8	16.2	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-01	-20.0	12.2	45.7	16.4	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-02	-20.1	11.9	46.1	16.3	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-03	-20.3	12.4	46.2	16.5	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-04	-20.3	12.0	46.2	16.5	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-05	-20.0	11.8	46.3	16.5	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-06	-19.9	11.9	46.2	16.4	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-07	-20.2	12.7	46.4	16.3	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-08	-20.3	13.2	46.1	16.3	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-09	-20.3	14.1	46.0	16.2	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-10	-20.4	13.0	45.7	16.2	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-11	-20.6	13.2	45.5	16.1	3.3
Ust'-Ilga	UIL_1990.011	H2016.010.S-12	-20.5	13.3	45.2	15.8	3.4
Ust'-Ilga	UIL_1990.012	H2016.030 S-01	-19.0	14.5	45.7	16.5	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-02	-19.1	13.4	46.3	16.6	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-03	-19.3	12.4	46.1	16.5	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-04	-19.3	12.4	46.4	16.7	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-05	-19.3	12.0	46.7	16.7	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-06	-19.5	11.4	46.5	16.6	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-07	-19.4	11.1	46.9	17.0	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-08	-19.5	11.3	45.4	16.3	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-09	-19.7	11.5	46.1	16.6	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-10	-19.8	12.1	45.6	16.3	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-11	-19.8	12.2	46.4	16.6	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-12	-19.7	12.2	44.5	16.0	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-13	-19.5	12.2	44.0	15.7	3.3
Ust'-Ilga	UIL_1990.012	H2016.030 S-14	-19.5	12.3	42.1	14.7	3.2
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-01	-19.7	11.6	46.0	16.3	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-02	-19.6	11.5	44.4	15.9	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-03	-19.4	10.8	45.8	16.1	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-04	-19.5	10.7	46.4	16.4	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-05	-19.5	10.5	45.8	16.3	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-06	-19.6	10.7	46.7	16.7	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-07	-20.0	11.3	46.7	16.7	3.3

Cemetery	**Master_ID**	**Sample_ID and sample number**	**^{13}C (‰)**	**^{15}N (‰)**	**C%**	**N%**	**C:N**
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-08	-19.8	11.5	46.0	16.3	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-09	-19.6	11.4	46.1	16.4	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-10	-19.0	10.0	46.3	16.5	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-11	-19.1	10.6	45.3	16.1	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-12	-19.7	12.1	45.8	16.3	3.3
Ust'-Ilga	UIL_1991.013.01	H2016.032 S-13	-19.8	12.3	45.9	16.2	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-01	-20.0	14.9	46.6	16.6	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-02	-19.8	13.7	45.6	16.1	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-03	-19.8	13.6	45.8	16.0	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-04	-19.8	12.8	45.7	16.4	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-05	-19.9	12.8	46.0	16.4	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-06	-20.2	12.7	45.8	16.3	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-07	-20.2	12.8	46.0	16.1	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-08	-20.0	12.5	45.5	16.0	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-09	-19.6	12.3	45.6	16.0	3.3
Ust'-Ilga	UIL_1991.013.02	H2016.009 S-10	-19.9	12.1	44.2	15.5	3.4

Bibliography

Åberg, G. 1995. The use of natural strontium isotopes as tracers in environmental studies. *Water, Air, & Soil Pollution* 79: 309–322.

Åberg, G., G. Jacks, T. Wickman and P.J. Hamilton 1990. Strontium isotopes in trees as an indicator for calcium availability. *Catena* 17: 1–11.

Alekseenko, E.A. 1999. Ket, in R.B. Lee and R. Daly (eds) *The Cambridge Encyclopedia of Hunters and Gatherers*: 156–160. Cambridge: University of Cambridge Press.

AlQahtani, S.J., M.P. Hector and H.M. Liversidge 2010. Brief communication: The London atlas of human tooth development and eruption. *American Journal of Physical Anthropology* 142: 481–490.

Ambrose, S.H. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of Archaeological Science* 17: 431–451.

Ambrose, S.H. 1991. Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs. *Journal of Archaeological Science* 18: 293–317.

Ambrose, S.H. and L. Norr 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate, in J.B. Lambert and G. Grupe (eds) *Prehistoric Human Bone: Archaeology at the Molecular Level*: 1–37. Berlin: Springer-Verlag.

Anderson, D.G. 1999. The Evenki of the lower Enisei Valley, in R.B. Lee and R. Daly (eds) *The Cambridge Encyclopedia of Hunters and Gatherers*: 142–146. Cambridge: University of Cambridge Press.

Antoine, D. and S. Hillson 2016. Enamel structure and properties, in J. Irish and G.R. Scott (eds) *A Companion to Dental Anthropology*: 223–243. Chichester: John Wiley & Sons, Inc.

Argounova-Low, T. 2009. Black food: Subsistence, diet, and exchange in Yessei Yakut Society. *Ethnohistory* 56: 479–507.

Arnold, J.E. 1996. The archaeology of complex hunter-gatherers. *Journal of Archaeological Method and Theory* 3: 77–126.

Austin, C., T.M. Smith, A. Bradman, K. Hinde, R. Joannes-Boyau, D. Bishop, D.J. Hare, P. Doble, B. Eskenazi and M. Arora 2013. Barium distributions in teeth reveal early-life dietary transitions in primates. *Nature* 498: 216–219.

Avery, J.K. 1992. *Essentials of Oral Histology and Embryology: A Clinical Approach*. St. Louis (MO): Mosby-Year Book.

Baxter, J.E. 2005. *The Archaeology of Childhood: Children, Gender, and Material Culture*. Walnut Creek (CA): Altamira Press.

Bazaliiskii, V.I. 2010. Mesolithic and Neolithic mortuary complexes in the Baikal Region, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 51–86. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Beaumont, J., E.C. Atkins, J. Buckberry, H. Haydock, P. Horne, R. Howcroft, K. MacKenzie, and J. Montgomery 2018. Comparing apples and oranges: Why infant bone collagen may not reflect dietary intake in the same way as dentine collagen. *American Journal of Physical Anthropology* 167: 524–540.

Beaumont, J., A. Gledhill, J. Lee-Thorp and J. Montgomery 2013a. Childhood diet: A closer examination of the evidence from dental tissues using stable isotope analysis of incremental human dentine. *Archaeometry* 55: 277–295.

Beaumont, J., A. Gledhill, J. Lee-Thorp and J. Montgomery 2013b. Protocol for sectioning human dentine: Expanded from Methods 1 and 2. Written as a response to questions arising from: Beaumont J., A. Gledhill, J. Lee-Thorp and J. Montgomery. 2013. Childhood diet: A closer examination of the evidence from dental tissues using stable isotope analysis of incremental human dentine. *Archaeometry* 55: 277–295.

Beaumont, J. and J. Montgomery 2015. Oral histories: A simple method of assigning chronological age to isotopic values from human dentine collagen. *Annals of Human Biology* 42: 407–414.

Beaumont, J. and J. Montgomery 2016. The Great Irish Famine: Identifying starvation in the tissues of victims using stable isotope analysis of bone and incremental dentine collagen. *PLoS One* 11: e0160065.

Beaumont, J., J. Montgomery, J. Buckberry and M. Jay 2015. Infant mortality and isotopic complexity: New approaches to stress, maternal health, and weaning. *American Journal of Physical Anthropology* 157: 441–457.

Ben-David, M. and E.A. Flaherty 2012. Stable isotopes in mammalian research: A beginner's guide. *Journal of Mammalogy* 93: 312–328.

Bender, M.M. 1971. Variations in the $^{13}C/^{12}C$ ratios of plants in relation to the pathway of photosynthetic carbon dioxide fixation. *Phytochemistry* 10: 1239–1244.

Bentley, R.A. 2006. Strontium isotopes from the earth to the archaeological skeleton: A review. *Journal of Archaeological Method and Theory* 13: 135–187.

Bergman, I., L. Östlund and O. Zackrisson 2004. The use of plants as regular food in ancient Subarctic economies: A case study based on Sami use of Scots pine innerbark. *Arctic Anthropology* 41: 1–13.

Binford, L.R. 2001. *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. Berkeley: University of California Press.

Bird, D.W. and R. Bliege Bird 2000. The ethnoarchaeology of juvenile foragers: Shellfishing strategies among Meriam children. *Journal of Anthropological Archaeology* 19: 461–476.

Bird, D.W. and R. Bliege Bird 2002. Children on the reef. *Human Nature* 13: 269–297.

Bird-David, N. 2005. Studying children in 'hunter-gatherer' societies: Reflections from a Nayaka perspective, in B.S. Hewlett and M.E. Lamb (eds) *Hunter-Gatherer Childhoods: Evolutionary, Developmental and Cultural Perspectives*: 92–101. Abingdon: Routeledge.

Bliege Bird, R. and D.W. Bird 2002. Constraints of knowing or constraints of growing? *Human Nature* 13: 239–267.

Blurton Jones, N., K. Hawkes and P. Draper 1994. Foraging returns of !Kung adults and children: Why didn't !Kung children forage? *Journal of Anthropological Research* 50: 217–248.

Blurton Jones, N. and F.W. Marlowe 2002. Selection for delayed maturity. *Human Nature* 13: 199–238.

Bocherens, H. and D. Drucker 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: Case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology* 13: 46–53.

Bocherens, H., M. Mashkour, D.G. Drucker, I. Moussa and D. Billiou 2006. Stable isotope evidence for palaeodiets in southern Turkmenistan during Historical period and Iron Age. *Journal of Archaeological Science* 33: 253–264.

Bogin, B. and B.H. Smith 2000. Evolution of the human life cycle, in S. Stinson, B. Bogin and D. O'Rourke (eds) *Human Biology: An Evolutionary and Biocultural Perspective*: 377–424. New York (NY): Wiley-Liss.

Bonafini, M., M. Pellegrini, P. Ditchfield and A.M. Pollard 2013. Investigation of the 'canopy effect' in the isotope ecology of temperate woodlands. *Journal of Archaeological Science* 40: 3926–3935.

Bourbou, C., B.T. Fuller, S.J. Garvie-Lok and M.P. Richards 2013. Nursing mothers and feeding bottles: Reconstructing breastfeeding and weaning patterns in Greek Byzantine populations (6th–15th centuries AD) using carbon and nitrogen stable isotope ratios. *Journal of Archaeological Science* 40: 3903–3913.

Boutton, T.W., P.D. Klein, M.J. Lynott, J.E. Price and L.L. Tieszen 1984. Stable carbon isotope ratios as indicators of prehistoric human diet, in J.R. Turnland and P.E. Johnson (eds) *Stable Isotopes in Nutrition* (ACS Symposium Series): 191–204. Washington (DC): American Chemical Society.

Brill, W.J. 1977. Biological nitrogen fixation. *Scientific American* 236: 68–81.

Brown, T.A., D.E. Nelson, J.S. Vogel and J.R. Southon 1988. Improved collagen extraction by modified Longin method. *Radiocarbon* 30: 171–177.

Budd, P., J. Montgomery, B. Barreiro and R.G. Thomas 2000. Differential diagenesis of strontium in archaeological human dental tissues. *Applied Geochemistry* 15: 687–694.

Buikstra, J.E., L.W. Konigsberg and J. Bullington 1986. Fertility and the development of agriculture in the prehistoric Midwest. *American Antiquity* 51: 528–546.

Buikstra, J.E. and D.H. Ubelaker 1994. *Standards for Data Collection from Human Skeletal Remains* (Arkansas Archeological Survey Research Series 44). Fayetteville: Arkansas Archeological Survey.

Burt, N.M. and M. Amin 2014. A mini me? Exploring early childhood diet with stable isotope ratio analysis using primary teeth dentin. *Archives of Oral Biology* 59: 1226–1232.

Burt, N.M. and S. Garvie-Lok 2013. A new method of dentine microsampling of deciduous teeth for stable isotope ratio analysis. *Journal of Archaeological Science* 4: 3854–3864.

Calvin, M. and A.A. Benson 1948. The path of carbon in photosynthesis. *Science* 107: 476–480.

Cardoso, H.F. 2007a. Accuracy of developing tooth length as an estimate of age in human skeletal remains: The deciduous dentition. *Forensic Science International* 172: 17–22.

Cardoso, H.F. 2007b. Environmental effects on skeletal versus dental development: Using a documented subadult skeletal sample to test a basic assumption in human osteological research. *American Journal of Physical Anthropology* 132: 223–233.

Caut, S., E. Angulo and F. Courchamp 2009. Variation in discrimination factors ($\Delta^{15}N$ and $\Delta^{13}C$): The effect of diet isotopic values and applications for diet reconstruction. *Journal of Applied Ecology* 46: 443–453.

Cheung, C., Z. Jing, J. Tang, D.A. Weston and M.P. Richards 2017. Diets, social roles, and geographical origins of sacrificial victims at the royal cemetery at Yinxu, Shang China: New evidence from stable carbon, nitrogen, and sulfur isotope analysis. *Journal of Anthropological Archaeology* 48: 28–45.

Chisholm, B.S. 1989. Variation in diet reconstructions based on stable carbon isotopic evidence, in T.D. Price (ed.) *The Chemistry of Prehistoric Human Bone*: 10–37. Cambridge: Cambridge University Press.

Chisholm, B.S., D.E. Nelson and H.P. Schwarcz 1982. Stable-carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets. *Science* 216: 1131–1132.

Chisholm, B.S., D.E. Nelson, K.A. Hobson, H.P. Schwarcz and M. Knyf 1983. Carbon isotope measurement techniques for bone collagen: Notes for the archaeologist. *Journal of Archaeological Science* 10: 355–360.

Conceição, E.L.N. and H.F.V. Cardoso 2011. Environmental effects on skeletal versus dental development II: Further testing of a basic assumption in human osteological research. *American Journal of Physical Anthropology* 144: 463–470.

Coplen, T.B. 1994. Reporting of stable hydrogen, carbon, and oxygen isotopic abundances (technical report). *Pure and Applied Chemistry* 66: 273–276.

Cox, G. and J. Sealy 1997. Investigating identity and life history: Isotopic analysis and historical documentation of slave skeletons found in the Cape Town foreshore, South Africa. *International Journal of Historical Archaeology* 1: 207–224.

Cunningham, A.S. 1995. Breast-feeding: Adaptive behavior for child health and longevity, in P. Stuart-Macadam and K.A. Dettwyler (eds) *Breastfeeding: Biocultural Perspectives*: 243–264. Hawthorne (NY): Aldine de Gruyter.

Czermak, A., L. Schermelleh and J. Lee-Thorp 2018. Imaging-assisted time-resolved dentine sampling to track weaning histories. *International Journal of Osteoarchaeology* 28: 535–541.

Dean, M.C. 2006. Tooth microstructure tracks the pace of human life-history evolution. *Proceedings of the Royal Society B* 273: 2799–2808.

Dean, M.C. 2009. Extension rates and growth in tooth height of modern human and fossil hominin canines and molars, in T. Koppe, G. Meyer and K.W. Alt (eds) *Comparative Dental Morphology* (Frontiers of Oral Biology 13): 68–73. Basel: Reinhardt Druck.

Dean, M.C., A.D. Beynon, D.J. Reid and D.K. Whittaker 1993. A longitudinal study of tooth growth in a single individual based on long-and short-period incremental markings in dentine and enamel. *International Journal of Osteoarchaeology* 3: 249–264.

Dean, M.C. and A.E. Scandrett 1995. Rates of dentine mineralization in permanent human teeth. *International Journal of Osteoarchaeology* 5: 349–358.

Dean, M.C. and A.E. Scandrett 1996. The relation between long-period incremental markings in dentine and daily cross-striations in enamel in human teeth. *Archives of Oral Biology* 41: 33–241.

Deines, P. 1980. The isotopic composition of reduced organic carbon, in P. Fritz and J.C. Fontes (eds) *Handbook of Environmental Isotope Geochemistry, Volume 1*: 329–406. Amsterdam: Elsevier.

Demirjian A., H. Goldstein and J.M. Tanner 1973. A new system of dental age assessment. *Human Biology* 45: 211–227.

Demske, D., G. Heumann, W. Granoszewski, M. Nita, K. Mamakowa, P.E. Tarasov and H. Oberhänsli 2005. Late glacial and Holocene vegetation and regional climate variability evidenced in high-resolution pollen records from Lake Baikal. *Global and Planetary Change* 46: 255–279.

DeNiro, M.J. 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317: 806–809.

DeNiro, M.J. and S. Epstein 1977. Mechanism of carbon isotope fractionation associated with lipid synthesis. *Science* 197: 261–263.

DeNiro, M.J. and S. Epstein 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et Cosmochimica Acta* 45: 341–351.

DeNiro, M.J. and M.J. Schoeninger 1983. Stable carbon and nitrogen isotope ratios of bone collagen: Variations within individuals, between sexes, and within populations raised on monotonous diets. *Journal of Archaeological Science* 10: 199–203.

DeNiro, M.J., M.J. Schoeninger and C.A. Hastorf 1985. Effect of heating on the stable carbon and nitrogen isotope ratios of bone collagen. *Journal of Archaeological Science* 12: 1–7.

Dettwyler, K. and C. Fishman 1992. Infant feeding practices and growth. *Annual Review of Anthropology* 21: 171–204.

Dewey, K.G. 2013. The challenge meeting nutrient needs on infants and young children during the period of complementary feeding: An evolutionary perspective. *The Journal of Nutrition* 143: 2050–2054.

Doi, H., F. Akamatsu and A.L. González 2017. Starvation effects on nitrogen and carbon stable isotopes of animals: An insight from meta-analysis of fasting experiments. *Royal Society Open Science* 4: 170633.

Dori, I., E. Orellana Gonzales, G. Goude, A. Varalli, J. Moggi-Cecchi and V.S. Sparacello 2019. *Investigating patterns of growth disturbances in a Neolithic sample from Liguria (northwestern Italy, 4800-4400 BCE) from the analysis of enamel defects and diet*. [Poster]. 88th Annual Meeting of the American Association of Physical Anthropologists, 27–30 March, Cleveland (OH).

Drucker, D.G., A. Bridault, K.A. Hobson, E. Szuma and H. Bocherens 2008. Can carbon-13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. *Palaeogeography, Palaeoclimatology, Palaeoecology* 266: 69–82.

Dupras, T.L., H.P. Schwarcz and S.I. Fairgrieve 2001. Infant feeding and weaning practices in Roman Egypt. *American Journal of Physical Anthropology* 115: 204–212.

Dupras, T.L. and M.W. Tocheri 2007. Reconstructing infant weaning histories at Roman period Kellis, Egypt using stable isotope analysis of dentition. *American Journal of Physical Anthropology* 134: 63–74.

Eerkens, J.W. 1999. Common pool resources, buffer zones, and jointly owned territories: Hunter-gatherer land and resource tenure in Fort Irwin, Southeastern California. *Human Ecology* 27: 297–318.

Eerkens, J.W. and E.J. Bartelink 2013. Sex-biased weaning and early childhood diet among Middle Holocene hunter-gatherers in Central California. *American Journal of Physical Anthropology* 152: 471–483.

Eerkens, J.W., A.G. Berget and E.J. Bartelink 2011. Estimating weaning and early childhood diet from serial micro-samples on dentin collagen. *Journal of Archaeological Science* 38: 3101–3111.

Eerkens, J.W., B. Hull, J. Goodman, A. Evoy, J.D. Kapp, S. Hussain and R.E. Green 2017. Stable C and N isotope analysis of hair suggest undernourishment as a factor in the death of a mummified girl from late 19th century San Francisco, CA. *PloS One* 12: e0184921.

Eerkens, J.W., K. Sullivan and A.M. Greenwald 2016. Stable isotope analysis of serial samples of third molars as insight into inter- and intra-individual variation in ancient diet. *Journal of Archaeological Science: Reports* 5: 656–663.

Elamin, F. and H.M. Liversidge 2013. Malnutrition has no effect on the timing of human tooth formation. *PloS One* 8: e72274.

Ericson, J. E. 1989. Some problems and potentials for strontium isotope analysis for human and animal ecology, in P.W. Rundel, J.R. Ehleringer and K.A. Nagy (eds) *Stable Isotopes in Ecological Research*: 252–259. New York (NY): Springer Verlag.

Fédération Dentaire Internationale 1971. Two-digit system of designating teeth. *International Dental Journal* 21: 104–106.

Fernandes, R., J. Meadows, A. Dreves, M-J. Nadeau and P. Grootes 2014a. A preliminary study on the influence of cooking on the C and N isotopic composition of multiple organic fractions of fish (mackerel and haddock). *Journal of Archaeological Science* 50: 153–159.

Fernandes, R., A.R. Millard, M. Brabec, M-J. Nadeau and P. Grootes 2014b. Food reconstruction using isotopic transferred signals (FRUITS): A Bayesian model for diet reconstruction. *PloS One* 9: e87436.

FitzGerald, C.M. 1998. Do enamel microstructures have regular time dependency? Conclusions from the literature and a large-scale study. *Journal of Human Evolution* 35: 371–386.

Fitzhugh, B. 2003. *The Evolution of Complex Hunter-Gatherers.* Boston (MA): Springer.

Fogel, M.L. and N. Tuross 2003. Extending the limits of paleodietary studies of humans with compound specific carbon isotope analysis of amino acids. *Journal of Archaeological Science* 30: 535–545.

Fogel, M.L., N. Tuross and D.W. Owsley 1989. Nitrogen isotope tracers of human lactation in modern and archaeological populations, in *Annual Report of the Director, Geophysical Laboratory, 1988–1989*: 111–117. Washington (DC): Carnegie Institution of Washington.

Fraser-Shapiro, I. 2012. Studying Hunter-Gatherer Mobility Using Isotopic and Trace Elemental Analysis. Unpublished PhD dissertation, University of Alberta.

Fratzl, P. 2008. Collagen: Structure and mechanics, an introduction, in P. Fratzl (ed.) *Collagen*: 1–13. Boston (MA): Springer.

Fuller, B.T., J.L. Fuller, D.A. Harris, and R.E.M. Hedges 2006. Detection of breastfeeding and weaning in modern human infants with carbon and nitrogen stable isotope ratios. *American Journal of Physical Anthropology* 129: 279–293.

Fuller, B.T., J.L. Fuller, N.E. Sage, D.A. Harris, T.C. O'Connell and R.E.M. Hedges 2004. Nitrogen balance and d^{15}N: Why you're not what you eat during pregnancy. *Rapid Communications in Mass Spectrometry* 18: 2889–2896.

Fuller, B.T., J.L. Fuller, N.E. Sage, D.A. Harris, T.C. O'Connell and R.E.M. Hedges 2005. Nitrogen balance and d^{15}N: Why you're not what you eat during nutritional stress. *Rapid Communications in Mass Spectrometry* 19: 2497–2506.

Fuller, B.T., M.P. Richards and S.A. Mays 2003. Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy. *Journal of Archeological Science* 30: 1673–1684.

Gaur, R. and P. Kumar 2012. Effect of undernutrition on deciduous tooth emergence among Rajput children of Shimla District of Himachal Pradesh, India. *American Journal of Physical Anthropology* 148: 54–61.

Giller, P.S. and B. Malmqvist 1998. *The Biology of Streams and Rivers*. Oxford: Oxford University Press.

Goldman, C.R., J.J. Elser, R.C. Richards, J.E. Reuters, J.C. Priscu and A.L. Levin 1996. Thermal stratification, nutrient dynamics, and phytoplankton productivity during the onset of spring phytoplankton growth in Lake Baikal, Russia. *Hydrobiologia* 331: 9–24.

Greenwald, A.M., J.W. Eerkens and E.J. Bartelink 2016. Stable isotope evidence of juvenile foraging in prehistoric Central California. *Journal of Archaeological Science: Reports* 7: 146–154.

Guiry, E.J., J.C. Hepburn and M.P. Richards 2016a. High-resolution serial sampling for nitrogen stable isotope analysis of archaeological mammal teeth. *Journal of Archaeological Science* 69: 21–28.

Guiry, E.J., P. Szpac and M.P. Richards 2016b. Effects of lipid extraction and ultrafiltration on stable carbon and nitrogen isotopic compositions of fish bone collagen. *Rapid Communications in Mass Spectrometry* 30: 1591–1600.

Gurven, M., H. Kaplan and M. Gutierrez 2006. How long does it take to become a proficient hunter? Implications for the evolution of extended development and long life span. *Journal of Human Evolution* 51: 454–470.

Gustafson, G. and G. Koch 1974. Age estimation up to 16 years of age based on dental development. *Odontologisk revy* 25: 297–306.

Haavikko, K. 1970. The formation and the alveolar and clinical eruption of the permanent teeth. An orthopantomograhic study. *Suom Hammaslaak Toim* 66: 101–112.

Halcrow, S.E. and N. Tayles 2008. The bioarchaeological investigation of childhood and social age: Problems and prospects. *Journal of Archaeological Method and Theory* 15: 190–215.

Hammond, G. and N. Hammond 1981. Child's play: A distorting factor in archaeological distribution. *American Antiquity* 46: 634–636.

Hare, P.E., M.L. Fogel, T.W. Stafford Jr, A.D. Mitchell and T.C. Hoering 1991. The isotopic composition of carbon and nitrogen in individual amino acids isolated from modern and fossil proteins. *Journal of Archaeological Science* 18: 277–292

Hatch, K.A., M.A. Crawford, A.W. Kunz, S.R. Thomsen, D.L. Eggett, S.T. Nelson and B.L. Roeder 2006. An objective means of diagnosing anorexia nervosa and bulimia nervosa using $^{15}N/^{14}N$ and $^{13}C/^{12}C$ ratios in hair. *Rapid Communications in Mass Spectrometry* 20: 3367–3373.

Hatch, M.D. and C.R. Slack 1966. Photosynthesis by sugar-cane leaves: A new carboxylation reaction and the pathway of sugar formation. *Biochemical Journal* 101: 103–111.

Haverkort, C.M., V.I. Bazaliiskii and N.A. Savel'ev 2010. Identifying hunter-gatherer mobility patterns using strontium isotopes, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 217–242. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Haverkort, C.M., A. Weber, M.A. Katzenberg, O.I. Goriunova, A. Simonetti and R.A. Creaser 2008. Hunter-gatherer mobility strategies and resource use based on strontium isotope ($^{87}Sr/^{86}Sr$) analysis: A case study from Middle Holocene Lake Baikal, Siberia. *Journal of Archaeological Science* 35: 1265–1280.

Hawkes, K., J.F. O'Connell and N.B. Jones 1995. Hadza children's foraging: Juvenile dependency, social arrangements, and mobility among hunter-gatherers. *Current Anthropology* 36: 688–700.

Hawkes, K., J.F. O'Connell and N.B. Jones 2001. Hadza meat sharing. *Evolution and Human Behavior* 22: 113–142.

Hayden, B. 2009. Funerals as feasts: Why are they so important? *Cambridge Archaeological Journal* 19: 29–52.

Hedges, R.E.M., J.G. Clement, D.L. Thomas and T.C. O'Connell 2007. Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* 133: 808–816.

Henderson, R.C., J. Lee-Thorp and L. Loe 2014. Early life histories of the London poor using $\delta^{13}C$ and $\delta^{15}N$ stable isotope incremental dentine sampling. *American Journal of Physical Anthropology* 154: 471–644.

Herring, D.A., S.R. Saunders and M.A. Katzenberg 1998. Investigating the weaning process in past populations. *Journal of Physical Anthropology* 105: 425–439.

Hewlett, B.S. and M.E. Lamb (eds) 2005a. Hunter-Gatherer Childhoods. *Hunter-Gatherer Childhoods: Evolutionary, Developmental and Cultural Perspectives*. Abingdon: Routeledge.

Hewlett, B.S. and M.E. Lamb 2005b. Emerging Issues in the Study of Hunter-Gatherer Children, in B.S. Hewlett and M.E. Lamb (eds) *Hunter-Gatherer Childhoods: Evolutionary, Developmental, and Cultural Perspectives*: 3–18. Abingdon: Routeledge.

Hill, K. and H. Kaplan 1999. Life history traits in humans: Theory and empirical studies. *Annual Review of Anthropology* 28: 397–430.

Hillson, S. 1996. *Dental Anthropology*. Cambridge: Cambridge University Press.

Hillson, S. 2005. *Teeth*. Cambridge: Cambridge University Press.

Hillson, S. 2014. *Tooth Development in Human Evolution and Bioarchaeology*. Cambridge: Cambridge University Press.

Hobson, K.A., R.T. Alisauskas and R.G. Clark 1993. Stable-Nitrogen Isotope Enrichment in Avian Tissues Due to Fastening and Nutritional Stress: Implications for Isotopic Analysis of Diet. *The Condor* 95: 388–394.

Hobson, K.A. and R.G. Clark 1992. Assessing Avian Diets Using Stable Isotopes I: Turnover of ^{13}C in Tissues. *The Condor* 94: 181–188.

Hoefs, J. 2009. *Stable Isotope Geochemistry* (6th edition). Berlin: Springer-Verlag.

Huh, Y., D. Coleman and J. Edmond 1994. ^{87}Sr/^{86}Sr in Siberian Rivers, EOS. *Transactions of American Geophysical Union* 75: 142.

Hut, G. 1987. *Consultants' Group Meeting on Stable Isotope Reference Samples for Geochemical and Hydrological Investigations, September 16–18, 1985: Report to the Director General.* Vienna: International Atomic Energy Agency (IAEA).

Ip, S., M. Chung, G. Raman, P. Chew, N. Magula, D. DeVine, T. Trikalinos and J. Lau 2007. *Breastfeeding and Maternal and Infant Health Outcomes in Developed Countries* (Evidence Report/Technology Assessment 153). Rockville (MD): Agency for Healthcare Research and Quality.

Jarvis, A., H.I. Reuter, A. Nelson and E. Guevara 2008. Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database, viewed 10 September 2019, <https://srtm.csi.cgiar.org>.

Jochelson, W. 1908. The Koryak (Publications of the Jesup North Pacific Expedition 6, Parts 1-2; Memoirs of the American Museum of Natural History 10) Leiden: E.J. Brill Ltd.

Kamp, K.A. 2001. Where have all the children gone?: The archaeology of childhood. *Journal of Archaeological Method and Theory* 8: 1–34.

Katzenberg, M.A. 1989. Stable isotope analysis of archaeological faunal remains from southern Ontario. *Journal of Archaeological Science* 16: 319–329.

Katzenberg, M.A. 2008. Stable isotope analysis: A tool for studying past diet, demography, and life history, in M.A. Katzenberg and S.R. Saunders (eds) *Biological Anthropology of the Human Skeleton*: 413–442. Hoboken (NJ): John Wiley & Sons, Inc.

Katzenberg, M.A., V.I. Bazaliiskii, O.I. Gorinuova, N.A. Savel'ev and A.W. Weber 2010. Diet Reconstruction of Prehistoric Hunter-Gatherers, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 175–191. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Katzenberg, M.A., O.I. Goriunova and A.W. Weber 2009., Paleodiet reconstruction of Early Bronze Age Siberians from the site of Khuzhir-Nuge XIV, Lake Baikal. *Journal of Archaeological Science* 36: 663–674.

Katzenberg, M.A. and N.C. Lovell 1999. Stable isotope variation in pathological bone. *International Journal of Osteoarchaeology* 9: 316–324.

Katzenberg, M.A., H.G. McKenzie, R.J. Losey, O.I. Goriunova and A.W. Weber 2012. Prehistoric dietary adaptations among hunter-fisher-gatherers from the Little Sea of Lake Baikal, Siberia, Russian Federation. *Journal of Archaeological Science* 39: 2612–2626.

Katzenberg, M.A. and S. Pfeiffer 1995. Nitrogen isotope evidence for weaning age in a nineteenth century Canadian skeletal sample, in A.L. Grauer (ed.) *Bodies of Evidence: Reconstructing History Through Skeletal Analysis*: 221–236. New York (NY): Wiley-Liss.

Katzenberg, M.A., S.R. Saunders and S. Abonyi 2002. Bone chemistry, food and history: A case study from 19th century Upper Canada, in S.H. Ambrose and M.A. Katzenberg (eds) *Biogeochemical Approaches to Paleodietary Analysis*: 1–22. Boston(MA): Springer.

Katzenberg, M.A., S.R. Saunders and W.R. Fitzgerald 1993. Age differences in stable carbon and nitrogen isotopes ratios in a population of prehistoric maize horticulturalists. *American Journal of Physical Anthropology* 90: 267–281.

Katzenberg, M.A., H.P. Schwarcz, M. Knyf and F.J. Melbye 1995. Stable Isotope Evidence for Maize Horticulture and Paleodiet in Southern Ontario, Canada. *American Antiquity* 60: 335–350.

Katzenberg, M.A. and A. Weber 1999. Stable Isotope Ecology and Palaeodiet in the Lake Baikal Region of Siberia. *Journal of Archaeological Science* 26: 651–659.

Kawasaki, K., S. Tanaka and T. Ishikawa 1980. On the daily incremental lines in human dentine. *Archives of Oral Biology* 24: 939–943.

Keeling, C.D., W.G. Mook and P.P. Tans 1979. Recent trends in the $^{13}C/^{12}C$ ratio of atmospheric carbon dioxide. *Nature* 277: 121–123.

Kelly, R.L. 2013. *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*. Cambridge: Cambridge University Press.

Kendall, C., A.M.H. Eriksen, I. Kontopoulos, M.J. Collins and G. Turner-Walker 2018. Diagenesis of archaeological bone and tooth. *Palaeogeography, Palaeoclimatology, Palaeoecology* 491: 21–37.

King, C.L., S.E. Halcrow, A.R. Millard, D.R. Gröcke, V.G. Standen, M. Portilla and B.T. Arriaza 2018a. Let's talk about stress, baby! Infant-feeding practices and stress in the ancient Atacama Desert, Northern Chile. *Journal of Physical Anthropology* 166: 139–155.

King, C.L., A.R. Millard, D.R. Gröcke, V.G. Standen, B.T. Arriaza and S.E. Halcrow 2018b. A comparison of using bulk and incremental isotopic analyses to establish weaning practices in the past. *STAR: Science & Technology of Archaeological Research* 3: 126–134.

Kiyashko, S.I., P. Richard, T. Chandler, T.A. Kozlova and D.F. Williams 1998. Stable carbon isotope ratios differentiate autotrophs supporting animal diversity in Lake Baikal. *Comptes Rendus de l'Académie des Sciences-Series III-Sciences de la Vie* 321: 509–516.

Konopatskii, A.K. 1977. Drevnii mogil'nik u sela Manzurka [An ancient cemetery at the Manzurka settlement]. *Izvestia SO AN SSSR, Seriia obshchestvennykh nauk* 1: 71–76.

Kozhov, M.M. 1950. *Presnye vody Vostochnoi Sibiri (Bassein Baikala, Angary, Vitima, Verkhnego Techenia Leny I Nizhnei Tunguski) [Fresh Waters of Eastern Siberia (the Baikal Basin, Angara, Vitim, Upper Lena and Lower Tunguska)]*. Irkutsk: Irkutskoe oblastnoe gosudarstvennoe izdatel'stvo.

Kozhov, M.M. 1963. *Lake Baikal and its Life*. The Hague: Dr. W. Junk Publishers.

Kozhov, M.M. 1972. *Ocherki po Baikalovedeniiu [Essays on Baikal Studies]*. Irkutsk: Vostochno-Sibirskoe knizhnoe izdatel'stvo.

Kozhova, O.M. and L.R. Izmest'eva 1998. *Lake Baikal: Evolution and Biodiversity*. Leiden: Backhuys Publishers.

Kwok, C.S. 2015. Moving Beyond Childhood: Reconstructing Dietary Life Histories of Bronze Age and Byzantine Greeks using Stable Isotope Analysis of Dental and Skeletal Remains. Unpublished PhD dissertation, University of Calgary.

Krueger, H.W. and C.H. Sullivan 1984. Models for carbon isotope fractionation between diet and bone. *Stable Isotopes in Nutrition* 258: 205–220.

Lam, Y.M. 1994. Isotopic Evidence for Change in Dietary Patterns During the Baikal Neolithic. *Current Anthropology* 35: 185–190.

Lancy, D.F. 2015. *The Anthropology of Childhood: Cherubs, Chattel, Changelings* (2nd edition). Cambridge: Cambridge University Press.

Larsen, C.S. 1997. *Bioarchaeology: Interpreting Behavior from the Human Skeleton*. Cambridge: Cambridge University Press.

Lawrence, R.A. and R.M. Lawrence 2010. *Breastfeeding: A Guide for the Medical Professional* (7th edition). Maryland Heights (MO): Elsevier Mosby.

Lee, R.B. and I. DeVore 1968. *Man the Hunter*. New York (NY): Aldinde de Gruyter.

Lee-Thorp, J.A. 2008. On isotopes and old bones. *Archaeometry* 50: 925–950.

Libby, W.F. 1955. *Radiocarbon Dating* (2nd edition). Chicago (IL): University of Chicago Press.

Liden, K., C. Takahashi and D. Erle Nelson 1995. The effects of lipids in stable carbon isotope analysis and the effects of NaOH treatment on the composition of extracted bone collagen. *Journal of Archeological Science* 22: 321–326.

Lieverse, A.R. 2007. Human osteological evidence: Demography and health, in A.W. Weber, M.A. Katzenberg and O.I. Goriunova (eds) *Khuzhir-Nuge XIV, a Middle Holocene Hunter-Gatherer Cemetery in the Cis-Baikal, Siberia: Osteological Materials* (Northern Hunter-Gatherers Research Series 3): 233–252. Edmonton: Canadian Circumpolar Institute Press.

Lieverse, A.R. 2010. Health and behavior in the mid-Holocene Cis-Baikal: Biological indicators of hunter-gatherer adaptation and cultural change, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 135–173. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Lieverse, A.R. 2012. Human osteological evidence: Health, activity, and demography, in A.W. Weber, O.I. Goriunova, H.G. McKenzie and A.R. Lieverse (eds) *Kurma XI, a Middle Holocene Hunter-Gatherer Cemetery on Lake Baikal, Siberia: Archaeological and Osteological Materials* (Archaeology in China and East Asia 3; Northern Hunter-Gatherers Research Series 6): 173–202. Edmonton: Canadian Circumpolar Institute Press.

Link, D.W. 1999. Boreal forest hunter-gatherer demography and health during the middle Holocene of the Cis-Baikal, Siberia. *Arctic Anthropology* 36: 51–72.

Liversidge, H.M. 2008. Timing of human mandibular third molar formation. *Annals of human biology* 35: 294–321.

Logan, W.H. and R. Kronfeld 1933. Development of the human jaws and surrounding structures from birth to the age of fifteen years. *Journal of the American Dental Association* 203: 379–428.

Longin, R. 1971. New method of collagen extraction for radiocarbon dating. *Nature* 230: 241–242.

Losey, R.J., V.I. Bazaliiskii, A.R. Lieverse, A. Waters-Rist, K. Faccia and A.W. Weber 2014. The bear-able likeness of being: Ursine remains at the Shamanka II cemetery, Lake Baikal, Siberia, in C. Watts (ed.) *Relational Archaeologies: Humans, Animals, Things*: 65–96. London: Routledge.

Losey, R.J., S. Garvie-Lok, J.A. Leonard, M.A. Katzenberg, M. Germonpré, T. Nomokonova, M.V. Sablin, O.I. Goriunova, N.E. Berdnikova and N.A. Savel'ev 2013. Burying dogs in ancient Cis-Baikal, Siberia: Temporal trends and relationships with human diet and subsistence practices. *PLoS One* 8: e63740.

Losey, R.J., E. Jessup, T. Nomokonova and M. Sablin 2011. Craniomandibular trauma and tooth loss in northern dogs and wolves: Implications for the archaeological study of dog husbandry and domestication. *PLoS One* 9: e99746.

Losey, R.J. and T. Nomokonova 2017. Background, methods, and questions posed, in R.J. Losey and T. Nomokonova (eds) *Holocene Zooarchaeology of Cis-Baikal* (Archaeology in China and East Asia 7; Northern Hunter-Gatherers Research Series 7): 5–14. Darmstadt: Verlag Philipp von Zabern.

Losey, R.J., T. Nomokonova and O.I. Goriunova 2008. Fishing ancient Lake Baikal: inferences from the reconstruction of harvested perch (Perca fluviatilis) size at Ityrkhei, Siberia. *Journal of Archaeological Science* 35: 577–590.

Losey, R.J., T. Nomokonova and N.A. Savel'ev 2016. Humans and animals at Bugul'deika II, a Trans-Holocene habitation site on the shore of Lake Baikal, Russia. *Quaternary International* 419: 62–73.

Losey, R.J., T. Nomokonova and D. White 2012. Fish and fishing in Holocene Cis-Baikal, Siberia: a review. *The Journal of Island and Coastal Archaeology* 7: 126–145.

Malainey, M.E. 2011. *A Consumer's Guide to Archaeological Science: Analytical Techniques* (Manuals in Archaeological Method, Theory and Technique). New York (NY): Springer.

McKenzie, H.G. 2006. Mortuary Variability Among Middle Holocene Hunter-Gatherers in the Lake Baikal Region of Siberia, Russia. Unpublished PhD dissertation, University of Alberta.

McKenzie, H.G. 2010. Variability in Bronze Age mortuary practices in the Little Sea microregion of Cis-Baikal, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 87–106. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

McKenzie, H.G., A.W. Weber and O.I. Goriunova 2008. Mortuary variability at the Late Neolithic-Early Bronze Age cemetery Khuzhir-Nuge XIV in Cis-Baikal, Siberia, in A.W. Weber, O.I. Goriunova and H.G. McKenzie (eds) *Khuzhir-Nuge XIV, a Middle Holocene hunter-gatherer cemetery on Lake Baikal, Siberia: Archaeological Materials* (Northern Hunter-Gatherers Research Series 4): 219–266. Edmonton: Canadian Circumpolar Institute Press.

Mekota, A.M., G. Grupe, S. Ufer and U. Cuntz 2006. Serial analysis of stable nitrogen and carbon isotopes in hair: Monitoring starvation and recovery phases of patients suffering from anorexia nervosa. *Rapid Communications in Mass Spectrometry* 20: 1604–1610.

Michael, H.N. 1958. The Neolithic Age in Eastern Siberia. *Transactions of the American Philosophical Society* 48: 1–108.

Miller, A. 1984. Collagen: The organic matrix of bone. *Philosophical Transactions of the Royal Society* 304: 455–477.

Minagawa, M. and E. Wada 1984. Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between δ^{15}N and animal age. *Geochimica et Cosmochimica Acta* 48: 1135–1140.

Molleson, T., M. Cox, A.H. Waldron and D.K. Whittaker 1993. *The Spitalfields Project, Volume 2: The Anthropology. The Middling Sort* (Council for British Archaeology Research Reports 86). York: Council for British Archaeology.

Mooder, K.P., T.G. Schurr, F.J. Bamforth, V.I. Bazaliiski and N.A. Savel'ev 2006. Population affinities of Neolithic Siberians: A snapshot from prehistoric Lake Baikal. *American Journal of Physical Anthropology* 129: 349–361.

Mooder, K.P., T.A. Thomson, A.W. Weber, V.I. Bazaliiskii and F. Bamforth 2010. Uncovering the genetic landscape of prehistoric Cis-Baikal, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 107–119. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Moorrees, C.F., E.A. Fanning and E.E. Hunt Jr 1963. Age variation of formation stages for ten permanent teeth. *Journal of Dental Research* 42: 1490–1502.

Mithen, S.J. and S.R. Mithen 1990. *Thoughtful Foragers: A Study of Prehistoric Decision Making*. Cambridge: Cambridge University Press.

Moussa, N.M., V.I. Bazaliiskii, O.I. Goriunova, F. Bamforth and A.W. Weber 2018. Y-chromosomal DNA analyzed for four prehistoric cemeteries from Cis-Baikal, Siberia. *Journal of Archaeological Science: Reports* 17: 932–942.

Nanci, A. 2018. *Ten Cate's Oral Histology: Development, Structure, and Function* (9th edition). St Louis (MO): Elsevier.

Neuberger, F.M., E. Jopp, M. Graw, K. Püschel and G. Grupe 2013. Signs of malnutrition and starvation—reconstruction of nutritional life histories by serial isotopic analyses of hair. *Forensic Science International* 226: 22–32.

Nomokonova, T., R.J. Losey, O.I Goriunova, A.G. Novikov and A.W. Weber 2015. A 9,000-year history of seal hunting on Lake Baikal, Siberia: The zooarchaeology of Sagan-Zaba II. *PloS One* 10: e0128314.

Nomokonova, T., R.J. Losey, V.N. Iakunaeva, I.A. Emel'ianova, E.A. Baginova and M.V. Pastukhov 2013. People and seals at Siberia's Lake Baikal. *Journal of Ethnobiology* 33: 259–280.

Nomokonova, T., R.J. Losey, A. Weber, O.I. Goriunova and A.G. Novikov 2010. Late Holocene subsistence practices among Cis-Baikal pastoralists, Siberia: Zooarchaeological insights from Sagan-Zaba II. *Asian Perspectives* 49: 157–179.

O'Connell, T.C., C.J. Kneale, N. Tasevska and G.G.C. Kuhnle 2012. The diet-body offset in human nitrogen isotopic values: A controlled dietary study. *American Journal of Physical Anthropology* 149: 426–434.

Ohnuki-Tierney, E. 1974. *The Ainu of the Northwest Coast of Southern Sakhalin*. New York (NY): Holt, Rinehart and Winston.

Okladnikov, A.P. 1946. *Lenskiye Drevnosti, Vyp. 2 [Antiquities of the Lena, Part 2]*. Yakutsk: Yakut Gos. Tipografiya.

Okladnikov, A.P. 1950. *Neolit i Bronzovyi vek Pribaikal'ia (Chast' I i II) [The Neolithic and Bronze Age of the Cis-Baikal (Part I and II)]* (Materialy i Issledovaniia po Arkheologii SSSR 18). Moscow: Izdatel'stvo Akademii nauk SSSR.

Okladnikov, A.P. 1955. *Neolit i Bronzovyi vek Pribaikal'ia (Chast' III) [The Neolithic and Bronze Age of the Cis-Baikal (Part III)]* (Materialy i Issledovaniia po Arkheologii SSSR 43). Moscow: Izdatel'stvo Akademii nauk SSSR.

Okladnikov, A.P. 1961. The Paleolithic of Trans-Baikal. *American Antiquity* 26: 486–497.

Okladnikov, A.P. 1964. Ancient population of Siberia and its cultures, in M.G. Levin and L.P. Potapov (eds) *The Peoples of Siberia*: 13–98. Chicago: University of Chicago Press.

Okladnikov, A.P. 1971. *Arkheologicheskie Issledovaniia v Verkhov'iakh R. Leny v 1971 [Archaeological Fieldwork on the Upper Lena in 1971]* (Field Report No. R-1, 4485). Leningrad: LOIA USSR Academy of Sciences.

Okladnikov, A.P. and A.K. Konopatskii 1975. Hunters for seal on the Baikal Lake in the Stone and Bronze Ages. *Folk* 16–17: 299–308.

O'Leary, M.H. 1988. Carbon isotopes in photosynthesis. *Bioscience* 38: 328–336.

Osipov, B. 2018. The Ontogeny of Postcranial Robusticity and Shape in Middle Holocene Cis-Baikal Hunter-Gatherer Populations. Unpublished PhD dissertation, University of Alberta.

Osmani, S.R. 1992. On some controversies in the measurement of undernutrition, in S.R. Osmani (ed.) *Nutrition and Poverty*: 121–164. Oxford: Clarendon Press.

Ozga, A.T., M.A. Nieves-Colón, T.P. Honap, K. Sankaranarayanan, C.A. Hofman, G.R. Milner, C.M. Lewis, A.C. Stone and C. Warinner 2016. Successful enrichment and recovery of whole mitochondrial genomes from ancient human dental calculus. *American Journal of Physical Anthropology* 16: 220–228.

Parfitt, A.M. 2002. Misconceptions (2): Turnover is always higher in cancellous than in cortical bone. *Bone* 30: 807–809.

Parker, G.J., J.M. Yip, J.W. Eerkens, M. Salemi, B. Durbin-Johnson, C. Kiesow, R. Haas, J.E. Buikstra, H. Klaus, L.A. Regan and D.M. Rocke 2019. Sex estimation using sexually dimorphic amelogenin protein fragments in human enamel. *Journal of Archaeological Science* 101: 169–180.

Perry, M.A. 2005. Redefining childhood through bioarchaeology: Toward an archaeological and biological understanding of children in antiquity. *Archeological Papers of the American Anthropological Association* 15: 89–111.

Peskov, S.A., V.S. Nikolaev, A.M. Klement'ev 2016. Ust'-Il'ginskii mogil'nik na verkhnei Lene (po materialam A.P. Okladnikova) [The Ust'-Ilga cemetery on the Upper Lena (based on the work of A.P. Okladnikov)]. *Izvestiia Laboratorii drevnikh tekhnologii* 4: 19–36.

Pfeiffer, S. and L. Harrington 2019. Regional continuity and local challenges to resilience among Holocene hunter-gatherers of the Great Cape Floristic Region, South Africa, in D.H. Temple and C.M. Stojanowski (eds) *Hunter-Gatherer Adaptation and Resilience*. Cambridge: Cambridge University Press.

Piccolroaz, S. and M. Toffolon 2013. Deep water renewal in Lake Baikal: a model for long-term analyses. *Journal of Geophysical Research: Oceans* 118: 6717–6733.

Piesco N.P. and J.K. Avery 2002. Development of teeth: Crown formation, in J.K. Avery (ed.) *Oral Development and Histology*. New York (NY): Thieme Medical Publishers, Inc.

Pollard, A.M., P. Ditchfield, E. Piva, S. Wallis, C. Falys and S. Ford 2012. 'Sprouting like cockle amongst the wheat': The St Brice's Day massacre and the isotopic analysis of human bones from St. Johns College, Oxford. *Oxford Journal of Archaeology* 31: 83–102.

Price, T.D. 2015. An introduction to the isotopic studies of ancient human remains. *Journal of the North Atlantic* 7: 71–87.

Reitsema, L.J. 2013. Beyond diet reconstruction: Stable isotope applications to human physiology, health, and nutrition. *American Journal of Human Biology* 25: 445–456.

Richards, M.P., S. Mays and B.T. Fuller 2002. Stable carbon and nitrogen isotope values of bone and teeth reflect weaning age at the Medieval Wharram Percy site, Yorkshire, UK. *American Journal of Physical Anthropology* 119: 205–210.

Royer, A., V. Daux, F. Fourel and C. Lecuyer 2017. Carbon, nitrogen and oxygen isotope fractionation during food cooking: Implications for the interpretation of the fossil human record. *American Journal of Physical Anthropology* 163: 759–771.

Sahlins, M. 1972. *Stone Age Economics*. Chicago (IL): Aldine-Atherton.

Sandberg, P.A., M. Sponheimer, J. Lee-Thorp and D. Van Gerven 2014. Intra-tooth stable isotope analysis of dentine: A step toward addressing selective mortality in the reconstruction of life history in the archaeological record. *American Journal of Physical Anthropology* 155: 281–293.

Sassaman, K.E. 2004. Complex hunter–gatherers in evolution and history: A North American perspective. *Journal of Archaeological Research* 12: 227–280.

Scharlotta, I., O.I. Goriunova and A.W. Weber. 2013 Microsampling of human bones for mobility studies: Diagenetic impacts and potentials for elemental and isotopic research. *Journal of Archaeological Science* 40: 4509–4527.

Scharlotta, I., G. Goude, E. Herrscher, V.I. Bazaliiskii and A.W. Weber 2018a. 'Mind the gap'—Assessing methods for aligning age determination and growth rate in multi-molar sequences of dietary isotopic data. *American Journal of Human Biology* 30: e23163.

Scharlotta, I., G. Goude, E. Herrscher, V.I. Bazaliiskii and A.W. Weber 2018b. Shifting weaning practices in Early Neolithic Cis-Baikal, Siberia: New insights from stable isotope analysis of molar micro-samples. *International Journal of Osteoarchaeology* 28: 579–598.

Scharlotta, I. and A.W. Weber 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.

Scheuer, L. and S. Black 2004. *The Juvenile Skeleton*. New York (NY): Elsevier Academic Press.

Schoeninger, M.J. 1995. Stable isotope studies in human evolution. *Evolutionary Anthropology* 4: 83–98.

Schoeninger, M.J. and M.J. DeNiro 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* 48: 625–639.

Schoeninger, M.J., M.J. DeNiro and H. Tauber 1983. Stable nitrogen isotope ratios of bone collagen reflect marine and terrestrial components of prehistoric human diet. *Science* 220: 1381–1383.

Schour, I. and M. Massler 1941a. The development of the human dentition. *Journal of American Dental Association* 28: 1153–1160.

Schour, I. and M. Massler 1941b. *Development of Human Dentition Chart* (2nd edition). Chicago (IL): American Dental Association.

Schurr, M.R. 1997. Stable nitrogen isotopes as evidence for the age of weaning at the Angel site: A comparison of isotopic and demographic measures of weaning age. *Journal of Archaeological Science* 24: 919–927.

Schurr, M.R. 1998. Using stable nitrogen-isotopes to study weaning behavior in past populations. *World Archaeology* 30: 327–342.

Schurr, T., L.P. Osipova, S.I. Zhadanov and M.C. Dulik 2010. Genetic diversity in Native Siberians: Implications for the prehistoric settlement of the Cis-Baikal Region, in A.W.

Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 121–134. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Schwarcz, H.P. and M.J. Schoeninger 1991. Stable isotope analyses in human nutritional ecology. *Yearbook of Physical Anthropology* 34: 283–321.

Scott, G. 2008. Dental morphology, in A. Katzenberg and S. Saunders (eds) *Biological Anthropology of the Human Skeleton*: 265–298. Toronto: Wiley-Liss.

Sealy, J. 1986. Stable carbon isotopes and prehistoric diets in the southwestern Cape Province, South Africa (BAR International Series 293). Oxford: British Archaeological Reports.

Sealy, J. 2006. Diet, mobility, settlement pattern among Holocene hunter-gatherers in southernmost Africa. *Current Anthropology* 47: 569–595.

Sealy, J., M. Johnson, M. Richards and O. Nehlich 2014. Comparison of two methods of extracting bone collagen for stable carbon and nitrogen isotope analysis: Comparing whole bone demineralization with gelatinization and ultrafiltration. *Journal of Archaeological Science* 47: 64–69.

Sedlin, E.D., H.M. Frost, and A.R. Villanueva 1963. Age changes in resorption in human rib cortex. *Journal of Gerontology* 18: 345–349.

Sellen, D.W. 2009. Evolution of human lactation and complementary feeding: Implications for understanding contemporary cross-cultural variation, in G. Goldberg, A. Prentice, A. Prentice, S. Filteau and K. Simondon (eds) *Breast-feeding: Early Influences on Later Health*: 253–282. New York (NY): Springer.

Sharp, Z. 2007. *Principles of Stable Isotope Geochemistry*. Upper Saddle River (NJ): Pearson Prentice Hall.

Shepard, B.A. 2012. Political economic reorganizations among non-state societies: A case study using Middle Holocene mortuary data from the Cis-Baikal, Russia. *Journal of Anthropological Archaeology* 31: 365–380.

Shepard, B.A., O.I. Goriunova, A.G. Novikov, A.A. Tiutrin and A.W. Weber 2016. Macro-regional interconnections among ancient hunter-gatherers of the Cis-Baikal, Eastern Siberia (Russia). *Quaternary International* 419: 140–158.

Silvia, R. and K. Clements 1997. Protein and nonprotein nitrogen components in human milk, bovine milk, and infant formula: Quantitative and qualitative aspects in infant nutrition. *Journal of Pediatric Gastroenterol Nutrition* 24: 328–344.

Slack, C. R. and M.D. Hatch 1967. Comparative studies on the activity of carboxylases and other enzymes in relation to the new pathway of photosynthetic carbon dioxide fixation in tropical grasses. *Biochemical Journal* 103: 660–665.

Smith, A.J., N. Cassidy, H. Perry, C. Begue-Kirn, J.V. Ruch and H. Lesot 1995. Reactionary dentinogenesis. *International Journal of Developmental Biology* 39: 273–280.

Smith, B.H. 1984. Patterns of molar wear in hunter–gatherers and agriculturalists. *American Journal of Physical Anthropology* 63: 39–56.

Smith, B.H. 1991. Standards of human tooth formation and dental age assessment, in M.A. Kelley and C.S. Larsen (eds) *Advances in Dental Anthropology*: 143–168. New York (NY): Wiley-Liss.

Smith, B.N. and S. Epstein 1971. Two categories of $^{13}C/^{12}C$ ratios for higher plants. *Plant Physiology* 47: 380–384.

Smith, T.M. 2008. Incremental dental development: Methods and applications in hominoid evolutionary studies. *Journal of Human Evolution* 54: 205–24.

Smith, T.M. 2013. Teeth and human life-history evolution. *Annual Review of Anthropology* 42: 191–208.

Smith, T.M., C. Austin, K. Hinde, E.R. Vogel and M. Arora 2017. Cyclical nursing patterns in wild orangutans. *Science Advances* 3: e1601517.

Smith, T.M., L.B. Martin and M.G. Leakey 2003. Enamel thickness, microstructure and development in Afropithecus turkanensis. *Journal of Human Evolution* 44: 283–306.

Sofaer, J.R. 2006. *The Body as Material Culture: A Theoretical Osteoarchaeology*. Cambridge: Cambridge University Press.

Soja, A.J., N.M. Tchebakova, N.H.F. French, M.D. Flannigan, H.H. Shugart, B.J. Stocks, A.I. Sukhinin, E.I. Pafenova, F.S. Chapin III and P.W. Stackhouse Jr 2007. Climate-induced boreal forest change: Predictions versus current observations. *Global and Planetary Change* 56: 274–296.

Srinivasan, T.N. 1992. Undernutrition: Concepts, measurement, and policy implications, in S.R. Osamni (ed.) *Nutrition and Poverty*: 97–120. Oxford: Clarendon.

Stearns, S.C. 1992. *The Evolution of Life Histories*. Oxford: Oxford University Press.

Steele, K.W. and R.M. Daniel 1978. Fractionation of nitrogen isotopes by animals: A further complication to the use of variations on the natural abundance of ^{15}N for tracer studies. *Journal of Agricultural Science* 90: 7–9.

Stewart, N.A., R.F. Gerlach, R.L. Gowland, K.J. Gron and J. Montgomery 2017. Sex determination of human remains from peptides in tooth enamel. *Proceedings of the National Academy of Sciences* 114: 13649–13654.

Szulc, P., E. Seeman and P. Demlas 2002. Biochemical measurements of bone turnover in children and adolescents. *Osteoporosis International* 11: 281–294.

Tang, N., A. Le Cabec and D. Antoine 2016. Dentine and cementum structure and properties, in J.D. Irish and G.R. Scott (eds) *A Companion to Dental Anthropology*: 204–222. Hoboken (NJ): John Wiley & Sons, Inc.

Tarasov, P., E. Bezrukova, E. Karabanov, N. Takeshi, M. Wagner, N. Kulagina, P. Letunova, A. Abzaeva, W. Granoszewski and F. Riedel 2007. Vegetation and climate dynamics during the Holocene and Eemian interglacials derived from Lake Baikal pollen records. *Palaeogeography, Palaeoclimatology, Palaeoecology* 252: 440–457.

Tarasov, P.E., E.V. Bezrukova, S. Muller, S. Kostrova and D. White 2017. Climate and vegetation history, in R.J. Losey and T. Nomokonova (eds) *Holocene Zooarchaeology of Cis-Baikal* (Archaeology in China and East Asia 7; Northern Hunter-Gatherers Research Series 7): 15–25. Darmstadt: Verlag Philipp von Zabern.

Tarasov, P., W. Granoszewski, E. Bezrukova, S. Brewer, M. Nita, A. Abzaeva and H. Oberhansli 2005. Quantitative reconstruction of the last interglacial vegetation and climate based on the pollen record from Lake Baikal, Russia. *Climate Dynamics* 25: 625–637.

Thomson, A. 1899. The sexual differences of the foetal pelvis. *Journal of Anatomy and Physiology* 33: 359–380.

Tieszen, L.L., T.W. Boutton, K.G. Tesdahl and N.A. Slade 1983. Fractionation and turnover of stable carbon isotopes in animal tissues: Implications for δ^{13}C analysis of diet. *Oecologia* 57: 32–37.

Tieszen, L.L. and T. Fagre 1993a. Carbon isotopic variability in modern and archaeological maize. *Journal of Archaeological Science* 20: 25–40.

Tieszen, L.L. and T. Fagre 1993b. Effect of diet quality and composition on the isotopic composition of respiratory CO2, bone collagen, bioapatite, and soft tissues, in J.B.

Lambert and G. Grupe (eds) *Prehistoric Human Bone: Archaeology at the Molecular Level*: 121–155. Berlin: Springer-Verlag.

Townsend, G.C., S.K. Pinkerton, J.R. Rogers, M.R. Bockmann and T.E. Hughes 2015. *Twin Studies: Research in Genes, Teeth and Faces*. Adelaide: University of Adelaide Press.

Tsutaya, T., T. Nagaoka, J. Sawada, K. Hirata and M. Yoneda 2014. Stable isotopic reconstructions of adult diets and infant feeding practices during urbanization of the city of Edo in 17th century Japan. *American Journal of Physical Anthropology* 153: 559–569.

Tsutaya, T. and M. Yoneda 2013. Quantitative reconstruction of weaning ages in archaeological human populations using bone collagen nitrogen isotope ratios and approximate Bayesian computation. *PLoS One* 8: e72327.

Tsutaya, T. and M. Yoneda 2015. Reconstruction of breastfeeding and weaning practices using stable isotope and trace element analyses: A review. *American Journal of Physical Anthropology* 156: 2–21.

Tucker, B. and A.G. Young 2005. Growing up Mikea: Children's time allocation and tuber foraging in southwestern Madagascar, in B.S. Hewlett and M.E. Lamb (eds) *Hunter-Gatherer Childhoods: Evolutionary, Developmental, and Cultural Perspectives*: 147–172. Abingdon: Routeledge.

Tuross, N., M.L. Fogel and P.E. Hare 1988. Variability in the preservation of the isotopic composition of collagen from fossil bone. *Geochimica et Cosmochimica Acta* 52: 929–935.

Turov, M.G. 2010. *Evenki Economy in the Central Siberian Taiga at the Turn of the 20th Century: Principles of Land Use* (Northern Hunter-Gatherers Research Series 5). Edmonton: Canadian Circumpolar Institute Press.

Twiss, P.C. 1992. Predicted world distribution in C3 and C4 grass phytoliths, in G. Rapp and S.C. Mulholland (eds) *Phytolith Systematics: Emerging Issues*: 113–128. New York: Plenum Press.

Tykot, R.H. 2004. Stable isotopes and diet: You are what you eat, in M. Martini, M. Milazzo and M. Piacentini (eds) *Physics Methods in Archaeometry* (Proceedings of the International School of Physics 'Enrico Fermi' 154): 433–444. Bologna: Società Italiana di Fisica.

Ubelaker, D.H. 1987. Estimating age at death from immature human skeletons: An overview. *Journal of Forensic Science* 32: 1254–1263.

van der Haas, V.M., S. Garvie-Lok, V.I. Bazaliiskii and A.W. Weber 2018. Evaluating sodium hydroxide usage for stable isotope analysis of prehistoric human tooth dentine. *Journal of Archaeological Science: Reports* 20: 80–86.

Van der Merwe, N.J., and E. Medina 1991. The canopy effect, carbon isotope ratios and foodwebs in amazonia. *Journal of Archaeological Science* 18: 249–259.

Van der Merwe, N.J. and J.C. Vogel 1978. ^{13}C content of human collagen as a measure of prehistoric diet in woodland North America. *Nature* 276: 815–816.

Van der Sluis, L.G., P.J. Reimer and N. Lynnerup 2015. Investigating intra-individual dietary changes and ^{14}C ages using high-resolution δ^{13}C and δ^{15}N isotope ratios and ^{14}C ages obtained from dentine increments. *Radiocarbon* 57: 665–677.

Van Klinken, G.J. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26 687–695.

Vogel, J.C. 1978. Isotopic assessment of the dietary habits of ungulates. *South African Journal of Science* 74: 298–301.

Vogel, J.C. and N.J. Van Der Merwe 1977. Isotopic evidence for early maize cultivation in New York State. *American Antiquity* 42: 238–242.

Wada, E. and A. Hattori 1978. Nitrogen isotope effects in the assimilation of inorganic nitrogenous compounds by marine diatoms. *Geomicrobiology Journal* 1: 85–101.

Walker, R., K. Hill, H. Kaplan and G. McMillan 2002. Age-dependency in hunting ability among the Ache of eastern Paraguay. *Journal of Human Evolution* 42: 639–657.

Waters-Rist, A.L., V.I. Bazaliiskii, A.W. Weber and M.A. Katzenberg 2011. Infant and child diet in Neolithic hunter-fisher-gatherers from Cis-Baikal, Siberia: Intra-long bone stable nitrogen and carbon isotope ratios. *American Journal of Physical Anthropology* 146: 225–241.

Waters-Rist, A.L., K. Faccia, A. Lieverse, V.I. Bazaliiskii, M.A. Katzenberg and R.J. Losey 2014. Multicomponent analyses of a hydatid cyst from an Early Neolithic hunter–fisher–gatherer from Lake Baikal, Siberia. *Journal of Archaeological Science* 50: 51–62.

Waters-Rist, A.L. and M.A. Katzenberg 2010. The effect of growth on stable nitrogen isotope ratios in subadult bone collagen. *International Journal of Osteoarchaeology* 20: 172–191.

Weber, A. 1995. The Neolithic and Early Bronze Age of the Lake Baikal Region: A review of recent research. *Journal of World Prehistory* 9: 99–165.

Weber, A.W. 2003. Biogeography profile of the Lake Baikal Region, in A.W. Weber and H.G. McKenzie (eds) *Prehistoric Foragers of the Cis-Baikal, Siberia. Proceedings of the First Conference of the Baikal Archaeology Project*: 51–66. Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W. and R.L. Bettinger 2010. Middle Holocene hunter–gatherers of Cis-Baikal, Siberia: An overview for the new century. *Journal of Anthropological Archaeology* 29: 491–506.

Weber, A.W., R.P. Beukens, V.I. Bazaliiskii, O.I. Goriunova and N.A. Savel'ev 2006. Radiocarbon dates from Neolithic and Bronze Age hunter-gatherer cemeteries in the Cis-Baikal region of Siberia. *Radiocarbon* 48: 127–166.

Weber, A.W., R.A. Creaser, O.I. Goriunova and C.M. Haverkort 2003. Strontium isotope tracers in enamel of permanent human molars provide new insights into prehistoric hunter-gatherer procurement and mobility patterns: A pilot study of a Middle Holocene group from Cis-Baikal, in A.W. Weber and H.G. McKenzie (eds) *Prehistoric Foragers of the Cis-Baikal, Siberia. Proceedings of the First Conference of the Baikal Archaeology Project*: 133–153. Edmonton: Canadian Circumpolar Institute Press.

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

Weber, A., O.I. Goriunova and A.K. Konopatskii 1993. Prehistoric seal hunting on Lake Baikal: Methodology and preliminary results of the analysis of canine sections. *Journal of Archaeological Science* 20: 629–644.

Weber, A.W., O.I. Goriunova and H.G. McKenzie (eds) 2008a. *Khuzhir-Nuge XIV, a Middle Holocene hunter-gatherer cemetery on Lake Baikal, Siberia: Archaeological Materials* (Northern Hunter-Gatherers Research Series 4). Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W., O.I. Goriunova, H.G. McKenzie and A.R. Lieverse (eds) 2012. *Kurma XI, a Middle Holocene Hunter-Gatherer Cemetery on Lake Baikal*. Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W., O.I. Goriunova, H.G. McKenzie, A.G. Novikov, A.P. Sekerin and N.D. Ovodov 2008b. Grave descriptions, in A.W. Weber, O.I. Goriunova and H.G. McKenzie (eds) *Khuzhir-Nuge XIV, a Middle Holocene hunter-gatherer cemetery on Lake Baikal, Siberia: Archaeological Materials* (Northern Hunter-Gatherers Research Series 4): 33–184. Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W., M.A. Katzenberg and O.I. Goriunova (eds) 2007a. *Khuzhir-Nuge XIV, a Middle Holocene Hunter-Gatherer Cemetery on Lake Baikal, Siberia: Osteological Materials* (Northern Hunter-Gatherers Research Series 3). Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W., M.A. Katzenberg and O.I. Goriunova 2007b. Overview of the Baikal Archaeology Project and bioarchaeological studies of the Khuzhir-Nuge XIV cemetery, in A.W. Weber, M.A. Katzenberg and O.I. Goriunova (eds) *Khuzhir-Nuge XIV, a Middle Holocene Hunter-Gatherer Cemetery on Lake Baikal, Siberia: Osteological Materials* (Northern Hunter-Gatherers Research Series 3): 1–20. Edmonton: Canadian Circumpolar Institute Press.

Weber, A.W., D.W. Link, O.I. Goriunova and A.K. Konoptaskii 1998. Patterns of prehistoric procurement of seal at Lake Baikal: A zooarchaeological contribution to the study of past foraging economies in Siberia. *Journal of Archaeological Science* 25: 215–227.

Weber, A.W., D.W. Link and M.A. Katzenberg 2002. Hunter-gatherer culture change and continuity in the Middle Holocene of the Cis-Baikal, Siberia. *Journal of Anthropological Archaeology* 21: 230–299.

Weber, A.W., H.G. McKenzie and R. Beukens 2010. Radiocarbon dating of Middle Holocene culture history in Cis-Baikal, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 27–49. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

Weber. A., H.G. McKenzie, R. Beukens and O.I. Goriunova 2005. Evaluation of radiocarbon dates from the Middle Holocene hunter-gatherer cemetery Khuzhir-Nuge XIV, Lake Baikal, Siberia. *Journal of Archaeological Science* 32: 1481–1500.

Weber, A.W., R.J. Schulting, C. Bronk Ramsey, V.I. Bazaliiskii, O.I. Goriunova and N.E. Berdnikova 2016. Chronology of middle Holocene hunter-gatherers in the Cis-Baikal region of Siberia: Corrections based on examination of the freshwater reservoir effect. *Quaternary International* 419: 74–98.

Weber, A.W., D. White, V.I. Bazaliiskii, O.I. Goriunova, N.A. Savel'ev and M.A. Katzenberg 2011. Hunter–gatherer foraging ranges, migrations, and travel in the middle Holocene Baikal region of Siberia: Insights from carbon and nitrogen stable isotope signatures. *Journal of Anthropological Archaeology* 30: 523–548.

Webb, E.C., N.V. Honch, P.J. Dunn, G. Eriksson, K. Lidén and R.P. Evershed 2015. Compound-specific amino acid isotopic proxies for detecting freshwater resource consumption. *Journal of Archaeological Science* 63: 104–114.

Weiss, R.F., E.C. Carmack and V.M. Koropalov 1991. Deep-water renewal and biological production in Lake Baikal. *Nature* 349: 665–669.

White, D. and A. Bush 2010. Holocene climate, and Neolithic biocultural discontinuity in the Baikal region, in A.W. Weber, M.A. Katzenberg and T.G. Schurr (eds) *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*: 1–26. Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology.

White, T.D. and P.A. Folkens 2005. *The Human Bone Manual*. Burlington (MA): Elsevier Academic Press.

Whitmore, K.M., T.L. Dupras, L.J. Williams, R. Skipitytė, J.J. Schultz and R. Jankauskas 2019. Stable carbon and nitrogen isotope inter-and intra-individual dietary reconstruction from the late 14th to early 18th century site of Alytus, Lithuania. *American Journal of Physical Anthropology* 168: 279–291.

Willems, G., A. Van Olmen, B. Spiessens and C. Carels 2001. Dental age estimation in Belgian children: Demirjian's technique revisited. *Journal of Forensic Science* 46: 893–895.

Wood, J.W., G.R. Milner, H.C. Harpending, K.M. Weiss, M.N. Cohen, L.E. Eisenberg, D.L. Hutchinson, R. Jankauskas, G. Cesnys, M.A. Katzenberg, J.R. Lukacs, J.W. McGrath, E. Abella Roth, D.H. Ubelaker and R.G. Wilkinson 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples [and comments and reply]. *Current Anthropology* 334: 343–370.

Wright, L.E. and H.P. Schwarcz 1998. Stable carbon and oxygen isotopes in human tooth enamel: Identifying breastfeeding and weaning in prehistory. *American Journal of Physical Anthropology* 1061: 1–18.

Xia, Y., J. Zhang, F. Yu, H. Zhang, T. Wang, Y. Hu and B.T. Fuller 2018. Breastfeeding, weaning, and dietary practices during the Western Zhou Dynasty (1122-771 BC) at Boyangcheng, Anhui Province, China. *American Journal of Physical Anthropology* 165: 343–352.

Yoshida, T., T. Sekino, M. Genkai-Kato, N.P. Logacheva, N.A. Bondarenko, Z. Kawabata, T.V. Khodzher, N.G. Melnik, S. Hino, K. Nozaki, Y. Nishimura, T. Nagata, M. Higashi and M. Nakanishi 2003. Seasonal dynamics of primary production in the pelagic zone of southern Lake Baikal. *Limnology* 4: 53–62.

Zilberman, U. and P. Smith 2001. Sex- and age-related differences in primary and secondary dentin formation. *Journal of Dental Research* 15: 42–45.

Zohary, T., J. Erez, M. Gophen, I. Berman-Frank and M. Stiller 1994. Seasonality of stable carbon isotopes within the pelagic food web of Lake Kinneret. *Limnology and Oceanography* 39: 1030–1043.