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STUDYING HUNTER-GATHERER MOBILITY USING ISOTOPIC AND TRACE ELEMENTAL ANALYSIS

by

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ABSTRACT

This research comprises a series of papers to address the methodology of studying hunter-gatherer mobility in prehistoric populations. As a laboratory for this research, middle Holocene hunter-gatherer groups from Cis-Baikal, Siberia were analyzed as part of ongoing research by the Baikal Archaeology Project. Paper no. 1 focuses on theoretical considerations of how researchers approach the concept of mobility with regard to hunter-gatherers along with regional background information and discussions on the specifics of using geochemical techniques to track human mobility in the archaeological record. Paper no. 2 presents the methodology to enable laser ablation ICP-MS analysis of teeth for strontium isotopic research with specific focus on correction procedures for known interferences encountered using laser ablation as a sampling method. The paper also presents groundwork for a new approach in trace element analysis of teeth for provenancing purposes. Paper no. 3 presents the technique of micro-sampling of skeletal materials for laser ablation with specific focus on long bones. The purpose of micro-sampling is to target bone micro-structures to access diagenetically resistant portions of the bones and to recover biogenic strontium isotopic and trace elemental data. Paper no. 4 presents the results of extensive regional geochemical mapping including plants, water sources and faunal remains throughout the Cis-Baikal region. Coupled with this map is an analysis of molars from 16 individuals recovered from small cemeteries distributed across the Cis-Baikal region. General characteristics of the geochemical environment and mobility patterns elucidated through further provenance analysis are discussed too. Finally, in paper no. 5, a summary of all new findings is presented along with the assessment of the methods employed in this research. As theoretical and analytical considerations intertwine, the resultant inferences can provide astounding revelations about prehistoric populations. For the middle Holocene hunter-gatherers of Lake Baikal, Siberia, this approach provides valuable new insights and research directions.

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Chapter 1: Introduction

OVERVIEW

Siberia has played an important role in the development of humans as a species (Reich, et al., 2010) and the distribution of human populations throughout Eurasia and into the New World (Erlandson, et al., 2007, Schurr, 2004), as well as the historical processes that have led to the establishment of modern world (Anthony, 2007, Jordan, 2008). The full extent to which a region regarded as marginal or wilderness through much of the 20th century, has impacted the narrative of recorded history and prehistory is still largely underappreciated in the realm of Western scholarship. Language and geopolitical barriers have limited the exposure of the global audience to materials and research conducted in Siberia, leaving an area with a deep and rich history outside of many anthropological, ethnographic and historical discussions. Russian archaeologists have noted that perhaps the highest priority for research groups is the publication, discussion and general dissemination of previously excavated materials and research to non-Russians (Bazaliiski, 2003, Goriunova, et al., 2004).

The Baikal Archaeology Project (BAP), an international multidisciplinary research program aimed at investigating long-term culture change and continuity among Holocene boreal forest hunter-gatherers of the Lake Baikal region of Siberia, is part of a growing effort to elucidate the long and rich history of scholastic work conducted over the past 100 years. Results from this ongoing research program have demonstrated an intriguing ‘biocultural discontinuity’ in which two distinct periods of formal cemetery use, perhaps indicative of significant social complexity, dating to the Early (EN) and Late Neolithic (LN)–Early Bronze Age (EBA) periods are separated by an interval of approximately 1000 years with no archaeologically visible mortuary record (Weber, 1995, Weber and Bettinger, 2010, Weber, et al., 2002). These two intervals of formal cemetery use represent groups that are genetically dissimilar and show evidence for differences in dietary preferences, mobility patterns, population size and distribution, and aspects of mortuary ritual (e.g., Ezzo, et al., 2003, Katzenberg and Weber, 1999, Lam, 1994, Lieverse, 2005, 2010, Lieverse, et al., 2008, Lieverse, et al., 2007a, Lieverse, et al., 2007b, Link, 1999, Mooder, et al., 2003, Mooder, et al., 2006, Mooder, et al., 2005, Schurr, 2003, Stock, et al., 2010, Weber, et al., 2010a, Weber, et al., 2002). The mechanisms underlying the development and abandonment of large formal cemeteries in Cis-Baikal during the Early Neolithic and Late Neolithic–Early Bronze Age are still under investigation and have thus far been attributed primarily to social processes.

Mobility patterns are integral to the understanding of social processes in general and how groups can react to internal or external pressures. Russian scholars, particularly followers of A.P. Okladnikov (1950, 1955)– the founder of Baikal Neolithic archaeology –have not, to date, addressed matters of mobility in prehistoric populations during the Neolithic and Early Bronze Age, attributing changes in material culture to *in situ* cultural processes rather than any significant intra- or inter-regional population movements. Growing evidence based on different archaeometric data, has suggested that such a localized view of prehistoric cultural interaction, development, and mobility is not an accurate view in Cis-Baikal. However, inferences and interpretations of this evidence have yet to build a strong case against this established picture (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003, Weber, et al., 2002, Weber, et al., 2011b).

The archaeological data have been described using a best-fit approach to integrating archaeometric evidence with general understanding of hunter-gatherer diet, mobility, social and political relations (Weber, et al., 2002, Weber, et al., 2011a). The veracity of theories regarding hunter-gatherer mobility, either in the Cis-Baikal region, or elsewhere in similar boreal forest environmental settings, is still open to question thus adding uncertainty to conclusions employing them. Archaeometric data have the potential to provide sharpened understanding of past hunter–gatherer mobility. Given the uncertain relationship between data gathered to date and the actual human mobility inferred from such data, a reexamination of the nature of the analytical tools and explanatory structures employed is warranted to ensure that data gathered are answering the research questions being asked. This thesis is therefore focused on the analytical methods used to address questions of prehistoric mobility during the middle Holocene around Lake Baikal, Siberia.

REGIONAL BACKGROUND

Archaeological research in the Lake Baikal region in Eastern Siberia (between 52º and 58ºN in latitude and 99º and 110ºE in longitude) distinguishes between its two main subregions – Cis- and Trans-Baikal – in addition to the typical temporal and thematic divisions (Figure 1-1). Cis-Baikal includes the western and northern shores of the lake itself, the Little Sea, Ol'khon Island, the Lena River, the Angara River, associated drainages and mountain ranges and as far north as Ust'-Ilimsk. Trans-Baikal includes the eastern shore, the Upper Angara, Selenga and Barguzin rivers and associated drainages and mountain ranges (Michael, 1958, Weber, 1995). The southern tip of the lake itself and the Tunka Region are frequently included in the Cis-Baikal region due to their proximity to the Angara and due to archaeological similarities of cemeteries and artifacts recovered in the region (e.g., Shamanka II). Similarities in the archaeological record between the Cis- and Trans-Baikal have been noted by a number of researchers

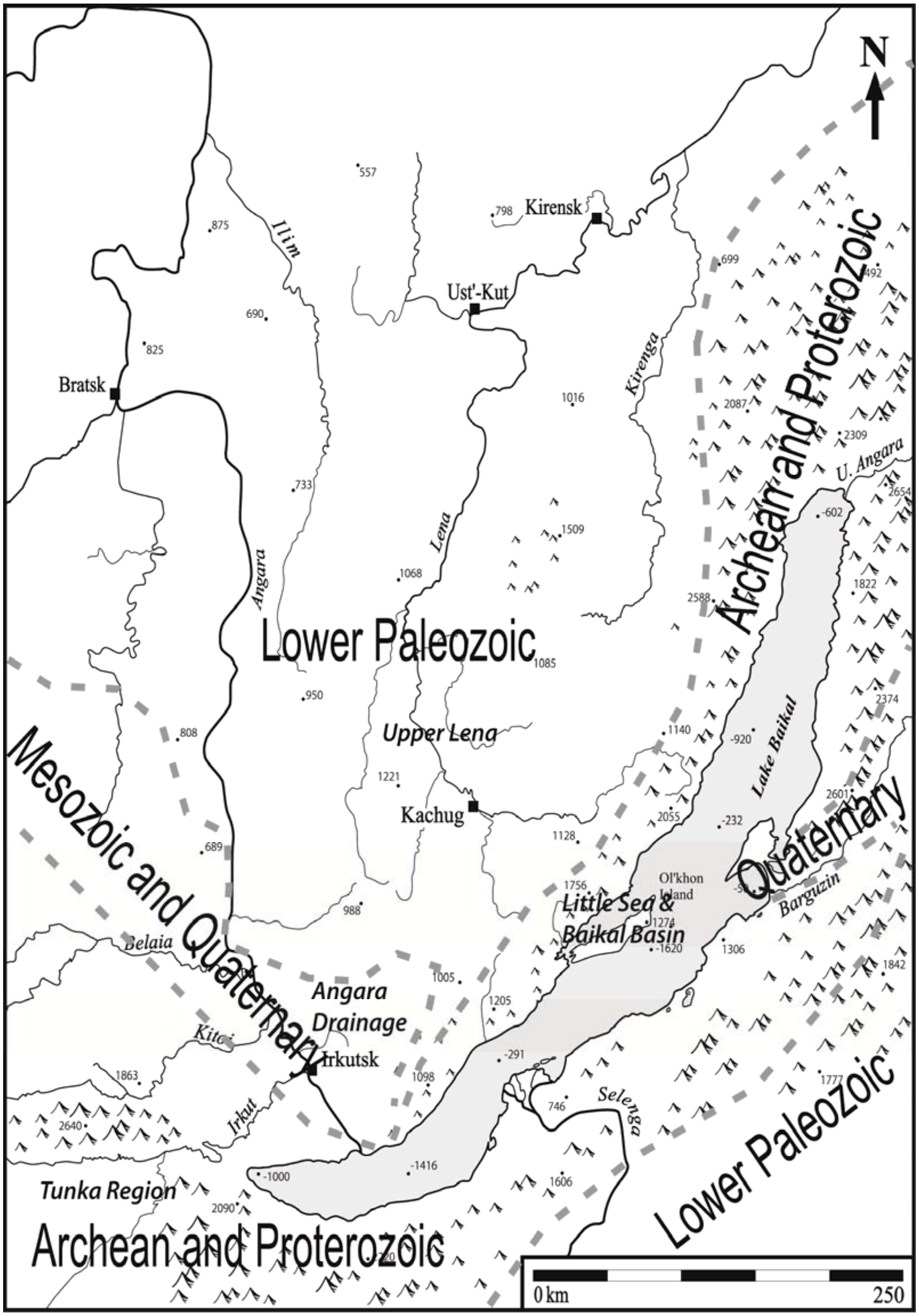

Figure 1-1: Cis-Baikal regional map with the age of dominant geologic formations and archaeological micro-regions

(see Weber, 1995); however, no systematic work attempting to compare the two subregions has yet been attempted.

The Cis-Baikal region has received more archaeological attention than the Trans-Baikal region because of the numerous modern large-scale construction projects along the Angara River. The Trans-Siberian Railway runs through the Cis-Baikal region, connecting Irkutsk to Moscow and Vladivostok and the cities in between. Irkutsk itself expanded greatly during the second half of the 19th century due to increased trade through the region and a population influx composed largely of exiles (including nobles, scholars and artists) from other parts of Russia resulting from the Decembrist Revolt, but also associated with greater exploratory interest in Siberia.

Excavations by N. Vitkovskii at the mouth of the Kitoi river in 1880-81 (Vitkovskii, 1880, 1881, 1882, 1889) and later in Irkutsk by many people near the "Lokomotiv" stadium (in conjunction with the construction of Trans-Siberian Railway in 1897) revealed graves later to be viewed collectively as the Kitoi mortuary tradition (Bazaliiski and Savel'ev, 2003). E.B. Petri conducted further archaeological fieldwork in 1912 and 1913 at Ulan-Khada on Lake Baikal, leading to the first attempt to synthesize the region's Neolithic prehistory which inspired later researchers such as Okladnikov, whose numerous works have had the most influential impact on regional studies in Siberia (Chard, 1958, 1974, Michael, 1958, 1992a, b, Weber, 1995).

Coinciding with the construction of three hydroelectric power plants on the Angara River (Irkutsk, Bratsk, and Ilimsk), the pace of archaeological excavations increased to a scale previously unknown in the region, and in much of the boreal world (Vasil'evskii, 1978). The entire coast of Lake Baikal and the banks of the Angara from Baikal to Ilimsk, as well as the shores of other smaller rivers (Ilim, Belaia), were subjected to archaeological reconnaissance, with the most promising sites excavated

(Weber, 1995). All identified endangered sites were at least tested, though this ranged from minimal testing to the excavation of thousands of square meters. Although salvage archaeology is a less than ideal approach to collecting archaeological materials systematically, it did at least grant a window into the recognizable archaeological remains along Lake Baikal and the Angara River.

This approach greatly advanced knowledge about regional archaeological materials, although it clearly produced a biased picture, as any site not in immediate danger from construction activities would have received little or no attention while lower lying areas in close proximity to Irkutsk, along the rivers and the Little Sea area received a great deal of attention. Based on available reports, this seems to indicate that there was little to no habitation or burial sites on the Trans-Baikal coast of the lake during the Neolithic or Early Bronze Age, although it seems unlikely that hunter–gatherer presence concentrated so much on one side of Lake Baikal (Weber, 1995). At present there is not enough archaeological evidence from the eastern coastline, or Trans-Baikal, for any useful interpretation.

Concerns for biased sampling of the region aside, there is a wealth of archaeological material, clearly showing that the inhabitants of the Cis-Baikal region during the middle Holocene were likely unique in their level of complexity and interactions with their environment. Again, it is possible that this is merely a misrepresentation due to the generally poor preservation conditions in boreal environments.

CULTURE HISTORY

The culture history of the Cis-Baikal region has been the driving force behind archaeological research in the region. Okladnikov (1950, 1955) provided the most influential synthesis of regional archaeological materials and noted significant variability in the archaeological record, enabling him to create his cultural historical chronology of the region consisting of the following stages: Khin (Mesolithic), Isakovo (Neolithic), Serovo (Neolithic), Kitoi (Neolithic), and Glazkovo (EBA). Technological innovations are the primary means by which cultural historical groups are distinguished in this model (Weber, 1995, Weber, et al., 2010a, Weber, et al., 2002). Technological improvements and changes in economy (progressively more fishing) and social and political organization (from matriarchal to patriarchal according to Okladnikov) identify transitions between Okladnikov's stages (Okladnikov, 1950, 1955). The Neolithic is identified by presence of the bow and arrow, ground stone tools, and ceramics rather than by the introduction of animal and plant domesticates as these did not arrive in Cis-Baikal until the Iron Age and historical times, respectively. Copper and bronze objects mark the beginning of the Early Bronze Age.

Although several Russian researchers challenged it (see Weber, 1995), Okladnikov's culture history model stood largely unchanged until the application of radiocarbon dating (Weber, 1995). With radiocarbon evidence, the differences between cultures became a confusing puzzle. Technological differences, particularly relating to fishing, had been important in the development of Okladnikov's model. With radiocarbon evidence, however, it was demonstrated that the highly advanced Kitoi culture was far older than previously believed, now placed at the beginning of the Neolithic, creating a discontinuity in the technological progression of Okladnikov's model (Weber, 1995).

Based on craniometric evidence, Gerasimov (1955) recommended that Isakovo and Serovo be combined into a single cultural unit. Radiocarbon dating showed very few Isakovo graves, which combined with similarities in the material culture to Serovo, led the BAP to drop Isakovo as a separate chronological group (Weber, 1995). The Serovo and Glazkovo had been placed at the middle and after the Neolithic, respectively, by Okladnikov (1950, 1955). Radiocarbon dates for Serovo and Glazkovo, however, overlap, suggesting they represent a continuous timespan bridging the LN and EBA (Weber, 1995). Therefore, in some studies BAP scholars (e.g., Weber, 1995, Weber, et al., 2010a, Weber, et al., 2002) have treated Serovo and Glazkovo as a single culture historical groups. However, it is more correct to view them as separate cultural and temporal units as emphasized recently (Weber, et al., 2011b). Continued research into the chronology of Cis-Baikal has led to revisions of the cultural history chronology, identified a significant discontinuity between mortuary traditions and raised further questions about the differences noted between the traditions (see Table 1-1) (Weber, 1995, Weber, 2011, Weber, et al., 2006, Weber, et al., 2010a, Weber, et al., 2002, Weber, et al., 2008, 2010b, Weber, et al., 2005b). While continued radiocarbon dating may result in further refinements, the larger picture is unlikely to change.

Table 1-1: Table of archaeological record after Weber et al. 2010a, b

Period	**Mortuary Tradition**	**Angara and South Baikal (cal BP)**	**Upper Lena (cal BP)**	**Little Sea (cal BP)**
Late Mesolithic	Lack of archaeologically visible mortuary sites	8800–8000	8800–8000	8800–8000
Early Neolithic	Kitoi and other	8000–7000/6800	8000–7200	8000–7200
Middle Neolithic	Lack of archaeologically visible mortuary sites	7000/6800–6000/5800	7200–6000/5800	7000/6800–6000/5800
Late Neolithic	Isakovo, Serovo	6000/5800–5200	6000/5800–5200/5000	6000/5800–5200/5000
Early Bronze Age	Glazkovo	5200/5000–4000	5200/5000–3400	5200/5000–4000

The Middle Neolithic (MN) has been defined by Weber and colleagues (e.g., Weber, et al., 2005a, Weber, 1995, Weber and Bettinger, 2010, Weber, et al., 2010a, Weber, et al., 2002) primarily by negative evidence. The formal cemeteries which were in use during the EN, LN, and EBA, were not in use during the MN. A formal cemetery is defined, for the purpose of Cis-Baikal (e.g., Weber, 1995, Weber and Bettinger, 2010, Weber, et al., 2002), as an area used repeatedly and more or less exclusively for the disposal of a group's dead (Goldstein, 1981). This contrasts with informal mortuary practices and isolated graves that can involve various kinds of disposal practices and patterns scattered widely over the landscape (e.g., bodies buried in earth alone, abandoned and exposed to the elements, tossed into water courses or crevices), or the use of otherwise functional structures (refuse pits, middens, ditches, dwellings, temples, etc.) (Weber and Bettinger, 2010). The length of the MN is perhaps still longer, and each of the three mortuary traditions defining the EN, LN, and EBA somewhat shorter than indicated by Table 1-1, due to the statistical errors inherently associated with radiocarbon dating, with ongoing work to clarify the duration of each cultural period or mortuary tradition (Weber, et al., 2005a, Weber, et al., 2006, Weber, et al., 2010a, Weber, et al., 2008, 2010b).

THESIS CONTENT

The body of this thesis is focused on experimental development of new methods for the geochemical analysis of hunter-gatherers particularly with regard to individual migrations, mobility, and travel. Chapter 2 provides background to the analytical work on bone chemistry presented in the main body of the thesis. This includes some brief theoretical considerations of how researchers approach the concept of mobility with regard to hunter-gatherers, distinctions between related terms, Cis-Baikal geology, bone and tooth formation processes, and bone and tooth diagenesis along with discussion of geochemical techniques used to track human mobility in the archaeological record.

Chapter 3 presents the methodology to enable laser ablation ICP-MS analysis of teeth for strontium isotopic research using correction procedures for known interferences encountered using laser ablation as a sampling method. The paper also presents groundwork for a new approach in trace element analysis of teeth for provenancing purposes.

Chapter 4 presents the technique of micro-sampling of long bones for laser ablation. The purpose of micro-sampling is to target bone micro-structures to access diagenetically resistant portions of the bones and to recover biogenic strontium isotopic and trace elemental data.

Chapter 5 presents the results of extensive regional geochemical mapping, including plants, water sources and faunal remains throughout the Cis-Baikal region. Coupled with this map is an analysis of molars from 16 individuals recovered from small cemeteries distributed across the Cis-Baikal region. General characteristics of the geochemical environment and mobility patterns elucidated through further provenance analysis are discussed too.

Finally, in Chapter 6, a summary of all new findings is presented along with the assessment of the methods employed in this research. As theoretical and analytical considerations intertwine, the resultant inferences can provide new important insights about prehistoric populations. For the middle Holocene hunter-gatherers of Lake Baikal, Siberia, this approach provides valuable new information and research directions.

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Chapter 2. Hunter–gatherer mobility patterns during the middle Holocene of Cis-Baikal: theoretical and methodological considerations

By: Ian Scharlotta

INTRODUCTION

This thesis is focused on archaeological science, or on the application of scientific laboratory techniques to examination of archaeological materials of all kinds. This is a rapidly growing and dynamic subfield of archaeology. Bone chemistry is one aspect of archaeological science that relates osteology and bioarchaeology with analytical methods used to study skeletal tissues and the explanatory frameworks used to translate raw geochemical data into behavioral information. Bone chemistry has a well-established focus on diet, subsistence, and mobility as broadly defined concepts (e.g., Ambrose and Krigbaum, 2003, Bentley, 2006, Bowen, 1979a, Boyde, 1972, Bratter, et al., 1977, Caley, 1951, 1967, Goffer, 1980, Hare, 1980, Katzenberg and Harrison, 1997, Price, 1989, Price, et al., 1992, Price, et al., 2002, Price, et al., 1985). Strontium (Sr) isotope analysis is a method most frequently used to study migration or mobility patterns, primarily on agropastoral groups (e.g., Beard and Johnson, 2000, Bentley, 2006, Bentley, et al., 2002, Cabrera, et al., 1999, Conlee, et al., 2009, Evans, et al., 2006, Grupe, et al., 1997, Knudson and Buikstra, 2007, Price, et al., 2002, Price, et al., 1994). The goal of this thesis is to modify the Sr method in such a way that it is more directly applicable to studying hunter-gatherer's mobility.

Assessment of mobility, whether of past human populations or herds of modern fauna, begins with the assumption that there is an event that can be observed, quantified and used to explain the behavior of the individual or population. For example, variation in the migration distance and direction of a hypothetical roe deer population corresponds to a behavioral shift that can be explained in light of internal or external factors (e.g., predation pressure). When applied to extant populations (human or animal), the concept of mobility does not present any immediate challenges. Movements or migrations occur (phenomena) and can be observed and quantified to build explanations of behavior. The same is not true in the context of archaeological populations particularly when such vague concepts as “lifetime mobility” are used (Pollard, et al., 2007: 188).

The difficulty, not readily apparent in studies of extant animals, is that mobility is used in archaeological and ethnographic literature as a typological (essentialist) concept (e.g., Binford, 1980, 1990, Delagnes and Rendu, 2011, Grupe, et al., 1997, Kelly, 1990, 1992, Lightfoot, 2008) that serves to document variation but contains no behavioral information without specific temporal boundaries. For example, a seasonally mobile group could be said to be sedentary for the majority of the year, moving on a seasonal basis between base camps located near resources or social contacts. As such, behavioral information such as how mobile the group is will be determined by the temporal boundary (e.g., annual, sub-annual, seasonal, etc.). These temporal boundaries are selected to reflect appropriately fine resolution to be able to speak to the behaviors being explained. Observations made while following a hypothetical deer population from point A to point B, beginning at time X and ending at time Y, can be compared between various legs of the observed journey and with other recorded movement events. Mobility as observed from monitoring this hypothetical population is the average of a series of single movements, or more specifically a statistical description of events observed. The annual or lifetime “mobility” assumed to exist is merely a statistical description of an abstract concept. The “mobility” that we reconstruct was experienced differently by each individual analyzed. Mobility is an active process or the quality of being in motion and has limited value as a behavioral measure without reference to external conditions.

The situation gets more complicated when researchers are reconstructing mobility events using proxy measures, e.g., various geochemical signatures. For example, this hypothetical roe deer population could be making the same number and distance of moves each year. If this population is moving across a homogenous geochemical region, proxy data for this mobility will show equally that there could have been movement within a homogenous region or no movement at all. If this population is moving across a varied geochemical region, proxy data will reflect interaction with numerous different geochemical areas and so clearly distinguish between large or small movements. To put this in the context of Cis-Baikal research, preliminary geochemical data suggest that the upper Lena micro-region is fairly homogeneous in its Sr isotopic ratios (0.709–0.711, mean=0.7096), thus similar data are expected throughout the entire micro-region. Data from the Angara drainage show much greater heterogeneity, but produce a similar mean Sr isotopic ratio to the upper Lena (0.707–0.716, mean=0.7098). Therefore, the same deer (or human) population could travel extensively throughout both regions and yield similar average Sr isotopic ratios in spite of vastly different experiences. Long-term average values are thus not necessarily good correlates for behavioral actions.

The concept of climate is another useful example of limited use of phenomena described in statistical terms. Nobody experiences regional or global climate, only localized weather conditions: the specific temperature, precipitation, cloud cover etc., present in the immediate proximity of the observer. Climate is an abstract concept formed by collecting data from broad regions and establishing statistical descriptions of similar areas and changing conditions over a set period of time. Variation in these descriptions is systematically removed to provide simplified explanations of dominant conditions through spans of time and space. Thus, high level abstractions such as *lifetime mobility* and *climate* do not provide an accurate view of the behavior or the environmental setting, respectively, pressures that are central to explanations of environmental or population changes.

Behavior is a variable concept. Variation in the essentialist view is primarily noise clouding understanding of which kind is at hand and playing no role in the process of change. Essentialism assumes that kinds exist objectively and that they transform (change or evolve) wholly into new kinds of (for example) subsistence strategies, pottery styles, stone tools, settlement systems and so forth. Materialism, in contrast, holds that kinds do not exist (they are merely high level abstractions). Rather, it is the variants that are real; evolutionary change is understood in terms of changes in population characteristics over time or, in other words, differential persistence of variation over time (Dunnell, 1971, Lyman and O'Brien, 1998, O'Brien and Holland, 1990). Using essentialist units of analysis for a concept that is varied and so materialist in nature is prone to problems such as circular reasoning, limited inquiry, and a lack of parsimony in explanations (Lyman and O'Brien, 1998, Palmer and Donahoe, 1992). Problems associated with using essentialist units are frequently the result of differences between starting or implicit assumptions of the units employed and the goals of the research. Materialist and essentialist units are not inherently good or bad; they are differentially flexible instruments designed for a specific job that may lack the precision to handle new questions effectively. Therefore, consideration of the units of analysis can play a major in how variation is documented and ultimately how change is explained in the examination of how things work.

Variation is what selection acts upon, initiating change in the average population values of mobility. Before researchers can claim that change has occurred in the pattern of mobility in a given population (i.e., middle Holocene populations in Cis-Baikal), it is necessary to establish a good understanding of the range of variation present in the population. If the range of variation differs between different micro-regions or temporal groups, then an argument can be made for change over time or space. In order to refine understanding of the range of variation, it is practical to move away from concepts such as *lifetime mobility* and instead develop and employ terminology that can provide data on events with the greatest possible geographic and temporal resolution. For proxy measures of mobility patterns, this means generating accurate provenance information for as many different spans of time in a given individual's life as possible.

The use of multiple skeletal elements to approximate different time spans is a good start (e.g., Cox and Sealy, 1997, Sealy, et al., 1995), but can provide biased results that are difficult to interpret. For example, Haverkort et al. (2008) sampled multiple human teeth near the cingulum, providing data for the tail end of the growth period of each tooth crown. Anything short of major movement events in between the growth periods of the teeth analyzed will thus not be visible. Consequently, while the authors could argue for the timing of mobility events with fairly good precision, the nature of these events was uncertain and no smaller scale events could be elucidated. For hunter-gatherer (h-g) populations suspected of making numerous annual or sub-annual movements, these data do not provide adequate resolution to support arguments for change through time or space or explanations of behavioral activities reliant upon such an assertion. What is needed is the means to micro-sample skeletal elements and to generate data with finer temporal and spatial resolution.

Concurrent with a goal of improving the technological capabilities used to gather data, is the explanatory frameworks associated with these data. There is a great deal of variation between the conditions and experiences of individuals during their lives. Analytical methods used in archaeology frequently focus on cultural and biological conditions of large groups of people rather than individuals and so may be missing aspects of the varied individual experiences during life. The approach known as *bioarchaeology of individual life histories* combines different aspects of bio- and archaeological sciences, human osteology to employ a suite of methods that provide insight into the variability of past human behavior at the individual level (Meiklejohn and Zvelebil, 1991). Central to developing individual life histories is the use of multiple lines of evidence (e.g., osteological, dental, genetic, mortuary and geochemical) to develop long strings of information from as many points during the life of specific persons as possible (Corr, et al., 2009, Haak, et al., 2008, Sealy, et al., 1995, Smits, et al., 2010, Zvelebil and Weber, In preparation). Life history is a process, so reconstructing it requires micro-data from as many different stages of life as possible. Micro-sampling of multiple skeletal elements provides insight into intra- and inter-individual variation, which is necessary for the development of individual life histories. One problem that hinders accurate assessment of provenance using chemical analysis is bone diagenesis. Changes in the chemical composition of archaeological bone in the burial environment can cloud the accuracy of provenance determinations or even yield compromised and useless data. Thus in pursuit of precise knowledge of variation in mobility patterns, we also contend with possible alterations of the skeletal materials being analyzed. Diagenesis is a microscopic scale process of physical and chemical changes to materials. As with the use of abstractions like *lifetime mobility*, individual analytical results should not be treated as averaged data for materials assumed to be homogenous. Skeletal materials are not homogenous in life and will be unevenly altered by diagenesis and will thus have internally variable sample quality. If possible, any alterations that have impacted a sample should be precisely identified and corrected for. As diagenetic changes are microscopic in scale, the identification and correction of these changes must operate on the microscopic scale. The subject of bone and tooth diagenesis is discussed in more detail later in this chapter.

Similarly, attempts to assess human mobility patterns need to operate on the microscopic scale rather than rely on essentialist assumptions of sample homogeneity. Meaningful behavioral information should be drawn from effective characterization of variation present, rather than from spans of time reflecting lifetime or multi-year averages.

HUNTER-GATHERER MOBILITY

> "When I'm a kid we're always moving. Never stay around one place for long. We got to move, otherwise we find no food. Even then sometimes there's no food for a while, so people in camp go hungry. Wherever there's food, well, we got to move to that place." Kutchin man (Nelson, 1986: 273)

Mobility is a key element of h-g adaptations and exerts a strong influence on other elements of people's lives (Kelly, 1995). Proxy measures (e.g., geochemical analysis) are utilized in order to reconstruct mobility patterning as behaviorally meaningful information. Provided that analytical data do provide meaningful behavioral information, understanding of mobility patterns offers insight into other aspects of the economic, social, and cultural world of h-g groups. Many of the dimensions of the concept of mobility as discussed by Kelly (1995) cannot be explored using Sr analysis, thus I am interested in more specific questions. For example:

- Where people were moving within the Baikal region?
- Is it possible to determine how large prehistoric mobility ranges were?
- Is there any evidence of migrations or routine interaction between the micro-regions and perhaps areas outside of the Cis-Baikal region?
- What is the range of inter- and intra-individual variation in mobility?
- Are the traditional methods appropriate to address these questions?

Terminology

Terms such as mobility, travel, movement, and migration are used in archaeological and ethnographic literature with inadequate precision and frequently have different intended meanings. In archaeological usage, terms like *travel* and *movement* are often interchangeable. *Travel*, as used here, refers to a specific event in which a particular actor (e.g., a human) transgresses from point A to point B. *Movement*, as used here, refers to the same event in which an object is transported from point A to point B, however, the actor need not be one and the same as the material or person said to have moved. Travel implies that movement has occurred, but movement can occur without the subject having travelled (i.e., artifacts being traded or a dead human body transported to its final resting location). *Mobility*, on the other hand, is an expression of the ability to be mobile, or the capability to be moved and so is not interchangeable with travel or movement. Mobility implies that movement or travel has occurred as a singular event from place to place, or as a series of events within a given span of time. Thus, while mobility is specifically the capacity for movement, in general application it is a measure of the relative frequency and distance of movements over a set amount of time. Mobility, in this way, is a covering term, or shorthand to indicate that a sequence or series of events has occurred without having to repeat the details of the action at every instance. For example, *lifetime mobility* refers to the total number of movements incurred during a lifetime while *logistical* and *residential mobility* relate more closely to the amount of travel occurring in a population for economic reasons; yet both approaches invoke a capacity for movement and a record of series of events. Mobility is necessary in order to travel/move/migrate. One cannot travel/move/migrate without a degree of mobility. To what degree one needs to be mobile in order to travel/move/migrate is a question of scale. Not much mobility is required to move around a single camp, however, a higher degree of mobility is necessary to travel longer distances from site A to B. One needs a yet higher degree of mobility to 'migrate' as this incorporates more travel and the transportation of one or more individuals and their possessions in order to inhabit a new location. Travel and movement do not express this aspect of scale ranging from individual actions to those including entire populations and their material goods.

Migration is intrinsically different from mobility or movement because it incorporates an element of permanence. Discussions over the nature of migration as a concept and its identification in archaeological remains are ongoing and have noted numerous details (e.g., population backflow and visiting) that can make separating movement from migration difficult (e.g., Anthony, 1990, 1992, Chapman and Dolukhanov, 1992, Lee, 1966, Lightfoot, 2008, Manning, 2005, Ravenstein, 1885, 1889). For example, 'seasonal migration' to a winter camp on Ol'khon Island, would be a valid term denoting semi-permanence, a change in locale and the intention to return the following year. However, repeated, sub-annual migrations would be more easily explained as part of a cyclical annual mobility pattern, though as defined here could be viewed as both a movement sequence and as a fine resolution migration (cf. Sealy and van der Merwe, 1986). This is different from events such as a single purpose movement of individuals for economic, social, or ritual purposes to Ol'khon Island from which they would return once the purpose was fulfilled. Archaeologically, the difference should be visible from evidence of reuse of the site over an extended period of time, as opposed to a site with similar materials, but no chronological evidence for extended usage. Thus the difference is in the permanence of the action and the intention to return, or not, that distinguishes the formation of a temporary camp from a migration.

Differentiating movement from mobility from migration in mobile archaeological populations (h-g or pastoralists) without permanent sedentary communities is a difficult problem. In order to approach this problem, we first need to grasp the dynamics of mobility at large and within a specific population to ascertain next where and how often people are in motion. From this we can identify patterning that could suggest periodic major shifts in a base of operations, or the establishment of a new community indicative of a migration.

Local Signals and Migration

The difficulty in emphasizing the usefulness of geochemical methods for examination of h-g mobility is that most approaches focus on the identification of a "local" signal and then identification of individuals as either local or nonlocal, (Bentley, 2006, Price, et al., 2002). Nonlocal individuals may or may not be ascribed provenance depending on the scale of regional comparisons available. This effectively limits discussion of mobility within a population to the details of a migration or kinship structures involving long-distance exchange (cf. Grupe, et al., 1997).

The concept of a "local" signal and the focus on migration have been integral to the development of Sr isotopic research since Price et al.'s (1994) landmark pilot study at Grasshopper Pueblo. The focus of this study was on migration and residential mobility practices; however, the integral ideas of how to establish a local population signal and then identify outliers, have since become standard operating procedure whether or not a given piece of research has the same goals. The two key elements of this standard method are: 1) a local signal is established, from which outliers beyond 2 standard deviations can be identified; and 2) differences between bone and tooth values relative to this local signal can be used to further identify migration or mobility events. Many researchers have adopted these central tenets of Sr research (e.g., Bentley, 2006, Ezzo, et al., 1997, Ezzo and Price, 2002, Grupe, et al., 1997, Wright, 2005), with some recently stating specifically that 2σ boundaries is the standard method for identifying outliers (Conlee, et al., 2009, Thornton, 2011). The 2σ method does not work equally well in all environments. Geochemically homogenous regions can mask the movement of people, leaving only individuals originating from outside the region, at potentially great distances, being identified as outliers.

One important development to this method has been the implementation of bioavailable Sr data based on faunal, floral or soil values (e.g., Beard and Johnson, 2000, Evans and Tatham, 2004, Ezzo, et al., 1997, Haverkort, et al., 2010, Haverkort, et al., 2008, Hodell, et al., 2004, Hoppe, et al., 1999, Kusaka, et al., 2009, Kusaka, et al., 2011, Montgomery, et al., 2007, Price, et al., 2002, Price, et al., 2008, Weber, et al., 2003, Wright, 2005). This focus on the geochemistry of the local foraging range from an identified settlement (i.e., within 10 km) rather than interpreting a "local" signal from a proxy source such as bone data, normally distributed or mean population values, provides a more accurate picture of the localized bioavailable Sr environment. The research goal of identifying immigrants in a sedentary localized population remains the same.

In order to apply methods clearly established to answer questions of migration to more specific questions of mobility, researchers also answer the additional question of where populations are going. Effective provenancing for the development of patterns of mobility can be conducted using the methods described above as long as suitable matches for different "local" populations or areas are available (e.g., Balasse, et al., 2002, Burton, et al., 2002, Chenery, et al., 2010, Nehlich, et al., 2009, Sealy and van der Merwe, 1986, Tafuri, et al., 2006, Towers, et al., 2010, Viner, et al., 2010). The range of possible mobility patterns that can be effectively identified using this method is limited to those that operate on sufficiently large scales of time to mimic the effects of migration or long-term mobility events.

This presents a problem for attempts to use Sr isotopic ratios for the study of h-g mobility. Barring cases where significant annual or seasonal resources are repeatedly accessed (e.g., salmon, reindeer, pine nuts), the consistent or predictable dietary intake and physical provenance of h-g groups over time cannot be certain. Mixing models can only effectively resolve mobility between known regions if they are chemically distinct (e.g., Balasse, et al., 2002). Thus, to develop understanding of mobility patterns in situations where permanent resources or settlements cannot be assumed, these methods should be reexamined.

Principles of Strontium Catchment

Sr ratios in herbivore bone reflect the isotopic signatures in the plants that these animals eat and the water that they drink. Thus these signatures are a direct reflection of their bioavailable geochemical environment. An herbivore foraging range will therefore roughly equate to its Sr-catchment (Bentley and Knipper, 2005, Price, et al., 2002). Herbivores will be mobile within their foraging range primarily due to the availability or accessibility of forage (e.g., new growth, free of snow, and so forth). The situation is slightly different for carnivores as their Sr-catchment will reflect their dietary intake rather than simply their geographical territory. The territory of a predator, human or otherwise, will intersect and contain portions of the territories of numerous prey animals, though it will likely not encompass the full procurement ranges of these species. Therefore the Sr ratios of their prey animals may derive from geological regions outside of the predator's geographic territory. This highlights the important concept of effective geochemical background as a step beyond bioavailable geochemical signatures. Herbivores provide direct translations of bioavailable geochemical values in plants, thus whatever portion of soil geochemistry can be mobilized into the food chain. Carnivores subsist largely or solely on other animals, thus their bioavailable geochemical values will not directly translate into either their actual movements on the landscape or their bounded procurement territory. The only evidence to relate carnivores directly with their physical territory is the water that they drink, any vegetal matter they may consume (e.g., berries), or small animals (e.g., rodents, lizards, etc.) whose entire range will be much limited in scale and thus contained within the carnivore's territory. Thus, both human and animal predatory Sr signatures may reflect procurement ranges both larger and different from their actual territories.

In geologically diverse regions, interpretation of bioavailable geochemical signatures can be complicated by the fact that animals with small home ranges (e.g., *suslik*) may have adjacent geographical territories but exist on different bedrock formations thus displaying different Sr ratios. Larger species, such as moose and red deer frequently cross geologic boundaries during the course of an annual foraging cycle and will average the $^{87}Sr/^{86}Sr$ ratios in their tissues. Thus interpretation of the bioavailable geochemical data can be unintentionally biased during field collection based on sample availability.

As noted in many studies (e.g., Beard and Johnson, 2000, Bentley, 2006, Bentley and Knipper, 2005, Ezzo, et al., 1997, Ezzo and Price, 2002, Haverkort, et al., 2008, Hodell, et al., 2004, Price, et al., 2002, Weber, et al., 2003), understanding of human geochemical signatures (from bones or teeth) is best achieved in the context of the biologically available geochemical environment. Regardless of the actual geochemical properties of the rocks and soils, all that scientific analysis will show is the interaction between human consumer and the biologically available geochemical environment. That is, aspects of the rocks and soils that can be dissolved, absorbed by plants and become part of the food chain. Understanding of the water sources is premier as the fundamental vector for both plants' and animals' interactions with their environment, and thus the compositional signatures that will be imparted upon their human consumers.

Modern surface water may not reflect compositional characteristics of the same water source throughout prehistory as erosion factors can alter the geological interaction or contribution to the water's composition through time. Sampling of smaller water courses and geochemical contributions to the larger rivers as well as identification of localized geologic features can help address this matter. In the Baikal region, small (e.g., Bugul'deika, Manzurka, etc.) and medium (e.g., Irkut) rivers provide important information for the development of regional distribution maps of geochemical signatures, corresponding to very specific geographical areas as opposed to the averaged total of entire drainages represented by large rivers (e.g., Lena). Consequently, in this research, the longer the bodies of water, the more samples were collected for analysis.

Water that is consumed directly is an important interaction vector for all living animals, is not the primary contributor of geochemical signals imparted on skeletal tissues. Biologically available chemical components are present in far higher concentrations in plants (approximately 10 times higher for elements such as Sr), than in water (cf. Bentley, 2006). In a boreal forest environment, plant foods are likely not great contributors to the human diet, but do comprise the majority or entirety of the diets of animals that humans would have had subsisted on. Animals eat a variety of plants that are inedible to humans and so will have a much broader interaction with the geochemical environment. To track the range of potential inputs into animal's diets, sampling of plants is necessary throughout the archaeological micro-regions of Cis-Baikal. If possible species with different root structures (i.e., depths; see species collected for analysis in Chapter 5) should be collected in order to assess better the possible range of biologically available geochemical values in both direct consumable plant matter and in contribution towards local soil production.

Haverkort et al. (2008) noted that the majority of their Baikal faunal samples did not have exact provenience and could only be attributed to regions or micro-regions. Each individual animal will have its own foraging range which may overlap entirely or not at all. This leaves the potential for great disparity between the geographic coordinates of the sampling location (i.e., modern find or archaeological site) and the location of the foraging range (i.e., geochemical interactions with the environment) the animal experienced in life. Archaeological faunal materials present an additional problem in that the animals could have been transported quite long distances from hunting grounds to processing sites. The utility of large, frequently migratory, fauna – modern or archaeological – as source of reference materials is thus compromised by the missing information about the location of the animals' foraging ranges. For example, a sample of roe deer recovered from the Little Sea may actually come from an animal that spent most of its life on the Upper Lena.

Small animals are the preferred choice for reference samples, at least for studies involving agro-pastoral groups, as they generally have limited and spatially rather fixed foraging ranges that are thus more conducive to the understanding of the distribution of the biologically available geochemical tracers. The problem here is that in regions where large fauna are available, small fauna usually does not contribute much to the general diet and likely did not contribute much in the case of hunter–gatherer groups examined here. There is currently no evidence to support significant usage of small fauna for food in Cis-Baikal. In the Baikal region, small fauna from archaeological sites is rarely available for sampling and collection of modern specimens is rather impractical. Furthermore, the terrain of the Cis-Baikal region is highly variable, much of it not conducive to systematic sampling of small fauna within the time frame available for fieldwork which would result in a reference dataset biased towards a few pockets with more open taiga-steppe terrain and close to the excavated archaeological sites (e.g., Little Sea).

Since plant and water samples have fixed and confirmed provenience and reflect bioavailable geochemical data with greater chronological stability, they provide a more accurate picture of prehistoric bioavailability of geochemical tracers than modern or archaeological fauna can provide. In sum, for this research plants and water are materials of choice for reference purposes.

CIS-BAIKAL GEOLOGY

Geochemical analysis for research into mobility can only be effective in regions where the environment is geologically and geochemically diverse and relatively stable in time and space. If there is no variation in the geochemical background of the region, geochemical results will be homogenous and thus will not provide any useful behavioral information. Luckily, the Baikal region is geologically and geochemically diverse. Within Cis-Baikal there are four main geological zones that roughly correspond to archaeological micro-regions (Figure 2-1): (1) the Baikal basin; (2) the drainage of the upper and middle Angara River; (3) the basin of the upper Lena River; and (4) the Tunka region.

In the Angara drainage, bounded by the Eastern Sayan Mountains to the west and the Central Siberian Plateau to the east and extending north towards Bratsk, the bedrock are of Archaean–Proterozoic age. Bedrock consist of granites, metamorphic schists and porphyritic volcanics at a depth of 2.3 km. Covering the basement are Cambrian sediments that consist mainly of dolomites with layers of limestones, rock, anhydrites, clays, sandstones, argillites, gritstones, marls and gypsum. The Cambrian material is

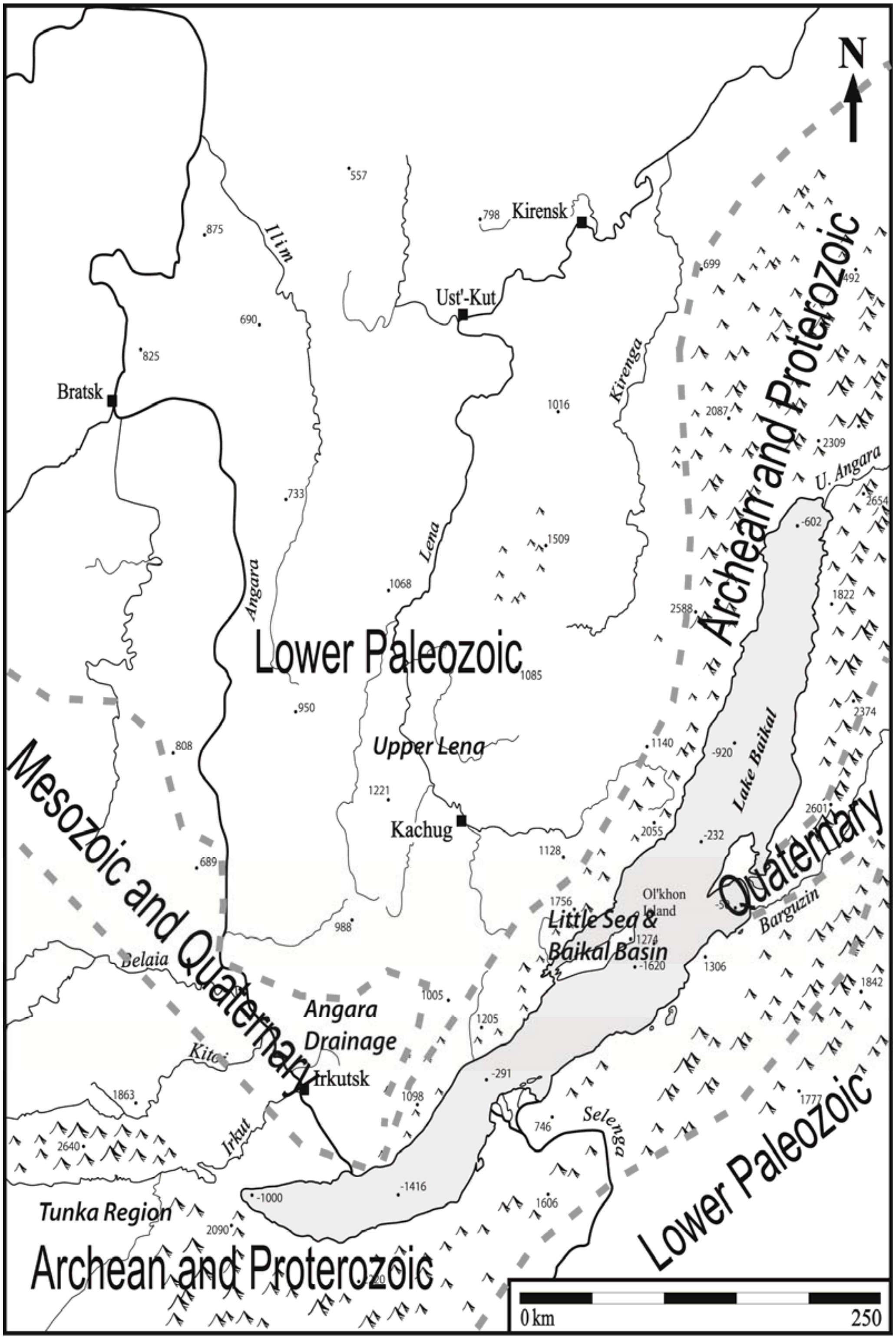

Figure 2-1: Cis-Baikal regional map with the age of dominant geologic formations and archaeological micro-regions (following Haverkort et al., 2008; Galazii 1993).

covered by 100 m of Jurassic sediments made up of sandstones, siltstones and coal beds. Adding to this variability are the valleys connecting with the Eastern Sayan Mountains (e.g., Kitoi and Belaia Rivers) drawing from mixed metamorphic, unmetamorphosed and magmatic complexes of Archaean and Early Proterozoic ages (Donskaya, et al., 2008, Gladkochub, et al., 2006). Various exposures of these bedrock and Quaternary sediments, primarily clays, are expected to yield $^{87}Sr/^{86}Sr$ values in the range of 0.705–0.712 (Fagel and Boës, 2008, Haverkort, et al., 2008, Shouakar-Stash, et al., 2007).

The Upper Lena watershed cutting through the Central Siberian Plateau as the river heads northwards and the surrounding plateau are underlain by Archaean–Proterozoic basement at around 2.2 km depth overlain by Cambrian and Precambrian sediments. These sediments consist primarily of dolomites interlayered with evaporites of gypsum, anhydrite and halite rocks and beds of limestone and sandstone at different depths and beds of limestone and sandstone (Donskaya, et al., 2008, Gladkochub, et al., 2006). The thickness of the covering sediments and the relative geochemical homogeneity of the plateau yield expected $^{87}Sr/^{86}Sr$ values fairly tightly clustered around 0.709 (Haverkort, et al., 2008, Huh, et al., 1994, Huh, et al., 1998b). Values for Lake Baikal water are reported as 0.7085 (Kenison Falkner, et al., 1992).

The Baikal basin includes the lake itself, the coastal areas as well as the Little Sea area enclosed by Ol'khon Island, the Baikal uplift zone, the Primorskii and Baikalskii mountain ranges and is characterized by relatively high $^{87}Sr/^{86}Sr$ (~0.720–0.735) values due to the presence of Archean and Proterozoic granites (Donskaya, et al., 2008, Galazii, 1993, Gladkochub, et al., 2006).

The Tunka region, covering the Irkut River valley running south of the Eastern Sayan Mountains and connecting the southwestern tip of Lake Baikal with Lake Khovsgol in Mongolia, consists of basement rock from the Sayan-Baikal fold belt, also of

Archaean and Proterozoic age. The Sharizhalgay uplift zone in the Eastern Sayan Mountains and bordering the Siberian Plateau includes metamorphic and magmatic complexes of similar age (Donskaya, et al., 2008, Gladkochub, et al., 2006). There is a diffuse zone of Cenozoic volcanism to the south and west of the southwest end of Lake Baikal, spanning from the East Sayan and Tuva to the Gobi and Mongolian Altai (Johnson, et al., 2005, Rasskazov, 1994, Rosen, et al., 1994). Furthermore, the area also features an essentially non-volcanic Late Oligocene–Quaternary sedimentary basin composing much of the eastern portion of the valley (Rasskazov, 1994). All this yields a complex range and distribution of expected ^{87}Sr/^{86}Sr values in the Tunka micro-region, likely overlapping both values seen in the Angara drainage and the Baikal basin.

Fluvial geochemical results available for Siberian rivers emphasize different compositional data than those frequently employed in either biogeochemical or in artifact provenance studies. Previous examinations of radiogenic isotopes in Cis-Baikal have focused solely on ^{87}Sr/^{86}Sr ratios (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003). ^{87}Sr/^{86}Sr data for Siberian rivers and Lake Baikal have been published as part of the fluvial geochemistry, encouraging the usage of this approach for studying h-g mobility (Huh, et al., 1994, Huh, et al., 1998a, Kenison Falkner, et al., 1992). These data also contain information for Na, K, Mg, Ca, Cl, Si and ^{87}Sr/^{86}Sr values for Siberian drainages and Cr, V, and Sr for Lake Baikal. In stable isotope studies, these elements are generally not mentioned as they do not have isotopes that exhibit natural fractionation, however in terms of general compositional studies such data provide a more complete geochemical picture and invaluable insight into the forthcoming human data.

While the four geological zones constitute a useful general framework of reference, the biologically available Sr isotope ratios in various animals provide more direct guidelines and models for analysis and interpretation of the human data (Beard and

Johnson, 2000, Bentley, 2006, Bentley and Knipper, 2005, Ezzo, et al., 1997, Ezzo and Price, 2002, Hodell, et al., 2004, Price, et al., 2002). Because Holocene foragers used terrestrial as well as aquatic resources, analyses have been conducted on both ecosystems (Haverkort, et al., 2008, Katzenberg and Weber, 1999). On a regional scale the terrestrial samples display a wide range of Sr isotope ratios and a few interesting patterns can be observed.

First, the size of the animal Sr-catchment and proximity to geological formations with high ^{87}Sr/^{86}Sr appear to be the main factors controlling ^{87}Sr/^{86}Sr in terrestrial animals. For example, the specimens from the Little Sea micro-region produced the most variable, highest, ^{87}Sr/^{86}Sr ratios. Furthermore, animals with very small Sr-catchment (suslik, mouse) clearly have more variable ^{87}Sr/^{86}Sr than the animals with large catchments (red deer, roe deer) even in the areas where the background geological ^{87}Sr/^{86}Sr is quite uniform and low (e.g., on the upper Lena). The lowest ^{87}Sr/^{86}Sr (0.70882) was recorded for a mouse in the upper Lena basin and the highest (0.74330) for a suslik found near the entrance to the Sarma Canyon in the Little Sea area. The large herbivores also seem to conform to this pattern: in the Little Sea area, the moose, whose procurement range is relatively small (Franzmann, 2007), produced ^{87}Sr/^{86}Sr much more variable than found in the roe deer which is known for its very long treks (Clutton-Brock, 1982). And lastly, the Angara valley evinced some additional spatial differences between the areas to the east and to the west of the river (Haverkort, et al., 2008).

The overall variability in ^{87}Sr/^{86}Sr ratios for the aquatic specimens is limited, with the exception of three pike specimens from the Little Sea region. In this micro-region the pike with the highest ^{87}Sr/^{86}Sr of all aquatic samples came from the same area as the highest result for the suslik. Perch and dace are the only two fishes that were analyzed for both the Lena and Angara Rivers with the mean values of 0.70884 and

0.71023, respectively (Haverkort, et al., 2008). The differences observed in the Sr isotope ratios clearly show that these two river systems have different geochemical characteristics of the Angara valley (mean 0.70836, SD 0.000332, n=10) differs from the west side (mean 0.70985, SD 0.002569, n=5) in terms of ^{87}Sr/^{86}Sr, a pattern also visible in the data obtained for the terrestrial species.

Overall, these data demonstrate that in Cis-Baikal the biologically available ^{87}Sr/^{86}Sr is sufficiently variable to be useful for archaeological applications (Haverkort, et al., 2008). These differences consider not only the terrestrial ecosystem, but also the aquatic. The Little Sea area on Lake Baikal is clearly distinguishable from the rest of Cis-Baikal with its much higher on average ^{87}Sr/^{86}Sr and also, rather unexpectedly, much more variable values on the intra- and inter-species levels compared to the rest of Cis-Baikal. Interestingly, biologically available Sr in the eastern and western parts of the Angara drainage appears to be distinguishable too. The upper Lena, however, turned out to be similar to the eastern part of the Angara valley.

HUNTER–GATHERER MOBILITY IN CIS-BAIKAL

The study of h-g mobility during the Middle Holocene in the Cis-Baikal region of Siberia only recently has begun in spite of a long history of archaeological research that goes back to the 19th century. As noted above, Okladnikov (1950, 1955) identified different hunting and fishing toolsets amongst the graves of the different cultural stages. He believed that the Neolithic began with the Isakovo culture and that their extensive use of wooden bows supported their place as terrestrial hunters within the Lake Baikal region (Lam, 1994, Weber, 1995). The Serovo culture had a similar egalitarian system of burial and grave goods with a tool inventory dominated by compound bows and hunting gear showing a dependence on terrestrial hunting, but with clear use of riverine resources including harpoons, fishhooks, net sinkers, polished stone figurines carved in the image of different fish species, and fish bones (Weber, 1995). Okladnikov (1950) noted significant variation in the quantity of Kitoi grave goods associated with individuals and graves containing multiple individuals. Burial materials included relatively more fishing gear than arrow heads, the nearly ubiquitous composite “Kitoi” fishhooks, and the consistent use of red ochre to cover the deceased, indicating a heavy reliance on fishing and likely evidence for social stratification (Weber, 1995). The Glazkovo culture continued this progression of increased reliance on fishing and decline in terrestrial hunting further diversifying the h-g society of the region. Based on the environmental shifts at the Pleistocene/Holocene transition, this progression from terrestrial hunting to fishing seemed perfectly logical (Lam, 1994).

In 1994, Lam published the first, relatively small, set of carbon and nitrogen stable isotope data that could be used to test the veracity of the economic progression as described in Okladnikov’s (1950) cultural-history model. These initial results were somewhat surprising given the general acceptance of the Okladnikov’s model, as stable isotope data did not support them at all; high $\delta^{15}N$ (change in $^{15}N/^{14}N$ ratio) values demonstrated a clear reliance on aquatic resources for all groups; the $\delta^{13}C$ (change in $^{13}C/^{12}C$ ratio) values were ambiguous, but clearly did not support the fishing/hunting dichotomy Okladnikov proposed. This work was the first to show serious flaws in Okladnikov’s economic model, however, it still did not discuss mobility.

Katzenberg and Weber (1999), expanding on Lam’s preliminary work, with later elaboration in Weber et al. (2002), conducted a larger scale stable isotope analysis on human and faunal bone from the Neolithic and Early Bronze Age periods of Cis-Baikal for carbon and nitrogen; in order to study regional and temporal variation in diet and subsistence. Results for prehistoric diet in the Cis-Baikal suggest both regional and temporal variation in diet and subsistence, with groups living closest to Lake Baikal differing from groups living along the Upper Lena and the Angara River, sites more distant from the lake. All indicators suggest reliance on the fish and seals of Lake Baikal and minimal usage of terrestrial resources for the bulk diet while people further down the Angara River and along the Upper Lena River appear to have relied mainly on terrestrial herbivores for their protein source, with less reliance on riverine fish species. This argued for subsistence behavior relying on food resources close to home.

Mobility and migration were not discussed prior to the Weber et al. (2002) study where subsistence, population density and distribution were first linked directly to mobility patterns. Okladnikov attributed all cultural changes to *in situ* developments and limited intra- or inter-regional movements of people during the middle Holocene. Weber et al. (2002) changed this by tying stable isotope data into theoretical models of h-g subsistence and mobility. Using the revised model of cultural history (Table 1-1) and incorporating dietary isotopic data with subsistence and mobility models allowed for direct comparisons among regional and temporal groups. Dietary focus had clear implications for the potential movements of individuals and groups. This linkage between diet and mobility was effectively the beginning of mobility research in the Cis-Baikal region.

Similarities in patterns of subsistence, settlement, and mobility to the ethnographic models developed by Binford (1980), provided the first hypothetical picture of regional variation in mobility during the Holocene. Some elements of the logistical and residential mobility models were visible in archaeological data and working hypotheses for the EN and LN–EBA groups were developed to suggest that the in the EN groups relied on logistical mobility to provision groups while the during the LN–EBA, groups made more frequent residential moves with less logistical travel.

These typological classifications showed a number of similarities with cultural groups but were not ideal fits for the archaeological record. Ethnographic overviews from other parts of the world (Kelly, 1995, Metcalfe and Burlow, 1992) demonstrated that single groups could change strategies depending on a number of circumstances (e.g., season, type and location of resource, weather patterns). A better fit was found with the *travelers and processors* model developed by Bettinger and Baumhoff (1982). This model included variables such as subsistence, camp use, diet, demography, and mobility that all served to be useful in distinguishing between the EN and LN–EBA adaptive strategies. The contrasts and parallels between the EN and LN–EBA Cis-Baikal h-g groups and the travelers/processors dichotomy provided the working model for mobility prior to the implementations of geochemical techniques.

Mobility and territorial behavior, as addressed using dietary isotopic (C, N) analysis proved to be a more direct measure of mobility patterns than could be drawn from the *travelers and processors* model (Ezzo, et al., 2003, Katzenberg and Weber, 1999, Lam, 1994). Preliminary results suggested that EN individuals and groups pursued a restricted range of resources within spatially limited annual ranges. Dietary evidence in particular suggested well defined and fixed annual territories centered on the upper Angara and Irkut valleys.

Geochemical data for Lokomotiv (EN) and Ust'-Ida I (LN and EBA), in the Angara Valley, and Khuzhir-Nuge XIV, on the Little Sea (Figure 2-1), suggested that groups associated with these cemeteries all used different home ranges (Haverkort, et al., 2010). For LN and EBA mobility, two hypotheses were suggested: one invoked groups traveling to pursue the most abundant resources available in diverse settings across the whole of the Cis-Baikal area, the other a less regionally mobile pursuit of a broader range of resources within specific micro-regions.

Weber et al. (2003) published a pilot study of the potential for the application of Sr isotope analysis to provide new insights into the mobility and subsistence patterns of the Neolithic h-g groups of Cis-Baikal. To test the applicability of this technique, tooth enamel and femur samples were analyzed representing six adult individuals from the EBA Khuzhir-Nuge XIV cemetery on Lake Baikal. In contrast to studies involving sedentary farming groups, the goal was to assess changes in subsistence patterns over the life span of an individual, rather than to identify places of residence during early childhood and adulthood. Results from this study seemed to show that the long-term foraging ranges of adults in the region were fairly limited, focusing on the Little Sea area.

In a later study, Haverkort et al. (2008) expanded the pilot investigation by applying the Sr technique to a sample of 25 individuals from Khuzhir-Nuge XIV. The main goal of this study was to differentiate between two alternative models formulated from the results of the pilot study. A secondary goal of this study was to explore inter-individual variation in Sr ratios, and potential sociocultural correlates. The results showed a significant degree of intra- and inter-individual variation in Sr isotope ratios and long-term foraging territories focusing on the west coast of Lake Baikal (i.e., Little Sea) but including other parts of the Baikal region.

Recently, Weber and colleagues (Weber and Goriunova, 2012, Weber, et al., 2011b), have further analyzed dietary and mobility data produced for the Cis-Baikal region (Sr isotopes; C and N characteristics of river systems) to refine and enhance understanding of mobility and subsistence. Two different diets were identified: one including seal consumption (game–fish–seal) and one with much less or no seal at all (game–fish), even in the Little Sea micro-region where seal intake is to be expected. During the Early Bronze Age, the Little Sea and upper Lena micro-regions appear to be exchanging individuals through seasonal travel (i.e., annual foraging range) or some other type of routine interaction. The dietary difference could either have been the result of cultural practices separating inhabitants of the two regions, or suggest multiple rounds of seasonal interaction where some individuals were not near the lake when seal were available for harvesting. Subsistence and mobility studies complement one another as has been demonstrated by these and many other studies.

BONE AND TOOTH FORMATION AND ALTERATION

Demonstrating that a region has suitable bioavailable geochemical variation is one part of the puzzle. Obtaining behaviorally meaningful information requires additional consideration of the formation processes of the biological material being analyzed. Background information on how bone and tooth tissues develop is central to generating data with the best possible chronological resolution.

Tooth Mineralization

Teeth are dynamic mineral structures whose complexities are still being unraveled. It has long been recognized that the incremental *striae of Retzius* represented some aspect of matrix deposition but that there is a disconnect between this matrix deposition and the final mineralization that will finalize the mineral matrix (e.g., Brown, et al., 1960). At the time, micro-sampling of individual striae was not practical, thus the matter was largely ignored. There has recently however been a resurgence of interest in the formation process of the incremental growth lines as reflections of the circadian rhythm of enamel matrix secretion with the advent of micro-sampling techniques such as laser ablation and micro-drilling that could theoretically sample the enamel at such pertinent scales (e.g., Hillson, 2002, Horstwood, et al., 2008, Kang, et al., 2004, Prohaska, et al., 2002, Richards, et al., 2008).

Numerous hypotheses have been developed regarding the pattern and progression of enamel mineralization, however the common theme amongst all works is that the progression of mineralization of layers and/or maturation of matrices is patchy and effectively non-linear thus making the chronological relationship between incremental lines and geochemical signals rather tenuous (Bentley, 2006, Dolphin, et al., 2003, Fincham, et al., 1999, Hillson, 2002, 2005, Kang, et al., 2004, Montgomery and Evans, 2006, Suga, 1982, 1989, Tafforeau, et al., 2007). Broad trends whereby mineralization begins at the tooth cusp and finishes at the cingulum are still present, though the intermediate pathways are debatable.

Montgomery and Evans, (2006) and Fincham *et al.,* (1999) provide excellent discussion of the biomineralization of tooth enamel with respect to Sr isotope analysis. The process of mineralization spans a series of five distinct phases wherein an organic gel or protein superstructure is transformed into a mineral matrix: 1) secretion; 2) assembly; 3) matrix formation; 4) resorption prior to maturation; and 5) maturation (see Fincham et al. (1999), Fig. 8; Bentley (2006), Fig. 18). Following assembly, nanospheres of apatite will remain largely intact until maturation; however, although these individual crystal structures are reflexive of their formation environment, they will mingle with other crystals to form a heterogeneous lattice of crystals in the mature matrix. Effectively, at all stages prior to maturation, the enamel matrix remains an open chemical system vulnerable to alteration, overprinting, or simply averaging of the matrix at the scale of modern recovery techniques.

The practical ramifications of this open chemical system is that while the formation of tooth crowns progresses at a well-known rate and there are incremental growth lines to further support the logical conception of enamel matrix as a continuous linear formation, all work to date demonstrates that there is a disjunction between enamel formation and matrix maturation. So while we know that calcification of M1 begins at birth and ends with maturation and root formation between 3 – 4 years of age, we are left with nearly three years of that molar remaining an open chemical system and subject to potential averaging effects (Avery, 1992, Hillson, 2002). In spite of this difficulty, there is still some promise to the concept of micro-sampling tooth enamel. That incremental growth lines do not mineralize in a similar incremental fashion has been well demonstrated, however there are still some broad guidelines that remain true: 1) the crown of a tooth will fully mineralize before the root; and 2) though accomplished in a patchy or wave-like fashion, there are still broadly linear trends in mineralization progressing from crown to cingulum.

Ongoing research into this problem with herbivore teeth has demonstrated that there are long-term mixing effects in action during the formation and maturation of tooth enamel (Balasse, 2003, Balasse, et al., 2002, Britton, et al., 2009, Brown, et al., 1960, Hoppe, et al., 1999, 2003, 2004, Koch, et al., 1995, Montgomery, et al., 2010, Tafforeau, et al., 2007). Such research has highlighted a secondary problem with efforts to access the micro-structure of teeth and thus provenance their formational period. Formation of enamel proceeds using available mineral components within the body that come from the diet; however, there is a gap between intake of the raw ionic components of the mineral structure and their incorporation into mineral tissues. Specifically, this is the problem of residence time in the body for different elements.

Controlled feeding experiments have provided critical understanding of the incorporation and utilization of trace elemental and isotopic components in mammalian physiology (e.g., Ambrose, 1990, Ambrose and DeNiro, 1987, Ambrose and Katzenberg, 1998, Ambrose and Norr, 1993, Burton and Price, 1990, 1991, 1994, Burton and Wright, 1995, Lambert and Weydert-Homeyer, 1993a, b, Tieszen and Fagre, 1993). From such studies, we can infer generalized expectations for presence, retention, and concentration of different elements throughout skeletal and body tissues. Water has a short residence time in the body of only 14 days while bone-seeking elements such as strontium, calcium, and lead can remain in the body for 800–1600 days, with 10% of traceable doses remaining active after 400 days (Bowen, 1979b, Dahl, et al., 2001, Montgomery, et al., 2010).

Recent works (e.g., Britton, et al., 2009, Montgomery, et al., 2007, 2010) have demonstrated that this residence time in the body has an intriguing effect on isotopic signatures of a linearly-sampled herbivore tooth. Namely, an abrupt change in geochemical geography and/or diet will not manifest as a sharp transition in isotopic signals, but rather that there will be a gradual sloping change as contributions from different geochemical end-members vary within the body-water average being accessed for ionic component material in enamel formation.

At face value, this combination of lag time in mineral formation and maturation with body-water averaging of over a year should render moot discussions of micro-sampling human teeth for interim provenance information between the crown and cingulum. It should however be noted that there is an important difference between herbivore and human teeth. While it is quite likely that the same mineralization primers are in effect for both human and herbivore teeth and that the non-linear progression of mineral maturation is effectively the same, the time spans involved are different. For example, each bovine molar will form and fully mineralize over a span of 12–18 months (Montgomery, et al., 2010).

Each human molar, however, can theoretically span a time of 24–48 months between initial calcification and final mineral maturation, though it will likely occur in less than 36 months. Thus, there is a gap in comparative volumes and chronologies in discussing the differences between herbivore and human teeth. While many herbivore teeth are not good candidates for micro-sampling because their tooth formation rates will not outstrip uncertainties about residence time and mineralization rates, human teeth will likely exhibit some aspects of useful variability in isotopic signatures through formation time and thus through the enamel mineral structure. It is useful to keep in mind that while at present it is impossible to overcome the issue of residence time of dietary components and maturation time for the mineral matrix, it may still well be worth pursuing micro-sampling of human teeth in between cusp and cingulum.

Bone Formation

Serious consideration of the nature and effects of diagenesis on bone begin with considerations of the process by which bone is formed and terminology used. There are two histological types of mammalian bone, woven (non-lamellar, primary) and lamellar (secondary, mature). Bone, or bone matrix, in general discussion refers entirely to lamellar or secondary structures. Primary or woven bone develops during prenatal life and characterizes the embryonic skeleton, sites of fracture repair, and a variety of bone tumors (Cooper, et al., 1966). Forming rapidly, it lacks the structure and density characteristic of lamellar bone, and barring illness or abnormal development, represents only a temporary form of bone in humans. Woven bone is the more phylogenetically primitive bone type in evolutionary terms, with bundles of collagen fibers arranged in a non-oriented, random pattern; it is coarse and fibrous in microscopic appearance (Cooper, et al., 1966, White, 2000).

In functional terms, primary and secondary bone structures are linked processes in formation, differing primarily in form (structure) rather than in function (associated processes and/or composition). The point of distinction is that lamellar bone is essentially a replacing and not a primary tissue (Currey, 1960). Replacement begins with postnatal growth and most woven bone is fully replaced by the age of four years in humans, seen only in adults in instances of injury or illness (Cooper, et al., 1966). The ratio of bone cells to bone matrix, or rather living cells to inorganic matrix is higher in woven bone and the mineral content throughout the bone is more variable. However, beyond the differences in blood supply to different types of bone and how this can dictate mineralization, some uncertainty remains as to why this variability is present (Cooper, et al., 1966, White, 2000).

The structure of mature lamellar bone was first described in a treatise entitled *Osteologia Nova* in 1691 by Clopton Havers; with the observed structure depicted as consisting of longitudinal, parallel plates or laminae pierced by both transverse and longitudinal pores (Cooper, et al., 1966). This initial description focused on long bones, yet both compact (cortical, non-spongy) and trabecular (cancellous, spongy) bone are composed of lamellar bone tissue exhibiting this orderly, organized structure produced by the repeated addition of uniform lamellae during appositional growth. Havers noted "nutritious arteries," within this bone tissue, referring to the passages (blood vessels) that run longitudinally within bone, for which the term Haversian canal was given (Cooper, et al., 1966). Lamellar bone is a later step in bone formation, linked to the formation of compacted bone of such structure and thickness that it is unable to acquire adequate amounts of nutrients and dispose of waste via diffusion from neighboring blood vessels. The maturation of woven bone, termed laminar bone, forms a series of concentrically arranged laminae, separated by a net-like system of blood vessels (Currey, 1960). A notable feature of laminar bone is that the relative simplicity of the system allows for rapid growth, providing a way of increasing the thickness of bones quickly, developing a substantial framework of woven bone, that can then be replaced more slowly by lamellar bone.

Related to this formation process are hypercalcified (‘bright line’) lines that are correlated with the formation of new laminae. They seem to act as formation primers (Currey, 1960, Dhem, et al., 1976, Mori, et al., 2007, Mori, et al., 2003) and appear differently in animals (e.g., cows and horses) than they do in humans. Furthermore, the extent to which laminar is replaced by lamellar bone and the rate at which this occurs can vary greatly between species (Currey, 1960, Dhem, et al., 1976). Taken alone, this may seem like an academic detail, but these hypercalcified lines have notably different compositional traits including higher Ca and P content, lower crystallization and significantly lower physical and chemical resistances, that can have great import when considered in light of sampling concerns, diagenetic alterations and the laboratory handling procedures employed in compositional analysis (Mori, et al., 2007, Mori, et al., 2003).

For bone samples of concern to archaeologists and analytical chemical concerns relating to archaeology, lamellar or Haversian bone will be the dominant type of bone encountered. Haversian bone consists of a network of osteons aligned parallel to the diaphysis long axis and running a slightly spiral course (Cohen and Harris, 1958, Jaworski, 1991, Tappen, 1977). The formation of Haversian bone begins in humans early during postnatal growth and is the product of discrete spatially (circumscribed) and temporally (transient) coupled activity of osteoclast and osteoblast populations, forming the basic multicellular units, generally termed Haversian systems or osteons (Jaworski, 1991). Some texts (e.g., Ham and Harris, 1956, Maximov and Bloom, 1957) assert that Haversian systems are the unit of structure within bone, though this is an overarching claim as they are much more related to the age of an organism and the process of bone turnover than to any structural unit. Any useful discussion of the structural units of bone needs to focus on the collagen/bone crystal scale, as all larger units are strictly limited to the formation and remodeling of these structures (Currey, 1960).

The formation of lamellar bone begins in non-lamellar bone, with layers of bone being deposited within the space that contains vessels, marrow elements and loose connective tissue (Cooper, et al., 1966). As layers of bone build on the walls of this space, vessels become trapped as an island within lamellae of bone, giving rise to primary osteons (Cooper, et al., 1966, Enlow, 1963, Frost, 1963, White, 2000). After the initial formation of primary osteons, the process of remodeling takes over as the primary process involved in bone formation and ultimately bone mineralization.

The formation of the cavities noted by Clopton Havers is that of the formation of individual Haversian systems, or secondary osteons. The cavities are the blood vessels or vascular canals that are generally termed Haversian canals when they run parallel to the long axis of the bone and Volkmann's canal when they either connect these larger vascular canals or simply run perpendicular to the long axis of the bone (i.e., Cohen and Harris, 1958, Jaworski, 1991, White, 2000). There is some debate (e.g., Cohen and Harris, 1958, Cooper, et al., 1966) whether this differentiation is appropriate or accurate, though this matter is beyond the scope of this paper.

Individual osteons are approximately 200–300 microns (µm) in diameter and only make up a fraction of the total length of any given bone, generally only traceable over the course of several (3–5) millimeters (Cohen and Harris, 1958). The biggest difference between primary and secondary osteons is that secondary osteons are, by definition, cut through preexisting bone (cf. Jaworski, 1991), thus forming discrete but connected bone units that are separated from the surrounding bone tissues they replaced, by a thin protein-aceous membrane frequently referred to as a cement or reversal line

(Cohen and Harris, 1958, Currey, 1960, Jaworski, 1991). This cement line prevents the passage of material between osteons except via the Haversian and Volkmann canals, thus bone matrix within an osteon remains unchanged until the process of bone turnover ruptures/replaces the osteon itself and thus has some implications for the penetration of diagenetic effects.

Within the Haversian system there is the main blood vessel, lacunae (each harboring a living osteocyte), canaliculi connecting the lacunae and providing nutrients to the osteocytes and lamellae, or concentric rings of bone matrix (Jaworski, 1991, White, 2000). During the lifespan of an osteon, bone formation is ongoing, but not constant, creating rings of lamellae with high and low density collagen fibers, visible as light (bifringent, dense fibers) and dark (loose fibers) under polarizing light (Jaworski, 1991, Marotti and Muglia, 1988). Each lamella is between 2 and 7 μm thick, representing a period of growth. Thus, older osteons have more lamellae and younger osteons have fewer (Cohen and Harris, 1958, Cooper, et al., 1966, Jaworski, 1991). While the depositional process is ongoing, the mineralization of lamellae is not constant and does not proceed in a uniform fashion, even within an osteon (Cohen and Harris, 1958, Cooper, et al., 1966).

Mineralization involves individual fibrils and can include fibrils crossing lamellae, however, this only applies to the lamellae in close proximity to the Haversian canal, and the mineral density of mineralized matrix (once it occurs) does increase with depositional age (Cohen and Harris, 1958, Cooper, et al., 1966). Thus, moving away from the Haversian canal, mineralized lamellae will reflect increasing time depth, though the caveat remains that each lamella may not have mineralized before the younger neighboring lamella. This leaves useful discussion about the depositional chronology of lamellae within an osteon needing comparable lamellae to be separated by at least 3 μm in between lamellae under consideration. The distance of a full lamella is necessary before one can reasonably assume that mineralization has occurred prior to the formation of the next lamella.

Lamellae within an osteon are the useful unit of discussion with regard to mineralization and deposition as the only relatively homogenous mineralized unit within bones as a whole and even within the osteons of Haversian bone. As noted by Cooper et al. (1966), the mineralization process begins with the individual fibrils of collagen, with crystals forming both within and on the fibrils that form the mineralized region, which then proceed to gradually enlarge and coalesce to form a fully mineralized matrix. This operation only characterizes the basic mineralization of Type I collagen and not Type II collagen found in the epiphyseal cartilage associated with growth plates, or any other types of collagen (Hunter, 1991, Revell, 1986). Given that Haversian bone becomes the dominant form of bone by the approximate age of five years, this should not be a point of concern for archaeologists, except for studies focusing on infants, as the details of bone formation and mineralization are different during this early period in life (Cooper, et al., 1966).

The actual process of mineralization is somewhat complex, relying on a number of interrelated factors and mechanisms. The local elevation of calcium and phosphate ion levels to levels that would enable spontaneous precipitation of mineral; the presence of substances which would provide sites for the nucleation of mineral (e.g., collagen fibers); and finally the presence of substances preventing mineral formation and their removal or inactivation to allow subsequent calcification (Hunter, 1991, Revell, 1986). The biochemistry involved in the signaling for necessary mineral ions, the availability of such ions and the presence or absence of substances guiding the actual mineral formation are important, however, as they do not alter the composition of the bone matrix, are not vital to the discussion here.

Most of the mineral present in normal lamellar bone is located within the collagen fibrils; the volume present outside the collagen fibrils is only 5–10% (Boyde, 1972, Glimcher, 1976, Revell, 1986). Collagen molecules secreted into the extra-cellular space by the osteoblasts are assembled into fibrils in a three-dimensional array prior to impregnation with mineral (Revell, 1986). There is, therefore, a stage in the calcification of bone in which the collagen fibrils in the extracellular tissue space are free of solid-phase calcium and phosphate. Furthermore, the current best model of the array of collagen molecules within a fibril has them overlapping about 9% of their length and linear aggregates are staggered laterally to form a fibril in which there are spaces between the ends of molecules, generally referred to as holes, with the overlapping ends and spaces region being the hole zone (Glimcher, 1976, Hodge and Petruska, 1963, Revell, 1986).

The deposition of a mineral phase within and on the surface of the fibrils occurs preferentially in the hole zone of the fibril, and there continues to be a preferential distribution of the mass of the mineral phase at this site as against the overlap zone, at least until full mineralization of the fibril occurs (Glimcher, 1976). After the impregnation of fibrils with solid-phase mineral, a number of rate-dependent processes occur concurrently within the fibril, including: heterogeneous nucleation of new amorphous calcium phosphate, and the growth of amorphous calcium phosphate particles and transition of these to poorly crystalline bioapatite with nucleation onto the surfaces of amorphous calcium phosphate, with most of the additional material being deposited by secondary nucleation (Glimcher, 1976). Although mineral is preferentially deposited in the hole zone, solid-phase calcium and phosphate particles are deposited in pores in both the hole zone and the overlap region, and the mass of mineral and number and size of particles increases with time so that eventually larger particles will completely fill the holes and pores (Glimcher, 1976, Revell, 1986).

While the form of the mineralization is reasonably well understood, there still remains a certain amount of biochemical magic underlying the actual process that governs this action within bones and the various proteins, or other substances, that activate and inhibit this process at various points. This being said, it is important to take a step back from this level of detail, as this description of the mineral matrix leaves open the penetration of numerous diagenetic agents that, if introduced to all but the fully mineralized portions of osteons, could destroy or alter the incomplete mineral crystals within this structure. In some respects this renders the issue into terms of either fully crystallized or not and thus dangerously exposed to alteration, though this also grants the means to easily identify significant diagenetic alteration and the underlying structure that makes the crystallinity index a useful measure of degradation (Weiner and Bar-Yosef, 1990).

The mineral structures of bone are primarily a calcium phosphate mineral structure termed bioapatite, similar in structure and composition to hydroxylapatite, though with some significant differences. General understanding has the mineral phase of bones and teeth in humans being likened to the mineral hydroxylapatite ($Ca_5(PO_4)_3(OH)$ or $Ca_{10}(PO_4)_6(OH)_2$), though there is reason to believe that this has been in error. The physical structure of a mineral as well as its growth morphology is to some degree controlled by its composition, just as the formation process of the crystalline solid apatite controls the density and strength of the bone. The formation process of the mineral is not merely governed by the flow and availability of individual elements; all the necessary components (calcium, phosphorus, oxygen, and the appropriate channel-filling ions (Cl^-, F^-, or OH^-)) have to be present in the proper proportions to operate within the protein/substance triggers that dictate the biomechanical process of bone mineralization (Glimcher, 1976, Wopenka and Pasteris, 2005).

Apatite is one of the flexible mineral structures, so the exact composition and structure of the apatite mineral is somewhat variable. As a flexible mineral, apatite is very accommodating of chemical substitutions (e.g., carbonate replacing phosphate or strontium replacing calcium). Carbonate substitution, yielding either carbonate-hydroxylapatite ($Ca_{10}(PO_4)_5(CO_3)(OH)_2$ or $Ca_5(PO_4,CO_3)_3(OH)$) or calcium carbonate ($CaCO_3$ and generally precipitated along with H_2O from $Ca(OH)_2+CO_2$) are quite common, though quickly stretch the limits of flexible hydroxylapatite, requiring the term bioapatite as a more general category to incorporate the variable composition and structure of apatite crystals found in teeth and bones (Millard, 2001, Weiner and Wagner, 1998, Wopenka and Pasteris, 2005).

The appropriateness of the classification as apatite is not in question, whatever the ultimate form of the apatite. Concern has been raised about the appropriateness of calling any portion of bone or tooth mineral hydroxylapatite in any form, as the mineral in the skeleton frequently appears not to be hydroxylated, measuring as deficient in OH^- much of the time (Wopenka and Pasteris, 2005). The substitution of carbonate ions into hydroxylapatite changes its growth morphology from needles to platelets and alters the crystal lattice causing structural distortions at the surfaces of minute particles, possibly constraining the compositional range of the bulk solid by inhibiting the incorporation of OH^- into nanocrystalline apatite (Wopenka and Pasteris, 2005). From a quick examination of the mineral structures and the available ionic reactions that can occur, it seems likely that a significant amount of calcium carbonate that is generally interpreted as contamination, is actually produced as part of the mineralization process, particularly in light of the importance of H_2O to bone mechanical functioning, and potentially should be investigated further (Weiner and Wagner, 1998).

Taphonomy and Diagenesis of Bone

Having been formed and mineralized, the bone becomes part of the archaeological record of the dead person of animal before being excavated. Via the processes studied by taphonomy, alteration is essentially a given and can occur at all scales, from molecular loss and substitution, through to crystallite reorganization, porosity and microstructural changes and, in many cases, to the disintegration of the complete unit (Lyman, 1994, Nielsen-Marsh and Hedges, 1999, Nielsen-Marsh and Hedges, 2000a, Weiner and Bar-Yosef, 1990).

The study of taphonomy is concerned with any changes that can occur between the time of death and the recovery of a bone, or more generally the transition of organic matter from the biosphere into the geologic record (Lyman, 1994). The process of taphonomy can be broken down into two general categories, biostratinomy, or the preburial effects and diagenesis, or post-depositional effects. As this discussion is focused on the compositional changes that might result from such processes, it is useful for a brief thought about the potential effects of the recognized potential impacts. The impacts of biostratinomy can include, but are not limited to digestion, trampling, exposure, butchering and defleshing, cooking, burning, excarnation and deliberate burial (Millard, 2001).

The majority of these impacts are physical, breaking down the bone structure into smaller pieces and/or penetrating the structure of the bone as a whole, exposing previously protected portions of bones to environmental effects. It is not to say that this physical impact does not alter significantly the composition of the bone, but rather that most samples that have undergone substantial physical alteration and/or deterioration are generally not good candidates for compositional analysis. This is due to the increased alteration of the fragments, the ever present concerns about the archaeological context, and the uncertainty that any given fragment of bone may or may not belong to the organism about which researchers are asking questions.

Several of the biostratinomic effects do have notable potential compositional effects. Digestion exposes bones to a caustic digestive tract of variable intensity depending on the particular animal species involved, which immerses the bone in organic acids. This leaves samples that survive the digestive tract etched, stripped of many lipid and/or protein barriers and exposed to a solution capable of at least partially dissolving the bone matrix itself, and then vulnerable to further changes after excretion (Andrews and Armour-Chelu, 1998, Lyman, 1994).

Cooking and burning will have similar effects depending on exposure to heat, though cooking will have effects more similar to digestion. Simply put, heated liquids often have similar degradation effects as do acids, though ultimately, unless the heat is high enough to alter the mineral matrix of the bone, any compositional alterations will be a combination of the dissolution of soluble minerals, degradation of collagen fibers, and deposition/precipitation from the mixed solution of the liquid in contact with the bone and any soluble minerals already dissolved into solution, though this strongly resembles the effects of exposure and diagenesis (Bada, et al., 1989, Millard, 2001, Roberts, et al., 2002, Sillen, 1989, Sillen and LeGeros, 1991, Sillen and Morris, 1996, Sillen and Parkington, 1996, Sillen and Sealy, 1995).

Finally, bones can also be exposed to the elements such as ambient heat, solar radiation, mechanical weathering through wind, sand, water, ice/freeze-thaw cycles. All of these actions, except for the heat, will either deposit extraneous material or will tend to dissolve the mineral matrix of the bone. Natural exposure to heat (rarely above about 80 degrees Celsius) cannot alter the mineral matrix of bone alone, leaving its impacts on the collagen fibers running amidst the mineral matrix. Bone is strong and resistant to heat due to its combination of organic and mineral phases. However, if the collagen fibers become dried, warped, altered or destroyed, then the remaining mineral is relatively fragile and will likely succumb to mechanical effects or be drawn into solution by liquid contact.

In sum, biostratinomic effects certainly impact the integrity and potentially the composition of any given bone even before it enters a buried context and is forced to contend with diagenetic effects, though many of the same processes are repeated in diagenesis. The largest alterations of biostratinomic effects are the physical fracturing of the bone matrix, thus exposing the matrix to greater potential chemical interactions upon deposition as mentioned already in the late 19th century:

> "The nature of the bones, that of the soil, its dryness or humidity, its permeability by air and water, the more or less ancient date of burial, the depth at which they lie, have a considerable effect of the condition of the bones." (Joly, 1887: 88)

Diagenesis for skeletal tissues is affected by intrinsic factors of the tissue specimen, such as its size, porosity, chemical and molecular structure and by extrinsic factors such as sediment pH, water and temperature regimes, and bacterial actions (Von Endt and Ortner, 1984). Diagenesis is strictly concerned with the impacts on archaeological materials after deposition has occurred and can be divided along a number of different lines, with diagenetic impact/attack being the most important factors.

Three different types of diagenetic impact can be broadly identified: organic diagenesis, inorganic diagenesis and microbial attack. However, Martill's (1990: 285-287) suggestion of viewing diagenesis as a process that takes place in three "environments" – the bone tissue itself, the pore spaces and cavities within the bones, and the sediment surrounding the bone – is also relevant. This combination of foci on the nature of diagenesis highlights the key points of the entire complex interactions involved; namely, what is changing, how is it changing, and where these changes are occurring.

In terms of "environments," the first is governed by ionic substitution of apatite minerals with other minerals; the second focuses on how pore spaces and trabeculae are filled with diagenetic minerals that can be compared with the sedimentary matrix of the burial context to look for changes in burial location and/or changes in the sedimentary matrix of the burial during the interment period; and finally, the sedimentary matrix in which vertebrate remains are buried affects the outer surface of the bone, the nature of ground water (both its chemical makeup and transportability), and whether buried vertebrate remains are crushed or deformed based on the presence or absence of diagenetic cements in the sediments (Lyman, 1994, Martill, 1990). To address how these diagenetic changes impact each of these environments, it is useful to return our attention to the processes of diagenesis and their impact on archaeological materials.

Microbial attack begins very shortly after death, frequently taking over a body within hours (Millard, 2001). Including fungi and bacteria, microbial attack begins with soft tissues, but rapidly progresses to bones, with evidence of histological changes within three months in some cases (Bell, 1990, Bell, et al., 1991, 1996, Hackett, 1981, Jackes, et al., 2001, Jans, 2008, Jans, et al., 2004). The first descriptions of microbial attack on mineralized tissue were published in 1864 by C. Wedl, who found tunnels of approximately 8 μm in diameter in sections of teeth exposed to untreated well water and in fossil reptile teeth; this type of tunneling was thus defined as Wedl or centrifugal tunneling by Hackett (1981). These tunnels range in diameter from 5–10 μm and appear empty with well-defined calcified walls, implying that collagen and mineral are both resorbed by the fungi (Jans, et al., 2004).

Three other types of microbial attack described by Hackett (1981) as "linear longitudinal," "budded," and "lamellate," all appear to be caused by bacteria, though the species responsible is unknown (Jans, et al., 2004). These types of microscopically focal destruction can be distinguished histologically by morphology (size and shape), the presence of hypermineralized rim and the presence of a lamellate content (Hackett, 1981, Jans, et al., 2004). While a significant agent of alteration under most environmental conditions, Hedges et al. (1995) showed that waterlogged terrestrial sites yielded very well preserved bone, indicating that the agents of change require an aerobic environment. The upside of microbial attack is that it leaves very distinct traces within the bone matrix and the changes are discrete and visible (Hedges, 2002).

Organic diagenesis involves mainly the decay and loss of collagen, though any attempt at radiocarbon dating (Hassan, et al., 1977), aDNA (Handt, et al., 1994, Richards, et al., 1995), amino acid racemization dating (Collins, et al., 1999, Pollard and Heron, 1996), or lipid survival (Evershed, et al., 1995, Stott, et al., 1997) will inevitably entail assessment of organic diagenesis. Microbial attack on collagen also falls under organic diagenesis as it targets the organic portion of the bone (Hedges, 2002). Collagen survival is greatly dependent upon temperature, thus in cool northern Europe, microbial attack is the main concern, while for older bones and in hotter climates, a temperature-sensitive loss mechanisms seem to be prevalent (Collins, et al., 1999, Hedges, 2002).

Detailed physical chemical models centering on hydrolytic mechanisms of collagen loss (e.g., Collins, et al., 1999) have been proposed, and proven useful in suggesting other chemical aspects involved in the process. For example, these models have suggested that where collagen becomes strongly cross-linked (as in tanning processes, but also through condensation reactions with soluble soil organics such as humic acids) it may be stabilized to hydrolytic loss (Hedges, 2002). It remains to be shown whether any significant collagen loss processes other than hydrolysis or microbial action routinely operate.

Organic diagenesis is an interesting area because of both its complexity and potential to access the body of information contained in the non-mineralized portion of the body. The ability to remove proteins and/or collagen from archaeological samples is not that difficult; the problem is determining what is it that is left, and what useful information it contains. Several studies have focused specifically on this problem and tried to understand the decomposition history of extractable proteins (Ambrose, 1993, Collins, et al., 1999, Nielsen-Marsh, et al., 2000, Nielsen-Marsh, et al., 2009, Turner-Walker, 2008). In terms of compositional alteration, the biggest source of diagenetic effects are humic substances moving from soil to bone during burial where these substances can chemically link to collagen, affecting its isotopic composition (Millard, 2001).

van Klinken and Hedges (1992) investigated the collagen–humic reaction and whether purified collagen could be recovered from its products. They found that humic acids react rapidly with collagen in vitro, and that some standard chemical treatments do not entirely remove them. Likely the most useful application of the study of organic diagenesis has been the discovery that some of the changes that alter collagen to the extent of providing unreliable isotopic measurements are subtle and can only be detected by a combination of measurements (i.e., C/N ratio, amino-acid composition, and infra-red spectroscopy) (Deniro and Weiner, 1988a, b).

Inorganic phase diagenesis can be divided into three processes: loss, gain and internal changes (Millard, 2001). Dissolution is the primary operator for any mineral loss in a bone, though much of weight loss (~20%) and porosity increase (~50%) can be attributed to loss of collagen (Hedges, 2002). Hydrological models assume that internal pore waters to be saturated and that no significant exchange of water occurs, but that diffusion between the pore waters and the surrounding soil water governs the rate of loss of bone minerals, mediated by a Nernst layer around the bone's surface with the environment (Hedges, 2002, Hedges and Millard, 1995).

The rate at which this diffusion occurs can be calculated based on the hydrologic activity at the site and the concentration gradient around the bone, which is dependent on the soil water composition (Hedges, 2002). As a result, the most dissolution takes place when conditions change and become greatly under saturated, either due to a reduction in pH, or through recharging with fresh water.

Uptake of groundwater solutes also occurs through diffusion, with a diffusive adsorption model (e.g., Hedges and Millard, 1995) adequate to explain, in many cases, both the concentration gradient and the uranium daughter product isotopic distribution observed from the external surface to the center of cortical bone (Hedges, 2002). This same approach works with other minerals (e.g., Sr) as it takes much less time for other minerals to reach equilibrium, barring issues with recrystallization within the bone matrix (Hedges, 2002, Hedges and Millard, 1995, Tuross, et al., 1989). It also seems that once any collagen is lost from bone, charged species of endogenous and exogenous origin are likely to take up residence and that the brown staining often found extending inwards for only a short distance from the periosteal surface of buried bone is a similar kind of diffusion-reaction effect (Hedges, 2002).

Crystallinity generally increases with diagenetic alteration and with increased time in the same conditions, although the precise mechanisms involved are not well defined as most indications of crystallinity are from the infra-red splitting factor (IRSF) (Hedges, 2002, Weiner and Bar-Yosef, 1990) or the X-ray diffraction (XRD) line width (Bartsiokas and Middleton, 1992). Crystallinity is also affected by chemical changes, especially uptake of F^- of or CO_3^-, or the transformation of bioapatite to brushite in acidic environments (Molleson, 1990). Changes to the actual crystallite size, and strain, can be detected through either IRSF or XRD (Hedges, 2002).

The presence of collagen ensures the stability of the mineral matrix, thus the ultimate source of crystallinity change is in the microbial and organic diagenetic effects that impact collagen, yet the resulting changes are part of inorganic diagenesis. On theoretical grounds, the expectation is for crystallinity to increase once substantial collagen has been lost. There is usually enough adsorbed water in bone to keep bone pores filled and to maintain equilibrium with the crystal phase, so the process can continue at a rate that is essentially internally buffered and not very responsive to most ambient environmental conditions, this being complicated by chemical changes in the bioapatite and by microbial reconstitution of the micromorphology (Hedges, 2002). Based on crystallinity changes, investigations of micro-regions within the bone should provide much more helpful data than simply reporting an averaged value (Hedges, 2002).

In order to quantify the effects of diagenesis, a number of different approaches have been developed. Widely used is Hedges et al.'s (1995) histological index (Table 2-1) that provides a means of gauging the impact of microbial attacks on the structure of a given bone sample and a tool to examine changes in preservation relating to geography, stratigraphy and chronology. To determine the extent of porosity changes, mercury intrusion porosimetry is frequently used in diagenetic studies (e.g., Nielsen-Marsh and Hedges, 1999).

Table 2-1: Histological index values assigned to summarize the degree of diagenetic change (after Hedges et al. 1995)

Index	Approx. % of intact bone	Description
0	<5	No original features identifiable other than Haversian canals
1	<15	Small areas of well-preserved bone present, or some lamellar structure preserved by pattern of destructive foci
2	<33	Clear lamellate structure preserved between destructive foci
3	>67	Clear preservation of some osteocyte lacunae
4	>85	Only minor amounts of destructive foci, otherwise generally well preserved
5	>95	Very well preserved, virtually indistinguishable from fresh bone

Porosity measurements on archaeological bones have revealed close relationships between changes in the porosity, remaining protein content and mineral alterations, as the different types of degradation tend to happen concurrently if not directly correlated (Nielsen-Marsh and Hedges, 1999). Mercury intrusion is also invaluable in helping to define the changes to surface area and hydrological conductance of a bone sample, as these are the determinants of the degree of alteration to bone in its burial environment (Nielsen-Marsh and Hedges, 1999). Coupled with the suite of techniques developed in tandem with attempts to ascertain organic diagenesis effects (e.g., C/N ratio, amino-acid composition, and infra-red spectroscopy), these techniques allow for preliminary results to be gathered for potential bone samples, ascertain the level of diagenetic impact for new sites, and grant a foundation for presentation of results once the analysis is completed.

Regardless of the form of diagenesis, the number of ways in which the various factors can alter the composition of the bone matrix is limited. Microbial attacks are generally discrete intrusions that may or may not target collagen. Organic diagenesis is the process of how collagen decays and is lost, though the ability of certain humic substances to penetrate bone and attach to collagen is somewhat worrisome. Diffusion reactions and internal remodeling dictate inorganic diagenesis. Interestingly, with all of the research and work conducted on the nature of diagenetic effects, virtually no attention has been paid to how this will specifically manifest in the details of bone matrix.

As noted earlier, newer lamellae are present in all living osteons, and these newest lamellae will likely not be fully mineralized, still highly soluble and closest to the cavities that were Haversian canals until the organisms' death. With specific note that the internal bone water is generally sufficient to maintain a closed system that require the diffusion of ions either in or out, it does not require very much imagination to deduce that the remaining liquid-phase minerals on free-floating collagen fibrils will dissolve the partially mineralized structures of the young lamellae to create the saturated solution and the base material for any recrystallization.

Linked to this is the idea of liquid penetration, for while caniculi connect all living osteocytes, the diffusion capabilities through these caniculi will be limited, particularly so given that they lead to the secluded and fully mineralized bioapatite portions of older lamellae and the inherent difficulty of either a saturated or partially saturated solution in dissolving a largely insoluble mineral crystal rather than either diffusional contact with the external environment or the preferential dissolution of decaying mineral structures. Thus, even if in diffusion equilibrium with the external environment, diagenetic ions will have a difficult time reaching the mature mineral structures until microbial attack can break down the matrix and eliminate the collagen fibrils holding everything together. Furthermore, as specifically noted, no materials cross the cement lines of osteons even when the systems are alive, thus it will be difficult to penetrate the cement line even if the protein structure does not grant any buffering effects.

Osteocytes have a limited life span (~25 years), and their mineralized structures are replaced as new osteons cut through the existing bone. As a result, the interstitial lamellae (bone matrix between the cement lines of living osteons) is mineralized material from dead osteons, thus any remaining matrix is not connected to any active caniculi and will be very hard pressed to be in dissolution contact with bone fluids post-mortem. Given the nature of the post-mortem bone liquid solution, it is unlikely that the ideal balance of ionic raw materials will be present to enable the precipitation of largely insoluble bioapatite mineral crystals rather than the precipitation of more soluble mineral forms, especially in the absence of guidance from nucleation or any of the protein/substance signals that control bone formation and mineralization during life.

Finally, depending on the age and species of the organism, different proportions of available poorly mineralized bioapatite crystals for dissolution (i.e., hypercalfied bright lines and laminar bone) and/or the effects of the different bone structures and how they are in contact with the bone liquid. Thus there are number of reasons to believe that there will be significant variability within the bone matrix in terms of the impact and effects of diagenesis, regardless of the form(s) in operation over any given period of time.

The true impacts of these details come in the standard sampling practices employed by analysts. Basic procedure is to either cut a section of bone out of a long bone (e.g., femur section) or preparing a bone powder from whatever element is to be sampled and wash this material with Millipore water and likely involving some step of acid leaching (e.g., acetic acid as described in Nielsen-Marsh and Hedges, 2000b) to remove diagenetic formations. After a number of steps and repeated cleaning, the prepared sample will either be powdered for introduction via TIMS (thermal ionization mass spectrometry) or put into solution for IRMS (isotope ratio mass spectrometry).

There are other laboratory protocols involved in the process, but all methods currently introduce an averaged/homogenized sample of skeletal material to be viewed as a single point value. If this were done using the material immediately beneath the periosteum, or from a child under the age of 5, then the bone being sampled would not be fully formed Haversian bone and would have significantly different compositional traits (for analysis and in regard to interaction with diagenetic effects) as would a sample taken from an adult. Likewise, for studies trying to compare the effects of diagenesis for humans and faunal materials, some thought should be given as to the bone structure of the animals used as reference samples so that the results will actually be comparable rather than simply a study in how different bone forms were affected by the same process; unless, that is the main research question.

To prevent this bulk sampling of complex bone matrix and interpretive limitations inherent to this approach, point sampling (LA-ICP-MS) or backscatter scanning electron microscopy (SEM) should be employed. SEM can map the layout of different minerals, however its detection limits prevent its use in identifying the location of many trace elements and thus might not accurately map the full extent, distribution, and penetration of diffusion diagenetic effects within a bone or tooth sample. The advantage to the SEM method is it allows distinguishing visually the elements or units within the bone matrix and obtaining some compositional data that can be overlaid with the visual images to gain a better understanding of the nature of diagenetic attack and its compositional impacts.

Another option is multiple point samples taken with a laser ablation system attached to a multi-collector-inductively-coupled-plasma-mass-spectrometer (MC-ICP-MS). The laser ablation system can sample points as small as 5 µm in diameter and through the MC-ICP-MS, get detailed compositional data including trace elements and isotopic ratios for that point. This system could be used to point-sample along the edges of cement lines, sampling both older lamellae in recent osteons and interstitial lamellae representing a previous generation of bone growth and then compare these points to each other, to other lamellae in other osteons, and to younger lamellae in the same and other osteons. The result would be a great deal of compositional data, taken at a scale currently unused in skeletal compositional studies and in such a manner that the effects of diagenesis could either be recorded and removed mathematically (modeling) or avoided altogether by choosing stable sample sites within the bone matrix.

Generating behaviorally meaningful data is challenging in light of the ever present uncertainties about removing all diagenetic effects from a bone sample and the limited interpretive value of geochemical signals provided by testing homogenized samples of bone. This study employs the method of micro-sampling as the primary means of avoiding diagenetic effects and obtaining data that are meaningful for the examination of h-g mobility patterns at the individual level. Remaining chemical alterations from diagenesis can be identified and corrected for with greater precision in this fashion.

RESEARCH GOALS

Incorporating the formation processes of skeletal tissues with the concept of mobility to yield behaviorally meaningful information for the Cis-Baikal region is an important aspect of answering research questions like those noted above. There are a number of intermediate steps necessary to provide adequate understanding of the interactions linking the target behavioral information with the analytical results and the ultimate explanations of prehistoric actions. The first step is consideration of the formation and anthropogenic processes occurring prior to analysis.

Dietary Averaging and Biases

One unique aspect of the Baikal Archaeology Project is the availability of a variety of data and research specialists, resources that are rather unique in their focus on examination of the same collections. Having multiple types of data on the same individuals enables consideration of analytical methods otherwise generally impossible to employ. That biogeochemistry is heavily influenced, or biased, by dietary patterns is no surprise as the entirety of our physicality and life history is essentially a record of what we have eaten, drunk, or inhaled. Mobility studies and dietary stable isotope analyses generally run on parallel trajectories but frequently are not integrated with each other to their full potential. It is understandable that in the formative literature regarding compositional analysis for mobility purposes, agricultural populations were the most frequent subjects. Perhaps this is why the vagaries of dietary variability were not discussed in much detail. A similar tacit acceptance of roughly equal dietary patterns playing into h-g studies through the guise of timescale and dietary averaging has remained and is not without logical power. Dietary averaging, however, should not be assumed, particularly in light of recent studies suggesting significant dietary differences that are tied to seasonal activities (Nielsen-Marsh and Hedges, 2000a, Weber, et al., 2011a).

Human teeth do not mineralize in a strictly linear fashion as a bounded timespan of formation equating to a year or more, the type of formation that would make micro-scale analysis of dietary or mobility data much more straightforward. Long bones, in current methods are understandably treated as long-term averages of either dietary or mobility behavior. Given such timescales, dietary variation can easily seem unimportant as the approximate yearly average diet will likely be roughly the same throughout an individuals' life barring drastic changes in subsistence practices, locality or external factors. Further research will be necessary in order to test the possible impacts of dietary variation. Seasonal patterns and significant dietary differences present within the same, or contemporary, populations serve as a major impetus to try to access smaller timespans within an individual's life.

Light isotope studies rely on fractionation to yield explanations, a factor that dominates concerns about isotopic sources. Each animal carries its own isotopic signature that will be partially imparted onto the person who consumes the animal. This being said, the distribution of elements within the body of humans and animals is not homogeneous. Heavier elements such as copper, lead and strontium are bone-seeking elements (strontium much more strongly seeking than copper and lead) (Cabrera, et al., 1999, D'Haese, et al., 1999, Pors Nielsen, 2004, Wilson, et al., 1981). The largest remaining fraction of these heavy elements is contained within the blood, frequently leaving the content of all remaining body tissues at less than 0.5% of the total elemental presence in the body.

Outside of well-documented bone cominution or grease rendering activities, bones, and often blood, generally are not a major part of the human diet (e.g., Brink, 1997). As bone seeking elements, the concentrations of elements in the bones are many orders of magnitude higher than in the tissues generally sought for food, thus if any bone is ingested, it will significantly bias the resulting concentrations. Small variations (e.g., 5–10%) in the dietary contributions of terrestrial or aquatic animals, or of individual animals (e.g., red deer versus moose) could significantly alter or bias the final elemental concentrations and the associated isotopic ratios and thus the results of the analysis. Dietary and mobility analyses use similar chemical processes to address different aspects of the interaction between organisms and their chemical environment. However, specific discussion of the extent of potential dietary biasing of mobility data, or more broadly, correlations between dietary and mobility data have been conspicuously absent in the literature.

Bone Consumption by Humans

Cooking weakens the mineral structure of the bone and will prompt increased release of bone minerals. Any significant amount of bone stripped or cut off in meat processing could bias the results of dietary analysis relative to the expected contributions. Fish bones and bone marrow processing and grease soup production are likely the greatest sources of potential bias in this respect as the most likely means by which bones will be cooked or ingested with the animal tissues. Other subarctic and arctic groups with a heavy dependence on fish do not always remove the bones before smoking or salting and storing the fish. A prime example of this is a study of pottery residues showing the practice of cooking fish whole, including scales and bones (Koch, 1998), which is similar to a Norse practice of preserving cod (a large-boned fish) with the bones and then boiling the entire preserved fish into a porridge.

Fish generally are hard to fully de-bone without wasting a significant amount of edible tissue. With increasing cooking temperature (beginning at 60 C), the heat quickly breaks down the bone structure, essentially gelatinizing the entire bone (Richter, 1986). So, it may be reasonable to expect a significant amount of bones to have been directly consumed by any given individual, particularly given the ubiquitous nature of fish consumption amongst Cis-Baikal inhabitants (Weber, et al., 2011a). This will undoubtedly bias the strontium, copper and lead signals towards the aquatic environment from which the fish came.

It is realistic, however, to assume that all individuals in a group will be equally exposed to such biasing factors. If we assume that all aquatic foods stemmed from the same source or that groups were not imbibing foods from different aquatic micro-regions, then there is no reason for concern. The difficulty arises if hypotheses regarding seasonal movements are substantiated by mobility data. Then the question of what aquatic resources are consumed, and where are they from becomes very important. Statistical modeling could be performed to analyze and model the biasing impacts of dietary changes relative to hypothesized seasonal locations.

Methodological Improvements

Steps to improve the data quality would aid in efforts to elaborate explanations about prehistoric h-g mobility patterns, and are quite plausible. Examining formational overprinting is an effort that combines both laboratory analysis and data handling procedures. Diagenetic factors have received a great deal of attention in the bioarchaeological literature (e.g., Hedges, 2002, Hedges and Millard, 1995, Hedges, et al., 1995, Lyman, 1994, Von Endt and Ortner, 1984), however consensus has erred on the side of caution and developed measurements to ensure that samples are suitably unaltered and thus good candidates for analytical rigor as opposed to using samples that require significant efforts to remove diagenetic effects. Again, this is logically sound, any sample that has not been significantly altered by post-depositional processes is easier to analyze and understand than one that might include mitigating factors attached to the explanation. On the other hand, it is safe to assume that most archaeological bones are diagenetically affected to some degree, which stresses the importance of developing new methods, for example micro-sampling, to address this matter.

Since diagenetic alteration of bone progresses via specified biological and chemical interactions and predictable vectors (i.e., water contact), it is possible, at least in theory, to target diagenetically resistant portions of osteological materials. Thus, modification of analytical methods is indeed a viable option for current and future research and should take a place of prominence not only due to the potential impacts on the remainder of compositional bioarchaeological research but also due to new interpretive potentials such data would offer. Development and testing such methods is, therefore, among the most important goals of this research.

LABORATORY METHODS

Following understanding of the formation, taphonomic, and diagenetic processes, consideration turns to the laboratory methods used in light of such processes. Analytical data provide very specific information, thus improvements in laboratory methods can have significant impacts on the effective resolution of analyses performed.

Background

Since detailed discussion of the laboratory methods and analytical protocols used for isotope tests or compositional analysis of biological materials is provided in Chapters 3, 4 and 5 and the literature cited therein (e.g., Beard and Johnson, 2000, Bentley, 2006, Bentley and Knipper, 2005, Brothwell and Pollard, 2001, Cucina, et al., 2007, Ezzo, et al., 1997, Ezzo and Price, 2002, Haverkort, et al., 2008, Hodell, et al., 2004, Pollard, et al., 2007, Pollard and Heron, 1996, Price, et al., 2002, Weber, et al., 2003), only a summary of this information will be presented here.

Older academic work relied upon thermal ionization mass spectrometry (TIMS) which have developed into more recent studies relying upon solution-mode analysis using multi-collector inductively-coupled-plasma mass-spectrometry (MC-ICP-MS). Numerous studies have demonstrated the comparability of these methods, thus proof of interoperability between the analytical approaches is no longer necessary.

Previous h-g mobility studies in Cis-Baikal (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003) have been conducted using a combination of TIMS and solution-mode MC-ICP-MS. The logic behind altering the analytical approach is to make the best use of limited resources including archaeological materials, project funding, and analytical time. Usage of TIMS is rather expensive in terms of time, materials, and money, thus the conversion to solution-mode MC-ICP-MS technique. Solution-mode MC-ICP-MS is generally limited in terms of analytical time to approximately 20 samples per working day, not counting the time necessary to prepare the samples for analysis. Laser-ablation (LA) introduction drastically improves this analytical time and can vastly reduce the potential damage to tooth samples, assuming, of course, that LA data are consistent and interoperable with results produced by other methods.

Interferences and Corrections

Several recent studies (Cucina, et al., 2007, Horstwood, et al., 2008, Richards, et al., 2008, Simonetti, et al., 2008) have examined the potential and methodological approaches necessary for usage of this technique. The main problems associated with the increased speed and reduced physical impacts to archaeological materials associated with laser-ablation technique is that the way in which the laser interacts with tooth enamel causes interference to occur at mass 87 (via CaPO formation), an important part for $^{87}Sr/^{86}Sr$ ratio studies. Horstwood et al. (2008) and Simonetti et al. (2008) have separately reached the conclusion that for human tooth enamel samples, the impact of this interference is relative to the total Sr concentration in the materials, with far greater data comparability and reproducibility for samples containing more than 200 ppm Sr. The protocols and correction procedures presented in these works provide valuable foundation to begin assessment of the sample introduction method for usage in the present studies. There is no logical reason to pursue an analytical approach if the data will be incompatible with past studies, regardless of internal comparability or speed of analysis.

Examination of the studies conducted to date highlights a potential area for improvement in this regard. Standardization techniques play an important role in data acquisition and subsequent data handling procedures. The usage of prepared bioapatite standards is notably absent in the published works, which have relied instead upon more common standards such as Durango apatite and NIST SRM glass standards, both frequently used in archaeological provenance and geological studies. Cucina et al. (2007) outlines the usage of prepared apatite standards as an important element in matrix-matched standardization efforts. Laser-ablation works via the lasers' ability to vaporize efficiently the sample material for introduction into the ICP-MS instrument. The laser couples differently with different surfaces and concerns about texture and material composition weigh heavily in concerns about the accuracy and precision of the analytical results via ICP-MS (Scharlotta, 2010, Scharlotta, et al., 2011, Speakman and Neff, 2005). Thus testing with prepared apatite standards could help to monitor the formation of the isobaric interference at mass 87. Another aspect of this approach would be the ability to monitor mass 91 (^{91}Zr), any offset of which should occur through a similar process of interference from CaPO formed using ^{44}Ca as opposed to the much more common ^{40}Ca. The key to the two aspects are the standards used and comparison with samples analyzed employing well-tested methods.

Another potential area to improve the existing analytical methods based on laser-ablation regards bone sampling. In past and present studies there has been much debate about the usage of long bones for either dietary or mobility studies. The controversy lies in the tendency for slow turnover of long bone material in a somewhat unpredictable manner. Unlike rib bones that completely turnover their contents in fewer than 5 years, long bones can retain mineral structures in excess of 20 years. For analysis via TIMS or solution-mode MC-ICP-MS, the bone material is sectioned and homogenized, thus the resulting data reflect an averaged value for up to 20 years or so. Unlike tooth enamel, bone experiences natural turnover during the organisms' life and diagenetic alteration after deposition. This can pose a problem for any method that relies on a homogenized view of the sample material. In cases of diagenetic overprinting, the bone values would reflect a combination of lifetime averages and the overprinted soil values. Thus many researchers regard bone Sr data with suspicion at best. For Cis-Baikal samples, diagenetic overprinting seems unlikely at a broad scale simply because of the nature of differences between soil values and the bone values (Ezzo, et al., 2003, Haverkort, et al., 2008).

The potential for improvement lies in better understanding of the nature of diagenetic impact on bones. Taphonomic processes in general and diagenetic alteration of compositional signatures in particular occur through the vector of water contact. All interaction and exchange between the depositional environment and the buried material occurs through this vector and no other. What this means is that any portion of the bone that is not in active or complete water contact with the circulation system of the bone and thus the depositional environment will logically be more resistant to any changes that do occur. The advantage of laser-ablation over solution-mode analysis is the potential for micro-sampling of materials at scales as small as 5 μm in diameter.

This is significantly different from the scale of 1–2 mm sectioned and put into solution for TIMS or solution-mode analysis. The nature of bone remodeling, particularly in long bones, is that of secondary osteon formation and maintenance. Osteons form by cutting through existing bone mineral structure and then by laying down new materials. As new layers are deposited through time, they are increasingly removed from the water contact that occurs via the circulation system. Likewise, previously formed osteons, that are cut into are completely removed from water contact through blood replenishment or water contact in a depositional environment. Therefore, sampling of older sections of osteons, or osteons composing older bone matrix should either reflect unadulterated portions of the bone, or at least less-altered portions of the bone matrix.

ANALYTICAL APPROACH

There are many considerations that can impact the explanatory power of analytical data. Improved understanding of formation processes of samples analyzed and the laboratory methods employed will not in themselves guarantee answers to research questions. The reference data used to interpret these results crucially limit or, alternatively, empower the results from analyzing skeletal materials. Some information in the following sections was covered previously in a generalized capacity and is revisited here in context, as it applies to the analytical methods employed in this study.

Mapping Biogeochemical Variability

As noted in many studies (e.g., Beard and Johnson, 2000, Bentley, 2006, Bentley and Knipper, 2005, Ezzo, et al., 1997, Ezzo and Price, 2002, Haverkort, et al., 2008, Hodell, et al., 2004, Price, et al., 2002, Weber, et al., 2003), calibration and making sense of reference data for human bone samples is best achieved with materials that reflect the biologically available geochemical environment. Regardless of the geochemical properties of the rocks and soils, all that scientific analysis will show is the interaction between human consumer and the biologically available geochemical environment. For the majority of isotopic mobility studies, understanding of the water sources is premier. This is due to the fact that this is the fundamental vector for both plants' and animals' interaction with their environment, and thus the compositional signatures that will be imparted upon their human consumers.

Understanding of the biologically available geochemical environment can come through a variety of sample types; however, all share certain criteria to be regarded as effective reference samples. For example, studies involving small animals frequently assume that these animals will reflect the local water signatures and thus render direct sampling of the water sources redundant. This may have some consequences for interpretation of the data; however, with analytical time and expense being limited, it is a reasonable compromise. Ideally, a study will use data on both the local animals and on current surface water sources. Such surface water may not reflect compositional characteristics of the same water source throughout prehistory as erosion factors can alter the geological interaction or contribution to the water's composition through time. While this is an important consideration, the only real means to avoid this is to have a host of archaeological faunal samples to construct the comparison map. Such a situation would be preferable, but rather unrealistic given that the limitations of the archaeological record.

For studies of sedentary populations, analysis of local small animals can provide a good alternative approach to building a model of the local signature. However, for more mobile h-g groups, an assumption that the burial context reflects the habitation range may be deceiving. For studies in areas like Cis-Baikal, modern reference samples are essential because of the uncertain spatial relationship between cemeteries and habitation sites through both time and space. The usage of modern plant and animal samples in conjunction with modern water sources provides a valuable link between geochemical and biogeochemical backgrounds. If possible, water samples should be drawn from an even larger region than biological reference samples, in order to best represent the potential for identification of the source of outlier samples. Many animals have ranges that could bring them in contact with water sources from areas such as Lake Khovsgol in northern Monogolia and west of Lake Baikal, or the source waters of the Eastern Sayan Mountains, even though the animals themselves may be recovered within the Tunka Region (e.g., red and roe deer). Better understanding of the water composition would help to identify outlier contributors to the bulk composition of the animals and humans, such as the source of the very high Sr values noted by Haverkort et al. (2008).

Reference Materials

The usage of animal domesticates from developed agricultural contexts is risky. The compositional signals could reflect anything from the pasture signatures, to imported feed and water, nutritional supplements, or even imported animals. This is a rather serious concern in the majority of the modern world. Many regions have been populated by agricultural groups for a very long time, such that it is virtually impossible to find animal samples that are not impacted by anthropogenic factors. Ironically enough, the isolation of Siberia, both past and present, provides a boon for compositional research. Outside of the most developed areas of the Angara Valley, modern agricultural practices employing imported feed and nutritional supplements are limited.

For example, the Tunka region is primarily rangeland where the majority of village animal domesticates roam freely throughout the region, with fencing intended only to keep animals separated from crops reserved for human consumption. This does not invalidate concerns over the usage of domesticated or anthropogenically influenced faunal samples. What it does provide is an interesting condition of inversely related animal size and value as a reference sample. The larger domesticates, that would frequently be regarded as poor reference samples, appear to be relatively better samples than smaller animals.

The reasoning is fairly straightforward. With sedentary human populations, small animals such as rodents are generally drawn toward stored food sources, regardless of the relative abundance of the environment. In effect this virtually guarantees that any small animals recovered in association with human settlement to have a biased compositional signal reflecting the human food or trash biogeochemical values rather than that of the environment. Whereas the same argument for domesticated livestock not eating imported food could potentially be made, the likelihood that a rodent will consume some element of imported human food/food waste (i.e., bread made from non-local grain, or canned foods) is significantly higher. Weber et al. (2011) noted several cases of modern fauna with elevated nitrogen values.

For domesticated livestock to show a significantly altered biogeochemical signature, the fields from which they feed would need to have been heavily fertilized and/or supplemented by non-local fodder during the winter months. The majority of village residents lack the means to purchase significant amounts of either fodder or fertilizers (Metzo, 2001). The massive agricultural production efforts of the Soviet era frequently involved fertilizers, herbicides and pesticides, though these were generally focused on agricultural lands rather than rangelands and have drastically declined since 1991 (Gamzikof and Nosov, 2010). Agricultural practices generally preclude significant efforts to fertilize grazing lands for either captive or free-range livestock, even in North America where fertilization is extremely common.

In light of concerns about finding suitable faunal samples from either modern or archaeological sources, the studies presented here rely on reference geochemical signatures provided primarily by plant and water samples. Large and small modern and archaeological fauna were collected and analyzed where possible, however, provide only secondary geochemical background information. More detail on the protocol of collecting reference samples is provided in Ch. 5.

SUMMARY

The dominant theme in past h-g mobility studies is the usage of proxy measures to attempt to address the unknown dimensions of mobility. Examinations of the concept of mobility and associated attempts to integrate this concept into explanatory frameworks of individual life histories have highlighted several interesting factors. Taken at a broad scale, the trends in both research and conceptual development highlight the main elements of the concept of mobility as a process that is difficult to address with site-based analyses. Taken more specifically in regard to h-g groups, this integration provides an excellent framework with which to interpret the often ambiguous results of geochemical analyses. Laboratory data are essentially useless without an appropriate theoretical framework, thus there is a need to develop an integrated explanatory framework that speaks directly to the archaeological context being examined, h–g in this case. The theoretical concepts developed here can be coupled with the life history approach to enhance the explanatory capacity of mobility as a concept and provide insights into Cis-Baikal h-g mobility that would otherwise have remained unexplored. Coupled with analytical improvements to demonstrate accurately and precisely contact and duration of interaction with different geochemical environments, we can now attempt to answer a host of new research questions including the nature and range of physical mobility, diagenetic impacts on analytical data, effects of dietary patterns on correlated explanations (i.e., mobility, kinship), kinship patterning through time and space, and perhaps most importantly, a means for establishing the impacts of human agency on isotopic analyses. Improving laboratory techniques to generate data with the desired analytical precision and with an appropriate theoretical framework in mind are essential components in order to assess working hypotheses regarding mobility and subsistence and to develop the next generation of research questions in Cis-Baikal.

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Chapter 3: Assessing hunter-gatherer mobility in Cis-Baikal, Siberia using LA-ICP-MS: Methodological correction for laser interactions with calcium phosphate matrices and the potential for integrated LA-ICP-MS sampling of archaeological skeletal materials[1]

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INTRODUCTION

Strontium isotope analysis has traditionally relied on thermal ionization mass spectrometry (TIMS) due to its reliability and analytical precision. The advent of multi-collector inductively-coupled-plasma mass-spectrometry (MC-ICP-MS) as an alternative to TIMS coupled with either a laser micro-drill or a laser ablation (LA) unit for micro-sampling greatly expanded the possibilities for archaeometric research of Sr isotopes. Both laser micro-drills and laser ablation are far less destructive and enable higher spatial resolution for analysis than traditional TIMS and MC-ICP-MS methodologies, however micro-sampling for solution preparation still requires significant lab handling for sample preparation whereas laser ablation requires virtually no special handling (Horstwood, et al., 2008, Nowell and Horstwood, 2009). In spite of several studies using LA on human bone and high-Sr apatites (Bizarro, et al., 2003, Prohaska, et al., 2002), analysis of phosphate minerals by LA has not figured prominently in the scientific literature until recently (Cucina, et al., 2007, Horstwood, et al., 2008, Horstwood, et al., 2006, Richards, et al., 2008, Simonetti, et al., 2008, Vroon, et al., 2008, Woodhead, et al., 2005).

The goal of this study is to examine problems associated with the application of laser ablation as a sample introduction method for MC-ICP-MS on human skeletal materials. Previous research(Horstwood, et al., 2008, Simonetti, et al., 2008, Woodhead, et al., 2005) has indicated a number of potential problems in gathering accurate strontium isotopic data from calcium phosphate matrices using LA-MC-ICP-MS. In addition to interference from rubidium (^{87}Rb), doubly charged rare earth elements (Paton, et al., 2007), and calcium dimers (Woodhead, et al., 2005), there is the production of a polyatomic species of CaPO that interferes with the ^{87}Sr (Horstwood, et al., 2008, Simonetti, et al., 2008, Vroon, et al., 2008). This polyatomic species is apparently unique to laser ablation as it is not apparent with solution mode (SM) MC-ICP-MS. The exact source of this polyatomic species is uncertain; however it is a relatively minor contributor of isobaric mass 87 to most geological samples. Unfortunately, many archaeological skeletal samples have very low concentrations of Sr and are thus susceptible to significant error terms as a result of this polyatomic species while using LA-MC-ICP-MS.

Traditional Sr isotopic research has focused primarily on sedentary agrarian groups. With such groups, the focus of research is on identifying the local signature so that nonlocals (people, animals, etc.) can be recognized. Such an approach is perhaps of only limited utility for the broader study of hunter-gatherers, as many groups utilized large ranges of territory and would thus have more complex (averaged over larger areas) isotopic signatures reflecting their lifetime mobility. Such complexity drives interest in micro-sampling of skeletal materials to access greater chronologically refined insight into mobile individuals. However, further research is needed to fully understand the dynamic interaction between direct chemical interaction with the biologically available strontium, the formation of skeletal tissues, and data recovery from these tissues. This study is focused on the data recovery side of this problem, examining the range of variability in strontium isotope ratios and trace element composition found within human teeth.

HUNTER GATHERER MOBILITY IN CIS-BAIKAL

The Cis-Baikal region of Siberia denotes the geographic region including the western coast of Lake Baikal, the upper sections of the Angara and Lena river drainages, and the Tunka region adjacent to the southwestern tip of Lake Baikal (approximately between 52° and 58° N and 101° and 110° E). The topographic complexity of the rift valley that formed Lake Baikal led to the formation of a large number of micro-habitats, with a variety of seasonally available resources (Galazii, 1993, Weber, 2003, Weber, et al., 2002). The thermal capacity of Lake Baikal itself moderates the local climate, resulting in generally milder temperatures during the winter and cooler temperatures during the summer. As a result, the Angara River Valley remains relatively free of snow during the long winter which attracts various species of ungulates looking for forage and less restricted mobility (Haverkort, et al., 2010). There is a variety of large game found in the region including moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus pygarus*), reindeer (*Rangifer tarandus*), and mountain goat (*Capra sibirica*). Smaller species such as hare (*Lepus* sp.), suslik (*Spermophilus citellus*), wild boar (*Sus scrofa sibiricus*), marmot (*Marmota sibirica*), geese, and other waterfowl are also abundant in many areas around the lake. During the summer, large runs of black grayling (*Thymallus arcticus*) are found in the first section of the Angara River, and several fish species enter the tributaries of the Angara in large numbers to spawn. The shallow coves and bays in the Little Sea region of Lake Baikal, between Ol'khon Island and the west coast of the lake, also provide excellent opportunities for fishing and during the late winter when the lake is frozen, nerpa, the Lake Baikal seal (*Phoca sibirica*) can be hunted (Levin and Potapov, 1964, Losey, et al., 2008, Weber, 1995, Weber, et al., 1998). Ethnographic studies of boreal forest populations highlight the use of mushrooms, berries, and pine nuts as other non-medicinal resources (Haverkort, et al., 2010, Katzenberg and Weber, 1999, Lam, 1994). There is very limited evidence for plant use during the Neolithic, however there is sufficient ethnographic evidence for the role that plants play in boreal forager subsistence systems around the world to speculate upon their usage.

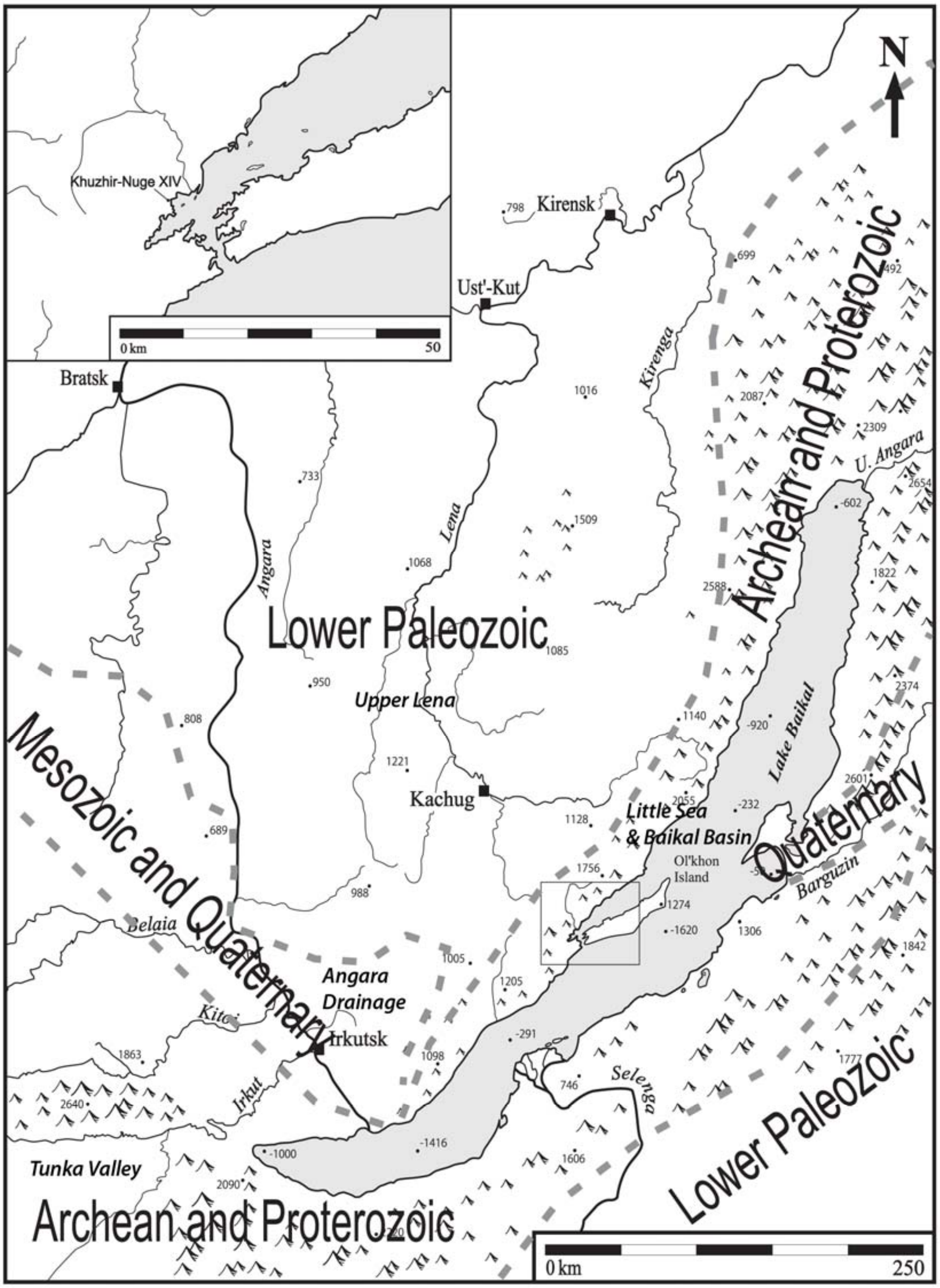

Figure 3-1: Lake Baikal, Siberia showing the location of the KN XIV cemetery, cultural micro-regions, and the age of the dominant bedrock formations (following Haverkort et al., 2008; Galazii 1993).

Within the Cis-Baikal region there are four main geological zones that roughly overlap with archaeological micro-regions (Figure 3-1). The main zones are 1) the

Baikal basin, including the lake itself, the coastal areas as well as the Little Sea area enclosed by Ol'khon Island; 2) the drainage of the upper and middle Angara River bounded by the Eastern Sayan Mountains to the west and the Central Siberian Plateau to the east and extending north towards Bratsk; 3) the upper Lena river basin cutting through the Central Siberian Plateau as it heads northwards; and 4) the Tunka region covering a sizeable valley running south of the Eastern Sayan Mountains and broadly connecting the southwestern tip of Lake Baikal to Lake Khovsgol in Mongolia. The upper and middle sections of the Angara River flow through Mesozoic and Quaternary deposits, with expected ^{87}Sr/^{86}Sr values in the range of 0.705-0.712. The upper Lena watershed and the surrounding Central Siberian Plateau are dominated by Cambrian and Precambrian limestones, with expected values fairly tightly clustered around 0.709 (Haverkort, et al., 2008, Huh, et al., 1994). Overall values for Lake Baikal water are reported as 0.7085 (Kenison Falkner, et al., 1992). The Baikal basin includes the Primorskii and Baikalskii mountain ranges and is characterized by relatively high ^{87}Sr/^{86}Sr (~0.720-0.735) due to the presence of Archean and Proterozoic granites (Galazii, 1993). Bedrock of similar ages occur around the southwestern shores of Lake Baikal and drainages adjacent to the Eastern Sayan Mountains, however our preliminary data for environmental sampling of biologically available strontium isotopes in the Cis-Baikal region indicate that these two regions have quite different ^{87}Sr/^{86}Sr values (Scharlotta, 2010). Both zones overlap ^{87}Sr/^{86}Sr ranges of neighboring regions (e.g., Angara Drainage), while only the Little Sea area exhibits values above 0.720. Further clarifications of the distinction between these two zones of similar age will be possible upon completion of regional sampling efforts.

KHUZHIR-NUGE XIV CEMETERY

The KN XIV cemetery is located on the west coast of the Little Sea micro-region of the Lake Baikal basin, near the southern end of Ol'khon Island and c. 3 km southwest of the mouth of the Sarma River (53°04'58" N, 106°48'21" E). It occupies the southeast slope of a hill rising from a shallow bay. With 79 graves and a total of 89 individuals unearthed, KN XIV is the largest Early Bronze Age hunter-gatherer cemetery ever excavated in the entire Cis-Baikal region (Weber et al. 2007). All the graves were only c. 30-60 cm deep sub-rectangular pits filled with rocks and loamy sand, and covered by surface structures built of stone slabs still visible on the surface prior to archaeological excavation. Most graves contained single inhumations, seven were double, and two were triple interments.

The north-south orientation of Grave 7 is consistent with the Late Neolithic Serovo culture of the Ol'khon region, while all the other graves show clear similarities with the mortuary tradition of the Early Bronze Age Glazkovo culture (Haverkort, et al., 2008, Weber, et al., 2003, Weber, et al., 2007). The most diagnostic EBA characteristics include the generally west-east orientation of the burials and such grave goods as copper or bronze objects (rings, knives, needles, and bracelets), kaolinite beads, and rings and discs made of white nephrite or calcite (Weber, et al., 2008). A recent analysis of approximately 80 ^{14}C dates indicates that the KN XIV cemetery was used continuously by EBA peoples for a maximum of 700 years between ~4650 and 3950 cal. BP but the majority of the burials (70%) date to between ~4450 and 4250 cal. BP (Weber, et al., 2005). Since the analysis did not reveal any obvious temporal trends in mortuary attributes, it seems to be justified to treat the cemetery with the exception of the much earlier Grave 7, as one analytical unit (McKenzie 2006; Weber et al. 2005).

In previous studies (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003) a sample of 25 individuals from KN XIV were analyzed for strontium isotope ratios and compared with 79 faunal samples collected throughout Lake Baikal and the Cis-Baikal region. Of these samples, there were 20 adult individuals for which all three molars and a femur sample were available, 5 subadult burials with only M1 and M2 crowns completed were included too. For the latter individuals (Burials 16, 35.2, 37.2, 39 and 45) the M3 was either not yet formed, or still forming. Partly developed crowns were not examined because such crowns are incompletely mineralized and this could have affected the isotope ratios. The five molar samples used for this research came from this pool of previously studied materials. Teeth from Burials 7, 12, 16, 35.1, and 35.2 were used in this study to provide continuity and comparability with previous studies on KN XIV.

This previous work has helped to expand the possible applications of strontium isotope research and helped to identify an interesting general pattern with several mobility profiles within KN XIV individuals. Broadly speaking, it appears that there was a significant amount of movement of individuals during their lifetime, whereby people buried at KN XIV were frequently not born in the Little Sea region, but only migrated there as subadults or adults (Haverkort, et al., 2010, Haverkort, et al., 2008). There was significant variability within the cemetery itself as to the origin and age of migration to the Little Sea with indications of correlated mortuary patterning that is the subject of ongoing research.

PRINCIPLE OF STRONTIUM CATCHMENT

Strontium ratios in herbivore bone reflect the isotopic signatures in the plants that these animals eat and the water that they drink thus are a direct reflection of their bioavailable geochemical environment. An herbivore foraging range will therefore roughly equate to its Sr-catchment (Bentley and Knipper, 2005, Price, et al., 2002). The situation is slightly different for carnivores as their Sr-catchment will reflect their dietary intake rather than simply their geographical territory. The territory of a predator, human or otherwise, will intersect and contain portions of the territories of numerous prey animals, though will likely not encompass the full procurement ranges of these species. Therefore the strontium ratios of their prey animals may derive from geological regions outside of the predator's geographic territory. This highlights the important concept of effective geochemistry as a step beyond bioavailable geochemical signatures. Herbivores provide direct translations of bioavailable geochemical values in plants, thus whatever portion of soil geochemistry can be mobilized into the food chain. Carnivores subsist largely or solely on other animals, thus their bioavailable geochemical values will not directly translate into either their actual movements on the landscape or their bounded procurement territory. The only evidence to directly relate carnivores with their physical territory is the water that they drink, any vegetal matter they may consume (e.g., berries), or small animals (e.g., rodents, lizards, etc.) whose entire range will be limited in scale and thus contained with the carnivore's territory. Thus both human and animal predatory strontium signatures may reflect procurement ranges both larger and different from their actual territories.

In geologically diverse regions, interpretation of bioavailable geochemistry can be complicated by the fact that animals with small home ranges (e.g., *suslik*) may have adjacent geographical territories but exist on different bedrock formations and thus have different strontium ratios. Larger species, such as moose and red deer frequently cross geologic boundaries during the course of an annual foraging cycle; averaging the $^{87}Sr/^{86}Sr$ ratios in their tissues. Thus interpretation of the bioavailable geochemistry can be unintentionally biased during sampling based on sample availability.

TOOTH MINERALIZATION

Teeth are dynamic mineral structures whose complexities are still being unraveled. It has long been recognized that the incremental *striae of Retzius* represented some aspect of matrix deposition but that there is a disconnect between this matrix deposition and the final mineralization that will finalize the mineral matrix (e.g., (Brown, et al., 1960)). At the time, micro-sampling of individual striae was not practical, thus the matter was largely ignored. However, there has recently been a resurgence of interest in the formation process of the incremental growth lines as reflections of the circadian rhythm of enamel matrix secretion with the advent of micro-sampling techniques such as laser ablation and micro-drilling that could theoretically sample the enamel at such pertinent scales (e.g., (Hillson, 2002, Horstwood, et al., 2008, Kang, et al., 2004, Prohaska, et al., 2002, Richards, et al., 2008)). Numerous hypotheses have been forwarded regarding the pattern and progression of enamel mineralization, however the common theme amongst all works is that the progression of mineralization of layers and/or maturation of matrices is patchy and effectively non-linear thus making the chronological relationship between incremental lines and geochemical signals rather tenuous (Bentley, 2006, Dolphin, et al., 2003, Fincham, et al., 1999, Hillson, 2002, 2005, Kang, et al., 2004, Montgomery and Evans, 2006, Suga, 1982, 1989, Tafforeau, et al., 2007). Broad trends whereby mineralization begins at the tooth cusp and finishes at the cingulum are still present, though the intermediate pathways are debatable. Montgomery and Evans, (Montgomery and Evans, 2006) and Fincham *et al.,* (Fincham, et al., 1999) provide excellent discussion of the biomineralization of tooth enamel with respect to Sr isotope analysis. The process of mineralization spans a series of five distinct phases wherein an organic gel or protein superstructure is transformed into a mineral matrix: 1) secretion; 2) assembly; 3) matrix formation; 4) resorption prior to maturation; and 5) maturation (see Fincham et al. (Fincham, et al., 1999) Fig. 8; Bentley (Bentley, 2006) Fig. 18). Following assembly, nanospheres of apatite will remain largely intact until maturation, however although these individual crystal structures are reflexive of their formation environment, they will mingle with other crystals to form a heterogeneous lattice of crystals in the mature matrix. Effectively, at all stages prior to maturation, the enamel matrix remains an open chemical system vulnerable to alteration, overprinting, or simply averaging of the matrix at the scale of modern recovery techniques.

The practical ramifications of this open chemical system is that while the formation of tooth crowns progresses at a well-known rate and there are incremental growth lines to further support the logical conception of enamel matrix as a progressive linear formation, all work to date demonstrates that there is a disjunction between enamel formation and matrix maturation. So while we know that calcification of M1 begins at birth and ends with maturation and root formation between 3 – 4 years of age, we are left with nearly three years of that molar remaining an open chemical system and a potential averaging effect (Avery, 1992, Hillson, 2002). In spite of this theoretical difficulty, there is still some promise to the concept of micro-sampling tooth enamel. That incremental growth lines do not mineralize in a similar incremental fashion has been well demonstrated, however we still have some broad guidelines that remain true: 1) the crown of a tooth will fully mineralize before the root; and 2) though accomplished in a patchy or wave-like fashion, there are still broadly linear trends in mineralization progressing from crown to cingulum.

Ongoing research into this problem with herbivore teeth has demonstrated that there are long-term mixing effects in action during the formation and maturation of tooth enamel (Balasse, 2003, Balasse, et al., 2002, Britton, et al., 2009, Brown, et al., 1960, Hoppe, et al., 1999, Hoppe, et al., 2003, Hoppe, et al., 2004, Koch, et al., 1995, Montgomery, et al., 2010, Tafforeau, et al., 2007). Such research has highlighted a secondary problem with efforts to access the micro-structure of teeth and thus provenance their formational period, that while formation of enamel proceeds using available mineral components within the body and that available components come from the diet, there is a gap between intake of the raw ionic components of the mineral structure and their incorporation into mineral tissues. Specifically this is the problem of residence time in the body for different elements. Water has a short residence time in the body of only 14 days; however strontium, calcium, and lead can remain in the body for 800–1600 days, with 10% of traceable doses remaining active after 400 days (Bowen, 1979, Dahl, et al., 2001, Montgomery, et al., 2010). Recent works (e.g., (Britton, et al., 2009, Montgomery, et al., 2007, Montgomery, et al., 2010)) have demonstrated that this residence time in the body has an intriguing effect on isotopic signatures of a linearly-sampled herbivore tooth. Namely that an abrupt change in geochemical geography and/or diet will not manifest as a sharp transition in isotopic signals, but rather that there will be a gradual sloping change as contributions from different geochemical end-members vary within the body-water average being accessed for ionic component material in enamel formation. At face value, this combination of lag time in mineral formation and maturation with body-water averaging of over a year should render discussions of micro-sampling human teeth for interim provenance information between the crown and cingulum, however it should be noted that there is an important difference between herbivore and human teeth. While it is quite likely that the same mineralization primers are in effect for both human and herbivore teeth and that the non-linear progression of mineral maturation is effectively the same, the time spans involved are different. For example, each bovine molar will form and fully mineralize over a span of 12–18 months (Montgomery, et al., 2010). However, each human molar can theoretically span a time of 24–48 months between initial calcification and final mineral maturation, though it will likely occur in less than 36 months. Thus, we have a gap in comparative volumes and chronologies in discussing the differences between herbivore and human teeth. While many herbivore teeth are not good candidates for micro-sampling because their tooth formation rates will not outstrip uncertainties about residence time and mineralization rates, human teeth will likely exhibit some aspects of useful variability in isotopic signatures through formation time and thus through enamel mineral volume/geography. We still must keep in mind that at present it is impossible to overcome residence time for intake and maturation time for the mineral matrix, it may well be worth pursuing micro-sampling of human teeth in between cusp and cingulum.

LASER ABLATION OF TEETH

The coupling of a laser ablation unit to either an ICP-MS or a MC-ICP-MS is no longer a novel concept to the fields of analytical chemistry and archaeology, and is rapidly becoming a mainstream tool for ongoing research and a key player in the advancement of micro-analytical techniques (cf. (Gratuze, 1999, Russo, et al., 2002, Speakman and Neff, 2005, Tykot and Young, 1996)). Studies involving skeletal materials were fairly late additions to the field, in part due to latent concerns about the materials being analyzed and their potential for diagenetic alteration at the proposed scale of analysis. However, in the last decade or so, ICP-MS studies on teeth and bones have picked up significantly and are now part of a healthy academic field of research (Bizarro, et al., 2003, Budd, et al., 1998, Copeland, et al., 2008, Copeland, et al., 2010, Cucina, et al., 2007, Horstwood, et al., 2008, Montgomery, et al., 2010, Prohaska, et al., 2002, Richards, et al., 2008, Simonetti, et al., 2008, Trotter and Eggins, 2006). Numerous studies have demonstrated the reliability of ICP-MS and MC-ICP-MS as compared to TIMS and INAA (cf. (Christensen, et al., 1995, James, et al., 2005, Kin, et al., 1999, Revel and Ayrault, 2000, Speakman and Neff, 2005)) using both laser ablation and solution mode sample introduction for both elemental composition and numerous isotopic series. ICP-MS and MC-ICP-MS are generally faster and less labor intensive than traditional analytical methods, however one of the trade-offs is the tacit recognition of the need for corrections for a variety of interferences. The identification of and correction for the seemingly endless string of interferences across the mass spectrum is an extremely important part of researchers ability to use confidently ICP-MS as an analytical tool. For single radiogenic isotopic series such as strontium, the list of potential problems includes known isobaric interferences (^{87}Rb), doubly-charge rare earth ions (Paton, et al., 2007), polyatomic species such as calcium dimers (Woodhead, et al., 2005), calcium phosphate (CaPO) (Horstwood and Evans, 2002, Horstwood, et al., 2008, Horstwood and Nowell, 2005, Richards, et al., 2008, Simonetti, et al., 2008, Vroon, et al., 2008), and other molecular species yet to be identified. While daunting and providing a divergence from the seemingly parsimonious relationship linking artifact and data via traditional analytical methodologies, identifying possible problems and monitoring for data quality are important parts of any analytical process and so should not be avoided. For Sr analysis, the largest if not most pernicious problems are isobaric interference from ^{87}Rb and a recently identified polyatomic interference from calcium phosphate, though an important distinction between the two should be made. Rubidium corrections are necessary for all ICP-MS and MC-ICP-MS analyses as the charged ^{87}Rb will carry the same mass-charge ratio as its ^{87}Sr counterpart, though this can be countered with accurate mass-bias calculations. This is not a problem associated with sample introduction methodology. On the other hand, polyatomics such as Ca dimers and calcium phosphate species are notably absent in solution-mode analysis as sample ions are held in acid and thus prevented from recombining as they are free to do in the carrier-gas environment of laser ablation chambers. From the perspective of an end-user, that such interference only manifest, or are only apparent at significant levels via laser ablation introduction both with and without aspirated acids introduced, is both interesting and discouraging for micro-sampling potentials. It is intriguing that complex molecules manifest in the highly charged plasma environment when introduced by a carrier gas but not as an aspirated solution, as both are theoretically entering into the plasma chamber as ionized particles.

Woodhead *et al.* (2005), Simonetti *et al.* (2008), Horstwood *et al.* (2008), and Vroon *et al.* (2008) have all discussed the presence of significant interference on mass 87 from a previously unidentified source, thus impinged on researchers' ability to accurately assess the $^{87}Sr/^{86}Sr$ ratios of phosphate matrices with laser ablation. As all mammalian skeletal tissues are varieties of phosphate mineral matrices, this is a major problem for efforts to access the life signals contained therein and thus in archaeologists' and paleontologists' ability to accurately interpret these signals and thus reconstruct the movement histories of these animals. It appears that the root of the problem is the excess of Ca and P present in the charged environment coupling with the oxide production rates within the MC-ICP-MS. In theory, Ca and P levels should be proportional in all parts of skeletal tissues, thus mineral replacements such as Sr, Ba, and the incorporation of other trace elements should be proportional as well, and interferences will be related to the oxide operational conditions of the instrument itself. This leaves us with several important points to consider: do we have reason to question any of these starting assumptions? Can we monitor the formation of CaPO during analysis and thus correct for it in ways other than those outlined in previous works? Can we recover useful geochemical information from skeletal tissues using laser ablation as a micro-sampling technique?

MATERIALS AND METHODS

Tooth enamel samples consist of five human molars from the KN XIV cemetery that have previously been used for analytical work by the Baikal Archaeology Project. Samples included 4 second molars from graves 7 (Sample #1997.211), 16 (1997.217), 35-1 (1998.355), and 35-2 (1998.359), as well as 1 third molar from grave 12 (1997.225). All samples were previously analyzed by Haverkort *et al.* (Haverkort, et al., 2008) and several were also analyzed via TIMS by Weber *et al.*(Weber, et al., 2003). All samples were analyzed for elemental composition using both SM-ICP-MS and LA-ICP-MS and likewise for $^{87}Sr/^{86}Sr$ ratios using SM-MC-ICP-MS and LA-MC-ICP-MS. All preparation and analyses were conducted at the Radiogenic Isotope Facility of the Department of Earth and Atmospheric Sciences at the University of Alberta.

Solutions were prepared by extracting fragments of enamel (between ~0.020-0.060 g) as close to the cingulum as possible to provide comparability between teeth with various levels of wear. Fragments were mechanically removed using a diamond cutting disk (NTI Diamond disc, Interflex-double sided, 8 mm diameter, 0.15 mm thickness) fitted to a Dremel tool. If necessary, samples were abraded with the disk to remove any adhering dentine. Sample locations were not side-specific as these teeth have been previously sampled, thus samples were taken where adequate materials remained, though largely stemming from areas immediately adjacent to previous sampling locations. Sample preparation occurred in a Class 100 clean room facility and followed procedures outlined in Simonetti *et al.* (Simonetti, et al., 2008) and Haverkort *et al.*(Haverkort, et al., 2008). Samples were sonicated for 15 min in milliQ (MQ) de-ionized water and then in 5% acetic acid for 15 min. After an overnight leaching in 5% acetic acid, the acid was removed and samples were rinsed with MQ prior to transfer to clean Teflon vial. A known amount of ^{87}Rb–^{84}Sr spike was added, followed by 4 mL of 16 N HNO_3 and 1 mL of 12 N HCl and capped to digest on an 80 C hotplate overnight. Digested samples were then dried overnight on the hotplate. Dried samples were dissolved in 3 mL of 0.75 N HCl and loaded into syringes with disposable filters. Filtered samples were loaded onto 10 cm cation exchange columns containing 1.42 mL of 200-400 mesh AG50W-X8 resin. Columns were rinsed with 3x1 mL of 0.75 N HCl, 3x1 mL of 2.5 N HCl and washed with 17 mL of 2.5 N HCl. Samples of 5 mL of 2.5 N HCl containing the purified Sr were collected into clean Teflon vials and left to dry overnight on the hotplate. Dried samples were dissolved with 1 mL of 2% HNO_3 prior to necessary dilution for MC-ICP-MS analysis. Analysis was conducted on a Nu Plasma HR MC-ICP-MS with a DSN-100 nebulizer. Strontium isotope data were acquired in static, multicollection mode using five Faraday collectors for a total of 400 s, consisting of 40 scans of 10 s integrations. The 'wash-out' period following the analysis of a sample was approximately 5 min. Prior to the aspiration of a sample, a 30 s measurement of the gas (+acid) blank was conducted to correct for ^{86}Kr and ^{84}Kr isobaric interferences. The isobaric interference of ^{87}Rb was monitored and corrected online using the ^{85}Rb signal. Accuracy and reproducibility of the analytical protocol based on long-term repeated analysis of a 100 ppb solution of the NIST SRM 987 strontium isotope standard 0.710242 ± 0.000041 (certified value 0.71034±0.00026).

Elemental samples of similar size underwent similar handing, though without the ^{87}Rb–^{84}Sr spike, and not loaded onto cation exchange columns. Digested samples were simply dissolved in 2% HNO_3 prior to quadrupole-ICP-MS analysis. Sample solutions were analyzed for 57 elements (Li, Be, B, Na, Mg, Al, P, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Ga, Ge, As, Rb, Sr, Y, ^{90}Zr, ^{91}Zr, Nb, Mo, Ru, Pd, Ag, Cd, Sn, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Pt, Au, Tl, Pb, Th, and U) using a Perken Elmer Elan6000 quadrupole ICP-MS, and instrument operating conditions as follows: RF power = 1200 W; dual detector mode; blank subtraction performed subsequent to internal standard correction; unit of measurement is cps (counts per second); auto lens on; use of 4-point calibration curves (0, 0.25, 0.50, and 1.00 ppm for Ca, Mg, and Fe; 0.005, 0.010, and 0.020 ppm for the remaining elements); sample uptake rate (using a peristaltic pump) was ~1 mL; sample analysis consisted of 35 sweeps/reading, 1 reading/replicate and 3 replicates; dwell times were 10 ms for Al, Mn, and U, and 20 ms for the remaining elements; total intergration times (dwell time x number of sweeps) were 350 ms for Al, Mn, and U, and 700 ms for the remaining elements (Appendix A). External reproducibility, based on repeated analysis of international whole rock standards is 5-10% (2σ level) for most elements.

Laser ablation for elemental analysis of samples was conducted using the Perken Elmer Elan6000 quadrupole ICP-MS coupled to a UP213 nm laser ablation system (New Wave Research, USA). The instrument was optimized using the NIST SRM 612 international glass standard reference material (RF power 1200 W, peak hopping acquisition, 50 ms dwell time).

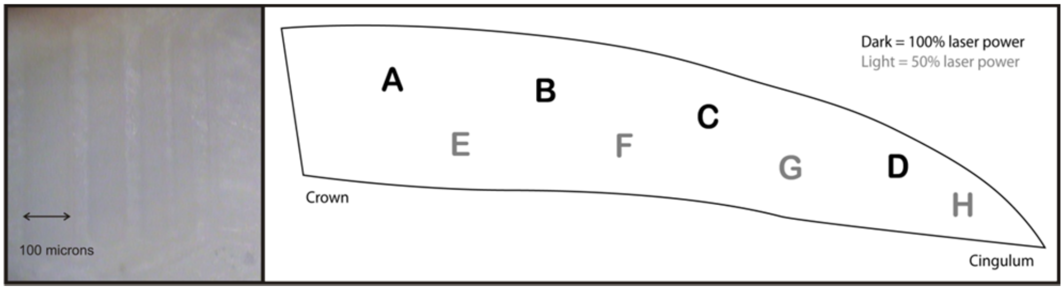

Figure 3-2: Sampling scheme used on sectioned teeth. Enlargement – laser ablation scars representing one sampling group.

Teeth were serially sampled (Figure 3-2) using LA-ICP-MS to examine the nature and extent of useful intra-tooth geochemical variability in tandem with attempts to monitor the formation of the CaPO polyatomic species. This sampling included 8 sampling locations or groups on each tooth, offset but approximately equally spaced between the bottom of the crown and the cingulum. Groups consisted of 5 lines each with a combination of laser spot size and laser power settings were employed to assess the impact of potential laser-matrix effects. Half of the sampling groups were conducted using 50% laser power, while the other half was run at 100% laser power. Line groups consisted of reducing laser spot sizes of 100, 80, 55, 40 and 25 μm in sequence, with a repetition rate of 20Hz and an energy density of ~13 J cm^{-2}. Experiments were conducted in a mixed He/Ar atmosphere (ratio of 0.5:0.1 L min^{-1}) within the ablation cell, and mixed with Ar (1.03 L min^{-1}) prior to entering the torch assembly. The laser ablation cell was flushed with a higher flow rate of He (up to 0.9 L min^{-1}) for approximately 1 min in-between laser ablation runs to ensure adequate particle washout. The NIST SRM 612 glass standard was used as the external calibration standard. Quantitation for 57 elements (Li, Be, B, Na, Al, Si, P, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, As, Rb, Sr, Y, ^{90}Zr, ^{91}Zr, Nb, Mo, Ag, Cd, In, Sn, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Au, Tl, Pb, Bi, Th, and U) were obtained and normalized to ^{24}Mg, as measured by solution analysis, as the internal standard using the GLITTER® (XP version, Macquarie University) laser ablation software (Appendix B). Mg was used instead of Ca in order to assess variability in calcium in these teeth.

Laser ablation for isotopic analysis was conducted using a UP213 nm laser system coupled to the Nu Plasma HR MC-ICP-MS with the sample-out line from the desolvating nebulizing introduction system (DSN-100 from Nu Instruments) to allow for simultaneous aspiration of a 2% HNO_3 solution. At the beginning of each analytical session, parameters for the introduction system and the ion optics were optimized by aspirating a 100 ppb solution of the NIST SRM 987 Sr isotope standard. Based on the results of the elemental laser ablation analysis, a full replication of the line groups was not done. Instead, overlying each full powered elemental sampling site, three parallel lines were analyzed using 100 μm laser spot size; 100% laser power; 20 Hz repetition rate; ~15 J cm^{-2} energy density (Appendix C). Half powered elemental sampling sites were not sampled for isotopic data as the elemental data were deemed to be of poor quality. Strontium isotope data were acquired in static, multicollection mode using five Faraday collectors for a total of 400 s, consisting of 40 scans of 10 s integrations, for data reported. Testing for potential collector setups included attempts at using eight collectors in order to extend the monitored mass range to include masses 90 and 91. Similar efforts were also attempted using dual-acquisition, static analysis to similar effect following Horstwood *et al.* (Horstwood, et al., 2008). Laser data were partially monitored by repeated analysis of a specimen of Durango Apatite with a reported value of 0.706327 ± 0.000724 by TIMS (Horstwood, et al., 2008). In one analytical session, an average value of 0.706118 ± 0.000035 were observed, and in a second, 0.706244 ± 0.000028. This sample is currently being intensively sampled for its ongoing use as a mineral standard for strontium analysis at the Radiogenic Isotopic Facility, however at present has been analyzed fewer than fifty times and thus can only be viewed with moderate confidence. As such, no attempts were made to standardize data for enamel samples to apatite values. Quantification of the oxide levels during analyses using UO^+/U^+ demonstrated levels of approximately 0.7%.

RESULTS AND DISCUSSION

This research included a number of different aspects, beginning with efforts to demonstrate the value in trace element analysis of human teeth for provenance and/or mobility purposes. The treatment of organic minerals in a similar fashion to complex inorganic minerals for the purposes of provenance analysis is a fairly new and expanding area of research within the realm of provenance analysis (cf. (Cucina, et al., 2007, Cucina, et al., 2005, Dudgeon, 2008)). The underlying concept is the same for any geochemical sourcing study, in that the range of variability must meet the strictures of the

"Provenance Postulate" (Weigand, et al., 1977). Though this has been demonstrated for populations on Rapa Nui (Dudgeon, 2008), and in distinguishing African immigrants in a Mexican cemetery (Cucina, et al., 2007, Cucina, et al., 2005); the range of useful variability in trace element composition must be determined for each geographical region. Thus, for cemeteries in Cis-Baikal, a new database of locally useful elemental variability must be generated. This research consisted of only 5 samples, however still presents a beginning to the formation of such a database.

We must first establish the veracity of hypothesized expectations for Cis-Baikal inhabitants. Within each sampling group, five lines of different sizes: 100, 80, 55, 40, and 25 μm, were drawn to demonstrate the impact that sample size has within a micro-sampling environmental. Figures 3-3 and 3-4 show the tooth results of different laser spot sizes being used on strontium and rubidium at full laser power; rubidium being representative of elements of low concentration (below 20 ppm) and strontium of elements of higher concentration. The results are not surprising as the direct relationship between the physical amounts of sample introduced into the ICP-MS is integral to the functioning of the equipment; however it does provide a reminder that mass ranges with low concentrations are subject to significantly larger error terms as beam size is reduced. As such, the use of low concentration mass ranges (i.e., rubidium or zirconiuim) for correction factors must be taken carefully as the sampling methodology can have a major impact on the effectiveness of such a correction factor. The difference in variability is strictly the results of resultant signal strength, which can be equally altered by changes in the spot size and the laser power. This variability viewed as confidence ellipses on bivariate plots will yield relatively larger or smaller ellipses.

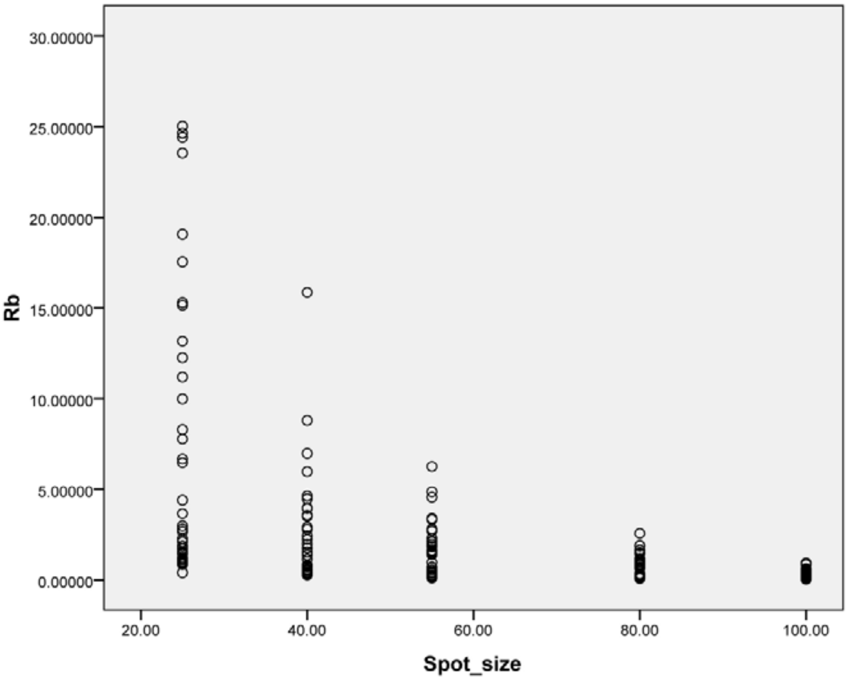

Figure 3-3: Rubidium values by spot size.

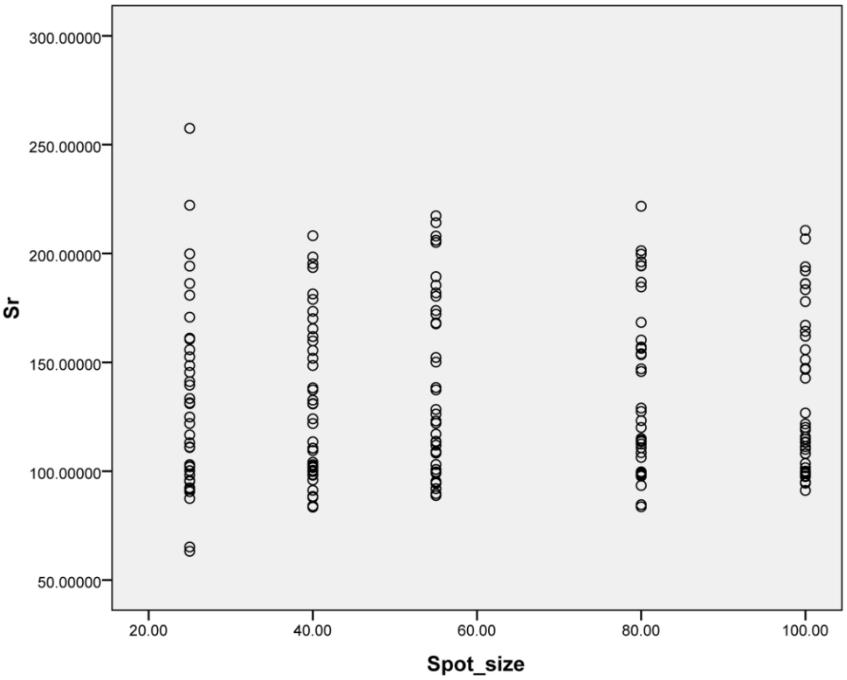

Figure 3-4: Strontium values by spot size.

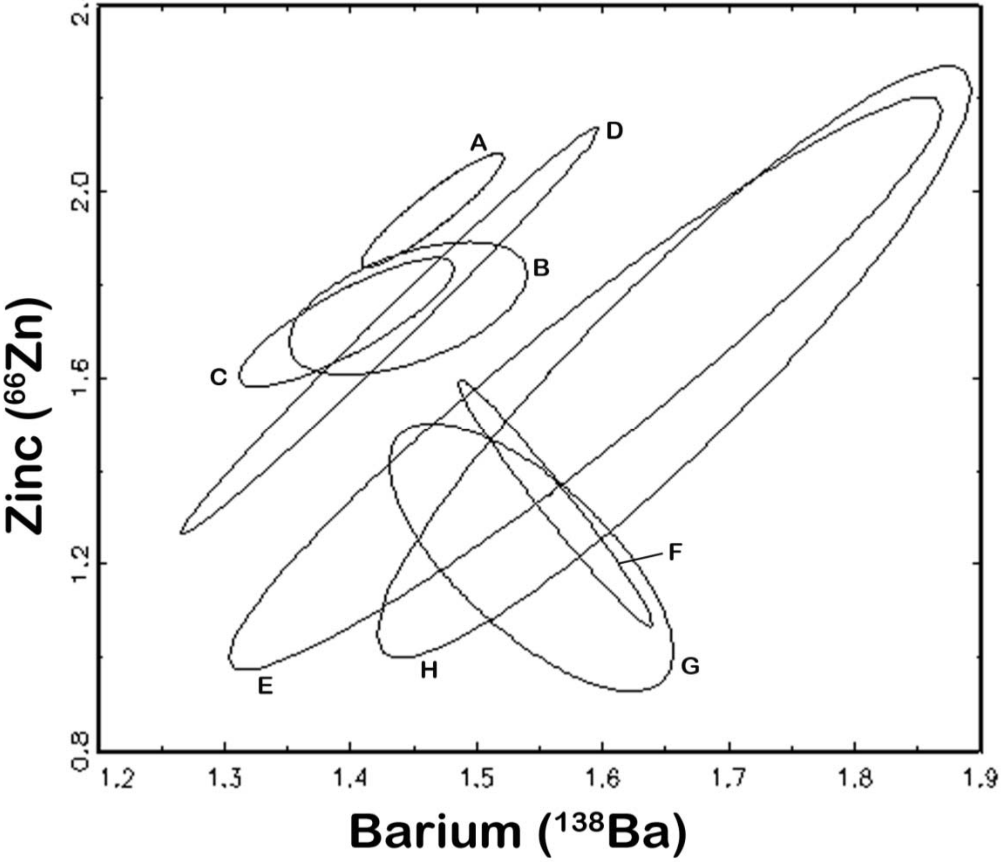

Figure 3-5: Impact of laser effects shown by groups' variability clustering by laser power rather than by internal variability.

Figure 3-5 demonstrates this as a compounded effect of both laser power and spot size as each ellipse represents one group of five laser lines of different size.

The extent of variability related to laser effects was somewhat surprising, not in that the concentrations were more variable, but rather that these data formed significantly different shapes in statistical space. This could be interpreted as reflecting significant internal variability within a single tooth, greater than may actually be present, simply as an effect of the laser power. As these data came from prehistoric hunter-gatherer teeth, it is possible that such variability is reflective of provenance shifts during the life of the individual, however with the neat divide between groups measured with 50% and 100% laser power, it is reasonable to assume that the ranges seen are in fact the result of the laser settings and not fully reflective of internal variability within the enamel matrix.

The next question is whether there is adequate variability reflected in the geochemical data from serial sampling of a tooth to potentially address the underlying concern of the disjunction between enamel matrix formation and the supposed dietary source of these signals. Figures 3-6 and 3-7 demonstrate that there is significant variability within the span of a single tooth. As noted by Britton *et al.* (Britton, et al., 2009) and Montgomery *et al.*(Montgomery, et al., 2010), the incorporation of a sudden change in geochemical input signal will lead to a moderately sloped interchange reflecting both the old and new end-members of the geochemical signal, so any significant change in the elemental data is likely outstripping the visibility of this effect, or showing snapshots along the transition slope still reflecting different values and statistical morphology. This is highly suggestive of the presence of useful variability in trace element composition in the hunter-gatherer population of Cis-Baikal comparable to effects noted in agrarian groups by Cucina *et al.* (Cucina, et al., 2007, Cucina, et al., 2005) and Dudgeon (Dudgeon, 2008). However, one interest aspect of the range of variability within a single tooth raises some concerns about the extent of the validity of the assumption that the hydroxyapatite matrix contains relatively stable quantities of Ca and P. Figures 3-8 and 3-9, show calcium and phosphorous projected against strontium, two elements that are supposed to be present in a fairly constant ratio throughout the tooth, should show similar patterning. The predictable nature of calcium phosphate matrices is the primary feature that enables geochemical research to be conducted on skeletal tissues.

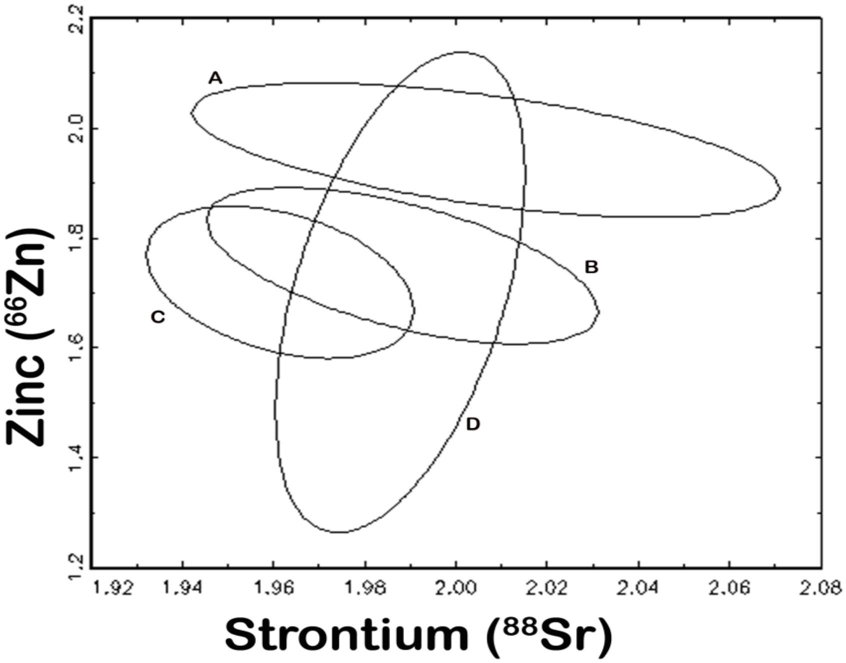

Figure 3-6: Strontium and zinc bivariate plot, suggests a transitional period during the early period of molar formation followed by a period of relative stability in geography and diet and the beginning of another transition towards the end of molar formation.

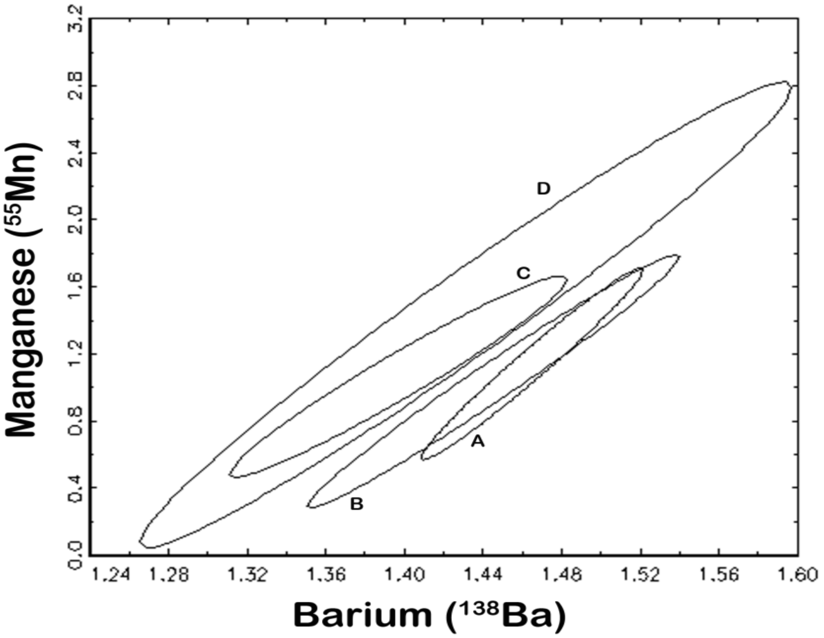

Figure 3-7: Barium and manganese bivariate plot shows an intriguing separation between paired groups A-B and C-D demonstrating a clear shift in geography or diet between the first and second half of the molar growth period.

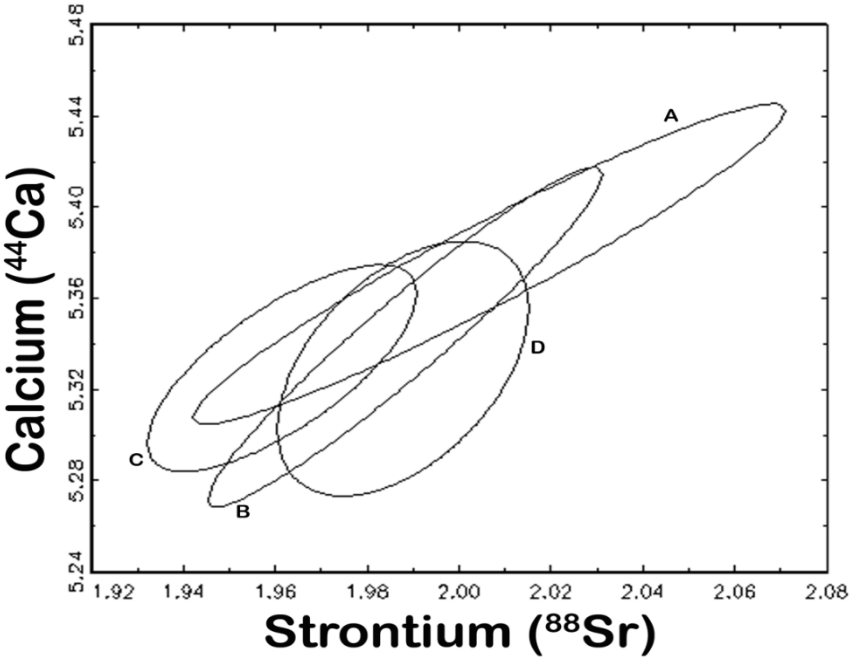

Figure 3-8: Strontium and calcium are strongly correlated as expected as interchangeable mineral components.

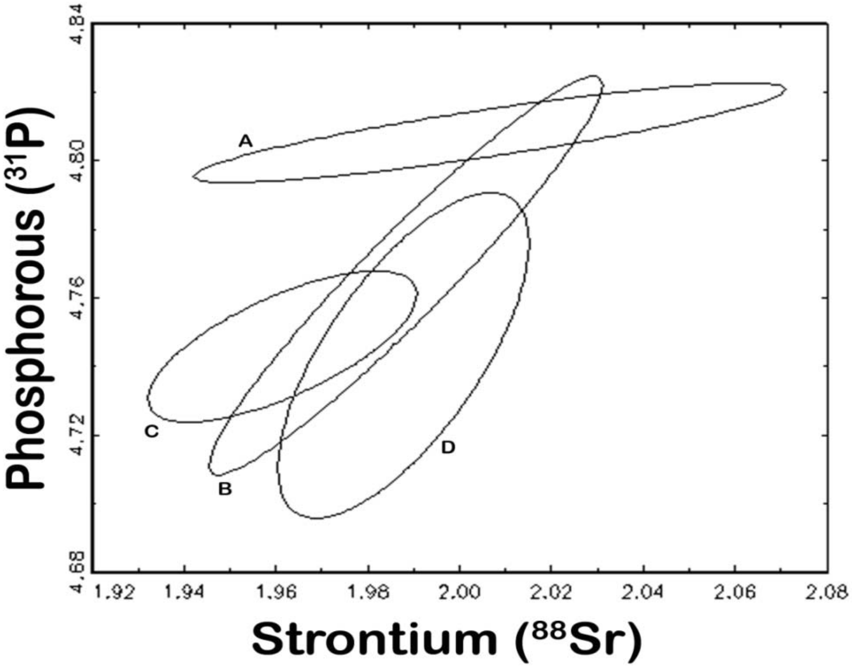

Figure 3-9: Surprising variability in the phosphorus values both in extent and direction with correlation not following suit of Sr/Ca ratios as is generally hypothesized.

The range of variability visible in this one sample is still within the ranges to be expected for normal Ca:P ratios of teeth not significantly altered by diagenetic processes, however the distribution and differences in statistical morphology is intriguing.

After establishing that trace element analysis is a useful tool for analyzing hunter-gatherers from Cis-Baikal, we must identify elements that may mirror or enhance provenance information acquired from $^{87}Sr/^{86}Sr$ ratios. Strontium isotope ratio is a well-developed analytical approach for provenancing skeletal tissues, however it has one major caveat in its ability to elucidate either origins or mobility of an individual; that it can only operate on the scale of the dominant bedrock formation and/or geologic zone. In some areas of the world, this is more than adequate to answer all of the current research questions relating to available cemetery populations. This is particularly true for agrarian groups, where questions are dominated by a local/nonlocal dichotomy where the primary goal is to establish the local signal and thus identify immigrants in a population, with the provenancing of the immigrants falling to secondary level of investigation. Geologically complex areas such as Cis-Baikal are broadly speaking, quite amenable to such a research approach as there are geologic formations spanning three major epochs in fairly well defined and non-overlapping geography, however we encounter several problems in this situation. Previous studies in Cis-Baikal have demonstrated that the $^{87}Sr/^{86}Sr$ technique works in the region, but also that there are two situations that cannot be clarified without further research: that there are some individuals who, though likely mobile, stayed within a single geological zone; and that there are two major zones of similar age and thus theoretically indistinguishable, leaving a rather difficult scenario where hypotheses regarding regional population exchange will inevitably be hampered by an inability to separate out individuals from these two regions. Two potential solutions to this problem are intensive environmental sampling in order to improve the comparison map available for samples, and the addition of another elemental and/or isotopic series to provide statistical depth to the data and enable multivariate analyses. Within Cis-Baikal, four elements appeared to meet the criteria for their ability to enhance the ^{87}Sr/^{86}Sr data: rubidium (Figure 3-10), cesium (Figure 3-11), barium (Figure 3-12), and rhenium (Figure 3-13). That Rb concentrations can mimic ^{87}Sr/^{86}Sr ratios is not too surprising as most radiogenic formations also contain higher levels of Rb and Sr, however this does not inhibit its value as an elemental signal in helping to elucidate further provenancing of samples within a radiogenic zone as there is still considerable variability in the raw concentrations of the element encountered in the environment. Rhenium functions in a similar fashion. Barium and cesium do not replicate ^{87}Sr/^{86}Sr data as effectively, demonstrating instead their usefulness in discriminating between groups within a single zone (Cs) or between individuals who all come from an area with similar ^{87}Sr/^{86}Sr values,

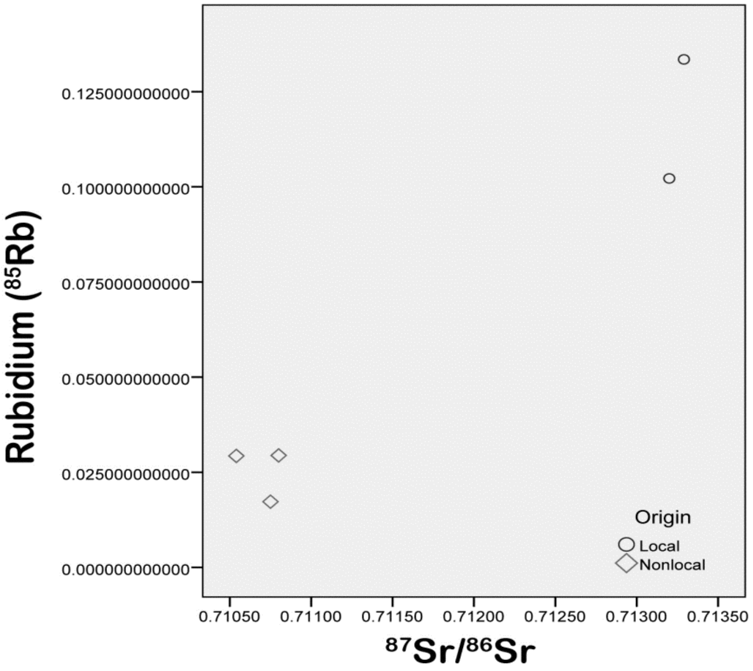

Figure 3-10: Rubidium replicates Sr isotope groupings.

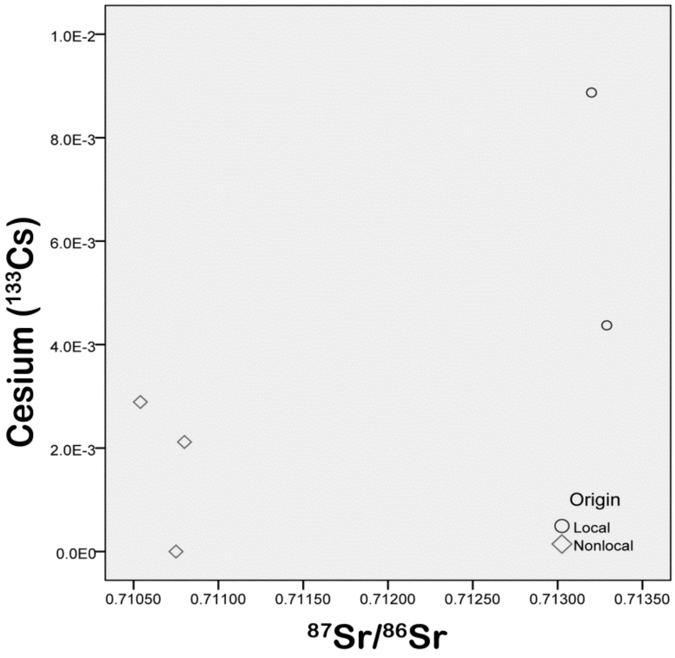

Figure 3-11: Cesium values largely replicate Sr isotope groupings, however suggest greater internal variability for “local” groupings than is suggested by isotopic analysis.

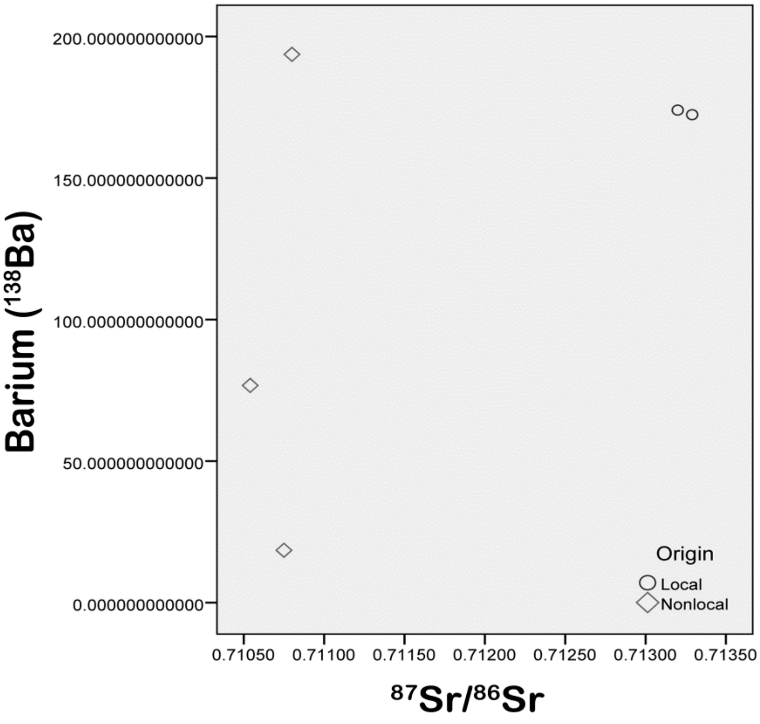

Figure 3-12: Barium values suggest greater variability in “nonlocal” interpretation than is indicated by Sr isotope values.

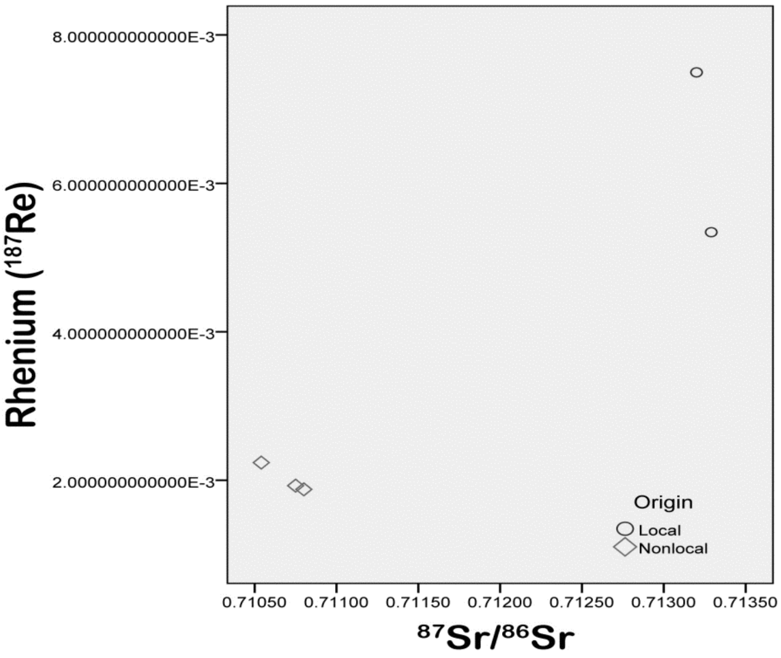

Figure 3-13: Grouping via rheniuim replicates Sr isotope groupings.

but markedly different Ba concentrations, and thus likely from different areas within

another zone. Barium has been suggested to reflect differences in trophic position for dietary contributions as well as geographical differences, though in either case significant behavioral differences are reflected by both Ba abundances and Ba/Sr ratios (Burton and Price, 1990, 1991, 1994, Burton, et al., 2003, Burton, et al., 1999, Gilbert, et al., 1994, Knudson and Price, 2007, Knudson and Tung, 2011). Examined more closely, rhenium and zinc values, for example, show a fair amount of variability throughout the geography of a single tooth (Figure 3-14), illustrating this individual's continual presence within a single geologic zone, in this case the Little Sea; however, also showing that they had notable variability in their interaction with rhenium through their environment via either dietary or mobility changes. It is always possible that a portion of the data was diagenetic rather than anthropogenic, however, significant patterning in statistical data speaks to either non-diagenetic processes, or sufficiently strong and microscopically focused diagenetic alteration as to be equally intriguing for ongoing research. Discussions over methodological approaches to obtaining accurate $^{87}Sr/^{86}Sr$ data using laser ablation frequently include debates over diagenetic alterations and the presence of various interferences. Doubly-charged rare earth elements frequently fall within the mass ranges monitored for $^{87}Sr/^{86}Sr$ analysis. Thus, their presence is of great concern. Theoretically, the presence of elements unable to make direct replacements in the mineral matrix strongly supports proponents of the view that all rare earth elements are diagenetic in origin and thus represent both contaminated samples and a dead end avenue for geochemical research. However, there are very often anomalies within any mineral matrix, especially so in organic matrices such as calcium hydroxyapatite, and these areas of imperfect mineral matrix are effectively traps for other mineral constituents, including trace elements in general. Furthermore, studies demonstrating the utility of trace elemental analysis on human teeth tend to overshadow concerns of diagenetic overprinting or alteration of samples preventing the recovery of useful compositional data from teeth. Following in light of this debate, we attempted to see if there were significant correlations between the strontium and barium values. Sr^{2+} replaces calcium within enamel at a rate not exceeding 1 in 10 ions, and so has a limited capability for accumulation within skeletal tissues even if abundant in the body water supply at the time of enamel formation. Similarly, Ba^{2+} sometimes substitutes strontium in the same position, again at a fraction of the potentially available positions in the matrix. So, significant shifts in the Sr:Ba ratios should hypothetically be a signal that there is diagenetic alterations that could render normal interference calculations for rare earth elements or other interferences inaccurate. However, in the teeth analyzed for this

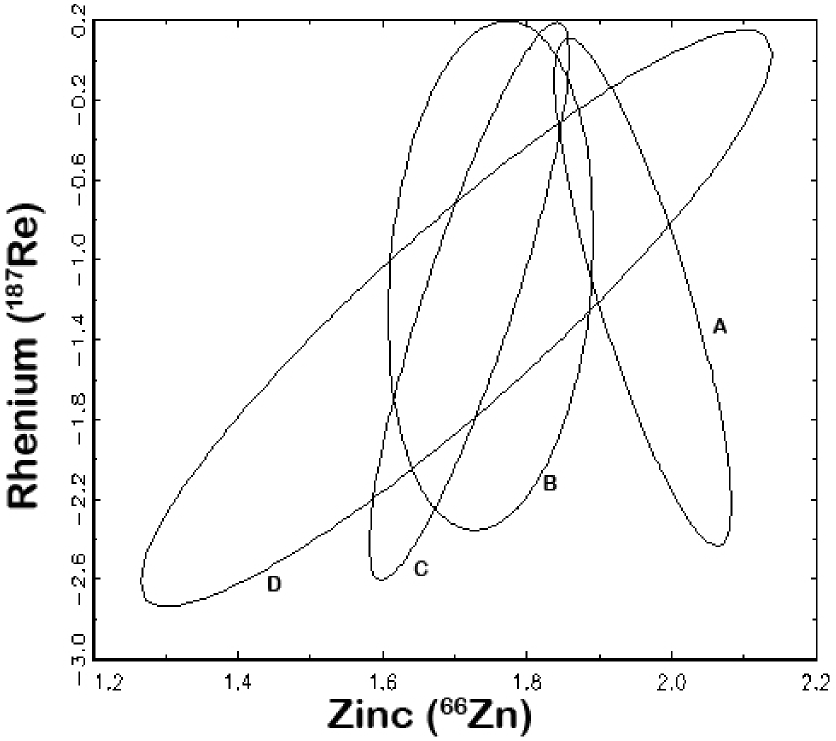

Figure 3-14: Rhenium values for a single "local" individual illustrate their continued residence within a geologic region, though with some smaller scale mobility. Ellipse notations match tooth sampling locations in Fig. 3-2

research, no significant correlations could be found linking Sr:Ba ratios with other forms of interference in ^{87}Sr/^{86}Sr analyses.

The last major goal of this research was to generate adequate data to test the potential for an online or *in situ* measurement of interference on mass 87 from the polyatomic molecule ^{40}Ca^{31}P^{16}O. Previous research has demonstrated that the formation of this polyatomic species is the source of significant interference for laser ablation analyses of strontium isotopes at such a scale that interpretations can be biased through methodological fault. As the ^{40}Ca^{31}P^{16}O is the result of interactions between the enamel surface, the laser and the charged oxidation environment of the plasma, however it remains unclear which element in the system is primarily responsible for this interference, or if it is truly an unavoidable consequence of having excess amounts of Ca, P and O in a charged environment. There are several uncertain variables in this equations, thus the easiest way to measure $^{40}Ca^{31}P^{16}O$ production during analysis would be to measure the related species $^{44}Ca^{31}P^{16}O$ that will skew values of mass 91 in relative proportion to the level of interference on mass 87. In order to measure the interference at mass 91, we need to compare the mass peaks of zirconium 90 and 91. A comparison of ^{90}Zr and ^{91}Zr between solution mode and laser ablation quadrupole-ICP-MS clearly shows the presence of the hypothesized offset between the two masses of Zr (Figure 3-15). The LA values include the data from small laser spot sizes as well as larger ones, so there is significantly more variability in the laser data than the solution data, though there is still a readily apparent offset and linear trend in the offset that can be used for a correction. Such a correction follows the logic that the visible offset in Zr values will correlate with the $^{87}Sr/^{86}Sr$ differences between laser and solution data.

As a test of this concept, we first utilized the published dataset from Simonetti *et al.*(Simonetti, et al., 2008) to see if using reported Sr concentrations we could "correct" the LA data and get results within the original error terms of the analysis. The published data contained Sr concentrations, but no information on Zr, so an added step was needed in this experiment. A linear relationship between the concentrations of Sr and Zr were drawn from the KN XIV analyses and applied to the reported Sr values in order to generate the expected offset of ^{91}Zr. This offset was then compared to the differences in $^{87}Sr/^{86}Sr$ data to gain a second linear relationship for the expected error from $^{40}Ca^{31}P^{16}O$ based on the levels of Sr and Zr (Figure 3-16). The dataset lacked information on specific corrections used, however the laboratory protocols from the time did not incorporate REE or Ca-dimer corrections, so additional blanket correction values were included in the process, however the correction procedure largely followed that outlined by Horstwood *et al.* (Horstwood, et al., 2008).

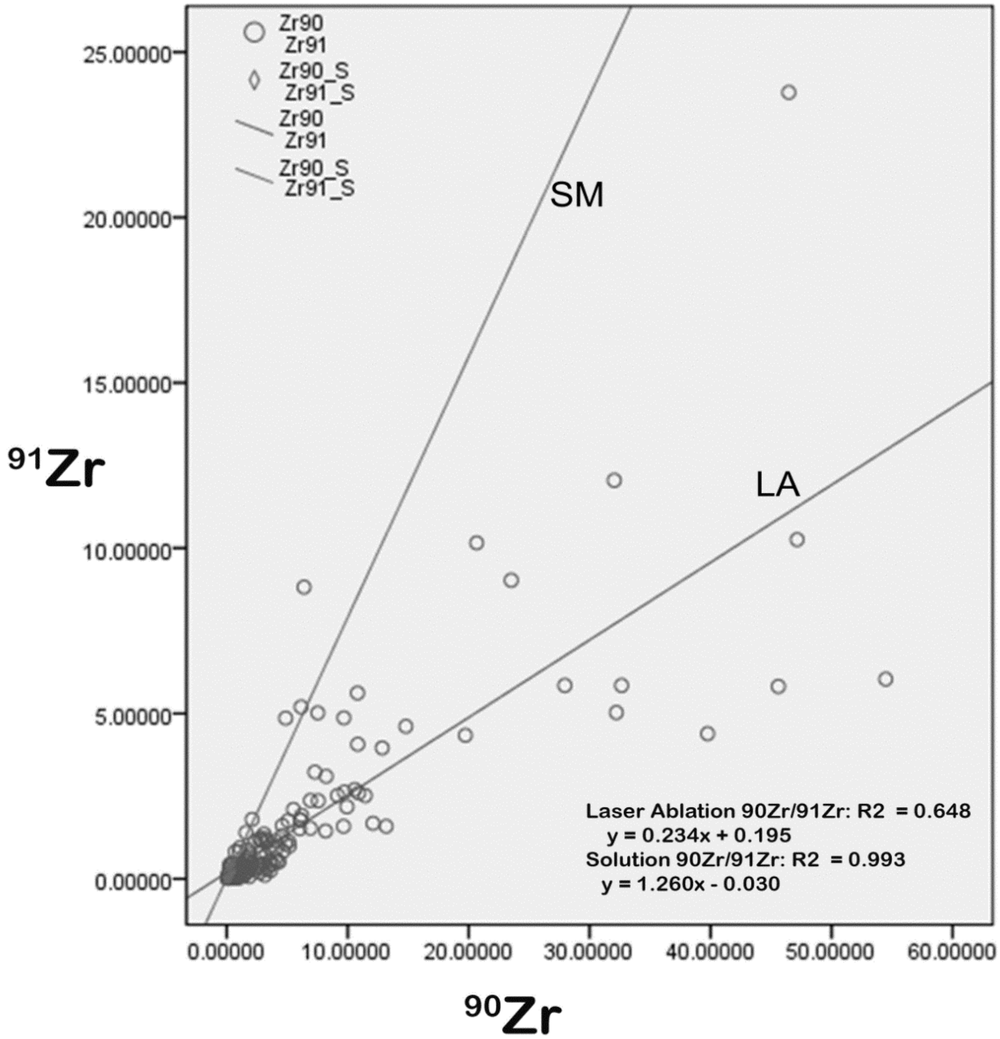

Figure 3-15: Comparison between ^{90}Zr/^{91}Zr between solution mode and laser ablation ICP-MS for KN XIV teeth.

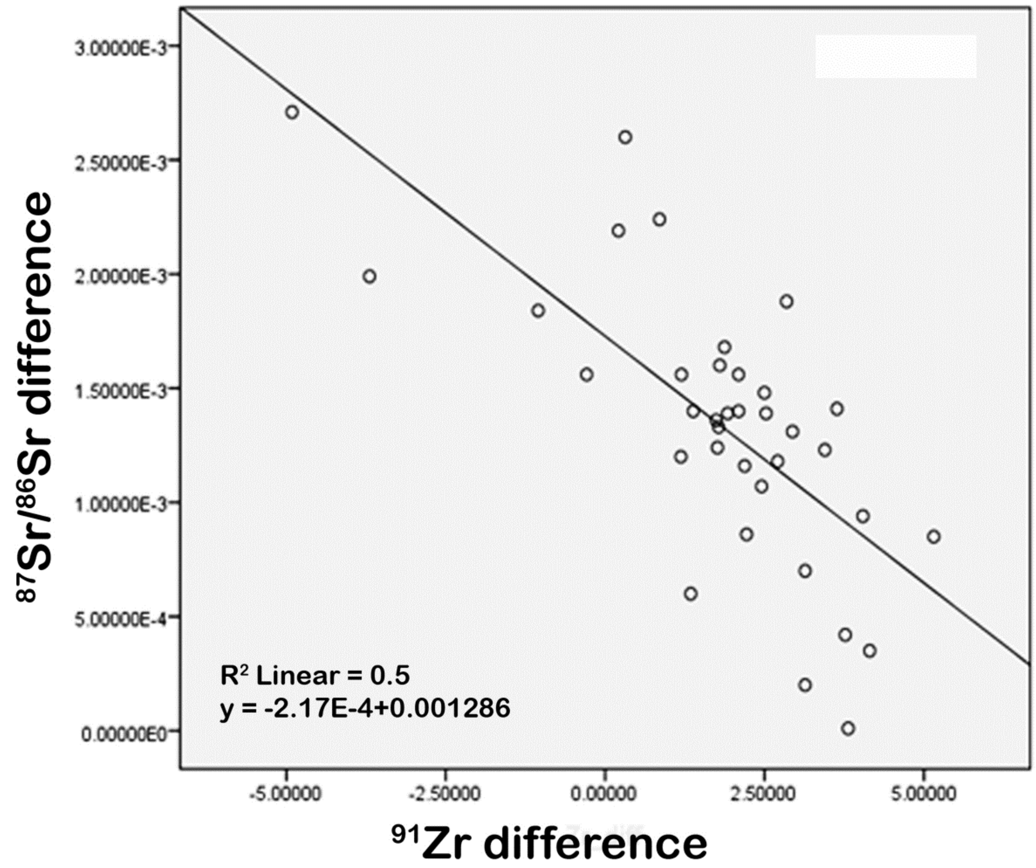

Figure 3-16: Zirconium difference extrapolated from strontium concentrations and compared with observed laser ablation– and solution mode–MC-ICP-MS differences for Simonetti *et al.*2008 data.

Due to the number of variables missing, there is a fair amount of uncertainty in the accuracy of the final "corrected" data, yet the new LA data largely fall on or near the SM data reported (Figure 3-17). Several of the values did not end within the original error terms, showing the difficulties in applying corrections to data with significant amounts of uncertainty attached and compounding concerns over the comparability of micro-sampling locations with the masses of enamel homogenized for solutions. The fact that the majority of samples fell surprisingly close to the SM values strongly supports the potential for this avenue of online correction. The difficulty with this situation is that

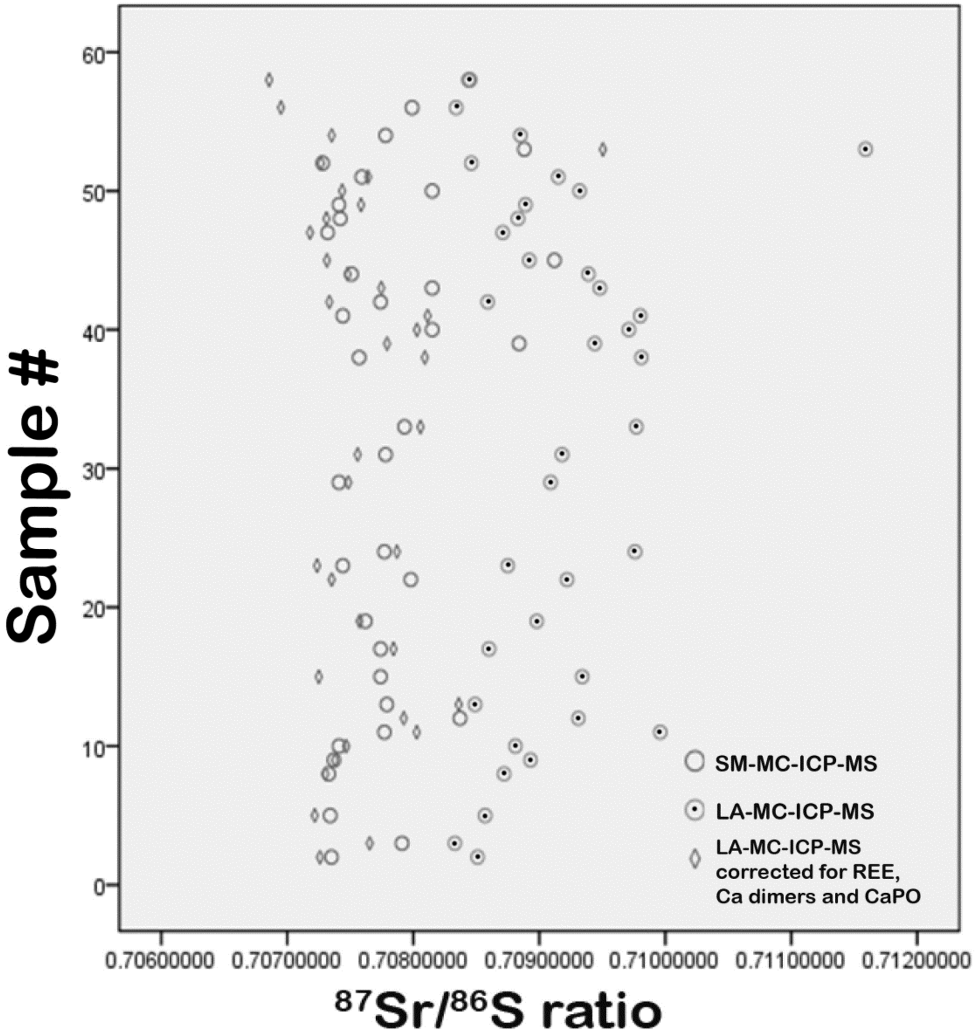

Figure 3-17: ^{87}Sr/^{86}Sr ratios by sample for SM, LA, and LA corrected for REE, calcium dimer and CaPO.

these data were drawn from quadrupole-ICP-MS analysis that is equipped with different electron-multipliers and will have different operating oxide conditions than both another quadrupole-ICP-MS and a MC-ICP-MS. This problem could theoretically be overcome if the quadrupole-ICP-MS and the MC-ICP-MS were connected to the same ablation chamber and online correlations could be drawn between ^{87}Sr/^{86}Sr values and Zr concentrations, however the RIF laboratory is not set up in such a fashion.

In order to enable *in situ* correction of mass 87 using mass 91 for ^{87}Sr/^{86}Sr analysis, the same machine must monitor both masses simultaneously. Unfortunately, the MC-ICP-MS used for this research was not sensitive enough to measure peaks at masses 90 or 91 without special tuning. It remains theoretically possible that this machine could be effectively used for LA ^{87}Sr/^{86}Sr analysis using a Zr offset correction; however the special tuning would render the procedure impractical and likely interfere with regular operations of the instrument. Thus at present, efforts to correct ^{87}Sr/^{86}Sr data for ^{40}Ca^{31}P^{16}O interference remain most ably demonstrated with the procedures used by Horstwood *et al.* (Horstwood, et al., 2008). Without the same depth of suitable reference materials and sample runs, we can still examine new data, but must approach it with some measure of caution. Taking the LA data for the Cis-Baikal samples and applying several different approaches to correction, we find a significant amount of variability. Applying the correction equation used for the Simonetti *et al.* (2008) directly, but with measured Zr concentrations, we clearly have an overcorrection (Appendix D). There is likely to be a significant divergence of the laser data from the single solution datum as we realize the disconnect between internal variability of a tooth's formation and the homogenizing effects of solution preparation, however are overcorrected by a ^{87}Sr/^{86}Sr ratio of approximately 0.002. A second attempt at using zirconium differences as a correction yield better results, which are well within the realm of uncertainty regarding internal variability relative to the solution data available. We find similar results from a correction drawn directly from strontium concentrations and bypassing zirconium offsets altogether. These later two corrections are difficult to assess without a coupled set of micro-sampled set of solutions. Given the added uncertainty of drawing these data from a different instrument, we were inclined to have greater faith in the strontium corrected laser data in this case. The strontium data are likely to be more similar between the two instruments and thus less prone to measurement errors within the scope of this experiment. These data also highlight a fair amount of internal variability regardless of which correction is used. Of the five teeth sampled, there is an average deviation of 0.000773 for $^{87}Sr/^{86}Sr$ ratios, with some individuals exhibiting significantly more variability than others. This is strongly suggestive of $^{87}Sr/^{86}Sr$ ratios indicative of mobility across geologic zones and/or changes in dietary geochemical interactions of these individuals.

CONCLUSION

Micro-sampling of complex minerals is a delicate balance between micro-sampling methodology, analytical precision and the formation events responsible for the initial complexity. This will be true whether the mineral matrix is organic or inorganic. For skeletal materials, there is greater uncertainty attached to the formation process and the contributing ionic pool of resources used to form the final matrix. Dietary intakes will be averaged within the body, for over a year for elements such as strontium, and the forming mineral structure remains an open chemical system for weeks or months after the formation of the structures visible as Retzius lines. This makes progress difficult to impossible for efforts to generate useful provenance and/or dietary data for individuals at a temporal scale smaller than a tooth as a whole. Evidence from herbivore teeth strongly suggest that lag times can outstrip effective mineralization rates, making intensive micro-sampling an unnecessary effort as the same trend lines can be generated with a fraction of the total analyses involved in intensive micro-sampling. The same may or may not be true for human teeth as they take longer to form and in a smaller volume than herbivore teeth, thus potentially incorporating geochemical information at a temporal scale either within the body residence time of heavy elements or sufficiently long that changes in body averages can become visible using mixing models to interpret such data effectively. The data generated for this research strongly support two conclusions: 1) that trace element analysis can provide a useful contribution to understanding provenance/mobility data for skeletal tissues; and 2) that micro-sampling of human teeth is a worthwhile effort, with laser ablation being a reasonable option with appropriate corrections applied.

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Chapter 4: Micro-sampling of human bones for mobility studies: diagenetic impacts and potentials for elemental and isotopic research[1]

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INTRODUCTION

Sampling and selection of analytical protocols are always important aspects of any geochemical analysis. For geological specimens, these choices often reflect the specific research question being pursued. The situation is rather more involved with complex and organic mineral structures for there are frequent difficulties in accessing the desired target data. In attempts at the analysis of archaeological human skeletal materials, important considerations include selection of an appropriate analytical technique, assessment of the kind and extent of diagenetic alteration of the samples, and the formation process and history of the analyzed skeletal material itself. For skeletal materials, the relationship between the formation process of the physical sample and the chemical interactions occurring during life being reconstructed via analysis can be complicated and open to interpretation.

Strontium (Sr) isotope analysis traditionally has relied on thermal ionization mass spectrometry (TIMS) due to its reliability and analytical precision. The advent of multi-collector inductively-coupled-plasma mass-spectrometry (MC-ICP-MS) as an alternative to TIMS, coupled with either a laser micro-drill or a laser ablation (LA) unit for micro-sampling, greatly expanded the possibilities for archaeometric measurement of Sr isotopes. Both laser micro-drills and laser ablation are far less destructive and enable higher spatial resolution for analysis than traditional TIMS and MC-ICP-MS techniques; however, micro-sampling for solution preparation still requires a significant amount of laboratory preparation whereas laser ablation requires virtually no special handling (Copeland, et al., 2008, Horstwood, et al., 2008, Nowell and Horstwood, 2009, Prohaska, et al., 2002). Although the use of LA for human teeth, bone and high-Sr apatites is relatively well established (Bizarro, et al., 2003, Prohaska, et al., 2002), adoption of the method to measure Sr isotope ratios in phosphate minerals is quite recent (Copeland, et al., 2010, Cucina, et al., 2007, Horstwood, et al., 2008, Horstwood, et al., 2006, Richards, et al., 2008, Simonetti, et al., 2008, Vroon, et al., 2008, Woodhead, et al., 2005).

A significant amount of research has been devoted to the subject of diagenesis of archaeological bone materials, highlighting both the importance and the complexity of the matter. The majority of archaeological bone is likely to be biologically altered to some extent (Jans, et al., 2004). Microbial attack is a significant factor of diagenetic alteration with a growing body of work focusing on the specific causes, processes and effects of this alteration (e.g., Jans, 2008, Jans, et al., 2004, Smith, et al., 2007). Such research has shed light on changes in the porosity, bone mineral (i.e., crystallinity changes), the decreases and ultimate loss of bone collagen and the relationship of many active agents involved in biodeterioration, though it has largely left unanswered questions regarding the potential for utilizing unaltered portions of bone for geochemical research (Jans, 2008, Smith, et al., 2007, Trueman, et al., 2008).

The goal of this study is to examine the applicability of laser ablation as a sample introduction method for MC-ICP-MS on human skeletal materials and its potential for providing useful insights on human mobility. Previous research (Copeland, et al., 2008, Horstwood, et al., 2008, Simonetti, et al., 2008, Woodhead, et al., 2005) has indicated a number of potential problems in gathering accurate Sr isotopic data from calcium phosphate matrices using LA-MC-ICP-MS. In addition to interference from rubidium (^{87}Rb), doubly charged rare earth elements (Paton, et al., 2007), and calcium dimers (Woodhead, et al., 2005), there is the production of a polyatomic species of CaPO that interferes with the ^{87}Sr (Horstwood, et al., 2008, Scharlotta, et al., 2011, Simonetti, et al., 2008, Vroon, et al., 2008). This polyatomic species is apparently unique to the laser ablation technique as it is not apparent with solution mode (SM) MC-ICP-MS.

The problem of CaPO polyatomic interference is limited to certain matrix types. For archaeological teeth, a method to correct for this interference is necessary in order to obtain accurate data from samples with low concentrations of Sr (Scharlotta, et al., 2011); however, for bone samples, there does not appear to be any significant offset in isotopic values resulting from this polyatomic species. Thus, confirmation that this problem is not a factor would ease the pathways of analysis and interpretation. Bones themselves provide enough ambiguity regarding structural formation, reformation, and subsequent alteration to cause concerns about sampling method without additional concerns regarding the use of micro-sampling. A long bone can reflect well over 20 years of an individual's life. Individual osteons generally have a lifespan of no more than 20–25 years and form themselves by cutting through and replacing old bone material (Frost, 1963). However, this does not necessarily translate to a simple age of the bone as equivalent to that of the current osteons; remnants of the old bone are frequently visible in histological analysis. These old portions are also represented in the homogenized powders and solutions of conventional sampling methods. Direct micro-sampling can alleviate this uncertainty by providing a clear link between what is being sampled and the target analytical data.

Previous Sr isotopic research has focused primarily on sedentary agrarian groups (e.g., Bentley and Knipper, 2005, Grupe, et al., 1997, Price, et al., 2002, Price, et al., 2008, Price, et al., 2007, Price, et al., 1994). With such groups, the focus of research is on identifying the local Sr signature so that organisms of nonlocal origin (people and animals) can be recognized. Such an approach is of only limited utility for the study of hunter-gatherers, as many groups utilized large territories and would thus have less localized (i.e., averaged over larger areas) isotopic signatures reflecting their lifetime mobility. This circumstance drives interest in micro-sampling of skeletal materials to access insights into mobile individuals with greater chronological resolution. However, further research is needed to understand better the dynamic interaction between the direct chemical contact of living organisms with the biologically available Sr, the formation of skeletal tissues, and data recovery from these tissues. This study is focused on the data recovery side of this problem, examining the range of variability in Sr isotope ratios and trace element composition found within human femur samples.

HUNTER GATHERER MOBILITY IN CIS-BAIKAL

The Cis-Baikal region of Siberia refers to the area including the western coast of Lake Baikal, the upper sections of the Angara and Lena river drainages, and the Tunka region adjacent to the southwestern tip of Lake Baikal (approximately between 52° and 58° N and 101° and 110° E). The topographic complexity of the rift valley that formed Lake Baikal led to the formation of a large number of micro-habitats, with a variety of seasonally available resources (Galazii, 1993, Weber, 2003, Weber, et al., 2002). The thermal capacity of Lake Baikal itself moderates the local climate immediately along its coastline, resulting in generally milder temperatures during the winter and cooler temperatures during the summer. As a result, the Angara River Valley remains relatively free of snow during the long winter which attracts various species of ungulates looking for forage and less restricted mobility (Formozov, 1964). There is a variety of large and medium-size game found in the region including moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus pygargus*), reindeer (*Rangifer tarandus*), and mountain goat (*Capra sibirica*). Smaller species such as wild boar (*Sus scrofa sibiricus*), hare (*Lepus* sp.), marmot (*Marmota sibirica*), suslik (*Spermophilus citellus*), and waterfowl such as geese are also abundant in many areas around the lake. During the summer, large runs of black grayling (*Thymallus arcticus baicalensis*) are found in the uppermost section of the Angara River near its source at Lake Baikal, and several fish species enter the tributaries of the Angara in large numbers to spawn. The shallow coves and bays in the Little Sea region of Lake Baikal, between Ol'khon Island and the west coast of the lake, also provide excellent opportunities for fishing and during the late winter when the lake is frozen, nerpa, the Lake Baikal seal (*Phoca sibirica*) can be hunted (Bagenal, 1972, Bronte, et al., 1999, Khlobystin, 1963, Khozhova and Izmest'eva, 1998, Levin and Potapov, 1964, Losey, et al., 2008, Weber, 1995, Weber, et al., 1998). Dietary studies of boreal forest populations report the use of mushrooms, berries, and pine nuts as other food resources (Haverkort, et al., 2010, Katzenberg and Weber, 1999, Lam, 1994, Marles, 2000). While there is limited archaeological evidence for plant use during the Baikal's middle Holocene, there is sufficient ethnographic information about the use of plants for food by foragers in similar boreal settings around the world to believe that at Baikal they were used to some extent too (e.g., Kelly, 1983, Marles, 2000, Winterhalder, 1981, 1982).

Within the Cis-Baikal region there are four main geological zones that roughly correspond to archaeological micro-regions (Figure 4-1): 1) the Baikal basin, including the lake itself, the coastal areas as well as the Little Sea area enclosed by Ol'khon Island; 2) the drainage of the upper and middle Angara River bounded by the Eastern Sayan Mountains to the west and the Central Siberian Plateau to the east and extending north towards Bratsk; 3) the upper Lena river basin cutting through the Central Siberian Plateau as the river heads northwards; and 4) the Tunka region covering a sizeable valley running south of the Eastern Sayan Mountains and connecting the southwestern tip of Lake Baikal to Lake Khovsgol in Mongolia. The upper and middle sections of the Angara River flow through Mesozoic and Quaternary deposits, with expected $^{87}Sr/^{86}Sr$ values in the range of 0.705–0.712. The upper Lena watershed and the surrounding Central

Siberian Plateau are dominated by Cambrian and Precambrian limestones, with expected values fairly tightly clustered around 0.709 (Haverkort, et al., 2008, Huh, et al., 1994). Overall values for Lake Baikal water are reported as 0.7085 (Kenison Falkner, et al., 1992). The Baikal basin includes the Primorskii and Baikalskii mountain ranges characterized by relatively high $^{87}Sr/^{86}Sr$ ratios (~0.720–0.735) due to the presence of Archean and Proterozoic granites (Galazii, 1993). Bedrock of similar ages occurs around the southwestern shores of Lake Baikal and drainages adjacent to the Eastern Sayan Mountains; however our preliminary results of environmental sampling of biologically available Sr isotopes in the Cis-Baikal region indicate that these two regions have quite different $^{87}Sr/^{86}Sr$ values. Both Archean and Proterozoic zones (Little Sea and Tunka Region) overlap $^{87}Sr/^{86}Sr$ ranges of neighboring regions (e.g., Angara drainage), while only the Little Sea area exhibits values above 0.720. Further clarifications of the distinction between these two zones of similar geological age will be possible upon completion of the regional sampling project which is in progress.

KHUZHIR-NUGE XIV CEMETERY

The KN XIV cemetery is located on the west coast of the Little Sea micro-region of the Lake Baikal basin, near the southern end of Ol’khon Island and c. 3 km southwest of the mouth of the Sarma River (53°04’58” N, 106°48’21” E). It occupies the southeast-facing slope of a hill rising from a shallow bay (Figure 4-2). With 79 graves and a total of 89 individuals unearthed, KN XIV is the largest Early Bronze Age hunter-gatherer cemetery excavated in the Cis-Baikal region (Weber, et al., 2008, Weber, et al., 2007).

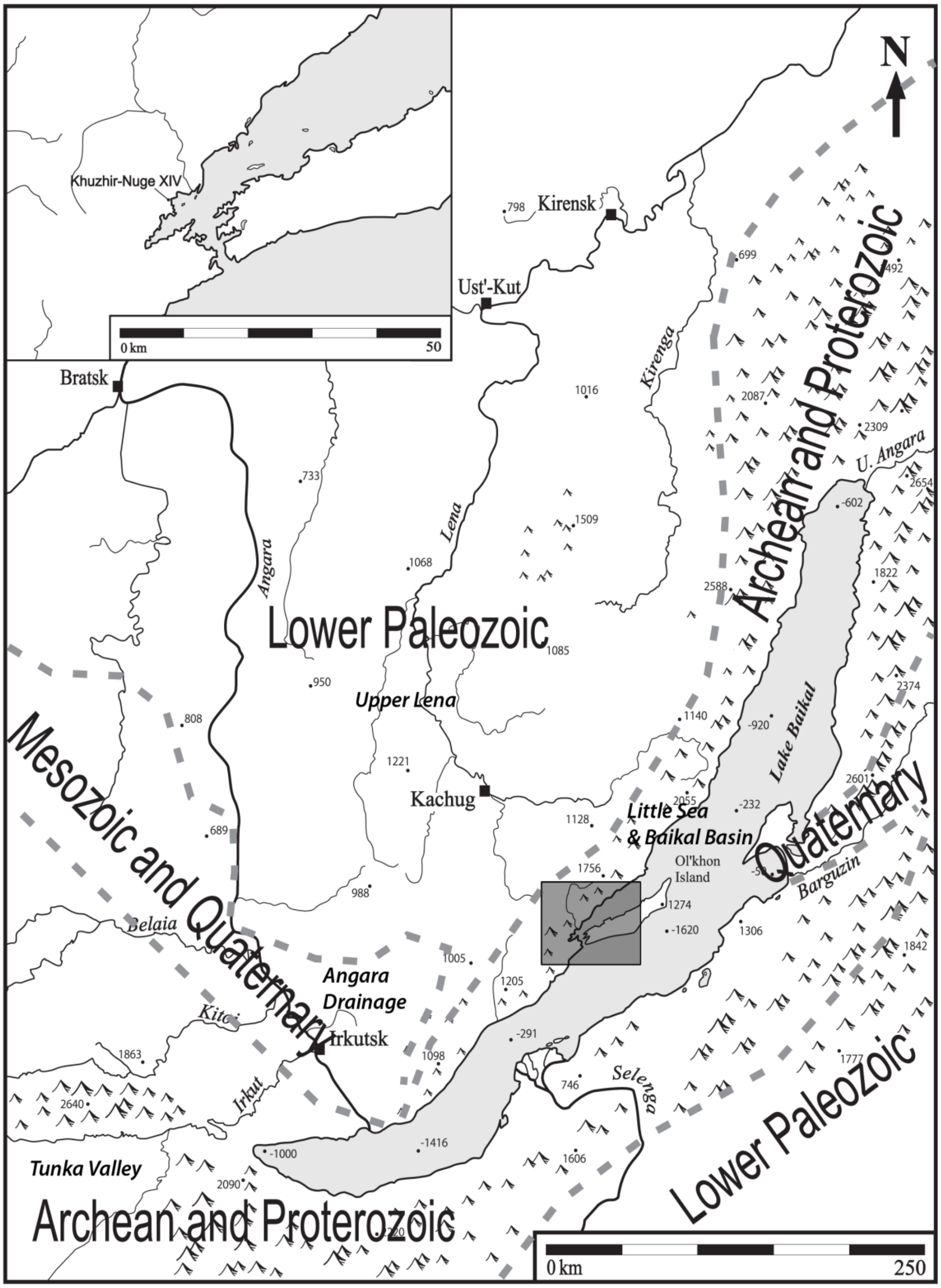

Figure 4-1: Lake Baikal, Siberia showing the location of the KN XIV cemetery, cultural micro regions, and the age of the dominant bedrock formations regions (following Haverkort et al., 2008; Galazii 1993).

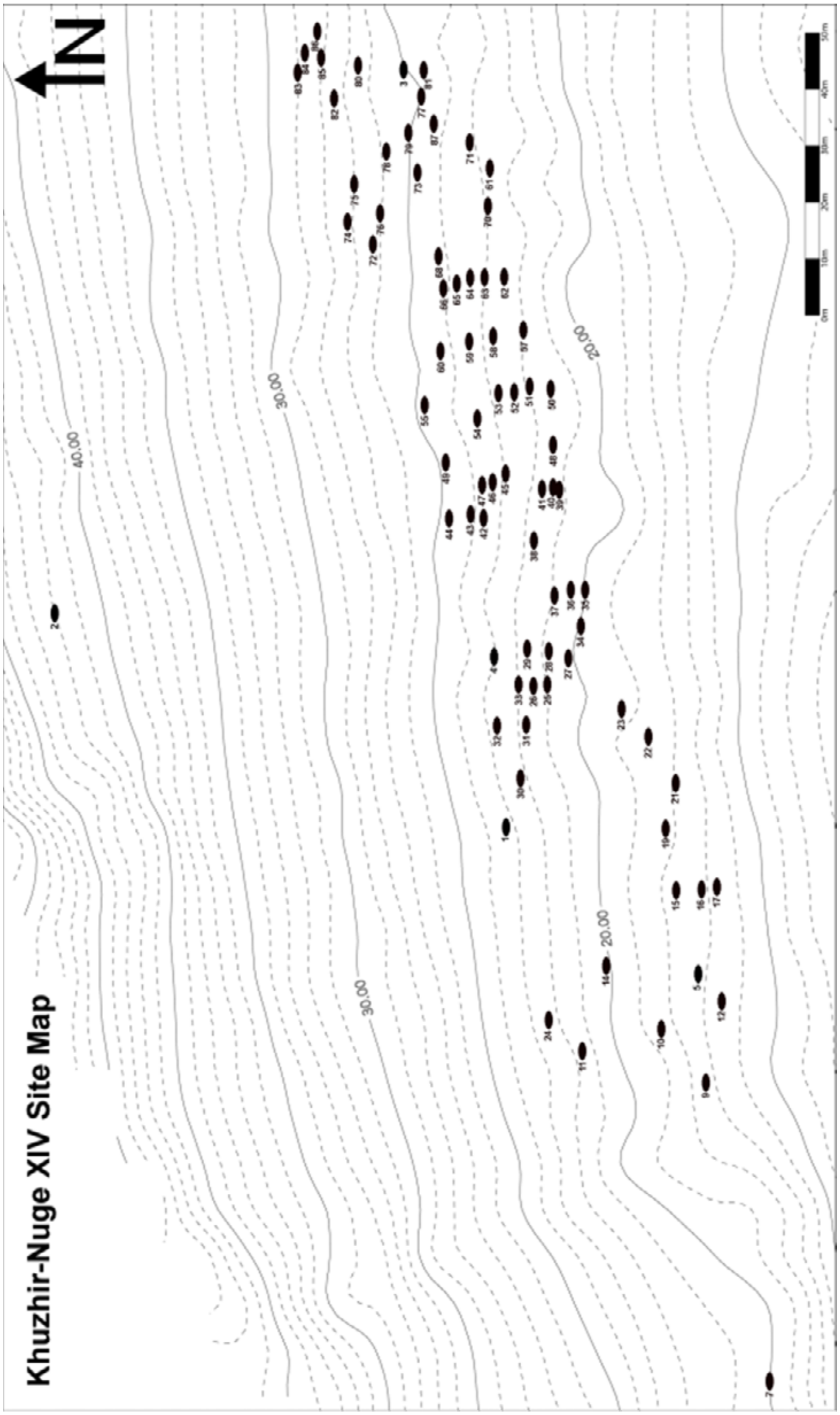

Figure 4-2: Site plan of Khuzhir Nuge XIV cemetery.

All the graves were no more than c. 30–60 cm deep sub-rectangular pits filled with rocks and loamy sand, and covered by surface structures built of stone slabs still visible on the surface prior to archaeological excavation. Most graves contained single inhumations, seven were double, and two were triple interments.The north-south orientation of Grave 7 is consistent with the Late Neolithic Serovo culture of the Ol'khon region, while all the other graves show clear similarities with the mortuary tradition of the Early Bronze Age Glazkovo culture (Goriunova and Mamonova, 1994, Konopatskii, 1982, Weber, et al., 2002). The most diagnostic EBA characteristics include the generally SW–NE orientation of the burials and such grave goods as copper or bronze objects (rings, knives, needles, and bracelets), kaolinite beads, and rings and discs made of white nephrite or calcite (Weber, et al., 2008). Analysis of approximately 80 ^{14}C dates indicates that the KN XIV cemetery was used continuously by EBA peoples for a maximum of 700 years between ~4650 and 3950 cal. BP but the majority of the burials (70%) date to between ~4450 and 4250 cal. BP (Weber, et al., 2005). However, more recent reassessment of the radiocarbon evidence suggests much shorter use of the cemetery, perhaps not exceeding 100 years (Weber, 2011). Since the analysis did not reveal any obvious temporal trends in mortuary attributes, it seems justified to treat the cemetery, with the exception of the much earlier Grave 7, as one analytical unit (McKenzie, 2006, Weber, et al., 2005).

In previous geochemical studies (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003) a sample of 25 individuals from KN XIV were analyzed for Sr isotope ratios and compared with 79 faunal samples collected throughout Lake Baikal and the Cis-Baikal region. The human materials included 20 adult individuals for which three molars (M1, M2 and M3) and a femur sample were available and 5 subadult burials with only M1 and M2 crowns completed. The six femur samples used for the current study came from this pool of previously tested individuals (Table 4-I). The work conducted previously has helped to expand the possible applications of Sr isotope research and to identify an interesting general pattern with several mobility profiles within KN XIV individuals.

Table 4-1: Averaged laser ablation and solution mode ^{87}Sr/^{86}Sr ratios of long bones. Master_ID: cemetery name in abbreviated form, excavation year, grave number, and the individual number when more than one interment was present.

Burial	**Master ID**	**Sample ID**	**Avg. Laser** ^{87}Sr/^{86}Sr	**2σ error**	**Soln.** ^{87}Sr/^{86}Sr	**2σ error2**	**14**C age BP
B.27.1	K14_1998.027.01	1998.304	0.710273	0.0007	0.71037	0.000013	4060 ± 120
B.35-1	K14_1998.035.01	1998.312	0.710882	0.0013	0.71012	0.000019	4030 ± 70
B.35-2	K14_1998.035.02	2003.597	0.710177	0.0018	0.71036	0.000027	3770 ± 140
B.39	K14_1999.039	2003.591	0.710305	0.0012	0.71066	0.000022	3930 ± 180
B.45	K14_1999.045	2003.623	0.710948	0.0013	0.71056	0.000021	4820 ± 90
B.57-2	K14_1999.057.02	1999.175	0.711272	0.0016	0.71096	0.000018	4080 ± 550

There was a significant amount of movement of individuals during their lifetime, whereby people buried at KN XIV were frequently not born in the Little Sea region, but only migrated there as subadults or adults (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber and Goriunova, 2012) also significant variability within the cemetery itself as to the origin of individuals, the time in life of migration to the Little Sea, dietary preferences, mortuary protocols, and spatial organization that is the subject of ongoing research (cf. Weber, 2011, Weber and Goriunova, 2012).

MICROBIAL BIODETERIORATION

Microbial attacks can be either fungal or bacterial in nature, however, fungal and bacterial attacks only rarely co-occur in the same bone (Jans, et al., 2004). Marchiafava et al. (1974) noted that invading fungal hyphae contained mineral in solution, whilst the tunnels they created held no redeposited minerals, suggesting that the dissolved mineral was likely transported out of the bone. Fungal alteration of bones forms tunnels up to 250 μm in diameter, dissolving and removing mineral from the bone, and can cross cement lines without apparent difficulty (Hackett, 1981). Yet, it is unclear whether this is the process of harvesting nutrients directly from the bone or if the fungi are using the bone as a medium while drawing nutrients from another source (Hackett, 1981, Jans, 2008). Cement lines have a high sulphur content and low calcium and phosphorous content, though a high Ca/P ratio, making them different enough in content and structure to inhibit bacterial progression (de Ricqles, et al., 1991, Jackes, et al., 2001, Martin and Burr, 1989). Bacteria appear to produce pores in bone, causing substantial degradation as they spread from blood vessels and fill osteons until they reach a cement line or another area already invaded by bacteria (Bell, 1990, Hackett, 1981, Hedges, 2002). This produces biodeterioration with a complex morphology while mineral is dissolved to expose collagen and redeposited as a hypermineralized rim at the edge of bacterial foci, reorganized rather than removed (Jans, 2008). It is unknown whether the rarity of co-occurrence of fungal and bacterial attacks is due to competition between the organisms, a lack of remaining nutrients after an initial alteration, or if such alteration creates environmental incompatibility for further alteration (e.g., intrusive phosphate minerals such as francolite or brushite deposited by bacteria cannot support fungi as a nutrient source or as a medium) (Child, 1995, Hedges, 2002, Jackes, et al., 2001, Jans, 2008, Jans, et al., 2004, Smith, et al., 2007).

Trace element assay has long been an important aspect of research on diagenesis in archaeological bone (e.g., Gilbert, 1975, Hedges, 2002, Nielsen-Marsh and Hedges, 2000, Pate, et al., 1989, Price, 1989, Radosevich, 1993, Trueman, et al., 2008, Tuross, et al., 1989). Much of the discussion has focused on what are the expected “normal” and "diagenetic" values for human skeletal tissues in a fashion similar to the use of C/N ratios as a measure of data integrity in dietary isotope studies (e.g., Burton, et al., 2003, Grün, et al., 2008, Grupe, 1998, Hedges, 2002, Lappalainen, et al., 1981, Maurer, et al., 2011, Molleson, 1988, Price, et al., 2002, Stojanowski and Knudson, 2011, Tütken, et al., 2008, Vrbic, et al., 1987). Clear relationships remain between the biogeochemical environment of an individual's lifetime and frequently also the diagenetic environment of their burial, however many researchers have written off the potential utility of trace element data as reflecting anthropogenic information (e.g., mobility; see Cucina, et al., 2007, Cucina, et al., 2004, Cucina, et al., 2011, Knudson and Price, 2007) in favor of the use of trace element data strictly for identification and removal of possibly diagenetically altered tissues. Debates over whether trace element compositional data reflects diagenetic or anthropogenic information have quieted in recent years as improved laboratory techniques (e.g., Garvie-Lok, et al., 2004, Koch, et al., 1997, Nielsen-Marsh and Hedges, 2000, Pate, et al., 1989) have enabled researchers to understand the nature of chemical changes and remove any mineral structures resulting from diagenetic alterations. Two caveats, however, remain to be addressed: first, sample pretreatments may not remove all diagenetic alterations and/or overcorrect for hypothesized alterations and thus bias the resultant data; and second, such approaches operate on the assumption that sample homogenization is an appropriate means to obtain anthropogenic geochemical information. One possible approach to alleviate both of these problems is to micro-sample bone structure, thus avoiding bone structures that exhibit bio-deterioration.

MATERIALS AND METHODS

As mentioned, femur samples included in this study represent six individuals from the KN XIV cemetery all of which previously have been examined (Table 4-1)

(Haverkort, et al., 2008). Femur samples were mounted in epoxy, thin-sectioned, mounted on slides and ground to a thickness of ~100μm to enable observation of internal structures. All samples were analyzed for elemental composition using LA-ICP-MS and for $^{87}Sr/^{86}Sr$ ratios using LA-MC-ICP-MS. All sample preparation and analyses were conducted at the Radiogenic Isotope Facility of the Department of Earth and Atmospheric Sciences at the University of Alberta, Edmonton.

Laser ablation for the elemental analysis was conducted using the Perken Elmer Elan6000 quadrupole ICP-MS coupled to a UP213 nm laser ablation system (New Wave Research, USA). The instrument was optimized using the NIST SRM 612 international glass standard reference material (RF power 1200 W, peak hopping acquisition, 50 ms dwell time). Individual osteons were sampled in a serial fashion using a 6μm beam, with a repetition rate of 20 Hz and an energy density of ~13 J cm^{-2}, beginning at the Haversian canal and progressing outwards towards the cement line to examine the nature and extent of useful intra-osteon geochemical variability (Figure 4-3). Osteons appearing intact and those showing variable levels of alteration were both sampled in this manner to observe the compositional changes associated with microbial deterioration. During bone remodeling, osteoid will be deposited at a rate of approximately 0.3–1.0μm per day (Frost, 1963, Parfitt, 1979, 1984). This is followed by a minimum lag time of one week before mineralization will begin. Thus, each laser ablation line could reflect less than a month during the individual's life. This is difficult to gauge precisely given numerous factors that can impact the growth and size of individual osteons (Parfitt, 1979, 1984). It is more likely that a given ablation line will approximate closer to a span of six months to one year within the last ten years of the individual's life.

Experiments were conducted in a mixed He/Ar atmosphere (ratio of 0.5:0.1 L min^{-1}) within the ablation cell, and mixed with Ar (1.03 L min^{-1}) prior to entering the torch assembly. The laser ablation cell was flushed with a higher flow rate of He (up to 0.9 L min^{-1}) for approximately 1 min. between laser ablation runs to ensure adequate particle washout. The NIST SRM 612 glass standard was used as the external calibration standard. Quantitative results for 58 elements (Li, Be, B, Na, Al, Si, P, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Co, Cu, Zn, Ga, Ge, As, Rb, Sr, Y, ^{90}Zr, ^{91}Zr, Nb, Mo, Ag, Cd, In, Sn, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Re, Au, Tl, Pb, Bi, Th, and U) were obtained and normalized to ^{24}Mg, as measured by solution analysis, as the internal standard using the GLITTER® (XP version, Macquarie University) laser ablation software (Appendix E). Mg was used instead of Ca in order to assess variability in calcium in these samples.

Laser ablation for isotopic analysis was conducted using a UP213 nm laser system coupled to the Nu Plasma HR MC-ICP-MS with the sample-out line from the desolvating nebulizing introduction system (DSN-100 from Nu Instruments) to allow for simultaneous aspiration of a 2% HNO_3 solution. At the beginning of each analytical session, parameters for the introduction system and the ion optics were optimized by aspirating a 100 ppb solution of the NIST SRM 987 Sr isotope standard. Experimentation with the laser size and power quickly highlighted a problem with a replication of the analyses conducted for elemental composition. Similar spot sizes were unable to yield high enough Sr signals to gain useable ^{87}Sr/^{86}Sr ratios. In order to determine the minimum spot size that could be effectively used on these bone samples, a size range experiment was conducted on Durango Apatite.

The results of this showed that a spot size as small as 60 µm, yielding signal strengths of 1–1.5V on ^{88}Sr, (100% laser power; 20 Hz repetition rate; ~15 J cm^{-2} energy density) could be effectively used; however, more reliable signals (3+ V) were gained

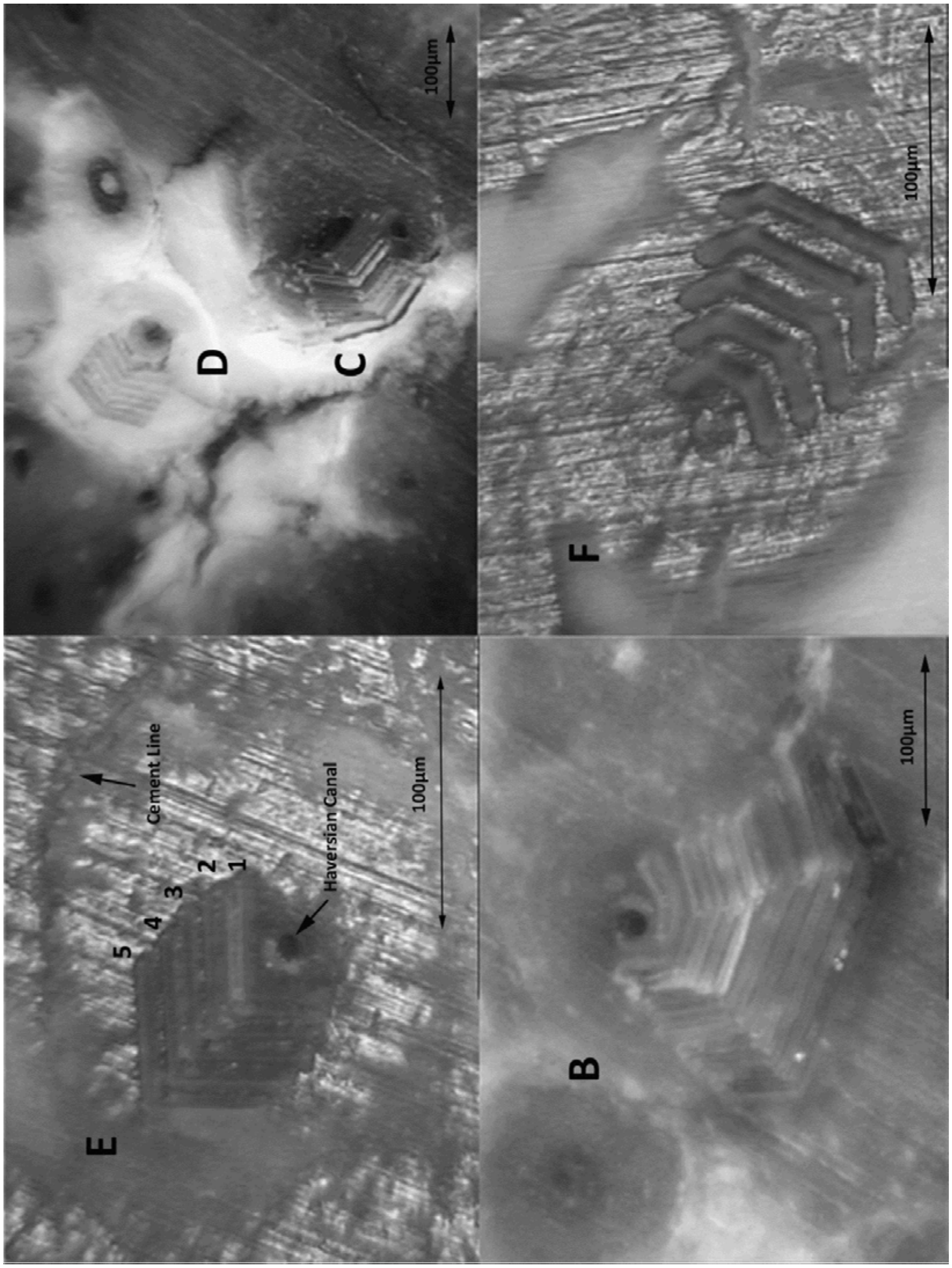

Figure 4-3: Laser ablation scars from analysis. Biodeterioration appears to progress from cracks and hypermineralized areas as has been noted in SEM studies (e.g., Bell 1990; Jackes et al. 2001). Letters denote osteon and data series. Scale = 100µm.

from analyses using sizes greater than 100µm. Sr levels are lower in most human samples than in Durango Apatite, so stable signals as low as 0.5V were accepted.

Analyses with questionable signals were repeated to ensure stability. Not all osteons are large enough to be able to hold a 100+ µm laser beam, so the majority of analyses were conducted using an 80 µm beam, with 100 µm being used on select large osteons. This large beam size limits temporal assessment within the bone to the age of a given osteon, thus the last several years of life of the individual. For each sample, nine intact osteons were analyzed along with five osteons that were suspected to have been impacted by diagenetic processes in order to assess the direction of and potential extent of diagenetic alteration of intact osteons (Appendix F).

RESULTS AND DISCUSSION

Elemental Composition

A number of conclusions can be drawn from the elemental and isotopic results. Areas of bone visually assessed as deteriorated or altered showed marked changes in trace element and isotopic profiles. That obvious signs of deterioration are coupled with skewed chemical data is less surprising than the observation of this progress. It appears that chemical changes precede the visual changes and that the chemical data are a better indicator of the bone mineral integrity as well as of the nature and extent of diagenetic alteration already in progress in any given sample. Foremost, the femur samples appear to suffer primarily from bacterial attack as opposed to fungal attack. Biodeteriorated regions are visible and show the characteristics described for bacterial attack in the literature such as mineral redistribution and redeposited phosphate with significantly lower Ca levels (e.g., Jackes, et al., 2001, Jans, 2008, Jans, et al., 2004). Also note that analyses begin at the Haversian canal with lower Ca values and that where the laser

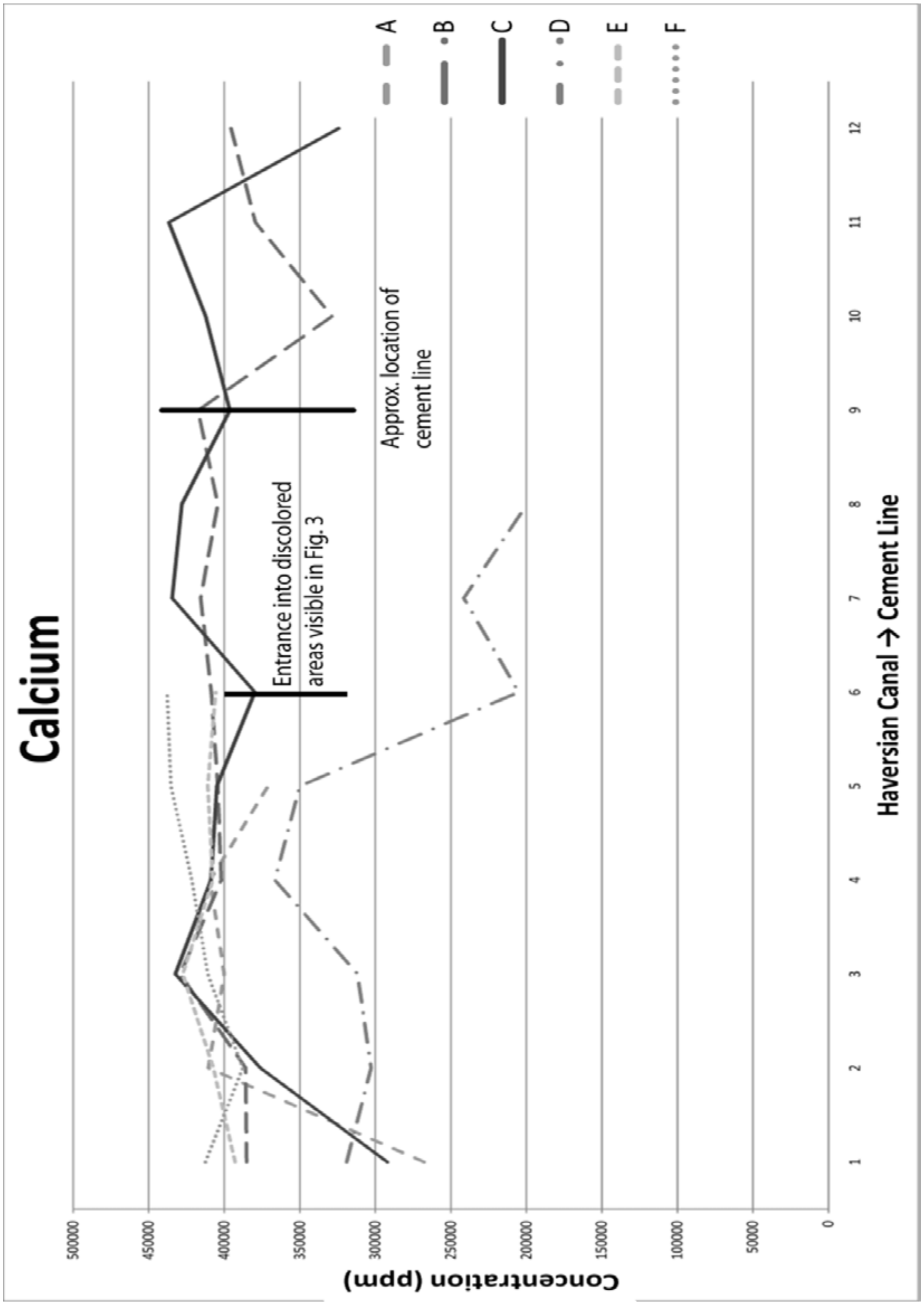

Figure 4-4: Calcium distribution (in ppm. concentrations) of six osteons of 2003.623 (K14_1999.045) beginning at the Haversian canal and ending at or past the cement line. Shorter series came close to, but did not cross the cement line at their ends. Longer series crossed the cement line approximately where noted.

approaches or crosses the cement line, Ca values spike down. Data series presented correspond with osteons shown in Figure 4-3 and are of six osteons within a single individual sample (Figure 4-4). Although the majority of the osteon appears to be intact, Series C shows where the biodeterioration begins (whitish discoloration in Figure 4-3): an intrusive phosphate mineral is already being formed and the cement line is no longer visible in the compositional data, though the laser's entry into the hypermineralized intrusive phosphate looks very similar. The presence of intrusive material is clearly visible in the Ca content of series D. It is important to be able to identify the type of microbial action and/or other diagenetic processes in a given sample to ensure that appropriate measures are taken prior to interpretation of the results.

Sr values display an interesting pattern, being present as a structural component and a trace element (i.e., floating in mineral traps within the matrix). Fully biodeteriorated portions demonstrate a loss of Sr in addition to a redistribution of the remaining portion present in the intrusive phosphates (Figure 4-5). Along with the stable Sr:Ca values (Figure 4-6), this suggests that the form of the intrusive phosphate is more akin to brushite than to francolite (Garvie-Lok, et al., 2004, Prohaska, et al., 2002), though this is difficult to assess conclusively (or with more certainty) from a limited sampling area. Prior to complete dissolution, Sr does appear to be resistant to diagenetic effects (cf. Radosevich, 1993). Ba shows an interesting aspect of trace element uptake within the osteon (Figure 4-7). Ba can act as a mineral replacement for Ca or Sr, yet those points closest to the Haversian canal suggest diagenetic Ba values (e.g., Burial 45) and that trace elements were not secured into the mineral matrix at the time of death and that the Ba of the most recently deposited bone matrix remained soluble upon burial. Other nonstructural elements (i.e., Fe) show marked redistribution associated with biodeterioration (Figure 4-8).

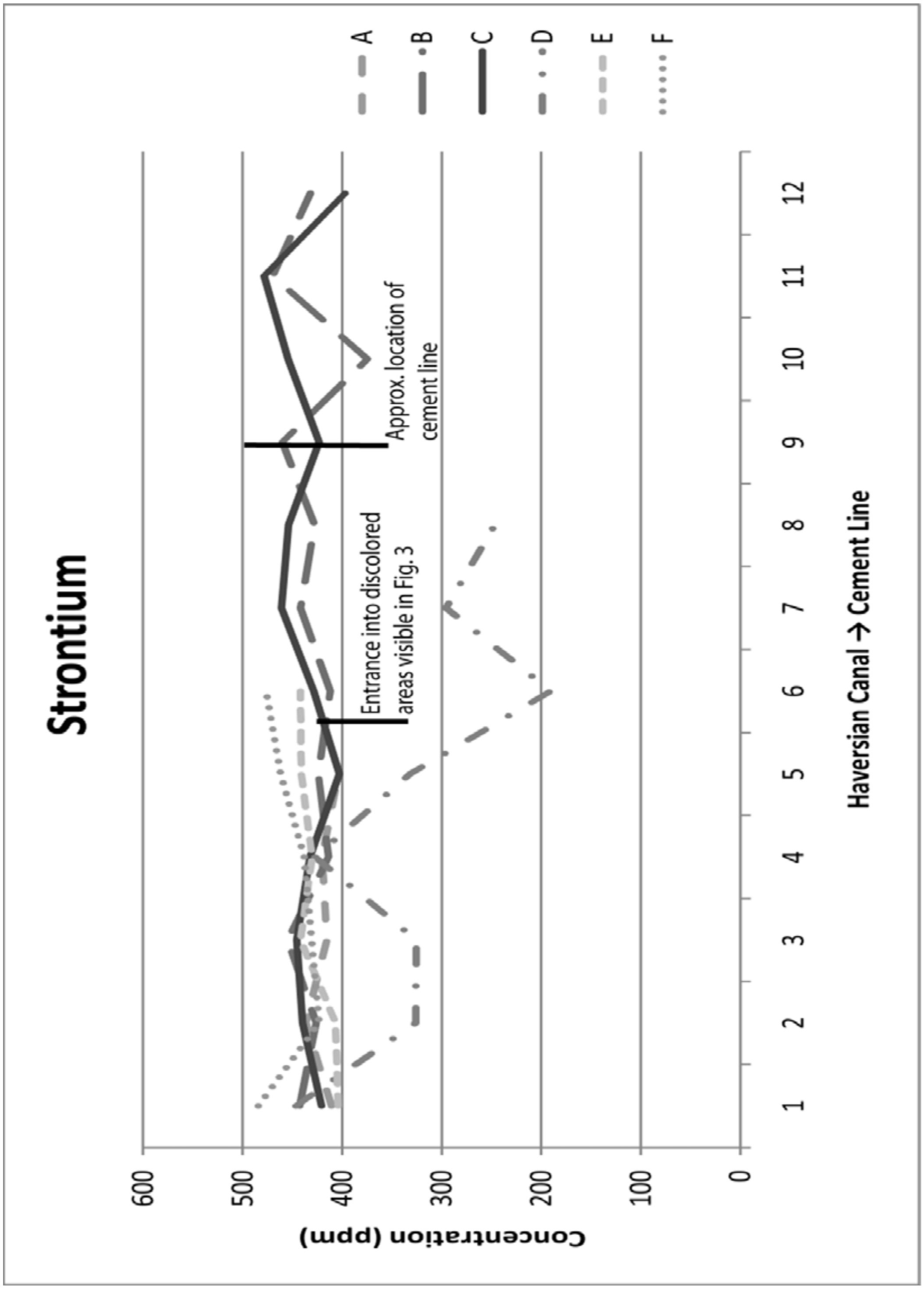

Figure 4-5: Strontium distribution (in ppm. concentrations) of six osteons of 2003.623 (K14_1999.045) beginning at the Haversian canal and ending at or past the cement line.

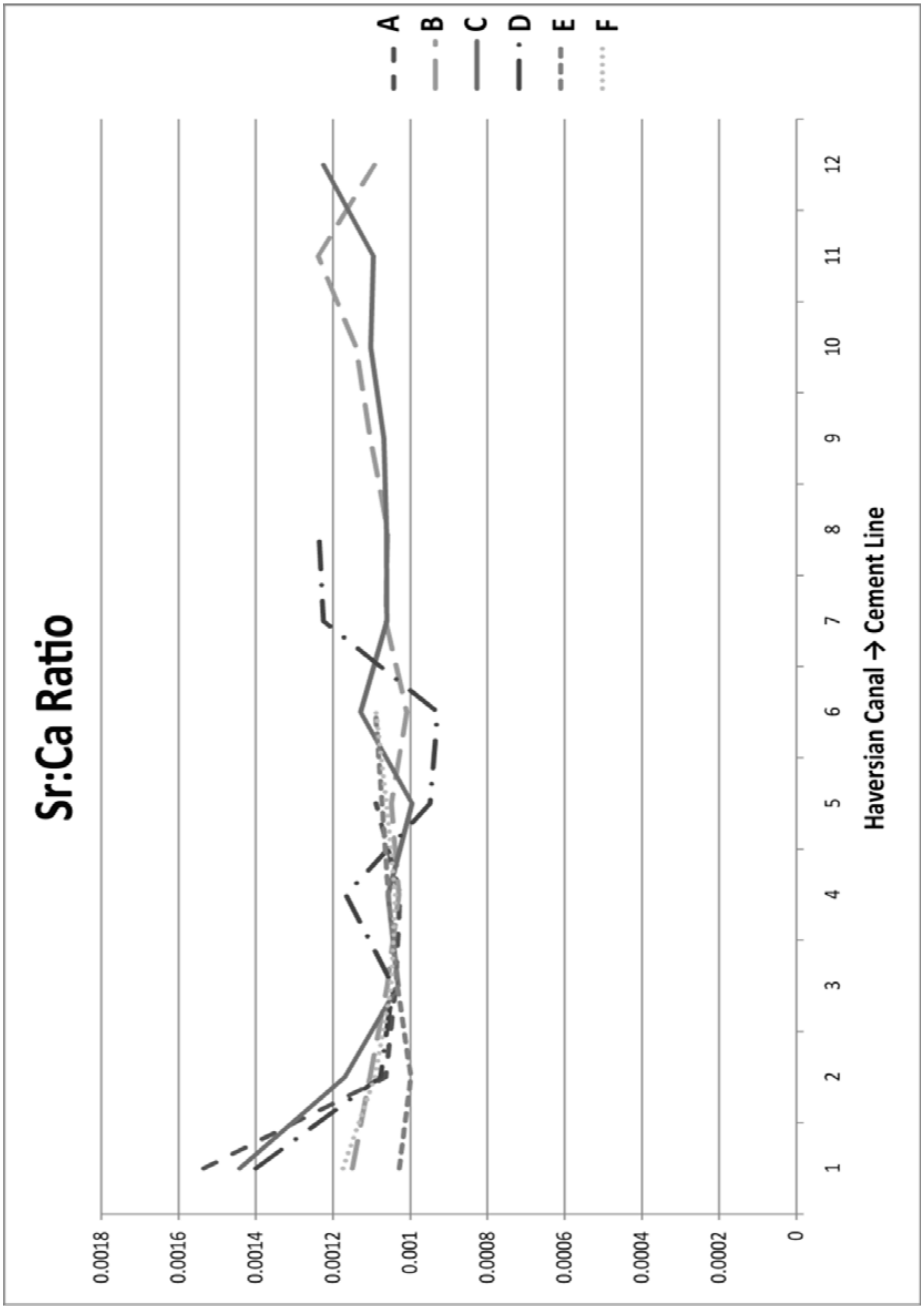

Figure 4-6: Strontium to calcium ratio distribution of six osteons of 2003.623 (K14_1999.045) beginning at the Haversian canal and ending at or past the cement line.

It is difficult to tell whether trace elements were deposited in the bone from the soil or if alteration lowered the Mg values used to calibrate the data. Analysis of trace elements and ^{87}Sr/^{86}Sr on teeth from the six individuals analyzed herein and several other individuals from Khuzhir-Nuge demonstrated a relationship between some trace elements and the mobility data traditionally provided by isotope analysis (Haverkort, et al., 2008, Scharlotta, et al., 2011).

In this population, rhenium (Re) replicated Sr isotope data (Scharlotta, et al., 2011). That similar patterning is seen across multiple osteons of the same individual suggest this to be anthropogenic and not diagenetic alteration. To see such duplication in diagenetic processes in multiple locations, each with unique history of preservation and potential alteration would be highly unlikely. Thus, variability, as well as repeated patterns between osteons, in Re values for Burial 45 suggest that there were at least three major movement events in this individual's life within the Little Sea region; into, out of, and returning to an area with higher Re (circled, Figure 4-9). The preservation of Re signatures is somewhat easier to see in other individuals, with Burials 35-2, 39, and 57-2 also likely showing three, and Burial 35-1 showing two major movement events during their lives. Individual 27-1 does not appear to have moved between geologic zones, or was possibly more contaminated than other samples, and would require further analysis to clarify the matter based on Re data alone.

Another element that showed strong promise for anthropogenic data was cesium (Cs). Individual 27-1 does appear to have made three major movements in his life (Figure 4-10). Based on Cs data, individuals 35-1, and 57-2 appear to have only made two major movements and so likely occupied area with a more even geochemical

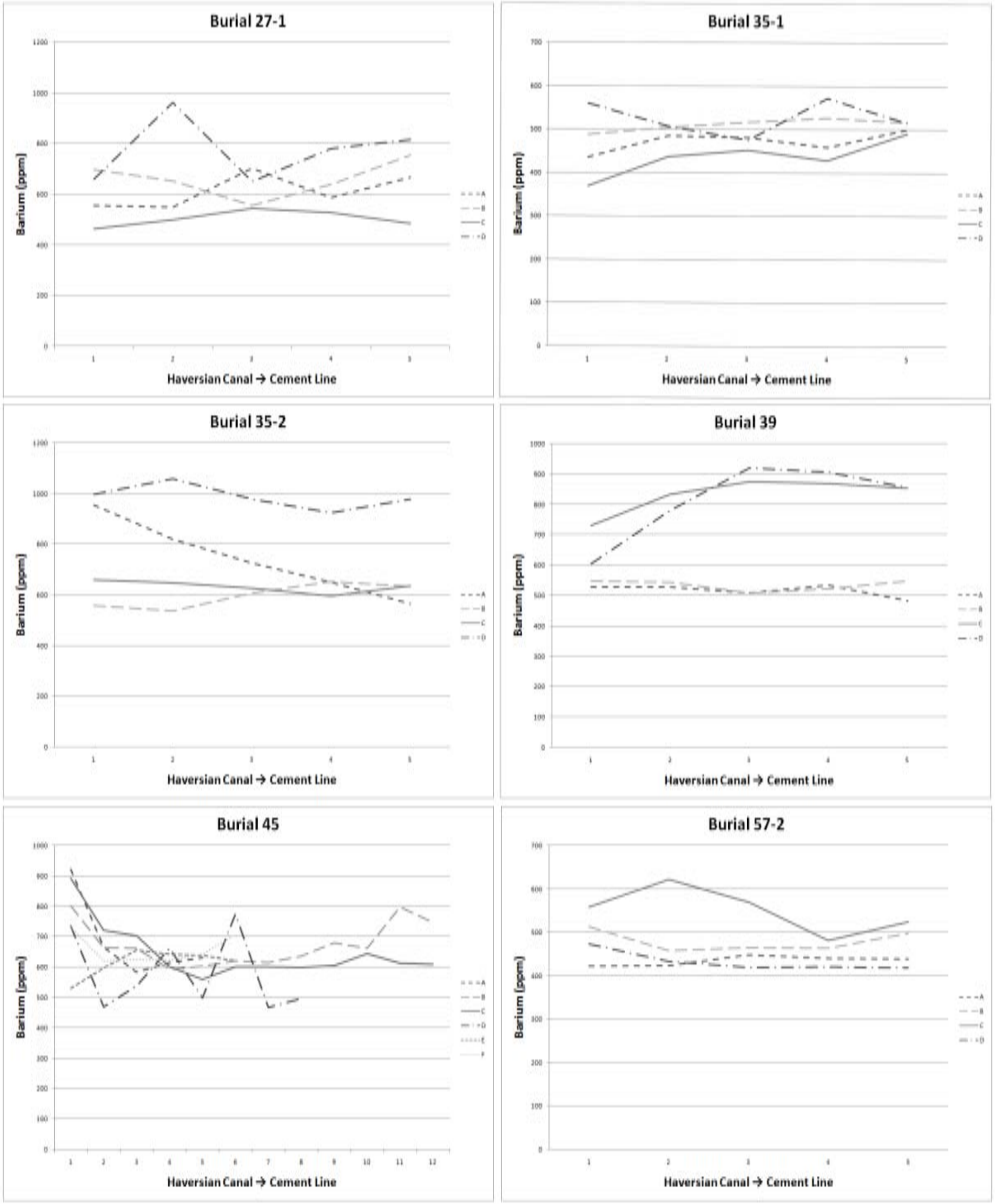

Figure 4-7: Barium distribution (in ppm. concentrations) of all six individuals beginning at the Haversian canal and ending at or past the cement line, each data series (A-F) reflects one osteon

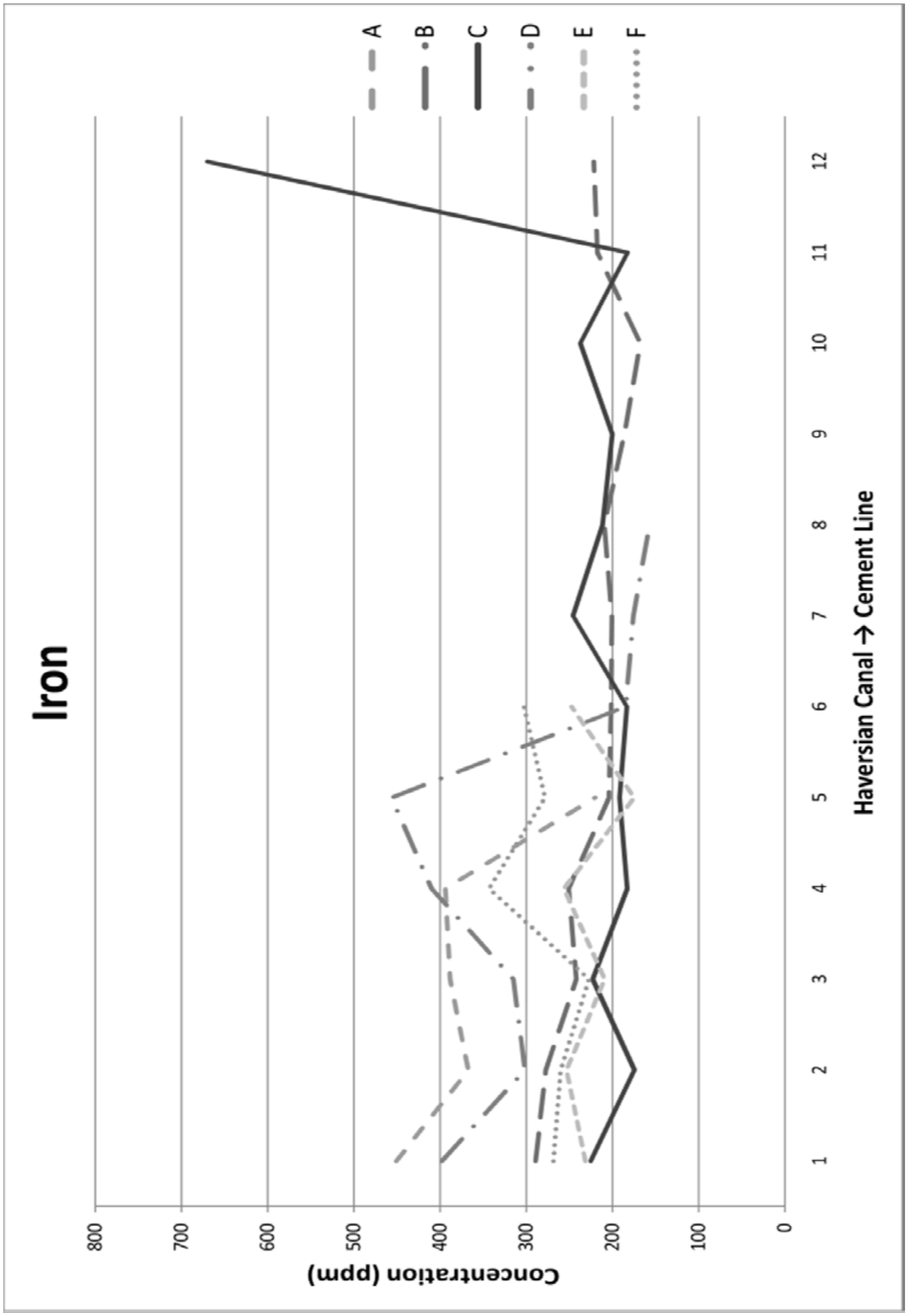

Figure 4-8: Iron distribution (in ppm. concentrations) of six osteons of 2003.623 (K14_1999.045) beginning at the Haversian canal and ending at or past the cement line.

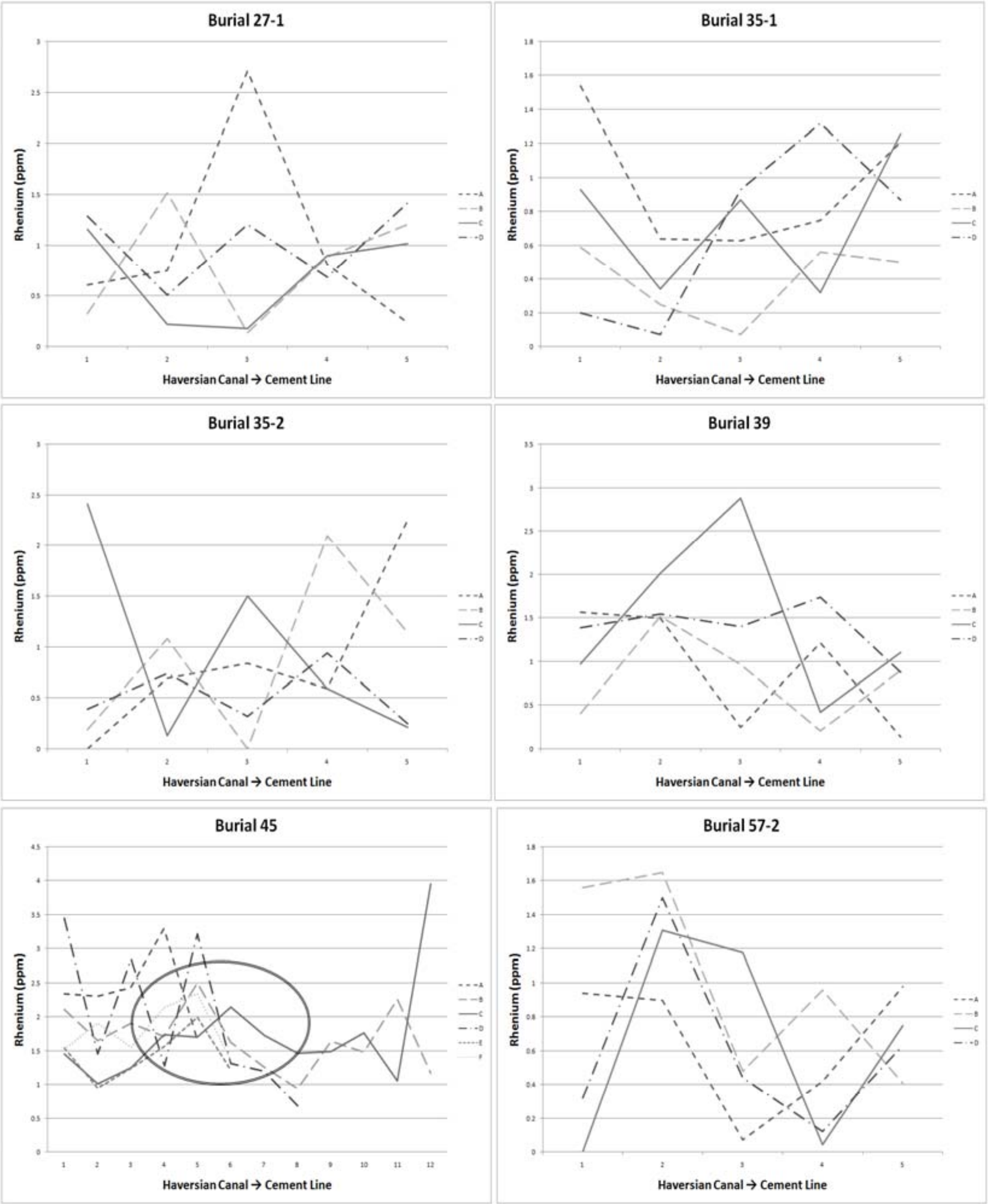

Figure 4-9: Rhenium distribution (in ppm. concentrations) of six individuals beginning at the Haversian canal and ending at or past the cement line, each data series (A-F) reflects one osteon.

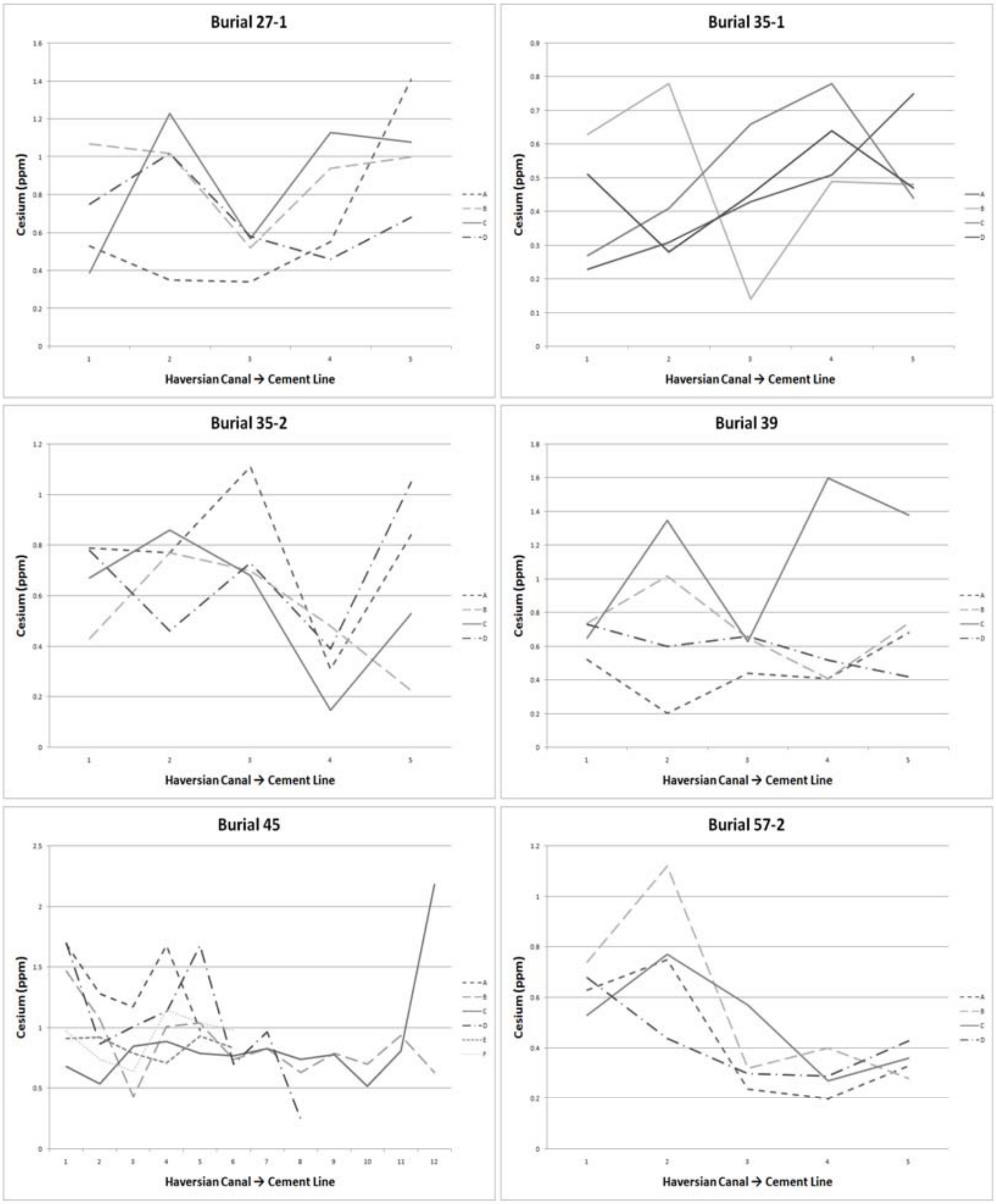

Figure 4-10: Cesium distribution (in ppm. concentrations) of six individuals beginning at the Haversian canal and ending at or past the cement line, each data series (A-F) reflects one osteon.

gradient as opposed to the sharp shifts noted in Re. Individuals 35-2, 39, and 45 still suggest three major movements, though with varying degrees of clarity. Cesium does not precisely replicate Sr isotopic values, but rather suggests greater degrees of mobility within geological areas with similar signatures, thus requiring further mapping for effective discussion of individual provenance.

Elemental compositional data are thus able to provide insight into the nature and extent of diagenetic alteration within samples that may appear visually intact and/or identical in preservation. These data also enable discussion of the role and manifested nature of different elements within primary bone structure and diagenetic mineral counterparts in archaeological bone samples. Finally, and most importantly from the perspective of this study, the elemental results can provide additional information on provenance and mobility of individuals during the later portions of their lives as well as locality and dietary contributions in adult individuals during the years immediately prior to death, both aspects generally extending beyond the accessible record of molar enamel formation. Further work with bone samples of young adults could help to elucidate problems or uncertainties with residence time of difference elements within the body system as a whole and within specific tissues as there would be overlapping records of bone and teeth, accessible in micro-scale.

Microbial Action

One additional point of interest with micro-sampling bones is that with the progression of microbial alterations, based upon observation of slides prepared for this research and locating intact osteons therein, there appears to be strong evidence that the periosteum harbors a disproportionate number of intact osteons in spite of the seemingly more direct contact with the burial environment. Consideration of this matter highlights one important aspect of bones, that they contain water themselves, and that their post-depositional alteration progresses with water contact (Hedges, 2002, Hedges and Millard, 1995). Regardless of the form of diagenesis, there are a limited number of ways in which the various effects can alter the composition of the bone matrix.

Microbial attacks are generally discrete intrusions that may or may not target collagen (Child, 1995a, b, Hedges, 2002, Hedges and Millard, 1995, Jans, 2008, Jans, et al., 2004). Organic diagenesis involves processes by which collagen decays and is lost, though the ability of certain humic substances to penetrate bone and attach to collagen is somewhat worrisome. Diffusion reactions and internal remodeling dictate inorganic diagensis. Newer lamellae are present in all living osteons, and will likely not be fully mineralized, still highly soluble and closest to the cavities that were Haversian canals until the organisms' death. With specific note that the internal bone water is generally sufficient to maintain a closed system that requires the diffusion of ions either in or out; the remaining liquid-phase minerals on free-floating collagen fibrils will dissolve the partially mineralized structures of the young lamellae to create the saturated solution and the base material for any recrystallization (Hedges, 2002).

Caniculi connect all living osteocytes, however the diffusion capabilities, or liquid penetration, through these caniculi will be limited (Wang, et al., 2005). Caniculi generally lead to secluded and fully mineralized bioapatite portions of older lamellae. Saturated or partially saturated solutions will have difficulty in dissolving a largely insoluble mineral crystal through such limited pathways (Sillen, 1989). As such, the liquid penetration of diagenetic solutions will be limited within the complex microstructure of bones and there will be preferential dissolution of decaying mineral structures. Thus, even if in diffusion equilibrium with the external environment, diagenetic ions will have a difficult time reaching the mature mineral structures until microbial attack can break down the matrix and eliminate the collagen fibrils holding everything together (Hedges, 2002, Millard, 2001, Nielsen-Marsh and Hedges, 2000a, Sillen, 1989).

Furthermore, no materials cross the cement lines of osteons even when the systems are alive, thus penetration of the cement line will be difficult even if the protein structure does not grant any buffering effects (Schaffler, et al., 1987). Osteocytes have a limited life span (~25 years), and their mineralized structures are replaced as new osteons cut through the existing bone (Frost, 1963, Maximov and Bloom, 1957). As a result, the interstitial lamellae (bone matrix between the cement lines of living osteons) is mineralized material from dead osteons, thus any remaining matrix is not connected to any active caniculi and will be very hard pressed to be in dissolution contact with bone fluids post-mortem. Given the nature of the post-mortem bone liquid solution, it is unlikely that the ideal balance of ionic raw materials will be present to enable the precipitation of largely insoluble bioapatite mineral crystals rather than the precipitation of more soluble mineral forms, especially in the absence of guidance from nucleation or any of the protein/substance signals that control bone formation and mineralization during life (Hedges, 2002, Millard, 2001, Sillen, 1989).

Finally, proportions of available poorly mineralized bioapatite crystals available for dissolution (i.e. hypercalcified bright lines and laminar bone) will be different for specific bone structures depending on how they are in contact with the bone liquid and depend on the age and species of the organism (Mori, et al., 2007, Mori, et al., 2003). Thus there are number of reasons to believe that there will be significant variability within the bone matrix as it relates to the impact and effects of diagenesis, regardless of the form(s) in operation over any given period of time.

Correction Methods

There is an ongoing debate in archaeology and geochemistry regarding problems with isotopic analysis of Sr in calcium phosphate matrices using laser ablation as an introduction method, for some aspect of the laser ablation sample introduction leads to the formation of a polyatomic species that interferes with mass 87 and thus interpretation of Sr isotope ratios (Horstwood, et al., 2008, Prohaska, et al., 2002, Scharlotta, et al., 2011, Simonetti, et al., 2008, Woodhead, et al., 2005).

Strangely enough, even though there is great similarity in the mineral matrices that form teeth and long bones, there is no evidence for significant alteration of isotopic signals from bones. Looking at the elemental data, there appear to be similar formations of the related polyatomic species at mass 91, though with fairly high error terms and low concentrations all around, yet there is no clear interference as a result. This can be seen in Figure 4-11; for each individual, the average ^{87}Sr/^{86}Sr value for the nine unaltered osteons falls close to that obtained for the same individual using solution-mode analysis. The values for the diagenetically altered osteons are, in contrast, clearly aberrant (Appendix F).

As these samples were recovered from a high-^{87}Sr/^{86}Sr region, it is entirely possible that diagenetic contaminants were not fully removed from samples during solution preparation and purification, thus leaving an elevated result that could mask the presence of interference resulting from laser ablation. This seems unlikely in this particular case as several of the samples' diagenetic portions yielded lower Sr isotope ratios, and only one burial (Burial 35-1) was suspected of having partial alteration on even intact osteons, and thus was likely to be almost completely compromised.

There are a few possible explanations for this, and likely others not considered here. First, the problem may be with the solution data masking the presence of

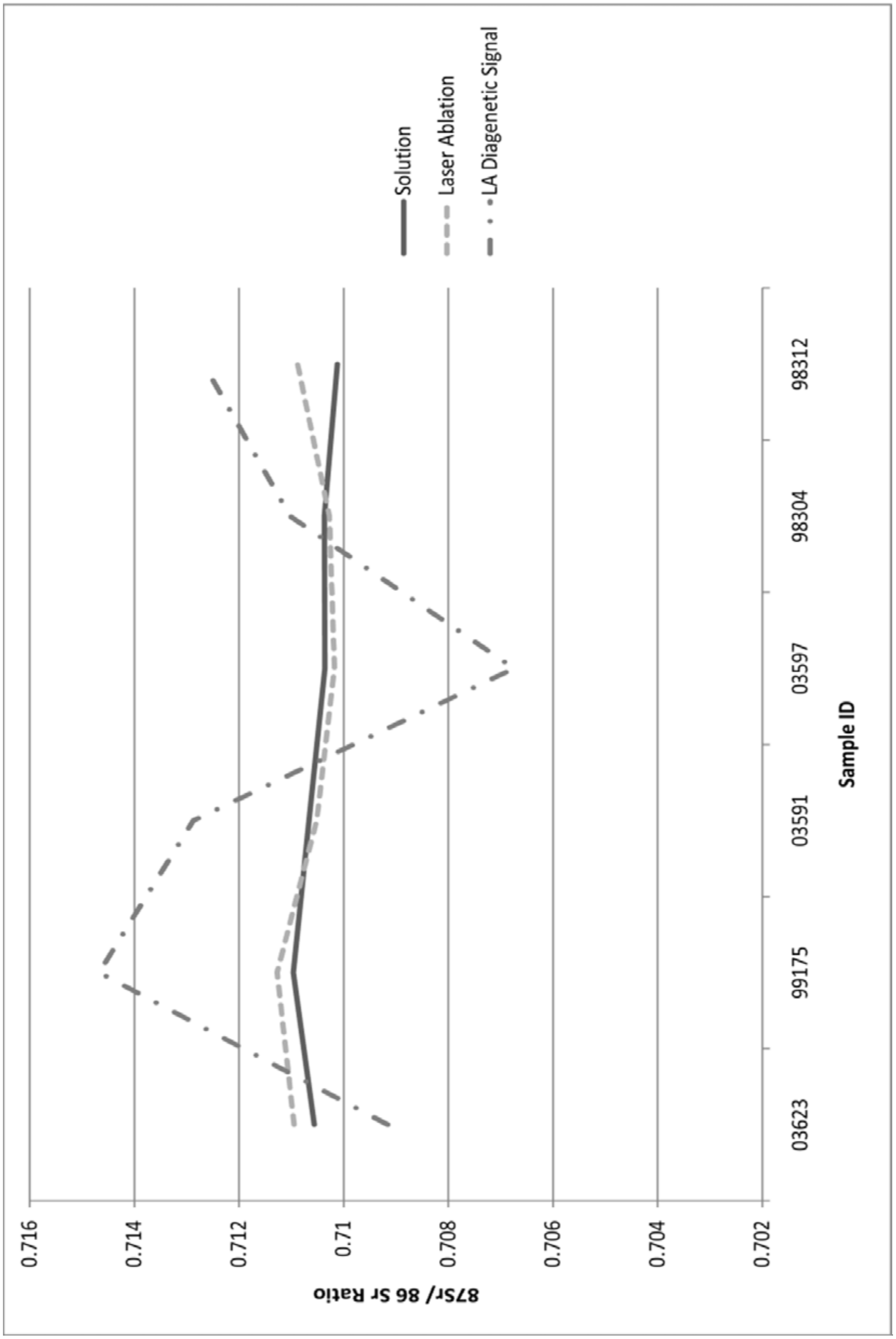

Figure 4-11: Solution mode and laser ablation ^{87}Sr/^{86}Sr ratios compared with diagenetically-impacted portions of bone.

interference in the laser data. Second, perhaps there is enough difference in the structure of the mineral matrices that the laser interaction does not actually create the polyatomic interference noted in tooth analysis and the elemental data are simply the result of large error factors on low concentrations. Third, what is being seen is actually a large coincidence, with a homogenized complex life history coming up with similar numbers as an altered laser averaging.

Solution preparation procedures are intended to remove diagenetic overprinting by eliminating the most soluble portions of the bone structure, namely those that were mobilized in the burial environment rather than life. However, there remains a degree of uncertainty as to what is being removed, what the true target data are (i.e., remaining solids after *n* leaches, or the *n*th leachate) and whether an efficient leaching has been achieved. This difficulty is further confounded by the complexity of bone structure and formation processes. Any long bone is a combination of material from potentially well over 30 years of an individual’s life. The lifespan of any given Haversian system is generally no more than 20–25 years; however, remnant portions of old Haversian systems, not fully removed by the cutting actions of visible osteons, frequently remain visible in histological slides. The true age of these remnants is often uncertain and they could thus contribute intact, diagenetically resistant bone material to the analytical result without much regard as to what its contribution is truly telling us about the individual as we do not have a good fix on the chronology of such portions. This matter is the focus of continued investigation to assess the intriguing source of this confusion.

CONCLUSION

Numerous laboratory procedures and a series of checks have been implemented to assess the quality of a bone sample and counteract or remove the effects of biodeterioration on bone sections or powders (e.g., Garvie-Lok, et al., 2004, Koch, et al., 1997, Nielsen-Marsh and Hedges, 2000). Such methods have proven effective and necessary, given the prevalence of biodeterioration, in accessing bio- and geochemical data obtained from archaeological bone. The downside of these techniques is that they all rely on homogenized sample tissue which makes impossible to identify important movement or dietary events within individual life histories.

While microscopic observations of biodeterioration are not new (e.g., Bell, 1990, Jackes, et al., 2001, Nielsen-Marsh and Hedges, 2000b), our data show that many chemical alterations reported in the literature can be avoided and/or monitored in tandem with chemical analyses of bones. Micro-sampling (i.e., laser ablation, micro-drilling) provides an avenue towards obtaining anthropogenic chemical data and, most importantly, individual life history events. Areas of biodeterioration can be avoided or corrections for specific alterations observed can be applied with greater finesse than bulk sampling approaches and potentially enable further use of archaeological materials that hold detailed data on diet, mobility, and health, all critical aspects of individual life history.

In the Cis-Baikal region, microsampling of individual osteons supports the hypothesis that these hunter-gatherers made numerous major movements during their lives from one area to another. Without more detailed geochemical mapping of the region it is difficult to speculate as to their exact locations during life, it certainly does appear that numerous individuals were moving into and out of the Little Sea region of Lake Baikal. Furthermore, that individuals were undertaking major travel to the Little

Sea either shortly before their death, or were transported to the area post-mortem, suggests a strong cultural importance of either the area, or the Khuzhir-Nuge XIV cemetery in particular.

In terms of general application, the tandem use of Sr isotope and elemental compositional analysis using LA-ICP-MS seems very feasible and effective. At present, the isotopic signatures of whole osteons can be observed and micro-sampling can be conducted using elemental data for further enhancement of provenance determination. Perhaps with future improvements in equipment, a more direct approach may become possible, but with the equipment available today, major progress in the amount and nature of information available from bone samples is already possible.

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Chapter 5: Spatial variability of biologically available ^{87}Sr/^{86}Sr, rare earth and trace elements in the Cis-Baikal region, Siberia: Evidence from modern environmental samples and small Neolithic and Early Bronze Age cemeteries.[1]

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INTRODUCTION

Strontium isotope ratios ($^{87}Sr/^{86}Sr$) of human and animal bones and teeth are a useful technique in determining migration and mobility patterns in past populations. Strontium isotope ratios broadly reflect the underlying bedrock geology, manifested in biologically available portions of the source materials (e.g., soils, plants, water, animals). Taken a step further, the question is whether a technique based roughly on differences between rather large geologic zones can be effective for tracking individual or group mobility on the landscape with resolution finer than evidence for major migrations between geologic zones. Such information would greatly benefit studies of prehistoric mobility, allowing for better informed discussions of where an individual came from and reaching beyond the question of whether they were born, lived and buried in the same locale.

The analysis of $^{87}Sr/^{86}Sr$ isotope systems in skeletal tissues, while rather robust as a technique, is complicated in that the processes by which strontium is transferred from the ground to the diet to the skeleton are susceptible to influence and alteration by subtle changes in diet and localized mobility (Bentley, 2006). These concerns are potentially less significant in the context of agrarian populations, or even pastoral groups which follow relatively fixed annual cycles, than in hunter-gatherers that can potentially experience diverse physical mobility and multiple dietary changes over the period of a single or several years.

In the Cis-Baikal region of Siberia, it has been hypothesized that hunter–gatherer groups formed centers with higher population densities near reliable food resources such as the productive fisheries on the Angara River and the Little Sea areas featuring a combination of cove-and-lagoon and littoral fishes, and the Baikal seal, the latter available pretty much everywhere along the open coast (Weber, et al., 2011). It appears that the mobility of such groups was largely limited to those relatively small areas. Long-distance relocation of individuals took place as well but in a fashion that appeared to be somewhat asymmetrical: some micro-regions attracting more individuals than others. These insights come from examination of $^{87}Sr/^{86}Sr$ values as well as carbon and nitrogen stable isotope signatures in a few large Neolithic and Early Bronze Age (EBA) cemeteries on the coast of Baikal (Khuzhir-Nuge XIV, Kurma XI), in the Angara valley (Lokomotiv and Ust'-Ida), the Shamanka II cemetery on the southern coast of Baikal and several other small cemeteries scattered around entire Baikal region (Weber, et al., 2011).

The current study focuses on mapping the distribution of the biologically available $^{87}Sr/^{86}Sr$ ratios and rare earth and trace element concentrations throughout much of the Cis-Baikal region and on examination of these geochemical tracers in human samples from several of small cemeteries. The skeletal samples examined here represent a few locations from the upper Lena valley, an area not tested previously but implicated as an important contact zone with groups on the coast of Lake Baikal (Little Sea) and to a lesser extent also in the Angara valley (Weber, et al., 2011). It is expected that both the environmental data and the results from small cemeteries will provide useful guidelines for the more comprehensive interpretations facilitated by the large cemeteries.

CIS-BAIKAL RESOURCES

The Cis-Baikal region of Siberia refers to the area including the western coast of Lake Baikal, the upper sections of the Angara and Lena river drainages, and the Tunka region adjacent to the southwestern tip of Lake Baikal (approximately between 52° and 58° N and 101° and 110° E). The topographic complexity of the rift valley that formed Lake Baikal led to the formation of a large number of micro-habitats, with a variety of seasonally available resources (Galazii, 1993, Weber, 2003, Weber, et al., 2002). The thermal capacity of Lake Baikal moderates the local climate immediately along its coastline, resulting in milder temperatures during the winter and cooler temperatures during the summer. As a result, the Angara River Valley remains relatively free of snow during the long winter which attracts various species of ungulates looking for forage and less restricted mobility (Formozov, 1964). There is a variety of large and medium-size game found in the region including moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus pygargus*), reindeer (*Rangifer tarandus*), and mountain goat (*Capra sibirica*). Smaller species such as wild boar (*Sus scrofa sibiricus*), hare (*Lepus* sp.), marmot (*Marmota sibirica*), suslik (*Spermophilus citellus*), and waterfowl are also abundant in many areas around the lake. During the summer, large runs of black grayling (*Thymallus arcticus baicalensis*) are found in the uppermost section of the Angara River near its source at Lake Baikal, and several fish species enter the tributaries of the Angara in large numbers to spawn. The shallow coves and bays in the Little Sea region of Lake Baikal, between Ol'khon Island and the west coast of the lake, also provide excellent fisheries and during the late winter and early spring, the Lake Baikal seal (*Phoca sibirica*) can be hunted on the ice along the open coast of the lake (Levin and Potapov, 1964, Weber, 1995, Weber, et al., 1998). Dietary studies of boreal forest populations report the use of mushrooms, berries, and pine nuts as vegetarian foods (Haverkort, et al., 2010, Katzenberg and Weber, 1999, Lam, 1994, Marles, 2000), however, to date there is very limited archaeological evidence for the use of such foods during the Baikal's middle Holocene.

CIS-BAIKAL GEOLOGY

Within Cis-Baikal there are four main geological zones that roughly correspond to archaeological micro-regions (Figure 5-1): (1) the Baikal basin; (2) the drainage of the

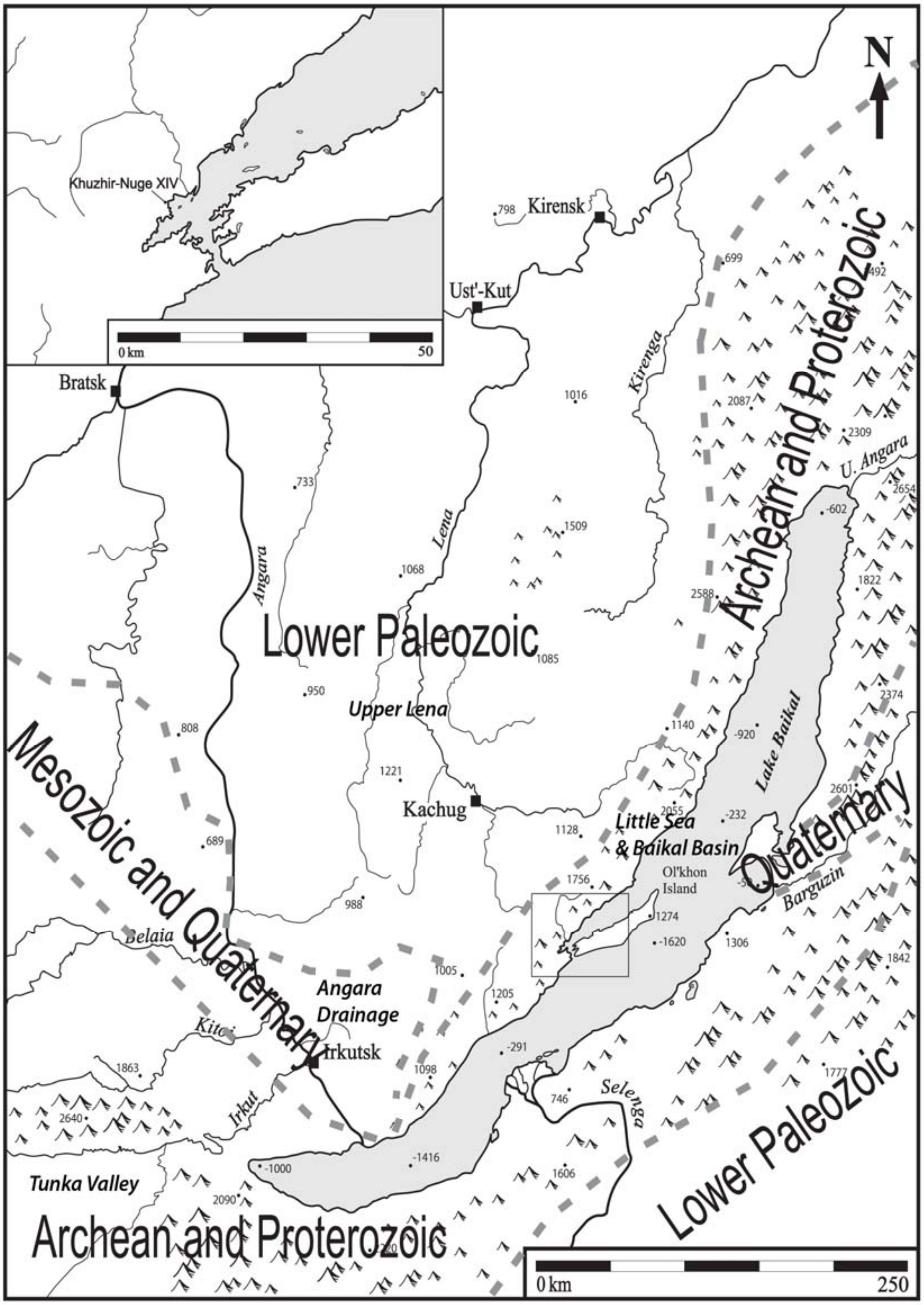

Figure 5-1: Map of the Cis-Baikal, Siberia region, dominant geological formations, and archaeological micro-regions (following Haverkort et al., 2008; Galazii 1993).

upper and middle Angara River; (3) the basin of the upper Lena River; and (4) the Tunka region.

In the Angara drainage, bounded by the Eastern Sayan Mountains to the west and the Central Siberian Plateau to the east and extending north towards Bratsk, the bedrocks are of Archaean–Proterozoic age consisting of granites, metamorphic schists and porphyritic volcanics at a depth of 2.3 km. Covering the basement are Cambrian sediments that consist mainly of dolomites with layers of limestones, rock, anhydrites, clays, sandstones, argillites, gritstones, marls and gypsum. The Cambrian material is covered by 100 m of Jurassic sediments made up of sandstones, siltstones and coal beds. Adding to this variability are the valleys connecting with the Eastern Sayan Mountains (e.g., Irkut, Kitoi and Belaia Rivers) drawing from mixed metamorphic, unmetamorphosed and magmatic complexes of Archaean and Early Proterozoic ages (Donskaya, et al., 2008, Gladkochub, et al., 2006). Various exposures of these bedrocks and Quaternary sediments, primarily clays, are expected to yield $^{87}Sr/^{86}Sr$ values in the range of 0.705–0.712 (Fagel and Boës, 2008, Haverkort, et al., 2008, Shouakar-Stash, et al., 2007).

The Upper Lena watershed, cutting through the Central Siberian Plateau as the river heads northwards, and the surrounding Central Siberian Plateau are underlain by Archaean–Proterozoic basement at around 2.2 km depth overlain by Cambrian and Precambrian sediments. These sediments consist primarily of dolomites interlayered with evaporites of gypsum, anhydrite and halite rocks and beds of limestone and sandstone at different depths and beds of limestone and sandstone (Donskaya, et al., 2008, Gladkochub, et al., 2006). The thickness of the covering sediments and the relative geochemical homogeneity of the plateau yield expected $^{87}Sr/^{86}Sr$ values fairly tightly clustered around 0.709 (Haverkort, et al., 2008, Huh, et al., 1994, Huh, et al., 1998). Values for Lake Baikal water are reported as 0.7085 (Kenison Falkner, et al., 1992).

The Baikal basin includes the lake itself, the coastal areas as well as the Little Sea area enclosed by Ol'khon Island, the Baikal uplift zone, the Primorskii and Baikalskii mountain ranges. This basin is characterized by relatively high ^{87}Sr/^{86}Sr (~0.720–0.735) values due to the presence of Archean and Proterozoic granites (Donskaya, et al., 2008, Galazii, 1993, Gladkochub, et al., 2006).

The Tunka micro-region, covering the middle Irkut River valley running south of the Eastern Sayan Mountains and connecting the southwestern tip of Lake Baikal with Lake Khovsgol in Mongolia, consists of basement rock from the Sayan-Baikal fold belt, also of Archaean and Proterozoic age. The Sharizhalgay uplift zone in the Eastern Sayan Mountains and bordering the Siberian Plateau includes metamorphic and magmatic complexes of similar age (Donskaya, et al., 2008, Gladkochub, et al., 2006). There is a diffuse zone of Cenozoic volcanism to the south and west of the southwest end of Lake Baikal, spanning from the East Sayan and Tuva to the Gobi and Mongolian Altai (Johnson, et al., 2005, Rasskazov, 1994, Rosen, et al., 1994). Furthermore, the area also features an essentially non-volcanic Late Oligocene–Quaternary sedimentary basin composing much of the eastern portion of the valley (Rasskazov, 1994). All this yields a complex range and distribution of expected ^{87}Sr/^{86}Sr values in the Tunka micro-region, likely overlapping both values seen in the Angara drainage and the Baikal basin.

TOOTH MINERALIZATION

Teeth are dynamic mineral structures whose complexities are still being unraveled. It has long been recognized that the incremental *striae of Retzius* represent some aspect of matrix deposition complicated however by the delay between this matrix deposition and the final mineralization of the matrix (e.g., Brown, et al., 1960). With the advent of micro-sampling techniques such as laser ablation and micro-drilling, there has been a resurgence of interest in the formation process of the incremental growth lines and the meaning of the information that can be recovered from these materials (e.g., Hillson, 2002, Horstwood, et al., 2008, Kang, et al., 2004, Prohaska, et al., 2002, Richards, et al., 2008, Scharlotta, et al., 2011). Numerous hypotheses have been forwarded regarding the pattern and progression of enamel mineralization, however the common theme amongst all works is that the progression of mineralization of layers and/or maturation of matrices is patchy and effectively non-linear thus making the chronological relationship between incremental lines and geochemical signals tenuous (Bentley, 2006, Dolphin, et al., 2003, Fincham, et al., 1999, Hillson, 2002, 2005, Kang, et al., 2004, Montgomery and Evans, 2006, Suga, 1982, 1989, Tafforeau, et al., 2007). Nevertheless, the broad trend whereby mineralization begins at the tooth cusp and finishes at the cingulum is still present, though the intermediate pathways are uncertain.

Montgomery and Evans (2006) and Fincham *et al.* (1999) provide comprehensive discussion of the biomineralization of tooth enamel with respect to Sr isotope analysis. The process of mineralization spans a series of five distinct phases wherein an organic gel or protein superstructure is transformed into a mineral matrix: (1) secretion; (2) assembly; (3) matrix formation; (4) resorption prior to maturation; and (5) maturation (see Fincham, et al., 1999 Fig. 8; Bentley 2006 Fig. 18). Effectively, during all stages prior to maturation, the enamel remains an open chemical system vulnerable to alteration, overprinting, or averaging of the mineral matrix. Modern recovery techniques (e.g., laser ablation) can sample volumes of material small enough to be significantly biased by micro-scale heterogeneity in the sample. In spite of difficulties with a disjunction between enamel formation and maturation and potential averaging effects (Avery, 1992, Hillson, 2002), there is still promise to the method of micro-sampling tooth enamel. That the various growth layers in human teeth lines do not mineralize in a similar fashion of linear accretion has been well demonstrated, however, as mentioned, there are a few general principles that remain valid: 1) the crown of a tooth will fully mineralize before the root; and 2) though accomplished in a patchy or wave-like fashion, there is broadly linear trend in mineralization progressing from crown to cingulum.

Ongoing research into this matter using herbivore teeth has demonstrated that there are long-term mixing effects in action during the formation and maturation of tooth enamel (Balasse, 2003, Balasse, et al., 2002, Britton, et al., 2009, Brown, et al., 1960, Hoppe, et al., 1999, Hoppe, et al., 2003, Hoppe, et al., 2004, Koch, et al., 1995, Montgomery, et al., 2010, Tafforeau, et al., 2007). This research has identified a secondary problem, namely the differences of residence time in the body for different elements and compounds. Water-soluble materials have a short residence time in the body of only 14 days; however strontium, calcium, and lead can remain in the body for 800–1600 days, with 10% of traceable doses remaining active after 400 days (Bowen, 1979, Dahl, et al., 2001, Montgomery, et al., 2010). Recent works (e.g., Britton, et al., 2009, Montgomery, et al., 2007, Montgomery, et al., 2010) have demonstrated that this residence time in the body has an intriguing effect on isotopic signatures of a linearly-sampled herbivore tooth. Namely, an abrupt change in geochemical geography and/or diet will not manifest as a sharp transition in isotopic signals, rather there will be a gradual sloping change as contributions from different geochemical end-members vary within the body–water average signal.

LASER ABLATION ON TEETH

Laser ablation studies involving skeletal materials began only recently, in part due to latent concerns about the risk of diagenetic alteration at microscopic scales of analysis. In the last decade or so, ICP-MS tests on teeth and bones have increased (e.g., Bizarro, et al., 2003, Budd, et al., 1998, Copeland, et al., 2008, Copeland, et al., 2010, Cucina, et al., 2007, Horstwood, et al., 2008, Montgomery, et al., 2010, Prohaska, et al., 2002, Richards, et al., 2008, Scharlotta, et al., 2011, Simonetti, et al., 2008, Trotter and

Eggins, 2006). ICP-MS and MC-ICP-MS are generally faster and less labor intensive than traditional analytical methods, however one of the trade-offs is the need for corrections for a variety of interferences. For Sr analysis, the largest, if not most pernicious problems are isobaric interference from ^{87}Rb (rubidium) and a recently identified polyatomic interference from calcium phosphate ($CaPO_4$). Rubidium corrections are necessary for all ICP-MS and MC-ICP-MS analyses as the charged ^{87}Rb will carry the same mass-charge ratio as its ^{87}Sr counterpart, though this can be countered with accurate mass-bias calculations. This is not a problem associated with sample introduction method. On the other hand, polyatomics such as Ca dimers and calcium phosphate species are notably absent in solution-mode analysis as sample ions are held in acid and thus prevented from recombining as they are free to do in the carrier-gas environment of laser ablation chambers.

Woodhead *et al.* (2005), Simonetti *et al.* (2008), Horstwood *et al.* (2008), Vroon *et al.* (2008) and Scharlotta *et al.* (2011) have all discussed the presence of significant interference on mass 87 from a previously unidentified source, thus impinging researchers' ability to assess accurately the ^{87}Sr/^{86}Sr ratios of phosphate matrices with laser ablation. As all mammalian skeletal tissues are varieties of phosphate mineral matrices, this is a major problem in accessing the life signals contained therein. This also affects data analysis and reconstruction of the movement of such animals. At the root of the problem may be the excess of Ca and P present in the charged environment coupling with the oxide production rates within the MC-ICP-MS. In theory, Ca and P levels should be proportional in all parts of skeletal tissues, thus mineral replacements such as Sr and Ba (barium), and the incorporation of other trace elements should be proportional too, and interferences should be related to the oxide operational conditions of the instrument itself. Horstwood *et al.* (2008, 2011) and Scharlotta *et al.* (2011) demonstrated the close relationship between Sr concentration in samples and the resultant error in ^{87}Sr/^{86}Sr ratios and examined the nature of this relationship and the effectiveness of several correction factors to eliminate the adverse effects of polyatomic interferences.

MATERIAL: ENVIRONMENTAL SAMPLES

As noted in many studies (e.g., Beard and Johnson, 2000, Bentley, 2006, Bentley and Knipper, 2005, Ezzo, et al., 1997, Ezzo and Price, 2002, Haverkort, et al., 2008, Hodell, et al., 2004, Price, et al., 2002, Weber, et al., 2003), understanding of human geochemical signatures (from bones or teeth) is best achieved in the context of the biologically available geochemical environment. Regardless of the actual geochemical properties of the rocks and soils, all that scientific analysis will show is the interaction between human consumer and the biologically available geochemical environment. That is, of the water sources as the fundamental vector for both plants' and animals' interactions with their environment, and thus understanding of the water is central to the compositional signatures that will be imparted upon their human consumers.

Modern surface water may not reflect compositional characteristics of the same water source throughout prehistory as erosion factors can alter the geological interaction or contribution to the water's composition through time. Sampling of smaller water courses and geochemical contributions to the larger rivers as well as identifying localized geologic features can help address this matter. Small (e.g., Bugul'deika, Manzurka, etc.) and medium (e.g., Irkut) rivers provide important information for the development of regional distribution maps of geochemical signatures, corresponding to very specific geographical areas as opposed to the averaged total of entire drainages represented by large rivers (e.g., Lena). Therefore, water samples were taken from accessible rivers (i.e., flowing at the time of sampling; Appendix G, Figure 5-2). Only one water sample was collected per each sampling location, with an effort to sample each river at consistent

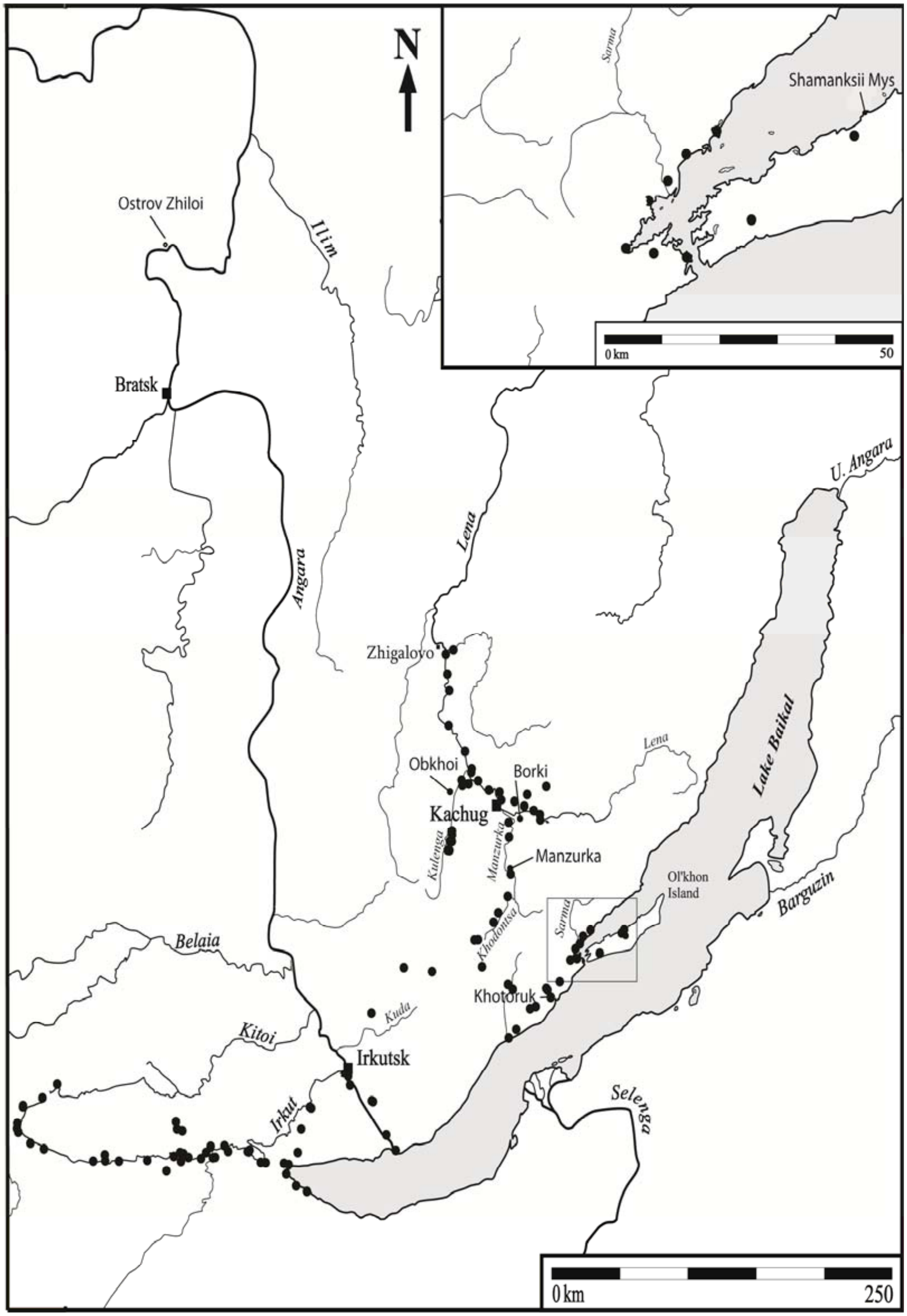

Figure 5-2: Map of the Cis-Baikal region, locations of cemeteries used in this study (named), and sites of environmental (water, plant) sampling.

intervals (c. 50 km). Consequently, the longer the body of water, the more samples collected for analysis. Water while an important interaction vector for all living animals, it does not comprise the primary contribution to geochemical signals imparted on skeletal tissues. Biologically available chemical components are present in far higher concentrations in plants (approximately 10 times higher for elements such as strontium), than in water. As noted, plant foods are likely not great contributors to the human diet here, but do however, comprise the majority or entirety of the diets of animals that humans would have had subsisted on. Animals eat a variety of plants that are inedible to humans and so will have a much broader interactions with the geochemical environment. To track the range of potential inputs into animal's diets, sampling of plants was conducted throughout the archaeological micro-regions of Cis-Baikal. A few plant samples were collected at each location and at intervals of 15 km. Additional plant specimens were frequently collected adjacent to water samples locations. If possible species with different root structures (i.e., depths) were collected in order to assess better the possible range of biologically available interactions in both direct consumable plant matter and in contribution towards local soil production.

Haverkort et al. (2008) noted that the majority of Baikal faunal samples available at the time did not have exact provenience and could only be attributed to regions or micro-regions. Each individual animal will have its own foraging range which may overlap entirely or not at all with the micro-region from which it was recovered. This leaves the potential for disparity between the geographic coordinates of the sampling location (i.e., modern find or archaeological site) and the location of the foraging range (i.e., geochemical interactions with the environment) the animal experienced in life. Archaeological faunal materials have an additional problem in that the animals could have been transported quite long distances from hunting grounds to processing sites. The utility of large, frequently migratory, fauna – modern or archaeological – as source of reference materials is thus compromised by the lack of information about the location of the animal foraging range. For example, a sample of roe deer recovered from the Little Sea may actually come from an animal that spent most of its life on the Upper Lena.

Small animals are the preferred choice for reference samples, at least for studies involving agro-pastoral groups, as they generally have limited and spatially rather fixed foraging ranges that are thus more conducive to the understanding of the distribution of the biologically available geochemical tracers. The problem here is that small fauna usually does not contribute much to the general diet and there is currently no evidence to support their dietary contribution in the case of hunter–gatherer groups examined here. Small fauna is rare at archaeological sites in the area and collection of modern specimens rather impractical (e.g., Novikov, et al., 2007, 2008). Furthermore, the terrain of the Cis-Baikal region is highly variable, much of it not conducive to systematic sampling of small fauna within the time frame available for fieldwork resulting in a reference dataset biased towards a few pockets with more open taiga-steppe terrain and close to the archaeological sites excavated over several years (e.g., Little Sea). These samples are included in the study only for general comparative purposes.

Since plant and water samples have fixed and confirmed provenience and reflect bioavailable geochemistry with greater chronological stability, they provide a more accurate picture of prehistoric bioavailability of geochemical tracers than modern or archaeological fauna can provide. In sum, plants and water are our materials of choice for reference purposes.

Assessment of biologically available $^{87}Sr/^{86}Sr$ and elemental data was conducted using a combination of plant (n = 179) and water (n = 60) samples, and faunal bone and teeth (n = 124) for a total of 363 samples (Figure 5-2, Appendix G**)**. Faunal samples included those used by Haverkort *et al.* **(**2008**)** and 51 new specimens taken from areas not sampled before (e.g., Tunka region). Sampled areas focused on archaeological micro-regions in order to examine the nature and extent of movement both within and between micro-regions.

MATERIALS: HUMAN SAMPLES

As mentioned, the main reason this study focuses on individuals from small cemeteries is that the geochemical research on Baikal materials conducted to date created a geographic and cultural bias toward large cemeteries in the Angara valley (e.g., Lokomotiv and Ust'-Ida) and Little Sea area (e.g., Khuzhir-Nuge XIV). Integration of the new human data with the information already available in the context of the much larger, spatially and quantitatively, set of environmental background values will provide for a more comprehensive and balanced regional framework of reference data with which to assess human movement across entire Baikal region. Six small cemeteries representing three out of four main archaeological micro-regions were available for analysis: Borki 1, Manzurka, and Obkhoi from the upper Lena valley, Ostrov Zhiloi from the Angara valley, and Khotoruk, and Shamanskii Mys from the Little Sea area (Figure 5-2, Table 5-1). No materials were available from the Tunka valley for this study as the only Neolithic–Bronze Age cemetery known to date in proximity to the Tunka valley is Shamanka II, subject of a separate large scale examination.

Table 5-1: General location, cultural, and chronological data for analyzed cemeteries.

Site	Chronology	Region	Individuals	Teeth
Ostrov Zhiloi	Neolithic	Angara	1	1
Khotoruk	Early Neolithic	Little Sea	7	20
Shamanskii Mys	Early Bronze Age	Little Sea	3	8
Borki 1	Early Bronze Age	Upper Lena	1	3
Manzurka	Early Bronze Age	Upper Lena	1	3
Obkhoi	Early Bronze Age	Upper Lena	3	8

Human samples consisted of 43 molars from 16 following individuals: Borki 1 (n = 1), Manzurka (n = 1) and Obkhoi (n = 3) from the upper Lena; Khotoruk (n = 7) and Shamanskii Mys (n = 3) from the Little Sea; and Ostrov Zhiloi (n = 1) from the Angara valley (Figure 5-2). For 11 individual, where possible, each individual was represented by 3 molars (M1, M2, M3), but for 5 individuals, not all molars were available for analysis. Molars grow in specific, well known sequential time spans, covering the range of juvenile growth from infancy to sub-adulthood (Hillson, 2002, 2005). Analysis of all three molar teeth from an individual provides detailed information about their movement during the full course of their childhood. Since each molar reflects several years of growth, every tooth was sampled at four points between the crown and the cingulum. The exact relationship between uptake, deposition and mineralization of tooth enamel is still unclear, however, given the span of time reflected by each tooth, 4 evenly spaced sampling locations should reflect ~6–10 months of temporal separation between final mineralization.

BORKI, MANZURKA, AND OBKHOI (UPPER LENA) AND OSTROV ZHILOI (ANGARA)

The three upper Lena cemeteries were excavated in the 1970s and are known only from the Russian fieldwork reports (Okladnikov, 1971) or a short preliminary publication (Konopatskii, 1977). While Borki and Obkhoi produced only EBA graves, 3 and 12 respectively, 1 Early Neolithic (EN) and 4 Early Bronze Age (EBA) graves were found at Manzurka. All individuals examined here date to the EBA. Although carbon and nitrogen stable rations for some of these individuals are known (Weber, et al., 2002), so far no geochemical tests have been carried out on materials from the upper Lena.

Ostrov Zhiloi, located on the middle Angara and excavated in the 1960–1970s, has been only very briefly described by Vasil’evskii (1978). Three graves were found and classified as Neolithic (i.e., EN or Late Neolithic – LN). Even though hundreds of Neolithic and EBA burials have been excavated in the Angara valley before and after the World War II, most have been lost and only the collections acquired since the 1980s are available for continuous examination. These, however, are strongly biased toward the large cemeteries of Lokomotiv and Ust'-Ida, both located on the upper section of the Angara. Hence the value of the Ostrov Zhiloi single skeleton.

KHOTORUK AND SHAMANKSKII MYS (LITTLE SEA)

Khotoruk is an EN cemetery located near the mouth of the Anga River on the northwest coast of Lake Baikal, about 50 km southwest of Ol'khon Island (Konopatskii, 1982, Mamonova and Sulerzhitskii, 1989, Weber, et al., 2006). Based on morphological properties of some of the grave goods, the cemetery has been dated to the EN which is consistent with the available radiocarbon dates (Mamonova and Sulerzhitskii, 1989, Weber, et al., 2006).

Shamanskii Mys, located on the west coast of Ol'khon Island (Goriunova and Novikov, 2010, Konopatskii, 1982, Okladnikov and Konopatskii, 1974/1975, Weber, et al., 2006), produced 11 graves. Based on the morphological properties of grave accoutrements, one grave was classified as EN, three as LN, and seven as EBA, which is also consistent with the available radiocarbon dates (Weber et al. 2006). Only the EBA individuals are examined in this study.

EN graves are generally very rare in the Little Sea area. Khotoruk is the only such cemetery tested to date outside of the Angara valley (Lokomotiv). The island location of Shamanskii Mys contrasts with the mainland EBA cemeteries in the Little Sea area (KNXIV). Both samples expand temporal and spatial scales of comparison between data sets. Carbon and nitrogen stable isotope results are also available for these materials (Weber et al. 2002).

SAMPLE PREPARATION AND ANALYSIS

Sample pretreatment varied depending on the material analyzed. For water samples, 10 mL was filtered through a 0.2µ fiber filter and evaporated to dryness prior to transport in polypropylene vials, rehydrated with milliQ (MQ) de-ionized water and evaporated to dryness in Teflon beakers under a laminar flow hood. Dried plant leaves or needles were ashed in a muffle furnace for 18 hours at 650º C prior to further processing.

Sample solution preparation occurred in a Class 100 clean room facility and followed procedures outlined in Haverkort et al. (2008) and Scharlotta et al. (2011). Plant, water and faunal samples were analyzed for elemental composition using solution mode-ICP-MS and for $^{87}Sr/^{86}Sr$ ratios using multi collector-ICP-MS. Dried strontium isotopic samples were dissolved with 1 mL of 2% HNO_3 prior to necessary dilution for MC-ICP-MS analysis. Analysis was conducted on a Nu Plasma HR MC-ICP-MS with a DSN-100 nebulizer. Accuracy and reproducibility of the analytical protocol based on long-term repeated analysis of a 100 ppb solution of the NIST SRM 987 strontium isotope standard 0.710242 ± 0.000041.

Elemental samples underwent similar handling, though not loaded onto cation exchange columns. Digested samples were dissolved in 2% HNO_3 prior to ICP-MS analysis. Sample solutions were analyzed for 49 elements (Li, Na, Mg, Al, P, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo, Ag, Cd, Sn, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ta, Au, Tl, Pb, Th, and U) using a Perken Elmer Elan6000 quadrupole ICP-MS. External reproducibility, based on repeated analysis of international whole rock standards is 5–10% (2σ level) for most elements (Supp. Mat. I).

Laser ablation for elemental analysis of human tooth samples was conducted using the Perken Elmer Elan6000 quadrupole ICP-MS coupled to a UP213 nm laser ablation system (New Wave Research, USA). Quantitative results for the same 49 elements analyzed in solution, were obtained and normalized to ^{24}Mg, as the internal standard using the GLITTER® (XP version, Macquarie University) laser ablation software.

Laser ablation for isotopic analysis of human teeth was conducted using a UP213 nm laser system coupled to the Nu Plasma HR MC-ICP-MS with the sample-out line from the desolvating nebulizing introduction system (DSN-100 from Nu Instruments) to allow for simultaneous aspiration of a 2% HNO_3 solution. At the beginning of each analytical session, parameters for the introduction system and the ion optics were optimized by aspirating a 100 ppb solution of the NIST SRM 987 Sr isotope standard. Machine drift was monitored using a Durango Apatite reference material (Supp. Mat. II). All laboratory work was conducted at the Radiogenic Isotope Facility of the Department of Earth and Atmospheric Sciences at the University of Alberta, Edmonton.

STATISTICAL METHODS

A combination of statistical techniques developed specifically for the unique needs of chemical sourcing were employed to analyze the resulting geochemical data, following established approaches described by Baxter (1994a, b), Baxter and Buck (2000), Davis (1986), Glascock (1992), Glascock et al. (1994), Hoard et al. (1992), and Truncer et al. (1998). Analyses of regional variance and means were conducted. Following this, in order to explore the data further and assess to what extent cultural regions could be separated in multivariate space, exploration using bivariate plots, principal components analysis and canonical discriminant analysis were conducted on a combination of ^{87}Sr/^{86}Sr isotopic data and elemental concentration data.

ENVIRONMENTAL RESULTS

Preliminary examination of $^{87}Sr/^{86}Sr$ variability in faunal material associated with archaeological micro-regions by Haverkort et al. (2010, 2008) demonstrated promising results. As the sample size was expanded to include more animal specimens, water and plant samples, the range of $^{87}Sr/^{86}Sr$ variability proved to be quite large (Table 5-2). Analysis of regional variance and means successfully exhibited differences; however the extent of overlap between micro-regions rendered moot effective correlations between geological, geochemical and archaeological areas as previously described. Rather than effectively mimicking bedrock geology with some attenuation for translating bedrock geology to biologically available Sr, there was a confounding overlap in the ranges of $^{87}Sr/^{86}Sr$ values through all micro-regions.

Table 5-2: Range and variance results of micro-regional comparisons for $^{87}Sr/^{86}Sr$ data grouped by sample type.

Descriptive Statistics

All Samples	N	Minimum	Maximum	Mean	Range	Std. Error	Std. Deviation	Variance
Angara	60	.70791	.71680	.7098197	.0088940	.00017288	.00133916	1.79E-06
Little_Sea	103	.70694	.77350	.7174613	.0665570	.00116915	.01186556	1.41E-04
Tunka	121	.70673	.71812	.7101078	.0113880	.00018092	.00194856	3.80E-06
Upper Lena	79	.70814	.71191	.7096936	.0037700	.00010883	.00096731	9.36E-07
Faunal	N	Minimum	Maximum	Mean	Range	Std. Error	Std. Deviation	Variance
Angara	39	.70811	.71680	.7096641	.0086900	.00023565	.00147160	2.17E-06
Little_Sea	54	.70694	.74614	.7151879	.0392030	.00123168	.00905094	8.19E-05
Upper Lena	14	.70849	.71112	.7097906	.0026320	.00022928	.00085790	7.36E-07
Tunka	17	.70881	.71097	.7094852	.0021600	.00018333	.00075589	5.71E-07
Water	N	Minimum	Maximum	Mean	Range	Std. Error	Std. Deviation	Variance
Angara	7	.70791	.71169	.7095367	.0037840	.00043510	.00115115	1.33E-06
Little_Sea	11	.70877	.77350	.7276372	.0647260	.00610954	.02026306	4.11E-04
Tunka	26	.70711	.71373	.7096870	.0066220	.00028721	.00146450	2.14E-06
Upper Lena	16	.70814	.70917	.7085601	.0010230	.00007369	.00029476	8.69E-08
Plants	N	Minimum	Maximum	Mean	Range	Std. Error	Std. Deviation	Variance
Angara	14	.70951	.71220	.7103945	.0026860	.00022765	.00085180	7.26E-07
Little_Sea	38	.70783	.75225	.7177463	.0444220	.00178740	.01101824	1.21E-04
Tunka	81	.70673	.71812	.7103102	.0113880	.00025282	.00220403	4.86E-06
Upper Lena	46	.70875	.71191	.7101648	.0031620	.00012243	.00083037	6.90E-07

Furthermore, even groups of similarly aged geologic formations (i.e., Archean and Proterozoic areas along the western coast of Baikal and Tunka) exhibited different $^{87}Sr/^{86}Sr$ values (Figure 5-1). The clear exception to this overlap is the Little Sea area which featured distinctly higher $^{87}Sr/^{86}Sr$ values making any contact with bioavailable Sr from this micro-region apparent. Previous work indicated a spike in both terrestrial and aquatic $^{87}Sr/^{86}Sr$ values associated specifically with the Sarma drainage adjacent to the KNXIV cemetery; however, this effect appears now to be more widespread through the micro-region (Figures 5-1, 5-3). Figure 5-3 provides a visual approximation of the expected bioavailable isotopic values throughout the major archaeological micro-regions based upon analysis of environmental samples and expanded to dominant topographic features of the landscape. The great variation in strontium isotopic values observed through environmental sampling highlights the important distinction between the dominant geological formations as the source of bioavailable radiogenic materials and the actual bioavailable isotopic values in the environment (cf. Sillen, et al., 1998).

Due to the complexity of the situation, multivariate statistical approaches were employed to enable geochemical group discrimination. Samples collected have varied elemental concentrations on orders of magnitude of difference. Data were converted to ratios relative to internal Mg concentrations in order to make the different sample types comparable. Ratios to all available elements were attempted, but none provided a better marriage of different sample types (water, plants, and human or animal skeletal materials). Faunal materials were excluded from the analysis at this point as the nature of the provenience information, as discussed above, frequently made individual archaeological micro-regional group or arbitrary geochemical sub-group membership uncertain. Remaining environmental comparisons were made on all plant and water samples. Principal component analysis (Figure 5-4) and discriminant function analysis

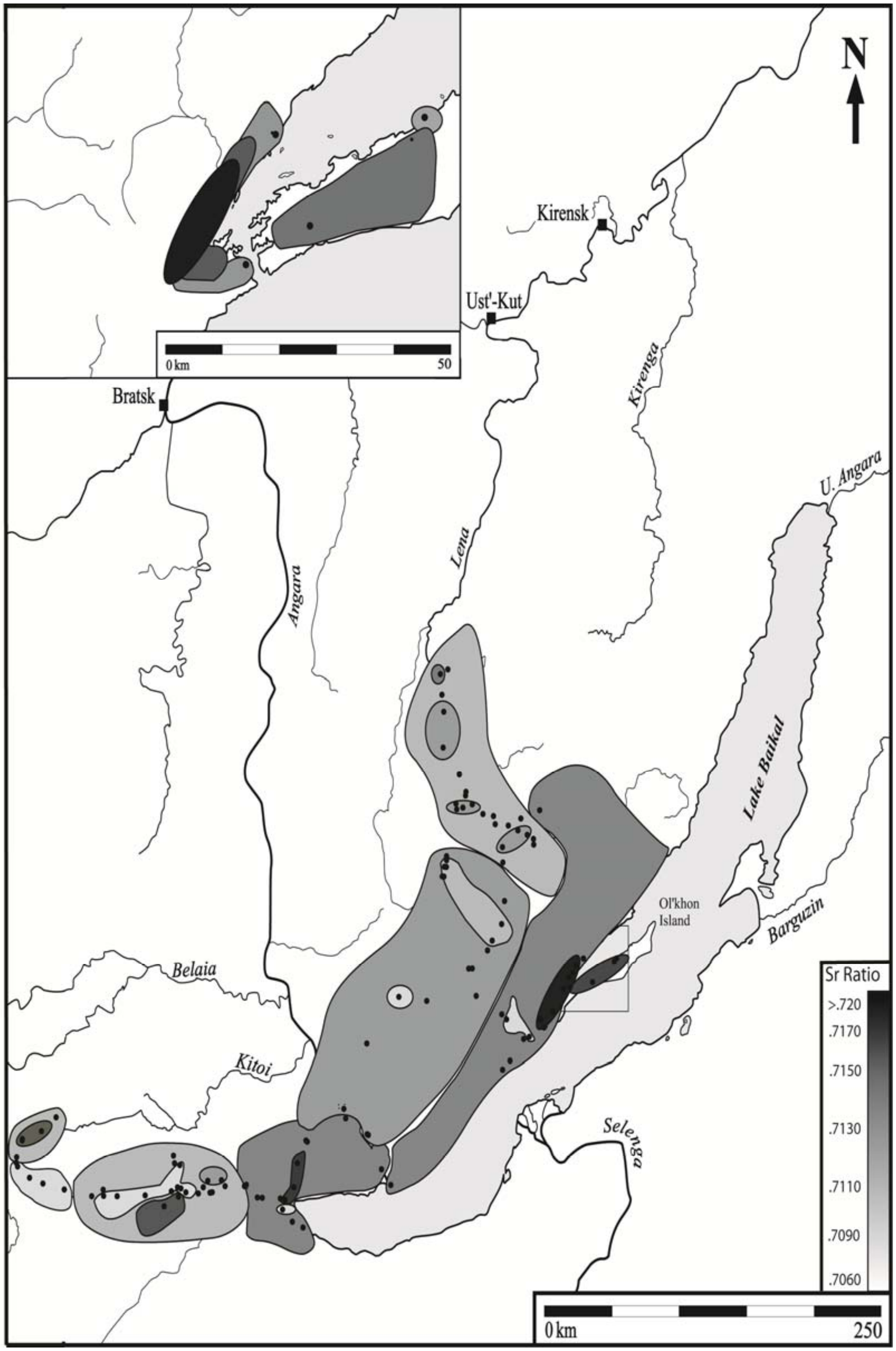

Figure 5-3: Approximate map of expected bioavailable $^{87}Sr/^{86}Sr$ isotopic distributions throughout the Cis-Baikal region based on water and plant sampling, and sites of environmental (water, plant) sampling.

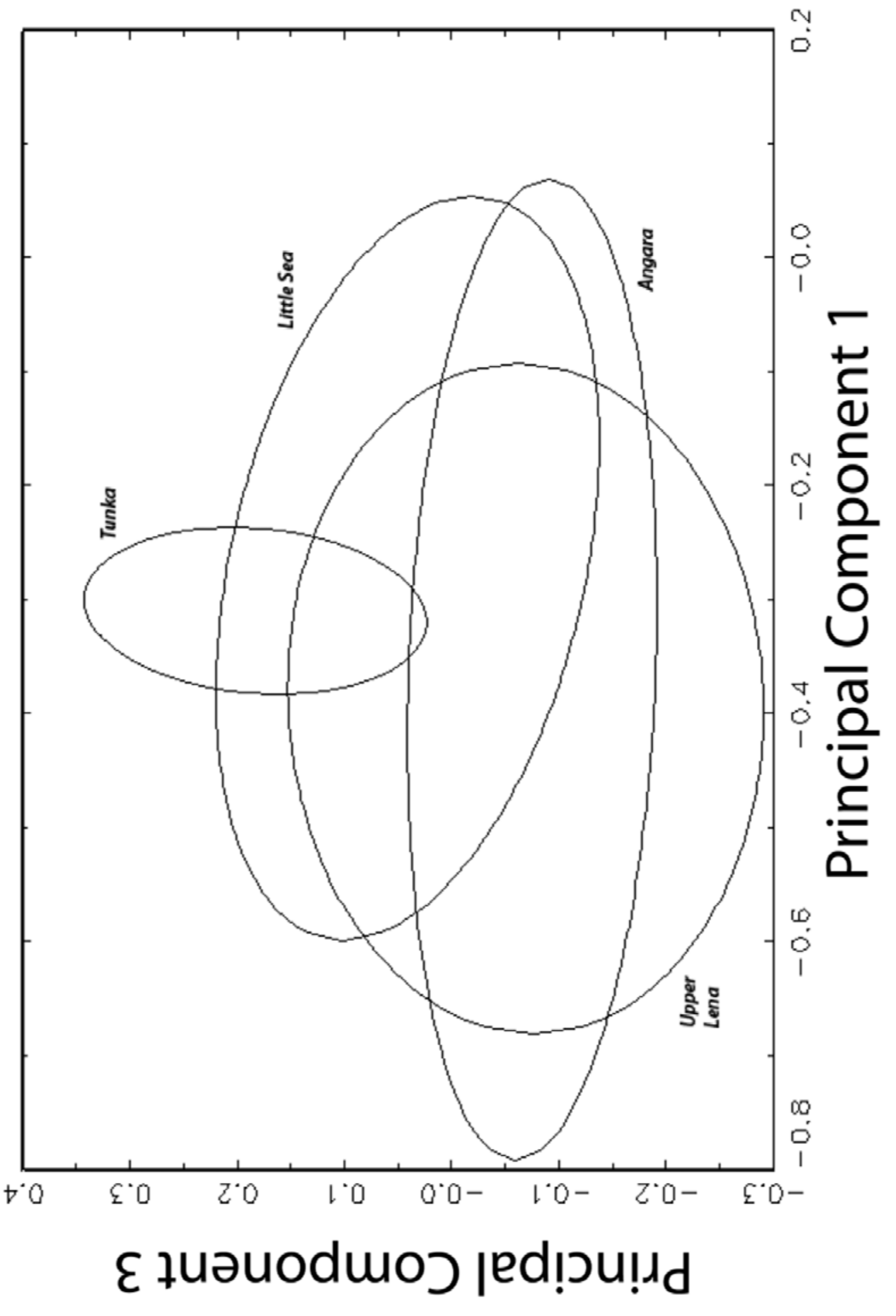

Figure 5-4: Bivariate plot showing the results of Principal Components Analysis employing complete isotopic and trace element data grouped by micro-region.

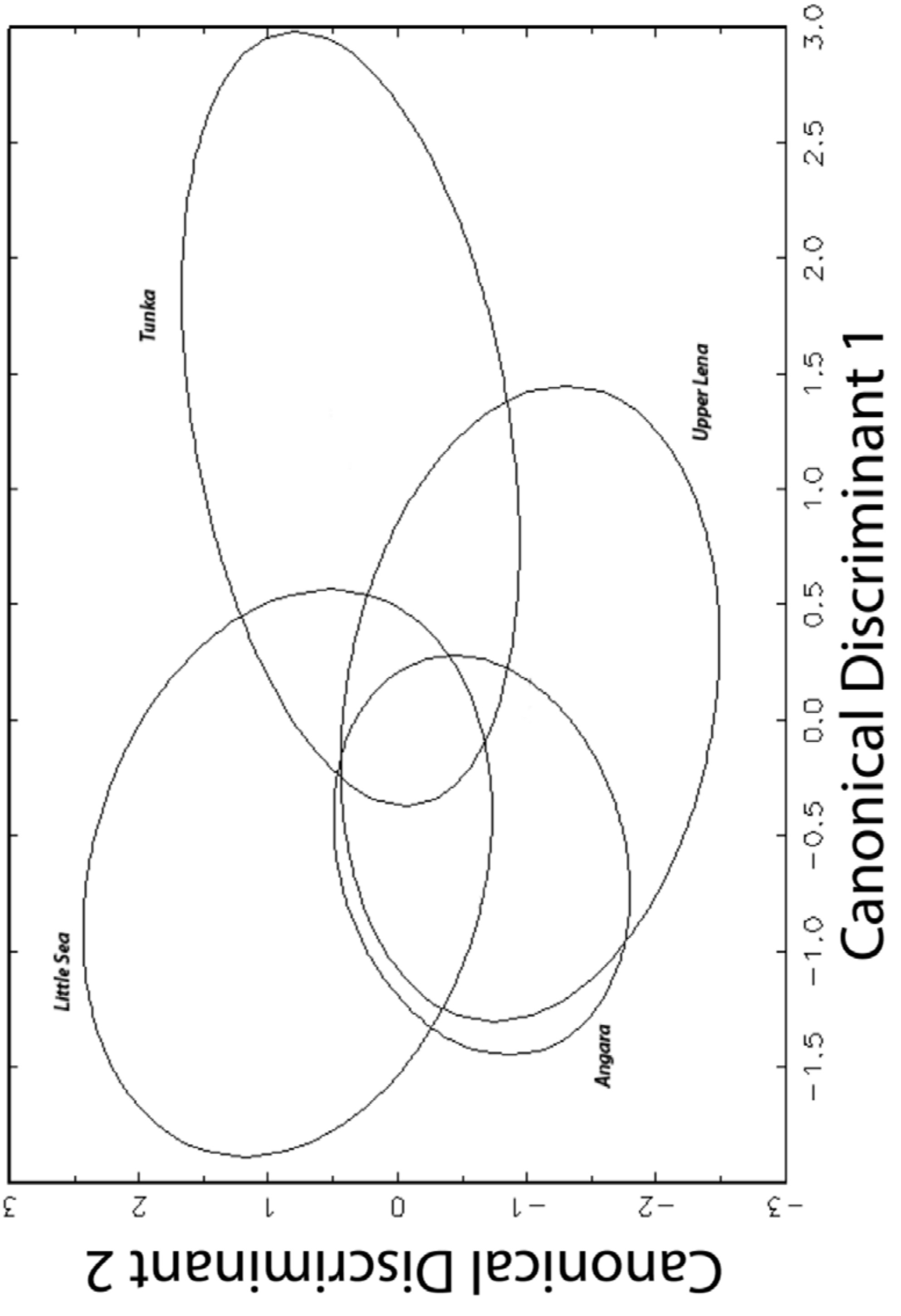

Figure 5-5: Bivariate plot showing the results of Discriminant Function Analysis employing complete isotopic and trace element data grouped by micro-region.

(Figure 5-5) were attempted on geochemical micro-regional groups reflecting the Middle Angara, Tunka, Baikal coast/Little Sea, and the upper Lena micro-regions.

Following this, micro-regional groups were subdivided into 2–4 groups each based on combinations of ^{87}Sr/^{86}Sr and elemental values for a total of 11 subgroups (Figure 5-6). These multivariate data are presented only as the 2 sigma confidence ellipses to improve visibility. Unfortunately, ^{87}Sr/^{86}Sr ratios presented the dominant vector of variability in these groups and the complexity in multivariate space does not support effective regional provenancing of individuals.

Given the observed geochemical complexity, a different approach was taken to discriminate the geological micro-regional groups. The entire data set was broken down into subclasses reflecting limited ranges of ^{87}Sr/^{86}Sr variability and then re-divided by micro-region; in this case, taking the whole range of Cis-Baikal ^{87}Sr/^{86}Sr values and dividing them into 8 subclasses (<0.708, 0.708–0.710,…, 0.718–0.720, and >0.720), and then within each of these geochemical subclasses, comparing the ^{87}Sr/^{86}Sr isotopic and elemental data between micro-regions. Geochemical subclasses do not correlate to specific geography, reflecting similarities present only in statistical space. This effectively moderates the dominant effect of the ^{87}Sr/^{86}Sr values within multivariate space. ^{87}Sr/^{86}Sr values are still crucial for accurate categorization within appropriate subclasses, but subsequently micro-regions are compared primarily based on elemental data. Conducted in this fashion, comparison between geochemical subclasses reveals rather distinct micro-regional differences (Figure 5-7).

HUMAN RESULTS

Human results were transformed using the same discriminant function matrix as environmental data and compared to established micro-regional subclasses groups to establish their provenance (Table 5-3). Strontium isotope ratios were directly comparable

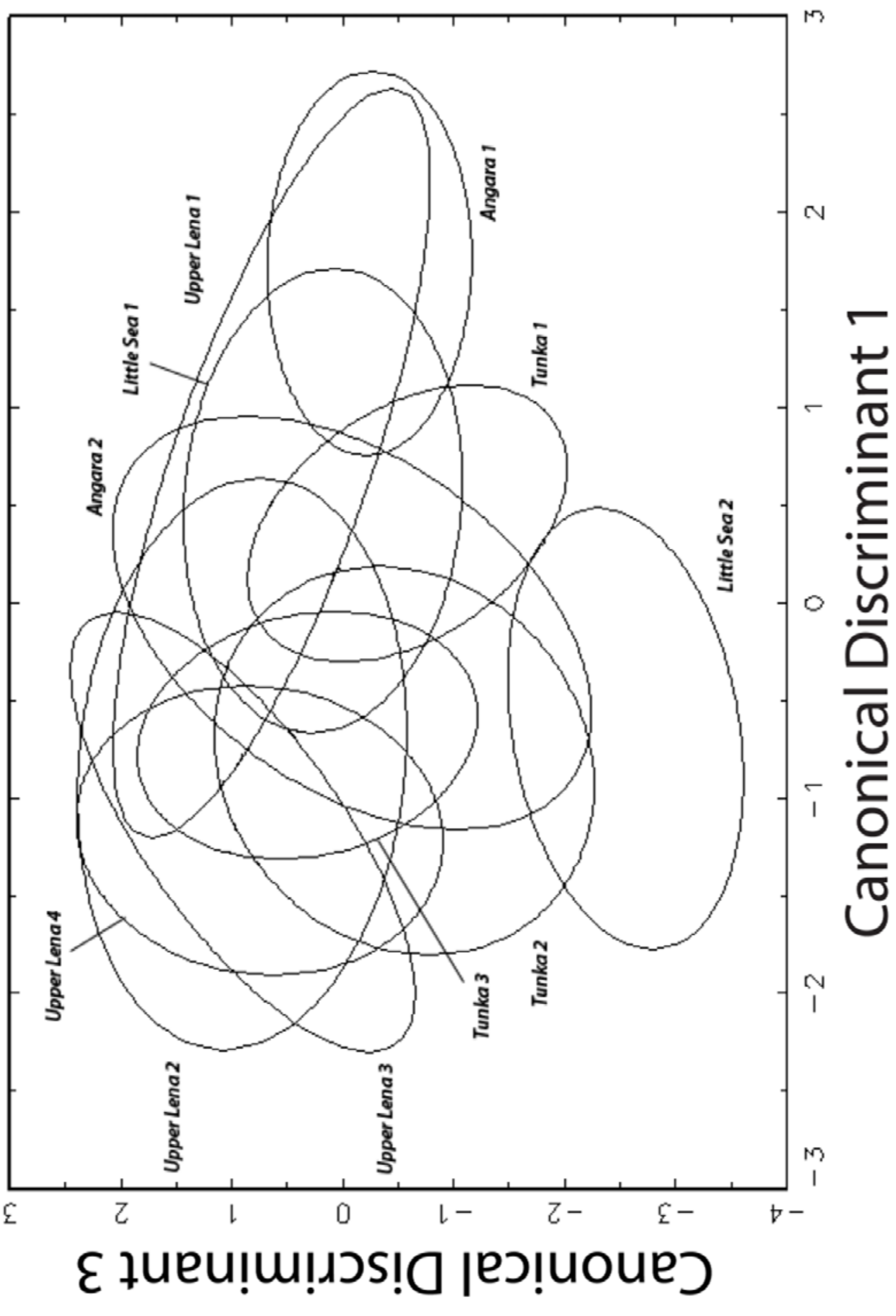

Figure 5-6: Bivariate plot showing the results of Discriminant Function Analysis employing complete isotopic and trace element data grouped by micro-regional subclasses as determined by cluster analysis.

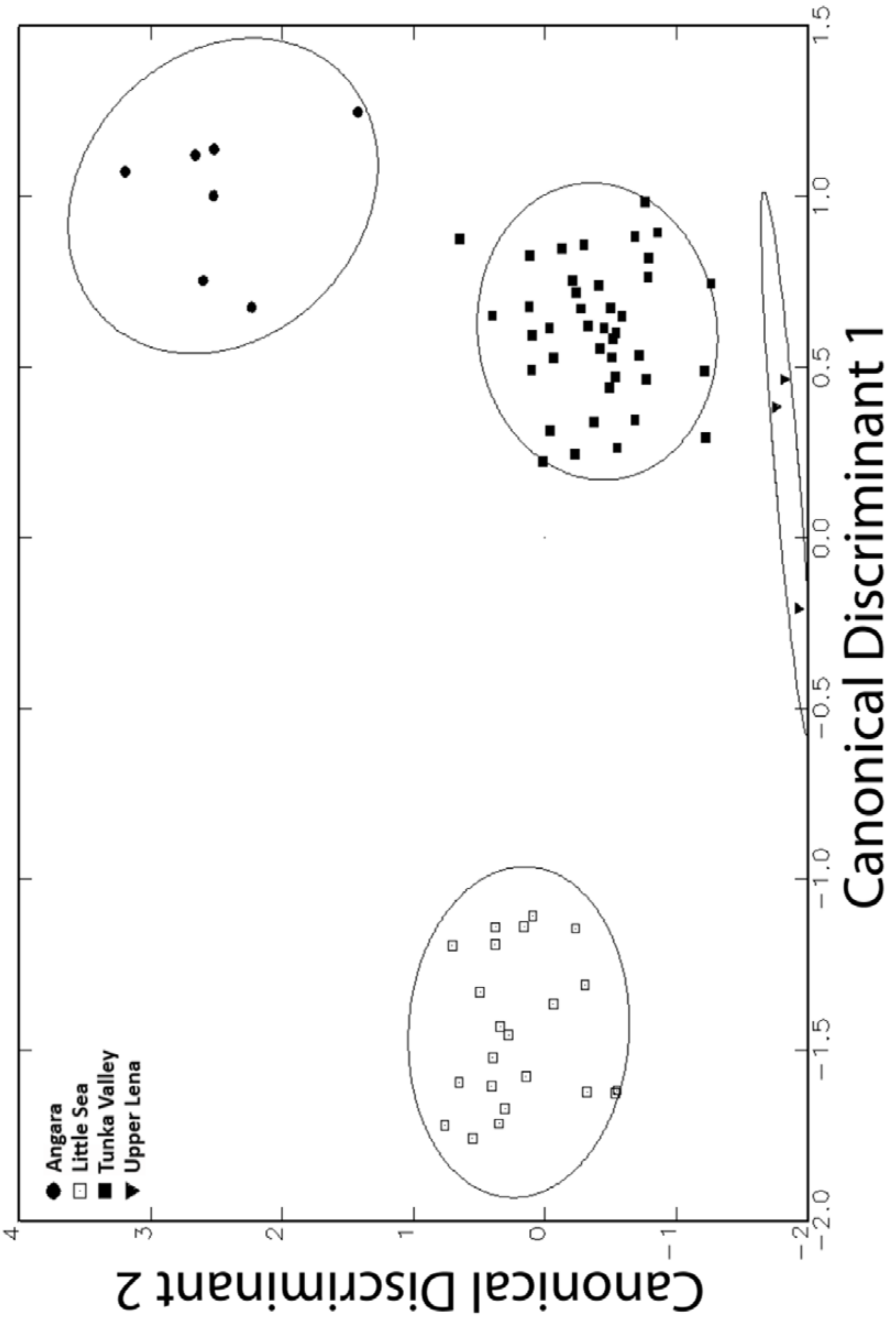

Figure 5-7: Bivariate plot showing the results of Discriminant Function Analysis employing trace element data grouped by micro-region within the $^{87}Sr/^{86}Sr$ range of 0.708–0.710.

across the different reference sample types, but trace elemental data had to be converted prior to comparisons. With disparate comparative materials, archaeological micro-regional group classifications were difficult and could not be verified by techniques such as Mahalanobis distance measurements. Instead, human samples were tested for their hypothesized group membership by a visual version of jackknifing. Samples added to a micro-regional subclass group would either cluster closely with the group, or stretch the group in the direction of the appropriate group membership. All samples were tested as members of all available groups before provenance determination and final group membership were established. Once classified by micro-regional subclass, samples were compared both visually to the reference samples in multivariate biplots (e.g., Figures 5-8 and 5-9) and through hierarchical cluster analysis to verify the geographic sampling site with the greatest affinity to the human sample analyzed.

Previous geochemical work in the Cis-Baikal region supported the feasibility of mobility research and suggested significant patterning of the $^{87}Sr/^{86}Sr$ values likely indicating different mobility or migration patterns. With an expanded environmental reference dataset, better understanding of the geological complexity in the region has come to light. As such, it is difficult to input the results for individuals recovered from small cemeteries (discussed here) into the interpretive framework presented by Haverkort *et al.* (2008). Discussion of this framework in light of new knowledge about $^{87}Sr/^{86}Sr$ ratio variability throughout the region is beyond the scope of this paper. Instead, qualitative discussion of the 16 individuals analyzed in this study will be provided in light of the new data. Table 5-3 contains provenance information for each examined molar.

Table 5-3: Provenance determinations for individual skeletal elements analyzed.

HSAMP_ID	MASTER_ID	SITE	ELEMENT	PROVENANCE
2000.220	BO1_1971.001	Borki 1	M1	Upper Lena/Little Sea
2000.221	BO1_1971.001	Borki 1	M2	Upper Lena/Little Sea
2000.222	BO1_1971.001	Borki 1	M3	Upper Lena/Little Sea
2000.190	KHO_1977.002	Khotoruk	M1	Little Sea
2000.191	KHO_1977.002	Khotoruk	M2	Little Sea
2000.192	KHO_1977.002	Khotoruk	M3	Little Sea
2000.194	KHO_1978.004.01	Khotoruk	M1	Little Sea
2000.195	KHO_1978.004.01	Khotoruk	M2	Little Sea
2000.197	KHO_1978.004.01	Khotoruk	M3	Little Sea
2000.171	KHO_1978.004.02	Khotoruk	M1	Little Sea
2000.172	KHO_1978.004.02	Khotoruk	M2	Little Sea
2000.173	KHO_1978.004.02	Khotoruk	M3	Little Sea
2000.187	KHO_1978.004.03	Khotoruk	M1	Little Sea
2000.188	KHO_1978.004.03	Khotoruk	M2	Little Sea
2000.179	KHO_1978.004.04	Khotoruk	M1	Little Sea
2000.180	KHO_1978.004.04	Khotoruk	M2	Little Sea
2000.181	KHO_1978.004.04	Khotoruk	M3	Little Sea
2000.183	KHO_1978.007	Khotoruk	M1	Little Sea
2000.184	KHO_1978.007	Khotoruk	M2	Little Sea
2000.185	KHO_1978.007	Khotoruk	M3	Little Sea
2000.175	KHO_Grave on the mountain (1978)	Khotoruk	M1	Little Sea/Angara Drainage
2000.176	KHO_Grave on the mountain (1978)	Khotoruk	M2	Little Sea/Angara Drainage
2000.177	KHO_Grave on the mountain (1978)	Khotoruk	M3	Little Sea
2000.201	SHM_1975.001	Shamanskii Mys	M1	Upper Lena/Little Sea
2000.202	SHM_1975.001	Shamanskii Mys	M2	Upper Lena/Little Sea
2000.203	SHM_1975.001	Shamanskii Mys	M3	Upper Lena/Little Sea
2000.205	SHM_1972.002	Shamanskii Mys	M1	Little Sea
2000.206	SHM_1972.002	Shamanskii Mys	M2	Little Sea
2000.207	SHM_1972.002	Shamanskii Mys	M3	Little Sea
2000.198	SHM_1973.003	Shamanskii Mys	M2	Upper Lena
2000.199	SHM_1973.003	Shamanskii Mys	M3	Upper Lena
2000.224	MNZ_1974.002	Manzurka	M1	Upper Lena
2000.225	MNZ_1974.002	Manzurka	M2	Upper Lena
2000.226	MNZ_1974.002	Manzurka	M3	Upper Lena
2000.212	OBK_1971.013	Obkhoi	M1	Upper Lena
2000.213	OBK_1971.013	Obkhoi	M2	Upper Lena
2000.214	OBK_1971.013	Obkhoi	M3	Upper Lena
2000.216	OBK_1971.005	Obkhoi	M1	Upper Lena
2000.217	OBK_1971.005	Obkhoi	M2	Upper Lena
2000.218	OBK_1971.005	Obkhoi	M3	Upper Lena
2000.209	OBK_1971.007	Obkhoi	molar	Upper Lena
2000.210	OBK_1971.007	Obkhoi	molar	Upper Lena
1997.284	OZH_000.006	Ostrov Zhiloi	molar	Little Sea

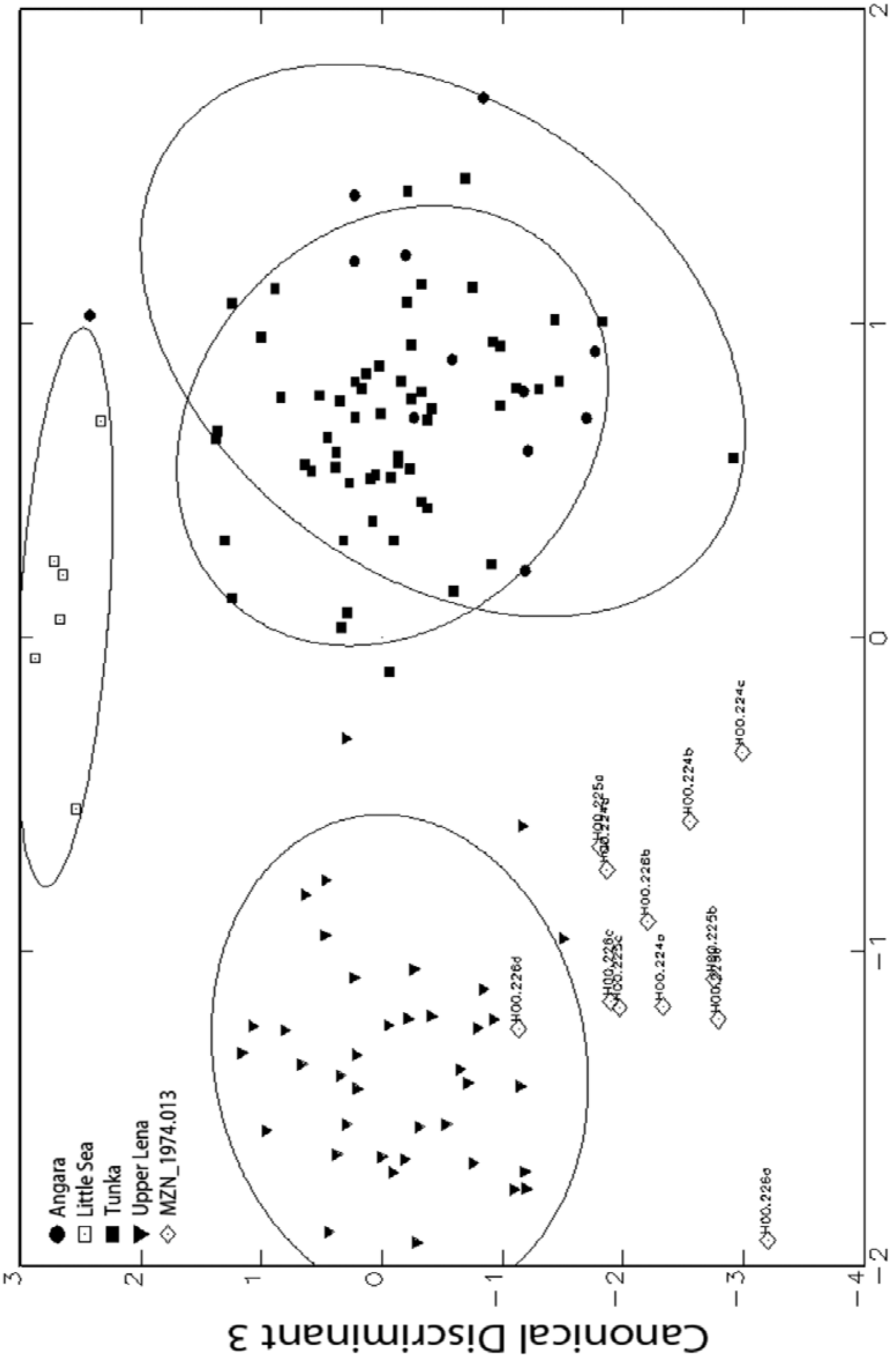

Figure 5-8: Bivariate plot showing for MZN_1974.013 projected with the results of Discriminant Function Analysis employing trace element data grouped by micro-regional subclass.

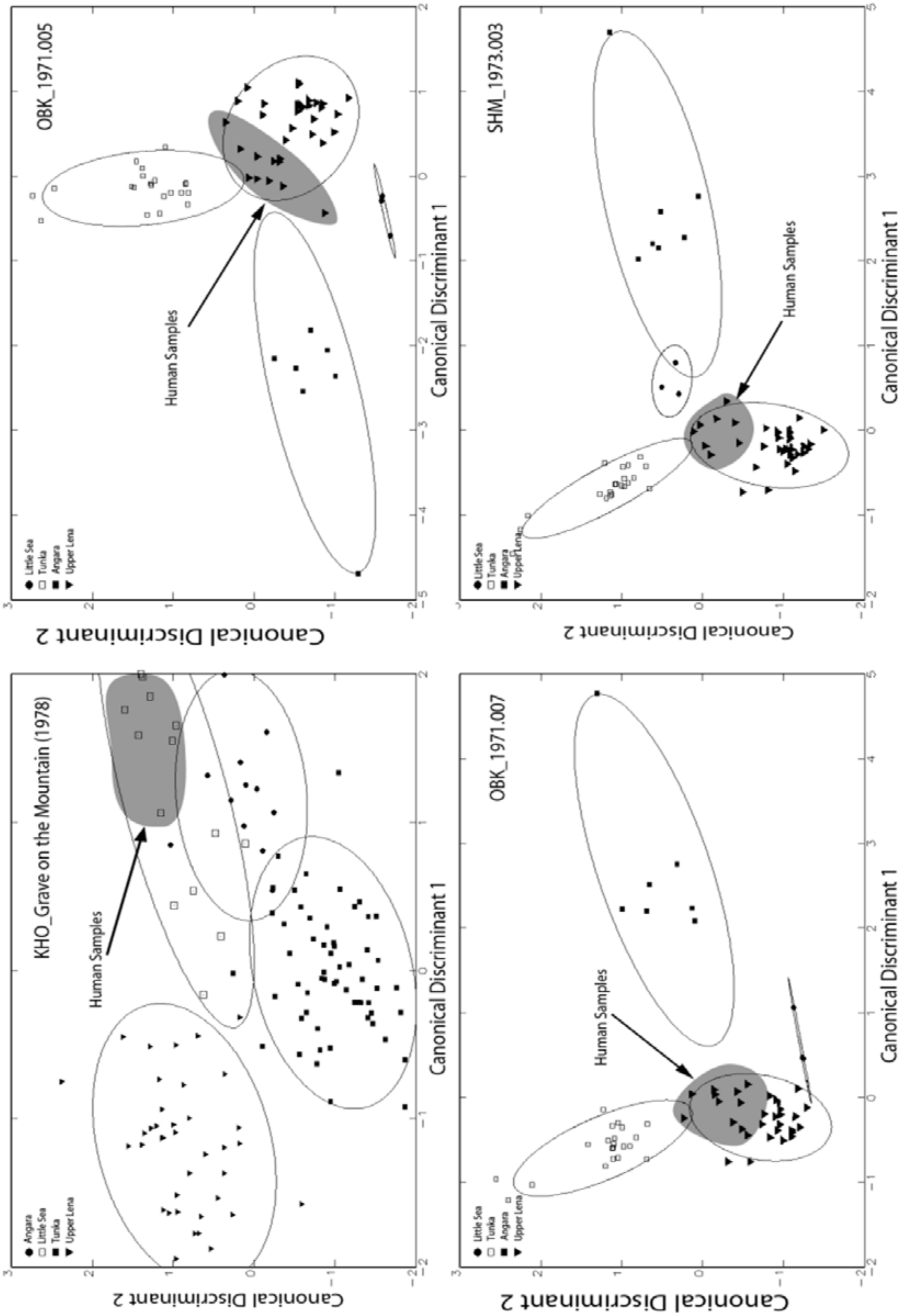

Figure 5-9: Bivariate plots for KHO_Grave on the mountain (1978), OBK_1971.005, OBK_1971.007, and SHM_1973.003 demonstrating the provenancing of human samples. Shaded areas include the majority of human samples.

BORKI 1

The one EBA individual (BO1_1971.001) from Borki had results for three molars that were fairly tightly clustered suggesting spatially limited mobility as a subadult within an area that was not covered by current geochemical survey and one where the body was buried. Provenance data showed equal affinity to both the Upper Lena and the Little Sea regions, likely indicating fairly stable residence in or near the mountains of the Primorskii Range upstream along the Lena River. This individual was interred near Kachug, an area well represented by the environmental data set, yet apparently did not enter it until adulthood.

MANZURKA

The geochemical results for the EBA individual (MZN_1974.013) from Manzurka are rather surprising for they suggest that this person spent significant portions of childhood in both the Manzurka and Khodontsa Valleys, both in close proximity to its final resting place. This is one of the few individuals who could be easily classified as "local", i.e., buried in the same area where they were born and spent much of their subadulthood. Data from the later portions of M1 and much M2 suggest interactions with regions of the Upper Lena not sampled yet.

OBKHOI

One individual (OBK_1971.005) stayed firmly within the Upper Lena region, was born near the Manzurka Valley, moved to the Khodontsa Valley by the age of ~5 years, moved next to areas not covered by the current map, and finally returned to the vicinity of Obkhoi as an adult or after death. One individual (OBK_1971.013) lived their life in areas in the vicinity of the confluence of the Kulenga and Lena Rivers (Kachug), however, also appears to have lived in areas of the upper Lena not sampled in this study.

These two individuals suggest fairly significant mobility within the upper Lena micro-region. The third individual (OBK_1971.007) lived most of their sub-adult life in the upper Lena region as well, likely in proximity to the Manzurka Valley. This individual was different, however, with a geochemical influence coming from the Little Sea region, slightly skewing results prior to moving finally closer to the Little Sea near the end of either M2 or M3 mineralization. This individual was in contact with and suggests broader connections between the Upper Lena and Little Sea micro-regions.

OSTROV ZHILOI

Based on available comparative data, this individual (OZH_000.006) appears to have grown up in the Little Sea micro-region. If so, this is very surprising given the substantial distance separating these two locations and the lack of waterways other than the Angara providing direct lines of movement between them. As such, this individual appears to have travelled quite significantly through their life, either joining with a local group, or died far afield from their birthplace, but still granted a formal burial.

KHOTORUK

Seven EN individuals from Khotoruk were analyzed and all appear to have lived their sub- and young adult lives within either the Little Sea micro-region or the Baikal Basin. Two individuals (KHO_1978.004.02 and KHO_1978.004.04) lived their lives on the southern and western shores of the Little Sea, staying within fairly high $^{87}Sr/^{86}Sr$ ratio zones indicative of the granitic rocks of Sarma Canyon and surrounding areas. Two individuals (KHO_1977.002 and KHO_1978.004.03) were born and spent their early childhood in similarly high $^{87}Sr/^{86}Sr$ ratio zones, but moved to areas with lower $^{87}Sr/^{86}Sr$ ratios earlier in their lifetime, by around age 5. It is possible that this shift could indicate the effects of weaning foods and a different diet for children and their mothers, though this remains speculative. Two individuals (KHO_1978.004.01 and KHO_1978.007) demonstrated some variability in their geochemical signatures and lived their sub-adult lives in an area of the Baikal Basin not sampled in this study. Lower $^{87}Sr/^{86}Sr$ ratios and trace element signatures suggest the area between the Kuda Valley and the shores of Lake Baikal as likely candidates for their provenance.

The final individual from Khotoruk (KHO_Grave on the Mountain) showed a rather surprising history of mobility. This individual was born in a rather low $^{87}Sr/^{86}Sr$ ratio zone (0.709) and gradually moved into progressively $^{87}Sr/^{86}Sr$ ratio zones as they grew up. There are small pockets of low $^{87}Sr/^{86}Sr$ ratios to be found within the Little Sea and neighboring Upper Lena regions, however the trace element data suggest instead that this individual was born not within the Angara drainage, but in an area fairly close to the boundary between the two (e.g., within the Kuda Valley). Initial movement likely took place while the individual was an infant, given the variability in M1 values. Another major movement took place before the beginning of mineralization of M3, likely around the age of 8 years. This was a series of movements, showing fairly small changes during the first half of crown formation, and then followed by a major movement to a higher $^{87}Sr/^{86}Sr$ ratio zone by the completion of M3 formation. Final values for this individual likely put them in the vicinity of Khotoruk as a sub-adult and remaining (or returning) there until death.

SHAMANSKII MYS

Each individual from the Shamanskii Mys cemetery exhibited a different mobility history, though all date to the EBA. Individuals analyzed included both those local to the Little Sea micro-region, and as well as non-local, or not-Little Sea, perhaps Upper Lena micro-region, childhood locale. This evidence includes both geochemical provenance, as well as stable isotope dietary information, showing individuals eating

Baikal seals and others subsisting on terrestrial and riverine, but not lake resources (see below; Weber, et al., 2011). The mix of Little Sea and other micro-regional geochemical and dietary signatures is intriguing evidence for the interment of individuals with varied backgrounds in a single cemetery. One individual (SHM_1972.002), showed relatively minor variations in their molar geochemical data, thus most likely stayed on Ol'khon Island. One individual (SHM_1973.003) appears to have grown up in the Upper Lena, in an area not heavily sampled, with tightly clustered $^{87}Sr/^{86}Sr$ ratios. This is somewhat surprising given dietary data for this individual that indicates significant consumption of aquatic resources, including seal, as an adult. Thus while this person lived their sub-adult life in the Upper Lena, they must have come to the Little Sea, and Ol'khon Island specifically for some significant amount of time prior to their death. And the third individual from Shamanskii Mys (SHM_1975.001), showed a significant amount of geochemical variability. Provenance determination was to a region somewhere between the Little Sea and the Upper Lena. The strongest affinity is for the region around Zhigalovo, but with much time spent in areas not sampled in this study. At some points in their development, this person was in greater or lesser contact with relatively high $^{87}Sr/^{86}Sr$ ratio zones (above 0.717 around age 7–8) that are only found near the Little Sea, and equally in contact with lower regions (0.709 around age 9–10 years). It is possible that the lack of clear provenance for this individual is the result of significant travel between the Upper Lena and Little Sea regions yielding averaging effects. Unfortunately no dietary information is available for this individual to help confirm the duration of final habitation on Ol'khon Island prior to death; however all other individuals from this site examined for carbon and nitrogen stable isotope ratios show consumption of the local aquatic foods (fish and Baikal seal; Weber et al. 2011).

DISCUSSION

These new results lead to a number of interesting inferences. First, there is a high level of agreement between the insights on mobility generated by this study and the insights gained via the most recent assessment of the regional dietary patterns (Weber et al. 2011) as well as the more detailed study of the various geochemical signatures assembled for the KN XIV cemetery in the Little Sea micro-region (Weber, et al., 2011). Given that the archaeological record is often incomplete or corrupted by diagenetic and taphonomic factors, to find individuals from several sites, frequently separated by a large distance that provide corroborating evidence is very encouraging as a form of verification. This generally supports the utility of geochemical data for mobility inferences and provides additional justification to continue this line of investigation and develop more comprehensive models of hunter-gatherer mobility and travel.

There is an asymmetry in the patterning of hunter-gatherer movement between various micro-regions in Cis-Baikal. The mobility of individuals was heavily focused on movement and interaction between groups residing in the Little Sea and on the upper Lena. Only one individual (KHO_Grave on the mountain) from the individuals representing the Little Sea area analyzed in this study or previously (i.e., 25 persons from KNXIV) by Haverkort and colleagues (2008), shows any contact with the Angara Drainage. This contact was marginal (e.g., Kuda Valley rather than Angara River itself). While there was a large EBA population living along the Angara and the southern coast of Lake Baikal, there is no evidence for significant movements of people between the Angara and the other three micro-regions (i.e., Tunka, upper Lena, and Little Sea). Weber and colleagues hypothesized the presence of just such an asymmetrical pattern of movement that is also supported by this new geochemical data (Weber and Goriunova, 2012, Weber, et al., 2011).

The data from Khotoruk support the notion that asymmetrical patterns of movement were also present during the EN. This data set also suggests that different patterns of movement and cultural contact were present during the EN and the LN–EBA. This inference is, however, based a very small sample of individuals from a single cemetery, additional evidence is greatly needed to verify it. The only demonstrable contact with the Angara was during the EN and the samples analyzed show significantly less mobility overall during the EN. This is intriguing given the geography, with the Kuda Valley providing a direct travel route between the Angara Drainage and the Little Sea and over relatively easy terrain. In contrast, overland movement between the Little Sea and the upper Lena is more challenging. The relative difficulty in travel could support the lack of movement between some micro-regions (e.g., upper Lena) but cannot explain the overall lack of movement, so some other factor must be responsible for this pattern.

Returning to the matter of EBA patterns, Shamanskii Mys data contribute further to the very interesting picture of mobility during this period. Based upon dietary evidence (Weber, et al., 2011), there are two distinct diet types within the Little Sea EBA population: GF (game-fish) and GFS (game-fish-seal). Sealing is predominantly a seasonal activity conducted on Lake Baikal from late winter to early spring (Weber, et al., 1998). Weber and colleagues (Weber and Goriunova, 2012, Weber, et al., 2011), based on the examination of the large KNXIV data set, hypothesized the movement of significant numbers of individuals between the upper Lena and Little Sea micro-regions on a seasonal basis. The seasonal nature of this movement produced two cycles of inter-regional mobility, one that brought people from the upper Lena to the Little Sea during the narrow window when seal meat is available for consumption and possibly to participate directly in the hunting of seals, and another pattern that brought non-locals to the Little Sea outside of the sealing season. Shamanskii Mys individuals (1973.003 and

1975.001) support the hypothesis that such interregional movements were not a unique feature of the KNXIV cemetery, but a broader phenomenon connecting the upper Lena with the Little Sea as part of regular travel and interactions. What is interesting, however, and worth further research, is that at Shamanskii Mys there are no individuals with the GF diet, while all mainland Little Sea cemeteries analyzed have people with both the GFS and GF diets.

Even more exciting is the correlation between inter-regional mobility and the presence of certain artifacts as grave goods. All three Shamanskii Mys individuals analyzed in this study were buried with nephrite artifacts, SHM_1973.003 and SHM_1975.001 each with white nephrite disks and SHM_1972.002 with a green nephrite knife (Konopatskii, 1982). This is very interesting considering the likely provenance of these artifacts. Green nephrite comes from the Angara micro-region or the Eastern Sayan mountains while white nephrite comes from northern Trans-Baikal in the Vitim volcanic fields (Johnson, et al., 2005, Sekerin and Sekerina, 2000). It has been suggested that there are far more sources of nephrite in the Baikal region (R. Losey, personal communication), however this research is still in progress and will hopefully elucidate the exact number of geochemically distinct nephrite sources and their provenance. It is intriguing that the local individual was buried with numerous grave goods and a green nephrite knife that was likely acquired indirectly through trade or through a specific trek to procure raw material to make such an object that only occurred during adulthood. This individual had no connection with the Angara Drainage during their childhood, remaining firmly within the Little Sea, yet was buried with an exotic artifact from a region that groups in both the upper Lena and the Little Sea had little direct contact. The other two individuals (SHM_1973.003 and SHM_1975.00) were of non-local birth and childhood, but were buried in the Little Sea and consumed seal during their adult lives. Both of these individuals were buried with white nephrite objects likely from Trans-Baikal.

The highly seasonal seal hunt is an excellent candidate for contact across the lake with the people from Trans-Baikal including the Vitim volcanic fields with the white nephrite and/or other mineral resources. Modern Buryat residents of Ol'khon Island and the Little Sea are noted to have close kinship ties to groups around Barguzin in Trans-Baikal and retain contacts across the ice (R. Losey, personal communication). This cross-ice movement could explain the presence of white nephrite from northern Trans-Baikal in the Little Sea. Seal hunts could also function as trading excursions involving contacts with groups living on the eastern coast of the lake or further into Trans-Baikal. Having a highly prestigious item (white nephrite) would go a long way towards explaining the nature of social contacts between the upper Lena and the Little Sea. It is quite plausible that long distance trade of valuables functioned as a strong draw-factor to make the trek across the taiga from as far as Ust'-Ilimsk (Ostrov Zhiloi) or vice versa relative to the subsistence or prestige value of the seal hunt itself. Rather trekking across the lake during the annual seal hunt, provides an avenue for goods to flow, the sharing of seal meat along with other exchanges providing a measure of hospitality or pretext for the exchange of goods. The individuals who never ate a seal in their last years of life could either have been individuals arriving outside of the sealing season or individuals returning from long distance treks inland (i.e., apart from Lake Baikal and possible seal consumption for multiple years, thus yielding a GF dietary signature).

The individual from Ostrov Zhiloi may be a good example of this kind of long distance trek though Ostrov Zhiloi has uncertain chronology (simply Neolithic), so it could represent an earlier phase of the patterns that become more evident during the EBA, or a rather unique EN individual. It is perhaps quite meaningful that only the two Shamanskii Mys individuals with a history of extensive movements also have exotic artifacts among their grave goods. This could be suggestive of differing cultural attitudes towards the value of long-distance travel and acquisition of exotic artifacts and their role in prestige building. Unfortunately the individuals in this study do not provide large enough a sample to verify such propositions.

Given how incomplete the archaeological record is, it is intriguing however that we have managed to clearly identify several individuals involved in now confirmed inter-regional movements between the upper Lena and the Little Sea. As such, the combined use of strontium and trace-element geochemical markers has the potential to provide many new insights on the broad regional scale facilitated by the large Cis-Baikal cemeteries such as Lokomotiv, Ust'-Ida, Shamanka II, KNXIV and Kurma XI.

Research and prehistoric mobility attempts to identify cultural patterning within the scientific data. In some cases, there is only circumstantial evidence to support the specific pattern (e.g., seasonal mobility, logistical foraging, and exogamous kinship structures). The data fit the proposed models only in most general terms but are often not paired with explicit discussion of the model expectation and possible disparities from such expectations. For example, identification of individuals that were not born within the local community is frequently used to posit the existence of exogamous kinship structures (e.g., Bentley, et al., 2002, Grupe, et al., 1997, Haverkort, et al., 2008). Such an assumption may not be warranted in the context of hunter-gatherers for at least two reasons. First, whether an extended kin group is exogamous or endogamous has no impact on where individual families actually live. It is generally observed and so widely assumed that endogamous groups tend not to travel as far away from their core community, however, there is no restriction against having members of the same kin group living in different geochemical regions. And second, there are a host of possibilities that would also explain an individuals' movement during life and residence near the burial community other than kinship without clear evidence of a specific exogamous structure. For example, if only non-local males or females were found in a cemetery population then the likelihood of an exogamous structure is high. If, as in the case of Cis-Baikal materials, individuals cannot be clearly sexed in all cases and those that can be, include both males and females of non-local birth, then further evidence is necessary to support the hypothesis of exogamy.

The first molar presents as much information about an individual's mother while nursing as it does about the given individual. Thus an individual suspected of non-local birth or childhood could have also been the child of a woman, together or individually joining the local group for a number of reasons such as having been taken as a captive or refugee and without standing in the new community. It is also possible that the same cemeteries were used by many hunter–gatherer groups that were culturally related at least by burial custom but with different subsistence and mobility patterns. As such, it seems the presence of non-local in a cemetery population is not enough to suggest exogamous marriage patterns. KNXIV individuals appeared to be fairly mobile (Haverkort, et al., 2008) in a complex geochemical environment, a pattern borne out in greater detail with the data from small cemeteries examined here. There seems to be far greater movement within archaeological micro-regions than between micro-regions. While the data set is still rather limited, the travel did not follow a clear pattern of revisiting specific locations (rivers, valleys, etc.) through time and suggests the residential movement of relatively small groups of people in an ad hoc pattern. Kinship structures have real ramifications for the individual, sub-group and core group subsistence and mobility decisions. Exogamous group membership is quite fluid, and Ives (1990) noted that exogamous hunter–gatherer groups were significantly smaller in terms of individual group size even though the extended kin networks were far greater in both geographic size and number of people involved. The kind of frequent residential movements with great variability in locale suggests just such small and fluid group movements during the EBA on the upper Lena and in the Little Sea. Combined with the clear long distance movement of some individuals (e.g., SHM_1973.003 and SHM_1975.001), this strongly suggests EBA groups had an exogamous kin structure as well as seasonal contacts with outsiders in conjunction with seal hunting activities on Lake Baikal.

CONCLUSION

Employment of geochemical tracers in studies of past hunter-gatherer mobility and migrations presents unique challenges. Cis-Baikal is uniquely situated in having a long history of hunter-gatherers who maintained formal cemeteries which consistently yield well-preserved human skeletal remains, in an environment with significant geological and thus geochemical variation. Many other areas of the world do not have this combination of materials and environment in which to address questions of mobility with geochemical methods. Foragers are frequently highly mobile and can have seasonally diverse diets. This makes methods developed for sedentary agrarian populations not applicable directly and calls for new approaches. Previous application of strontium isotopes to track mobility in Cis-Baikal hunter-gatherer groups showed promise and the adoption of the local v. nonlocal distinction quite suitable to monitor the movements of people throughout the region. Upon further investigation however, the highly variable distribution of biologically available strontium ratios ($^{87}Sr/^{86}Sr$) reveal a very complex geochemical environment that prehistoric Baikal foragers were in contact with. Consequently, to track human mobility more effectively the original approach required augmentation using trace element analysis. This tandem geochemical approach proved highly effective tool for discriminating regions with overlapping $^{87}Sr/^{86}Sr$ ratios as well as for provenancing prehistoric people. Our ability to track hunter-gatherer mobility is entirely dependent on the resolution of geochemical surveys. The greater the resolution of regional environmental sampling, the better the chance that interpretation of individual provenance data can reach beyond broad geologic zones and enters discussions about inter-regional movements. Individual mobility patterns appear to be quite variable supporting the notion that Neolithic and EBA Baikal hunter-gatherers outside were quite mobile and not tied firmly to the very productive fisheries on the Angara or in the Little Sea area. Several individuals show evidence of significant movement throughout much of the Cis-Baikal region, with predominant interactions occurring between the Upper Lena and the Little Sea micro-regions as opposed to significant intermixing of groups from the Little Sea and the Angara River as frequently implicitly assumed previously.

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Chapter 6: Synthesis and Conclusion

INDIVIDUAL LIFE HISTORY APPROACH

The development and growth of bio- and archaeological sciences have proceeded rapidly in the last 10 – 15 years. This recent focus on scientific methods can, however, be deceptive for scientific archaeology has been a driving factor in research, minimally, since the 1960's with the rise of New Archaeologists emphasizing scientific rigor as the foundation for archaeological research. Decades of discussion followed regarding the role of science in archaeology, how explanations based in new theoretical paradigms were able to elucidate aspects of prehistory and material culture, and whether anything had been gained by the academic community. Analytical data, like science in general, provide very specific information for a particular question. Understanding and drawing inferences from this data require an explanatory structure, namely archaeological theory.

The seeming recent increase in archaeological science has, perhaps, as much to do with the development and implementation of evolutionary archaeology as it does with technological developments that have opened new analytical opportunities (Zvelebil and Weber, In preparation). One specific approach, the bioarchaeology of individual life histories, perhaps best exemplifies this relationship. Modern Darwinian evolutionary theory differs from most other anthropological approaches foremost in a focus on individual actions and how variation in individual strategies can generate the group or population level changes that are frequently discussed in archaeology (O'Brien and Lyman, 2004, Shennan, 2002).

Hunter-gatherer mobility traditionally has been approached as a site-level concept (e.g. seasonal, temporary, transient, semi-permanent, permanent sites), rather than at the individual- or group-level (e.g., logistical or residential mobility; Binford, 1980). Archaeological materials provide insight into how long and when a site was used, for what purpose, or as an expanded concept including also demographic aspects of the archaeological sites encountered (*traveler/processor*; Bettinger and Baumhoff, 1982). Explanations drawn from these approaches are not geared to individual actions and may not provide details and insights into individual behavior. Current technology has outstripped the explanatory capabilities of traditional approaches and underscores need to incorporate historical narratives of individual action and life history generated using Darwinian evolutionary approaches.

Archaeological science, mobility research in particular, is very technologically driven with pressure to generate finer resolution data for individuals as traditional methods (e.g., site based analyses) cannot provide adequate data to answer the research questions posed by the theoretical perspectives of the life history approach. This thesis has focused on the methodological refinements associated with generating provenance data with resolution fine enough to differentiate between movement and migration patterns in prehistory. Querying the exact provenance of individuals during different intervals in their life has been a research goal for longer than it has been analytically possible to determine. Yet the improvement of technology has not altered research goals, but rather continually sharpens the contextualization possible with mobility data available and encourages further developments.

TECHNICAL IMPACTS

As mentioned above, the primary focus of research presented in this thesis has been on technical aspects of the methods used to assess chemically prehistoric h-g mobility and migrations. This focus has been prompted by the identification of an explanatory gap between the goals of theoretical frameworks, such as the life history approach, and the data being gathered to develop the story of individual lives. Hunter-gatherers pose additional challenges (see Chapter 2) for scientific analyses as many starting assumptions, such as static relationships with specific geographic ranges that are perhaps valid for agro-pastoralist populations cannot be confidently asserted for foraging populations. BAP scholars have completed much work on Middle Holocene cemetery populations within Cis-Baikal, providing ample data to support rich explanations of prehistoric activities and cultural patterns. The inclusion of multiple data types (e.g., dietary, osteological, mobility) and representative samples within each type greatly improves knowledge of and insights into any given individual; however, further improvements are possible.

Laser Ablation Correction Factors

The first goal of this dissertation research was to establish the feasibility of conducting geochemical research on a regional level with a large cemetery population. Given the constraints of conducting large-scale analyses using the TIMS method, this would not be a viable option. Thus, the question reverts to what methods are available that can provide geochemical data with sufficient precision and accuracy for archaeological purposes, as opposed to the best possible precision and accuracy, for a much more competitive overall cost (money, labor, and time) per sample. The 2003 pilot study came at a time when comparisons between solution mode (SM) MC-ICP-MS and TIMS were still under debate. A growing body of evidence suggested that the two analytical methods could provide compatible data at least for reference materials but at significantly lower costs and less physical damage to the sample (see Chapter 3 for more details). SM-MC-ICP-MS could be conducted for approximately ¼ the per-sample cost as compared with TIMS. The difference in data precision and reproducibility of strontium isotopic standard NBS-987 measured over several months is statistically significant; averaging 0.5 – 1 epsilon units (0.00005 – 0.0001) for SM-MC-ICP-MS and 0.3 – 0.5 epsilon units (0.00003 – 0.00005) for TIMS. Data precision and reproducibility is therefore separated by a factor of 2 between the two methods, however this level of uncertainty is negligible when considering archaeological samples. If the data produced by SM-MC-ICP-MS are adequate for the needs of archaeologists and can be used for ¼ the price, then researchers have the option of analyzing either four times as many samples for the same money, or to conduct a study for ¼ of the cost. In either case, this difference brings large scale geochemical research within reach of more archaeological research programs. BAP (Haverkort, et al., 2008, Weber, et al., 2003) began its research in this middle period when TIMS was still the standard method but SM-MC-ICP-MS was becoming an acceptable alternative technique, and so the study employed a combination approach where samples previously analyzed using TIMS were repeated using SM-MC-ICP-MS along with a large portion of individuals from the KNXIV cemetery. The study demonstrated the practicality of using new techniques and was one of the first large scale geochemical studies that focused on hunter-gatherers.

Solution preparation for strontium isotope analysis is a time consuming and labor intensive process spurring interest in alternative means of sample introduction and analysis. MC-ICP-MS analysis does not require the preparation of solutions, as would TIMS analysis and laser ablation (LA) provides additional advantages. The technique has existed on the peripheries of geochemical analysis for many years now, with periodic spikes in general interest specifically related to its ability to sample materials in a virtually non-destructive fashion. The primary caveat is that samples must be able to fit inside a sample chamber. For skeletal materials, this requires the removal of teeth from the mandible or skull and the removal of portions of bone small enough to fit inside this chamber. Sample preparation for SM-MC-ICP-MS or TIMS requires similarly destructive initial sample collection, though also completely compromises the removed sample in solution preparation. LA provides two critical benefits in this regard, allowing samples to remain intact for repeat analysis or for future studies, and enabling micro-sampling of skeletal materials.

Researchers gathered very promising early results (see references in Chapter 3), but soon realized that there were additional complications in using LA on skeletal materials. Two kinds of problems were identified: lack of adequate reference materials and unexpected interferences. Lasers couple differently with samples depending on various aspects of texture and density. Ideal reference materials are those with similar properties to the samples being analyzed. Most standard reference materials are developed for geochemistry rather than archaeology and often come in the form of impregnated glasses, clays, or mineral structures that make poor analogies to skeletal materials. Solutions to this problem can include the development of new reference materials such as faunal teeth or bone, or the growth of analogous minerals to the composition of tooth enamel and bone. Each of these approaches takes considerable time and expertise in development and maintenance, so they are generally beyond the scope of individual research projects and must be produced by labs that frequently deal with archaeological materials. The second problem, interferences, can often be compounded by the choice of reference materials. ICP-MS data are determined as relative intensities compared to known materials, i.e., reference samples.

Many reference samples do not have similar isotopic or elemental composition as the archaeological skeletal collections being analyzed. Without reference materials of similar matrix and chemical composition, any unknown interference encountered during the analysis can have undue effect on the results obtained for archaeological samples.

For example, Durango Apatite is a well characterized naturally occurring phosphate mineral that has been used in multiple geochemical labs as a reference material for archaeological and geochemical research. Unfortunately, Durango Apatite has relatively high Sr content (>400 ppm) and so it makes a poor comparison for skeletal materials that may have <100 ppm Sr. The high Sr content of reference materials like Durango Apatite also masks the presence of interferences that may only impact samples with much lower Sr content. This is the case for many archaeological skeletal materials, hence the problem with the polyatomic molecule (CaPO) was not easy to identify.

Several research groups successfully pointed out this molecule as that responsible for errant Sr isotope ratios in phosphate matrices like those that comprise teeth and bones. The independent conclusion of two research groups (Horstwood, et al., 2008, Simonetti, et al., 2008) was that this polyatomic molecule would only present a significant offset when analyzing materials with Sr content below 200 – 300 ppm. Understanding the analytical limitations of any method is critical to the progression and implementation of research programs; however, this identified cutoff poses a major challenge for hunter-gatherer research.

Sr is a bone-seeking element, with over 99% of the Sr found in bones of any human or animal being. Sr is available in plant foods at concentrations averaging 10 times higher than in human or animal bones. As a result, a diet high in animal protein will be generally low in Sr content. In areas such as the Subarctic and Arctic where there are few edible plants capable of large dietary contributions, individuals will quite often have very low Sr content in their teeth and bones. This poses a serious methodological hurdle for researchers working with hunter-gatherers, regardless of geographical region but compounded at higher latitudes where animal products necessarily contribute significantly to the average diet.

The results of Chapter 3 demonstrate that correction factors can be effectively applied to LA data for human teeth. By correlating the correction factor directly to the Sr content, the low-Sr content limitation is effectively neutralized. This removes the hurdle of Sr content to LA analysis of skeletal materials and allows for hunter-gatherer collections, like those from Cis-Baikal, to be analyzed timely and efficiently. Two different research labs identified the presence of polyatomic interference that limited effective LA analysis on human teeth to high-Sr samples. It remains unclear why neither group proposed a similar solution to this problem. Perhaps more important than the value of correction factors for Sr isotope ratio analysis, are the preliminary data supporting both micro-sampling as a useful avenue of research for human teeth and the tandem use of Sr isotope ratio analysis with trace element tests.

Micro-sampling of Human Molars

Micro-sampling has been another distinct focus of this dissertation research. Laser-guided micro-drills are an alternative to LA for micro-sampling of skeletal materials. As a sampling method, it has largely been limited to geochemical research focusing on the composition of single crystals within heterogeneous mineral matrices. Micro-sampling for geochemical research of this type involves goals and challenges that are similar to those involved in attempts at refining methods of analysis for archaeological skeletal materials. Micro-drills are a fairly new addition to geochemical laboratories and so are not very common. Once samples are removed, they are prepared as solutions for analysis via TIMS or SM-MC-ICP-MS.

As noted in Chapter 3, LA is significantly cheaper and faster to employ than SM analysis, with virtually no prior preparation necessary and frequently faster analysis time and throughput. Thus, micro-drills are certainly a suitable option for micro-sampling research, but will present the same types of hurdles for time and labor as will traditional solution-based sample preparations. As time and cost are frequently the deciding factors in archaeometric research, micro-drills present a capable but frequently unfeasible alternative to LA for any sort of micro-sampling research.

The main limitation of the traditional methods, from the perspective of the individual life history approach, is that they homogenize the sample material in a few ways. Foremost is the concern about the inclusion of diagenetic materials with the desired skeletal material (target data). Second is the inclusion of sample materials that correspond to quite different time intervals in the life of a particular person. For example, as bone remodels, portions can be entirely removed from the vascular system and remain isolated for many years before new bone formation eliminates this part of the bone (see Chapter 4). Teeth do not remodel, so this is not a concern, however the accidental inclusion of dentine or root material can equally bias the results. Third, and more generally, homogenization does not allow access to any potentially useful micro-structure within the samples. The entirety of the sample is averaged to generate a single datum that becomes representative of the full chronological extent that an element could represent. For example, a molar is reduced to a one datum point for the entire growth and mineralization span of many years and any discussion of behavioral changes occurring within that span are not possible based in this kind of information.

Thus, micro-sampling is crucial to the development or refinement of analytical techniques for research on hunter-gatherer in general and specifically to build individual life histories for prehistoric populations. As such, until the development of new sample-introduction or analytical techniques capable of providing a better combination of being virtually non-destructive, fast and economical, continued research into LA in pursuit of biogeochemical data from hunter-gatherers is the best course of action.

One caveat for implementing micro-sampling approaches to analyses is the possibility that sampling may be occurring at scales beyond the rate of formation. Teeth form and mineralize over an extended span of time with daily depositional bands visible under magnification. If these bands reflected mature enamel, then micro-sampling should aim to collect data from individual bands. If this is not the case, then further consideration of the mineralization process is necessary. Research into the mineralization and progression pattern of mammalian teeth has provided some perplexing results. Faunal samples, such as herbivore teeth, were initially thought to mineralize in a linear fashion following a similar pattern to eruption and use-wear. Recent research has increasingly suggested that this may not provide an accurate picture of mineralization (e.g., Britton, et al., 2009, Montgomery, et al., 2010).

Tooth mineralization appears to follow a patchy pattern where entire segments of teeth will complete their mineralization at the same time rather than following the linear progression of initial deposition. These researchers have suggested that micro-sampling of teeth may not be practical for this reason. The Sr data from Chapter 3 would suggest a similar type of averaging effect in human teeth. This result is not surprising considering the long residence time of Sr in the body (400+ days). Any major movements within this timespan will be averaged and masked to a certain extent unless crossing major geochemical zones.

Several human tooth samples analyzed in Chapter 5 do in fact show this pattern and further support the preliminary conclusions drawn from the work presented in Chapter 3. Sr isotope ratios considered alone do not provide much support for micro-sampling, showing little evidence for movement of individuals across geochemical boundaries. However, examination of trace elemental compositional data for the same individuals changes this picture entirely and highlights the limitations of using a single line of evidence (single element, single isotopic series, etc.). Thus, elemental data demonstrate useful variability present within micro-sampled portions of human molars. This suggests significant dietary or geographic changes that occurred during molar formation experienced within the bounds of a single geological or geochemical zone and also demonstrates the validity of pursuing micro-sampling of human teeth.

Micro-sampling of Long Bones

Bones and teeth are composed of very similar mineral structures, both of which are generally referred to as calcium hydroxylapatite. The difference is that bone is composed of a loose mineral matrix while tooth enamel is made of compact matrix; therefore bone is significantly more susceptible to chemical alteration in the burial environment than teeth. This risk of diagenetic alteration has long plagued chemical research involving bone, with results being questionable. Stable isotope analysis (e.g., carbon and nitrogen) has focused on data quality indices that can enable researchers to determine samples that will provide reliable data and those that are too degraded or are likely impacted by diagenetic factors. These indices, however, are not applicable to strontium isotope and trace element tests. Studies of mobility generally take one of two approaches: 1) avoiding bone altogether, assuming that it has been altered; or 2) attempting to measure bone values as well as local soil values to check for diagenetic impacts. The first approach cannot benefit researchers. The second approach assumes that potential diagenetic alterations are limited to overprinting and so will be readily apparent in the results with significantly divergent values. Chapter 4 discusses in detail the several diagenetic alterations and vectors to be concerned about.

The results of Chapter 4 highlight an interesting aspect of previous BAP research. Haverkort et al. (2008) noted that Sr bone data, examined at a group level, were less variable than any of the three molars. This limited variation called into the question the veracity of the data as diagenetic alteration would produce a similar pattern. Without further work, solving this dilemma seemed difficult. My own results validate the correct application of purification procedures in preparation of the original samples. The data generated in 2008 were closely duplicated by the LA technique for individuals analyzed in both studies. This leaves the question open as to why the bone data are so much less variable. Was adult mobility lower than sub-adult mobility? Or, are these data telling us of significant mobility averaged over long time and large area?

Bones are complicated structures, particularly long bones that undergo constant remodeling and include materials old and new. Bones reflect the recent and living history of the individual up until their death, so long as special care is taken into what portions of bones are being sampled. Standard sampling methods for chemical analysis convert all portions of the bone into a homogenized powder or solution. Chemical purification methods will help to eliminate diagenetic overprinting by removing the most soluble portions of the sample, but will leave the remaining bone material largely intact. Thus, the sample includes isolated portions of bone that can be over 20 years old, as well as newer material that will be less than 10 years old. The result is assumed to reflect the final 5-10 years of life, but can be biased by older portions of bone as well as those that were altered by diagenesis but not removed entirely. In cases such as Cis-Baikal where there are geological zones of very old rock with high Sr isotope ratios, the inclusion of this material for an individual who had not lived in this region for many years would alter their apparent adult provenance. As such, special care should be taken when assessing bones for chemical analyses to ensure that the desired target data are actually being obtained. Individual bone cells have limited lifespans, and the successful use of LA on tooth enamel suggests that these internal structures could be sampled in a direct and precise fashion.

Individual osteons can effectively be used for geochemical research (see Chapter 4). Micro-sampling of these osteons provides access to a wealth of data regarding the final years of life. If isolated, partially remodeled portions or islands of old bone can be identified within a sample, then a larger portion of the adult life can be analyzed. Osteons that were alive at the time of death have a maximum age of about 25 years, though are likely on average about 10 years old. As these mature cells have cut into and through older, dead osteons, remnants of these dead cells reflect a portion of life on average more than 10 years before the death of the individual. Analyzing osteons of different age and longevity within a bone sample can potentially provide a detailed record of an individual’s sub-adult and adult life, depending on the age of death of the individual.

Trace elemental analysis can be conducted at a scale of 5-10 microns, while, current LA units cannot provide adequate signal strength below approximately 80 microns to micro-sample individual osteons for strontium isotopic ratios, but can micro-sample osteons as a whole cell. This allows researchers to check for diagenetic alterations as part of the analysis as opposed to assuming that purification procedures have achieved the desired effect. Sampling of multiple osteons within a single piece of bone enables for a data quality check, identification of localized diagenetic alteration and values, and provides internal validation for target data reproduced between multiple osteons of similar age. Sr isotopic results and patterns in trace element concentrations are repeated between multiple osteons to ensure that no one datum is biased by analytical error or sample deterioration.

Diagenetic Research

Changing the effective resolution, from macro- to micro-sampling for chemical analysis on teeth and bones has implications beyond the groundbreaking impacts on the spatial and temporal resolution of archaeological mobility studies. Entering into microscopic analysis of skeletal materials opens an entire new domain of diagenetic research. Microscopic examination of skeletal materials has long been a staple of osteological research and provided the foundational understanding of diagenetic processes operating within bones.

Histological thin sections and sections of bone prepared for examination using scanning electron microscopy have elucidated many aspects of the physical changes occurring within diagenetically altered samples; however, the nature of chemical changes associated with observed physical changes has remained underexplored (e.g., Boyde, 1972, Child, 1995, Hackett, 1981, Hedges and Millard, 1995, Jackes, et al., 2001, Millard, 2001). That chemical changes occur as the result of microbial action and contact with the burial environment, is well established (cf. Jans, 2008, Jans, et al., 2004, Nielsen-Marsh and Hedges, 2000a, Nielsen-Marsh and Hedges, 2000b); however, systematic work focusing on the study of chemical changes and their progression relative to different diagenetic processes have been rare. Bone micro-sampling appears to have much to offer to significantly improve understanding of bone diagenesis.

Combining microscopic chemical analysis with the study of microbial biodeterioration provides the opportunity to track the progress of known diagenetic agents and the chemical changes that precede and are correlated with observable physical changes, providing a more complete (or comprehensive) understanding of the diagenetic process. Such precise knowledge on diagenetic alteration could lead to improved means of treatment and removal of diagenetic portions of samples and ensure sample hygiene and thus analytical data quality.

Reference materials

Establishing effective means of data recovery is one other important aspect of this dissertation research in that it provides the necessary context for archaeological interpretation of the chemical data. The greatest challenge that researchers studying hunter-gatherers face when trying to develop individual life histories using geochemical techniques involves availability of suitable reference materials. The dietary inferences that have shaped understanding of prehistoric subsistence, and to a lesser extent mobility patterns, are only possible through the characterization of possible foods within the region. Mobility inferences drawn from dietary isotopic data (carbon and nitrogen) are limited to identification of individuals who were subsisting on foods different from the local resources. For example, identifying individuals interred in the Little Sea micro-region who had diets consisting of terrestrial game and fish from mountain streams as opposed to deep water systems suggests that they spent the bulk of their final years away from lake resources.

Developing reference samples and ultimately the reference map necessary to provenance prehistoric individuals is a difficult task. Ideally, reference materials should be of the same kind as the archaeological specimens (i.e., teeth or bones) to be analyzed in order to provide a useful distribution map of bioavailable geochemical tracers in the landscape. Small animals are frequently considered as the best candidates for this purpose, having limited foraging ranges that provide accurate geographical information about local biogeochemical background. Unfortunately geologic formations are often not homogenous at the scale of small animal foraging ranges and the data obtained for small fauna can exhibit significantly geochemical variation over short distances. Any given small animal's geochemical data can thus be misleading; they could reflect the larger geological formation or they could just be a sub-localized anomaly with very different characteristics from the surrounding area. To counter uncertainties related to sub-local geochemical data, small animals representing systematic intervals covering the entire research area would be required. However, the requisite number of small animals renders such sampling strategy quite impractical.

Furthermore, small animals are not expected to constitute significant portions of the diet under circumstances where larger game or more economical resources are available. Hypothetically, it would be preferable to pursue reference materials that would be analogous to the actual foods encountered in prehistory. This, however, presents several challenges including uncertain linkages between the geographic locale of life and location of death for animals and possible changes in the biogeochemical environment since prehistory. Chapter 5 discusses the problems of using faunal materials for reference samples in mobility research in more detail. Briefly, where an animal lives and where it dies or where it becomes food for humans, and thus enters into the bioavailable geochemical equation and the location where it is sampled are frequently not one and the same.

Many large fauna (e.g., deer) have large foraging ranges and experience migrations of varying scope during their lives depending on the species. Migration patterns and foraging ranges are not static through individual life spans and over generations even with species such as reindeer that do tend to follow predictable patterns over numerous years. Simply put, there is no guarantee that the geographic location of the sample collection site is representative of the location of the animal's actual foraging range. In this regard, modern faunal materials hold exactly the same risks as archaeological materials, thus limiting their use as source of geochemical reference data. Such reference materials can be used if the effective geochemical resolution were limited to regions or micro-regions large enough to fully contain the foraging ranges of these species. Unfortunately, spatial correlations between archaeological micro-regions and animal or human foraging ranges are unknown and the goals of mobility research in Cis-Baikal aim to provenance individuals throughout their lives with geographical resolution on the scale of individual river valleys or similarly discrete formations.

If researchers are unable to use confidently either small or large fauna for reference materials, what environmental samples can be collected that will hold more spatially and chronologically stable provenience information (i.e., will be the same today as it was in the Middle Holocene)? Water and plants represent relatively static features in terms of bioavailable geochemical tracers. Barring major events such as volcanic eruptions or earthquakes, water courses will interact with the same or similar rocks and soils through many thousands of years and produce relatively stable bioavailable geochemical compositions. Plants are indicative of the soils that they grow in and are similarly resistant to alteration. Shifting wind patterns and the deposition of loess or the removal of finer sediments can alter the soil content in a relatively rapid fashion, but the overall geochemical composition of the soil will change rather slowly.

Therefore plant and water samples were used as reference materials. Sr isotope ratios are constant and can be compared between plants, water, animals, and humans without modification. Trace element data, however, require further consideration prior to use. Many elements, including Sr, are present in higher concentrations in plants by an order of magnitude relative to human samples. Similarly, water contains elements in concentrations roughly an order of magnitude lower than human bone or tooth samples. To make these materials comparable, data were examined as ratios to internal controls.

For this study, ratios to measured Mg concentrations were found to provide the best results for comparative analysis in multivariate statistical space. Using reference materials of different chemical composition presents technical challenges, but also provides valuable new insights.

The results of Chapter 5 would not have been possible using traditional sampling methods or reference materials. This work also provides a reference map that can be used for all future mobility studies in Cis-Baikal. To explore the potential of this biogeochemical reference map, individuals from several smaller cemeteries in the region were analyzed using the new methods. Original plans had been to develop individual life histories of mobility for 16 individuals and correlate them with the mobility patterns identified by Haverkort et al. (2008). With the completion of the reference map; it became apparent that more detailed conclusions were possible than a local/nonlocal determination in the fashion of the earlier study. Thus, the research direction shifted to generating provenancing results for individual life segments based on the reference map and human geochemical data.

Correlating geochemistry with specific geologic formations or sites is the driving force behind provenance analysis for artifacts as well as skeletal analysis. Vagaries of archaeological preservation and geochemical analysis have long made it easier to provenance artifacts than to provide similar inferences about human mobility. This demonstration of effective mobility tracking for prehistoric individuals with resolution finer than at the micro-regional level alters the types of research questions that can be addressed, opens up new avenues of research on Cis-Baikal hunter-gatherers, and provides a methodological framework for researchers studying hunter-gatherers elsewhere in the world.

Overall Methodological Contribution

Many of the analytical techniques underlying the research conducted here are not new, often employing equipment that has been available to chemical researchers for many years. For example, in spite of early interest in trace element studies of skeletal materials (e.g., Bratter, et al., 1977, Gilbert, 1980, Keeley, et al., 1977, Lambert, et al., 1979, Sowden and Stitch, 1957), much of this work was discredited as providing errant or inconclusive data on prehistoric diet and trophic position (Burton, et al., 1999, Hancock, et al., 1989, Price, et al., 1992). With dietary reconstructions proving ineffectual, the technique fell out of favor. The most notable results of the attempted use of trace element analysis for dietary reconstruction was the identification of diagenetic factors interfering with analytical results and so providing stronger evidence for diagenetic alteration of a sample than for any dietary signatures.

The potential for using trace elemental composition or abundances as a provenance technique rather than a dietary technique, has only surfaced relatively recently (e.g., Burton, et al., 2003, Cucina, et al., 2004, Cucina, et al., 2011, Knudson and Torres-Rouff, 2009, Knudson and Tung, 2011). Demonstrating that trace element signatures provide anthropogenic rather than diagenetic information is the largest hurdle to this avenue of research. Combining the trace elemental biogeochemical groups with an established isotopic technique used for migration research has proved invaluable in demonstrating useful (i.e., non-diagenetic) chemical variation within both teeth and bones at a microscopic level of analysis.

Providing a systematic assessment of the potentials for analysis of microstructures present within bones and teeth matrix, my research has demonstrated that this approach holds great potential for the future of migration and mobility research. Furthermore, changing the resolution from single skeletal elements to micro-sampling each element for analysis of individual life history has provided a major breakthrough in the types of research questions that can be effectively answered using chemical techniques. These include answers to such queries as those outlined in Chapter 2. Namely, that even with a limited sample size, there is evidence of two general patterns of mobility during the EBA; one involving regular, short-distance residential movements but without significant long-distance movement; and another in which individuals were trekking between the Little Sea, the Upper Lena, and possibly to regions such as Barguzin and the middle Angara. With this window into mobility patterns, it is likely that prehistoric mobility ranges were potentially quite large for some individuals or groups, though some individuals were not particularly mobile and may have lived their lives within the range of a few valleys. This suggests either a large range of variation in inter- and intra-individual mobility, or the presence of multiple mobility strategies within the regional population that could possibly reflect different social or cultural groups within Cis-Baikal. Further analysis will be needed to clarify if such patterning reflects migration rather than movement events. With a limited sample size of primarily teeth, it remains possible that individuals analyzed thus far represent migrants, who were permanent residents in the area they were interred (e.g., Little Sea); however, aside from interment location the results do not provide evidence for permanent relocation, and so are likely individuals who died during social or economic excursions, but were not permanent residents. This is in contrast with the interpretations generally drawn from Sr isotopic data. Traditional inferences would suggest that nonlocal individuals had migrated to the region of their death based on their designation as having been born elsewhere. There are myriad reasons why an individual could end up far from their birth location, migration being only one. Micro-sampled skeletal materials provide sufficient resolution to address questions of mobility rather than simply migration. This is the beginning of an entirely new avenue of research into diagenesis, skeletal microstructure, mobility, and other potential topics.

RELEVANCE FOR SUBSISTENCE, MOBILITY, AND BEYOND

Chemical analysis provides insight into materials (e.g., pottery, lithic, etc.) and prehistoric activities (e.g., mobility) that cannot be determined using such approaches as typological analysis. New and important aspects of h-g adaptions, including dietary patterns, have been elucidated. Based on representative evidence (i.e., carvings) and artifacts, Okladnikov postulated that moose was an important food item, and that Isakovo groups subsisted entirely on game, yet modern dietary analysis demonstrated this to be false (Katzenberg, et al., 2009, Katzenberg and Weber, 1999, Weber, et al., 2002). Stable isotope analysis revealed numerous additional insights and demonstrated that terrestrial and aquatic fauna contributed significantly to the diets of all Neolithic and Bronze Age hunter-gatherers in Cis-Baikal (Katzenberg, et al., 2009, Katzenberg and Weber, 1999, Lam, 1994, Weber, et al., 2002, Weber, et al., 2011). The remarkable discovery was the identification of two dietary patterns among contemporary individuals within the same cemetery (Weber, et al., 2011). Seal bones recovered from habitation sites along the coast of Lake Baikal speak to the harvesting and consumption of seals through multiple cultural phases, yet provide no evidence that individuals interred nearby may not have eaten seal during their adult life (Novikov, et al., 2007, 2008). Chemical analysis was necessary to identify this cultural pattern tied to mobility.

Mobility

Mobility research has experienced similar changes and new insights. Mobility and migrations were not discussed for the Cis-Baikal region during the Neolithic and

Bronze Age, neither by Okladnikov nor by his Russian followers until BAP scholars brought this important matter into research focus. Russian scholars argued that cultural changes were the result of *in situ* developments and the homogeneity of the material culture suggested limited exchange of people within and between regions. Limited evidence of changing burial practices and prestige goods (e.g., nephrite) that frequently traveled great distances provided the only clues that people, goods, or ideas were moving around. Thus the identification of numerous individuals at KNXIV who were born outside of the micro-region was rather surprising.

Based primarily on dietary data, Weber hypothesized the movement of people between the Little Sea and Upper Lena regions (Weber, et al., 2011). Multiple individuals analyzed in Chapter 5 were identified as being involved in this movement. Given the nature of the archaeological record, this is was a critical discovery. The geochemical research on mobility conducted for this dissertation (Chapter 5) confirmed the movement between these micro-regions and further supported the asymmetry of this pattern. In spite of similar material culture and burial practices throughout the micro-regions, thus far, no evidence supports significant population movement and exchange occurring between the Angara–Upper Lena, Angara–Little Sea, and from the Little Sea to the Upper Lena (Haverkort, et al., 2010, Haverkort, et al., 2008, Weber, et al., 2003, Weber, et al., 2011). One individual from Khotoruk (Chapter 5; KHO_Grave on the Mountain) appears to have lived in a region bordering both the Angara and Little Sea micro-regions and represents the only individual to have moved from anywhere near the Angara drainage to the Little Sea.

This research has focused on a relatively small number of individuals. The overall goal of the methodological improvements outlined and tested herein, is to study mobility patterns in prehistory. Unfortunately, with a small sample size, it is difficult to draw general conclusions regarding prehistoric mobility patterns. Thus, while detailed understanding of the movements of select individuals has been established, further work involving larger cemeteries will be necessary prior to significant discussions of mobility patterns in a regional context.

Kinship

The potential resolution of the new mobility data is such that inferences on kinship patterns could be addressed with larger datasets, a topic that has been very challenging to address archaeologically. The sample size of individuals from small cemeteries (Chapter 5) is limited, so clear conclusions cannot be drawn; however, the results are very intriguing. Exogamous kinship structures appear to be omnipresent during the EBA and likely during the LN as well. The few individuals analyzed so far from the EN appear to be significantly less mobile than those from the EBA. Further research is necessary, but it seems plausible that this is the first evidence to support differences in kinship structure between EN and LN–EBA populations. Weber and colleagues (2002, 2011) suggested differences in population density, distribution, and their provisioning, so reduced individual mobility during the EN confined within a micro-region further supports the likelihood that EN groups had an endogamous kinship structure.

Chapter 4 provides a first look at adult mobility patterns, and the possibility of bone data overlapping with sub-adult molar data for some individuals (e.g., individuals under age 30). Geochemical analysis of human molars limits discussions of mobility to sub-adulthood. Adult mobility patterns can be inferred using M1 (~0-3 years) as a proxy measure for the nursing mother, but are otherwise beyond direct reach. Children can generally be assumed to not travel alone, but will be accompanied by adults. M2 (~2-7 years) could be viewed as a proxy of the family group as the child will likely not yet be old enough to participate in major movements without family members. Furthermore, M3 (~7-12 years) could be viewed as a proxy of apprentice/adult (e.g., son/father) relationships and movements as the individual will be old enough to be an adult-in-training (participating in hunts), whether the learning pattern is through peers or through adult teachers. This allows for possible inferences to be drawn about different aspects of group movement relative to a single individual, but will not provide direct data on these matters.

Analyzing bone is full of potentials and pitfalls, providing the sole direct source of adult activities and misleading data if not carefully handled. Individuals from KNXIV analyzed in the bone micro-sampling pilot study showed multiple movements. The estimated timeframes reflected by individual osteons suggests that these were residential movements. Individuals remained in geochemically similar areas for long enough to completely shift their body water composition and bone composition. The frequency of these moves supports the results for EBA mobility patterns demonstrated in Chapter 5 namely that small residential groups were quite mobile and did not always remain close to productive fisheries (e.g., Angara, Little Sea).

The patterns of movement identified throughout these studies have also highlighted the importance of explanatory structure. As mentioned, the bioarchaeology of individual life history has been a strongly technologically driven approach to archaeological sciences; however, it is becoming increasingly evident that equal attention needs to be given to theoretical developments to ensure that adequate explanatory frameworks are available to interpret these entirely new kinds of data sets. Using new results to verify previous hypotheses is a laudable goal, but the power of these data seems to go far beyond this and to inform on previously unattainable aspects of past human behavior and interactions.

NEW FRONTIERS OF RESEARCH: BEYOND CIS-BAIKAL

The impact of the geochemical examination of the relatively few individuals from several middle Holocene cemeteries belies the great relevance and importance of continuing this avenue of research and extending it to the larger cemeteries that have received greater attention from BAP scholars (e.g., KNXIV, Kurma XI, Ust'-Ida, Lokomotiv, Shamanka II). The cumulative nature of scientific research will certainly yield worthwhile dividends as vastly increased understanding of prehistoric mobility and migration patterns becomes available for large numbers of individuals. This fact has already been demonstrated with the intensive dietary and chronological research conducted for Cis-Baikal and will hopefully yield equally intriguing actions within Cis-Baikal during the Middle Holocene including, perhaps, interactions with the greater Siberian and pan-Asian world.

Suggestions that Cis-Baikal was integrated into larger spheres of influence and cultural exchange have been made at various times since Okladnikov first published his comprehensive synthesis in the 1950s. Noted most often, have been similarities in stylistic artifacts (pottery, lithics, and metal). Authors such as Anthony (2007), Bobrov (1988), Chernykh (1992), Koryakova and Epimakhov (2007), and Vajda (2001, 2009) have specifically noted similarities between various Cis-Baikal "cultures" and those further west. The most observable connection has been through the recovery of nephrite artifacts as far away as Omsk, West Siberia, and the Borodino hoard in the Carpathian Mountains west of the Black Sea.

Nephrite is the most obvious of artifacts to be associated with inter-regional connections, due to its limited availability in specific locales near Lake Baikal, China and Central Asia. Scholars have mentioned a Nephrite, or Jade, Road that connected China with parts of Eurasia during the Bronze Age as a precursor to the later Silk Road, however this East-West movement is likely different from the connections linking Lake Baikal to other regions. Nephrites in Borodino (Moldavia) and Rostovka (Omsk, Siberia) were specifically attributed to Lake Baikal rather than other potential sources and were contemporaneous with EBA groups in Cis-Baikal. Interestingly, from the descriptions, axes/adzes at Borodino were likely green nephrite from the Eastern Sayan Mountains (west of Lake Baikal) while those at Rostovka and nearby Lebedi II were likely white nephrite from the Vitim volcanic fields in Trans-Baikal (northeast of Lake Baikal) (Anthony, 2007, Chernykh, 1992, Chernykh, et al., 2004, Koryakova and Epimakhov, 2007, Sekerin and Sekerina, 2000).

There is some discussion that as many as five or more nephrite sources are located within Cis- and Trans-Baikal (R. Losey, personal communication). Multiple distinct materials sources would greatly aid in identifying the origins and movement of artifacts both within the Lake Baikal region and areas abroad, however this will require further research. Without directly sourcing of these nephrite objects, it is difficult to be certain of their origins and the pathways that brought them to their archaeological sites. Nevertheless, these finds still present some interesting questions. As noted in Chapter 5, there were people moving between the Little Sea and the Upper Lena, possibly as far from Lake Baikal as Ust'-Ilimsk on the Angara or further, some of whom were buried with white nephrite. Thus, it is plausible that individuals from within northern and western Cis-Baikal were in contact with contemporary groups such as the Afanasevo to the west in Tuva, Minusinsk, and the confluence of the Angara and Yenisei Rivers. What is intriguing about this flow of goods is that thus far there is no solid evidence for significant movement of people between the Lower Angara or South Baikal on one side and either the Upper Lena or the Little Sea on the other. Green nephrite from the Lower Angara micro-region may not have been exchanged northward or following the Angara River. If the movement of nephrite followed the movement of people, then perhaps green nephrite objects from southern Cis-Baikal were exiting the region through Mongolia.

Weber et al. (2011) suggested possible contacts between South Baikal and the lower Selenga River in Trans-Baikal or Lake Khovs'gol in Northern Mongolia. The Selenga flows out of Northern Mongolia, into Southern Trans-Baikal and into Lake Baikal. During the EN, it appeared that multiple individuals from both Lokomotiv and Shamanka II had grown up on well-developed rivers much like the Selenga. Further mobility research will test this argument, but current evidence provides circumstantial evidence for contacts with Trans-Baikal and ultimately with Mongolia and the northern peripheries of what would later be the Xiongnu and Chinese spheres of influence. The postulated existence of trade networks connecting China to Western Asia and Eastern Europe through the deserts of Mongolia and Central Asia during the Bronze Age could indicate a second avenue of inter-regional contact with Lake Baikal.

Current evidence suggesting contact between the Selenga with Cis-Baikal during the EBA is limited to genetic evidence linking EBA burials at Ust'-Ida most closely to a Mongolian (Xiongnu era) necropolis located in Northern Mongolia on the Egyin Gol River, approximately 10 km from its confluence with the Selenga River (Keyser-Tracqui, et al., 2003). This suggests a measure of continuity in genetic population and inter-regional contacts between Northern Mongolia, the Selenga River and the Angara River, minimally beginning in the EBA and extending towards the Iron Age. The hypothesized contacts during the EN would suggest a far earlier beginning of this inter-regional contact and the possible interaction between populations that would later become the Serovo and Glazkovo in Cis-Baikal and the earlier morphologically, genetically and probably linguistically different Kitoi populations. Demonstration of this contact and movement seems likely given the verification of previous arguments proposed by Weber using geochemical data (Weber, et al., 2011). Aside from all archaeological data, there is, of course, no reason why such contacts should not exist at any point of the region's long prehistory.

Genetic evidence has also suggested that the Kitoi were most closely related to the extant Ket of Central/Northern Siberia (Mooder, 2008, Mooder, et al., 2003, 2006, 2005). Oral traditions for the Ket hold that they once lived further south, near the confluence of the Angara and Yenisei Rivers, but were driven northwards by hostile settlers with horses (likely Turkic speaking groups) (Vajda, 2001, 2008, 2009). Linguistic relics of populations ancestral to the Ket can be found in river and place names far south of their historical range. In the 16th Century, when Cossack troops, followed later by Russian traders, entered Central and Eastern Siberia, even in areas populated by Turkic speaking groups, Ket or Yeniseic linguistic markers were present in areas near the middle and lower reaches of the Angara and immediately west of the boundaries of Cis-Baikal (Vajda, 2009). Thus, it seems plausible that the population known as Kitoi while in Cis-Baikal continued to inhabit areas of the middle and lower Angara drainage after ending their cemetery traditions within Cis-Baikal.

Further evidence of contact between Kitoi descendants and agro-pastoral steppe groups can be found in the material cultures of the Afanasevo and Seima-Turbino Cultures in the Minusinsk Basin and the Altai Mountains. Metalworking in Siberia has an uncertain start date, with some of the earliest instances found in Cis-Baikal and in the Altai roughly contemporary with Afanasevo groups (Anthony, 2007, Chernykh, 1992, Chernykh, et al., 2004, Koryakova and Epimakhov, 2007). The likely source for these technologies is in the southern Altai, slightly earlier than cases found further north and east. Afanasevo groups previously had been attributed as the technological source due to similarities between their material culture and other steppe-pastoralist groups in northern Eurasia.

The odd part of collections were the lithic technologies that were dissimilar to any other steppe group known from Europe, Central Asia, Western Siberia or the Eurasian steppe zone. The closest similarities were found in Lake Baikal with Okladnikov's (1950, 1955) descriptions of primarily Kitoi material culture which he dated, erroneously, to the LN rather than the EN, the chronological position firmly established by extensive radiocarbon dates. Projectile points, compound lithic tools utilizing hafted micro-blades, wooden and bone socketing styles, unique composite fishhooks, as well as extremely rare bone plate armor were found in conjunction with nephrite rings and beads at sites like Lebedi II (Chernykh, 1992, Chernykh, et al., 2004). Also found at Lebedi II were numerous moose head carvings on pendants and on bone tools and bear-tooth pendants reminiscent of Kitoi grave goods in South Baikal.

Given that similarities were drawn predominantly from Okladnikov's work with Kitoi material culture cited as analogous but with errant chronological determinations, it seems quite likely that Afanasevo, or related, groups were in contact with the descendants of the Kitoi living either along the Angara or Yenisei Rivers and surrounding areas. The majority of technological similarities relate to widely available materials, but the working of and access to nephrite raises a few questions: Did populations related to the Kitoi continue to access nephrite sources near Lake Baikal? Were they in contact with new populations in Cis-Baikal? Or, were objects found in the Altai and further away on the steppes hoarded or conserved goods brought by Kitoi groups and subsequently exchanged or taken by new neighbors?

The exchange of goods and ideas was not simply an outflow from Cis-Baikal to surrounding regions, overland, following the Angara, or possibly following the Selenga into Mongolia. New burial practices show up in LN–EBA (Serovo-Glazkovo), for example at the KNXIV cemetery. Burials 7, 24, 34, and 51 all appear to have been interred with their knees elevated, a style without local precursors and nearly identical to burial practices seen throughout the steppes in kurgans and other Neolithic and Bronze Age cemeteries from Eastern Europe and eventually far into Trans-Baikal and Eastern Siberia (Anthony, 2007, Weber, et al., 2008, Weber, et al., 2007). Burials 9, 22, 55, and 58 may also have been interred in this fashion, but with less certainty of the elevation of the knees. Burials 7, 51, and 55 have dietary and Sr data from previous analyses. Individual 7 has GF diet and Sr indicative of residence in the Upper Lena. Individuals 51 and 55 both had GFS diet and Sr values suggestive of being native to Ol'khon Island or a part of the Little Sea not adjacent to the KNXIV cemetery or the southern half of the Little Sea coast that has extremely high Sr isotope ratios values. Even moderated by consumption of aquatic resources, the exceptionally high Sr values from these areas would not be masked. Burials 9 and 24 both contained nephrite artifacts that can be linked to intra- and inter-regional movements of people though the significance of these artifacts is uncertain. Finally, there is evidence of metallurgy, likely not an *in situ* development, rather an imported technology in the form of finished artifacts or the production methods themselves. Certainly, by the later portion of the EBA and the Middle Bronze Age, Cis- and Trans- Baikal would become involved in the technological development and production of metal goods; however, the early vestiges of this are uncertain at present.

FINAL REMARKS

While many of the connections, contacts and research directions mentioned above may prove difficult to follow up or verify, the methods outlined and tested in this thesis certainly provide the means to establish where the people themselves were moving. This research has demonstrated the correction methods necessary to enable effective laser ablation micro-sampling of tooth enamel, effectiveness and promising results of micro-sampling of bone micro-structures, and that these methods are effective in provenancing individuals relative to the new geochemical reference map. This can be combined with systematic geochemical research on human materials and provenancing of different artifact types (i.e., nephrite and metal objects) to provide clearer linkages between different groups at different points in time and space. With the tools to track human movement and artifact movement, researchers can better assess whether materials are being carried and exchanged directly or indirectly via inter-regional networks. Establishing the nature of local trade and cultural exchange networks, and the chronology of these networks is crucial to understanding how groups in Cis-Baikal may have interacted in the larger Pan-Asian world during the Neolithic and Bronze Age. Questions such as these will be addressed in part as larger cemeteries are analyzed using the new methods. The impacts of new technological developments (e.g., examination of H, S, and O isotopes), chemical analysis of different artifact classes and further examination of links to cultural groups and regions outside of Cis-Baikal will likely be as important as the impacts of BAP research have been to date.

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Appendix A: Solution mode 87Sr/86Sr ratios and elemental data for KN XIV teeth. Local/Nonlocal determinations from Haverkort et al. 2008.

Burial	Sample #	Tooth	^{87}Sr/^{86}Sr	2σ error	Li	Be	B	Na	Mg	Al	P	Ca	Ti	V	Cr	Mn
7	1997.211	M2	0.71075	0.000023	0.63	0.05	4.10	4701.5	1637.3	73.8	100564	219178	2.82	4.47	0.38	8.68
12	1997.217	M2	0.71320	0.000026	0.57	0.02	10.51	6572.0	2077.0	69.4	167574	340542	3.23	3.70	0.55	5.37
16	1997.225	M3	0.71329	0.000019	0.49	0.00	9.37	8344.9	3085.5	16.2	174015	342816	2.57	3.25	0.94	41.14
35.1	1998.355	M2	0.71080	0.000023	0.72	0.01	7.19	7667.8	2617.2	36.9	192947	407889	2.99	3.30	0.77	7.66
35.2	1998.359	M2	0.71054	0.000031	0.57	0.00	4.57	6431.1	2176.9	13.0	161437	342590	2.89	1.33	0.25	4.35

Burial	Fe	Cu	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ru	Pd	Ag
7	1070.68	0.36	81.90	0.57	0.01	0.57	0.02	114.65	1.83	0.08	0.07	0.01	0.09	0.22	0.03	0.01
12	1493.29	0.54	105.14	0.74	0.01	0.09	0.10	167.86	0.44	0.19	0.19	0.15	0.29	0.26	0.08	0.04
16	1449.09	0.89	59.29	0.75	0.01	0.08	0.13	190.18	0.51	0.33	0.39	0.12	0.37	0.22	0.06	0.03
35.1	1737.76	0.52	89.10	0.81	0.01	0.06	0.03	193.02	0.74	0.15	0.15	0.08	0.23	0.26	0.05	0.02
35.2	1414.44	0.34	97.90	0.73	0.01	0.06	0.03	103.17	0.18	0.07	0.08	0.03	0.21	0.14	0.02	0.01

Burial	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
7	0.04	0.03	0.02	0.00	18.52	4.55	25.23	0.60	2.02	0.29	0.07	0.28	0.03	0.14	0.03	0.08
12	0.03	0.18	0.34	0.01	174.01	0.49	0.41	0.09	0.32	0.05	0.06	0.05	0.01	0.03	0.01	0.02
16	0.04	0.38	0.18	0.00	172.40	0.45	0.21	0.07	0.26	0.04	0.06	0.05	0.01	0.03	0.01	0.02
35.1	0.03	0.09	0.12	0.00	193.71	0.80	0.48	0.13	0.52	0.08	0.07	0.08	0.01	0.05	0.01	0.03
35.2	0.01	0.06	0.05	0.00	76.75	0.17	0.15	0.03	0.11	0.02	0.03	0.02	0.00	0.01	0.00	0.01

Burial	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Pt	Au	Tl	Pb	Th	U	Little Sea Origin
7	0.01	0.06	0.01	0.02	0.01	0.03	0.00	0.01	0.00	0.06	0.00	0.27	2.34	0.07	Nonlocal
12	0.00	0.01	0.00	0.12	0.12	0.38	0.01	0.04	0.01	0.30	0.07	0.08	0.21	0.02	Local
16	0.00	0.01	0.00	0.17	0.11	0.28	0.01	0.03	0.01	0.25	0.04	0.14	0.20	0.02	Local
35.1	0.00	0.02	0.00	0.09	0.07	0.17	0.00	0.03	0.01	0.19	0.02	0.05	0.09	0.01	Nonlocal
35.2	0.00	0.01	0.00	0.03	0.03	0.08	0.00	0.01	0.00	0.08	0.01	0.06	0.03	0.00	Nonlocal

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Li	Be	B	Na	Al	Si	P	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Cu
97211_100_A	0.36	0.21	1.08	3650	241.2	207.2	64028	222294	0.09	4.27	2.88	1.01	35.3	112.8	0.33	0.53
97211_80_A	0.49	0.60	1.22	3548	43.9	117.7	63295	237604	0.16	1.69	2.99	0.72	9.6	57.9	0.08	0.34
97211_55_A	0.65	2.02	1.23	3653	6.41	104.6	61442	236212	0.38	4.81	3.11	1.62	4.2	42.4	0.12	0.69
97211_40_A	0.30	1.05	3.77	3716	47.9	146.6	64487	234468	0.44	5.07	2.47	2.11	12.8	52.5	0.12	0.93
97211_25_A	1.08	7.14	7.20	3815	18.7	403.1	65676	264531	1.99	21.4	3.50	9.87	9.9	44.1	0.82	4.10
97211_100_B	0.45	0.46	0.79	3658	21.5	104.3	58902	218526	0.08	0.85	2.60	0.88	5.8	55.8	0.07	0.24
97211_80_B	0.41	0.20	1.58	3725	25.7	55.4	61789	233482	0.16	1.47	2.39	1.00	6.0	58.2	0.07	0.25
97211_55_B	0.44	1.37	1.06	3742	39.4	120.3	59195	230186	0.33	4.78	2.81	1.52	9.3	50.6	0.13	0.61
97211_40_B	0.28	2.56	2.36	3569	75.0	83.0	59179	225281	0.45	5.90	1.69	2.12	14.6	66.0	0.16	0.91
97211_25_B	1.44	2.68	4.11	3175	265.4	476.9	53285	195904	1.37	15.2	1.90	7.14	31.6	128.4	0.61	3.09
97211_100_C	0.50	0.05	1.31	3650	14.9	101.7	55783	214246	0.08	0.66	2.25	1.05	5.9	54.4	0.04	0.21
97211_80_C	0.36	0.25	1.11	3642	21.5	69.4	57419	228728	0.15	1.82	2.37	1.44	7.6	53.5	0.20	0.30
97211_55_C	0.40	2.56	1.09	3608	35.9	135.8	55749	210288	0.26	2.65	2.11	1.18	11.7	50.5	0.11	0.41
97211_40_C	0.67	3.48	1.83	3416	43.0	129.5	54202	203894	0.45	4.25	2.10	2.28	16.7	59.8	0.16	0.93
97211_25_C	0.19	3.63	3.78	3474	95.0	287.0	55328	210874	1.48	17.6	1.53	7.03	23.6	78.3	0.33	2.68
97211_100_D	0.34	0.36	1.01	4132	19.1	101.3	51667	201906	0.10	0.82	2.20	0.93	10.0	51.1	0.13	0.16
97211_80_D	0.52	1.04	0.83	4204	37.8	95.7	58098	225548	0.19	1.53	1.94	0.75	9.8	49.5	0.12	0.25
97211_55_D	0.32	0.18	1.56	4010	51.8	129.6	55034	214956	0.29	2.74	1.94	1.70	15.9	65.9	0.16	0.52
97211_40_D	0.60	2.17	1.15	4147	63.0	156.8	56970	223171	0.43	4.14	2.28	2.25	43.3	83.7	0.33	0.93
97211_25_D	1.56	6.97	4.17	4207	148.6	272.6	55209	202297	1.41	17.1	2.01	6.81	214.2	161.5	2.09	2.78
97211_100_E	1.10	7.93	3.15	3895	10.1	154.1	48036	199831	0.88	8.08	3.12	4.24	1.5	41.3	0.39	1.39
97211_80_E	1.37	11.9	5.69	4216	392.2	403.7	49274	190208	1.95	15.3	1.96	8.88	26.4	122.1	0.83	2.89
97211_55_E	3.13	33.7	17.6	3802	1018.7	850.4	49334	169428	4.42	33.2	4.45	22.4	444.5	247.1	4.88	6.95
97211_40_E	5.44	23.8	22.8	4827	1198.3	1125.6	43453	166217	5.23	57.2	5.80	26.8	205.1	194.0	10.1	7.29
97211_25_E	26.0	160.2	59.5	5311	2086.0	4583.9	48566	190663	20.4	242.1	23.4	116.4	829.5	611.9	13.3	41.0
97211_100_F	0.35	2.80	1.20	3804	273.2	75.3	41279	155721	0.44	4.44	3.33	1.91	12.2	99.0	0.19	0.51
97211_80_F	1.20	2.12	3.89	3780	190.4	323.5	41964	167565	1.28	18.3	2.60	7.42	48.8	126.3	0.59	2.24
97211_55_F	1.81	0.00	9.57	3236	452.1	434.7	36926	147314	2.18	14.3	3.06	11.3	16.0	283.8	0.96	2.15
97211_40_F	1.78	5.31	6.65	2219	460.7	452.4	25899	100775	2.15	25.2	2.39	12.0	16.7	144.9	0.94	3.17
97211_25_F	4.18	17.9	12.3	1287.2	357.7	739.6	12963	44550	4.64	32.4	4.11	19.4	7.0	97.0	1.33	5.05
97211_100_G	0.51	1.31	1.58	3620	176.8	54.2	37093	147174	0.25	2.54	3.73	1.44	115.2	82.6	0.72	0.46
97211_80_G	0.30	0.45	1.18	2541	275.9	214.8	25103	100286	0.44	4.43	1.99	2.98	20.6	137.2	1.14	0.76
97211_55_G	2.77	12.9	6.89	2854	332.0	281.5	31469	129221	1.35	16.7	4.33	7.94	33.6	191.6	0.79	1.93
97211_40_G	1.84	0.00	6.83	2511	281.7	438.2	31200	117070	2.03	25.3	2.49	11.8	81.7	165.5	2.73	3.07
97211_25_G	0.00	19.0	6.33	2013	1399.9	535.6	16875	56438	2.56	30.7	2.81	14.3	238.6	309.8	4.20	4.31
97211_100_H	0.57	0.28	1.17	4637	262.3	84.2	46826	184186	0.39	5.41	3.66	1.95	353.3	171.4	10.1	0.57
97211_80_H	0.63	5.88	3.18	5196	692.5	354.3	53934	205958	1.08	9.20	2.70	5.62	315.0	193.5	7.32	1.73
97211_55_H	2.43	12.4	10.2	5194	833.2	450.1	54287	207797	2.14	23.2	3.04	12.6	504.3	388.3	7.08	3.39
97211_40_H	3.53	67.2	42.2	4132	946.7	3006.5	46712	206639	13.4	150.5	12.7	71.7	174.5	324.3	4.31	22.8
97211_25_H	21.2	92.1	72.7	3926	2336.83	3143.4	39578	170792	14.0	184.6	14.0	86.0	67.1	1350.0	8.11	24.6
97217_100_A	0.30	0.05	1.25	5323	4.03	87.9	73633	288065	0.10	1.05	1.29	1.17	1.2	86.8	0.52	0.44
97217_80_A	0.23	0.25	1.30	5153	2.83	75.3	78360	301801	0.19	1.32	1.11	0.89	1.2	81.1	0.13	0.27
97217_55_A	0.16	2.23	2.63	5178	0.84	188.5	76339	301185	0.39	4.09	0.83	2.03	1.4	68.0	0.16	0.62
97217_40_A	0.76	4.03	3.13	5337	1.83	131.7	78018	310309	0.82	5.57	0.67	3.75	0.9	77.8	0.29	1.05

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ag	Cd	In	Sn	Sb
97211_100_A	111.0	0.29	0.06	0.26	0.11	97.8	0.64	0.12	0.20	0.01	0.13	0.05	0.12	0.01	0.17	0.03
97211_80_A	87.4	0.28	0.12	0.59	0.10	99.1	0.20	0.03	0.03	0.01	0.19	0.03	0.12	0.02	0.13	0.03
97211_55_A	78.3	0.21	0.35	1.08	0.26	99.7	0.03	0.06	0.77	0.09	0.31	0.04	0.35	0.02	0.16	0.10
97211_40_A	86.5	0.23	0.43	1.33	0.29	99.8	0.25	0.10	0.53	0.05	0.47	0.15	0.65	0.06	0.32	0.11
97211_25_A	82.7	1.40	2.42	8.53	1.53	113.0	0.21	0.45	3.81	0.31	2.68	0.69	0.76	0.32	1.14	0.98
97211_100_B	58.7	0.16	0.06	0.25	0.05	98.9	0.10	0.02	0.09	0.01	0.13	0.03	0.05	0.01	0.10	0.03
97211_80_B	54.6	0.20	0.18	0.51	0.12	99.7	0.09	0.06	0.21	0.04	0.16	0.03	0.14	0.02	0.23	0.04
97211_55_B	45.2	0.23	0.36	1.21	0.23	99.6	0.14	0.02	0.22	0.06	0.27	0.13	0.23	0.02	0.22	0.13
97211_40_B	61.2	0.36	0.37	1.29	0.32	98.1	0.47	0.14	0.36	0.03	0.42	0.11	0.43	0.03	0.29	0.27
97211_25_B	63.2	0.99	1.82	4.97	1.10	90.6	1.46	0.40	2.61	0.28	2.98	0.51	2.47	0.06	0.95	0.76
97211_100_C	46.0	0.17	0.07	0.30	0.05	94.5	0.07	0.02	0.08	0.02	0.12	0.03	0.10	0.01	0.11	0.02
97211_80_C	50.7	0.16	0.11	0.54	0.09	93.4	0.12	0.02	0.11	0.03	0.14	0.06	0.10	0.02	0.12	0.05
97211_55_C	47.5	0.23	0.31	1.02	0.16	89.7	0.27	0.05	0.35	0.03	0.35	0.06	0.38	0.03	0.16	0.11
97211_40_C	56.5	0.25	0.50	1.46	0.28	88.4	0.56	0.04	0.44	0.06	0.30	0.11	0.65	0.07	0.25	0.23
97211_25_C	63.1	0.67	1.15	5.52	0.95	91.6	1.29	0.54	1.63	0.26	2.09	0.34	1.78	0.26	0.92	0.58
97211_100_D	31.9	0.18	0.06	0.23	0.04	95.0	0.15	0.03	0.10	0.01	0.11	0.03	0.03	0.01	0.16	0.03
97211_80_D	36.8	0.15	0.16	0.69	0.09	98.3	0.10	0.03	0.34	0.01	0.11	0.04	0.20	0.01	0.18	0.05
97211_55_D	49.0	0.33	0.24	1.07	0.19	94.4	0.30	0.11	0.50	0.04	0.19	0.04	0.36	0.06	0.19	0.08
97211_40_D	63.0	0.26	0.51	1.42	0.31	100.4	0.37	0.09	0.41	0.06	0.59	0.16	0.76	0.08	0.32	0.14
97211_25_D	88.5	0.86	1.58	4.82	0.85	98.2	1.08	0.29	1.85	0.14	1.00	0.64	1.88	0.25	0.98	0.19
97211_100_E	22.1	0.44	0.69	2.20	0.50	115.8	0.11	0.16	1.47	0.11	1.26	0.29	1.22	0.09	0.66	0.34
97211_80_E	25.3	1.32	2.24	6.29	1.14	114.9	1.93	0.34	1.56	0.47	1.20	0.76	2.23	0.27	0.97	1.02
97211_55_E	68.4	2.29	5.01	13.0	2.81	108.6	3.74	1.76	5.07	0.77	3.88	1.01	2.96	0.43	2.11	2.34
97211_40_E	59.3	2.61	5.47	19.0	3.94	102.1	4.43	2.36	7.56	0.94	4.73	2.77	6.23	0.83	3.45	1.09
97211_25_E	145.6	11.0	25.9	93.0	15.2	124.9	7.6	10.2	20.7	5.4	22.4	10.2	24.0	2.5	13.3	11.6
97211_100_F	29.7	0.45	0.42	0.86	0.27	98.8	1.07	0.18	0.72	0.02	0.55	0.15	0.66	0.02	0.28	0.08
97211_80_F	17.5	0.74	0.93	4.22	0.81	110.8	2.20	0.29	2.98	0.50	1.03	0.76	1.54	0.26	1.24	0.43
97211_55_F	17.8	0.84	2.42	5.82	1.50	111.9	3.57	0.44	1.99	0.43	0.47	0.57	3.26	0.42	1.48	0.91
97211_40_F	22.7	1.49	2.28	6.60	1.54	88.0	2.89	0.77	2.75	0.30	1.94	0.55	2.24	0.24	1.98	1.40
97211_25_F	28.1	2.29	4.00	13.6	2.81	65.2	1.75	0.52	4.32	0.84	4.07	2.24	2.60	0.39	2.14	1.45
97211_100_G	21.5	0.27	0.26	1.37	0.16	103.6	1.18	0.10	0.23	0.09	0.31	0.08	0.19	0.03	0.20	0.07
97211_80_G	15.1	0.34	0.42	2.25	0.32	83.6	1.93	0.11	0.83	0.07	0.64	0.14	0.55	0.11	0.38	0.05
97211_55_G	11.7	0.98	1.58	4.60	0.96	108.3	3.67	0.42	1.30	0.34	1.74	0.53	1.41	0.19	1.26	0.42
97211_40_G	19.1	1.45	2.56	6.75	1.38	102.3	1.60	0.31	3.33	0.41	1.64	0.78	4.02	0.33	1.39	1.06
97211_25_G	19.3	1.30	2.43	9.05	1.86	92.3	3.72	1.11	3.31	0.30	1.80	0.67	1.89	0.35	2.22	1.05
97211_100_H	24.3	0.35	0.41	1.45	0.25	101.6	1.25	0.11	0.51	0.08	0.55	0.15	0.41	0.06	0.33	0.11
97211_80_H	28.9	0.77	1.19	3.52	0.70	108.5	2.75	0.22	1.75	0.34	1.56	0.41	0.52	0.15	0.88	0.55
97211_55_H	55.7	1.13	2.39	5.99	1.56	108.6	3.88	1.23	2.76	0.32	4.31	1.06	1.70	0.11	2.50	0.94
97211_40_H	88.1	7.62	15.7	43.8	8.79	131.1	5.01	2.52	11.5	1.74	8.83	4.69	15.9	1.39	7.67	3.61
97211_25_H	106.7	9.6	14.7	65.9	10.0	199.9	23.3	4.6	14.8	2.3	19.8	7.0	11.9	2.5	11.7	4.7
97217_100_A	54.8	0.62	0.08	0.22	0.11	113.4	0.01	0.04	0.11	0.01	0.10	0.03	0.07	0.01	0.23	0.04
97217_80_A	60.3	0.47	0.18	0.70	0.10	113.6	0.02	0.02	0.22	0.03	0.24	0.03	0.13	0.02	0.14	0.07
97217_55_A	61.8	0.43	0.37	1.27	0.28	113.7	0.10	0.08	0.64	0.10	0.29	0.19	0.51	0.04	0.33	0.29
97217_40_A	52.9	0.38	0.79	2.15	0.40	113.5	0.03	0.15	1.16	0.14	0.73	0.34	1.19	0.12	0.57	0.42

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
97211_100_A	0.01	31.9	2.48	2.59	0.39	1.35	0.18	0.05	0.13	0.02	0.11	0.02	0.03	0.00	0.04	0.01
97211_80_A	0.02	27.7	1.11	0.47	0.13	0.54	0.09	0.02	0.06	0.01	0.05	0.01	0.02	0.01	0.05	0.01
97211_55_A	0.04	26.2	0.08	0.06	0.02	0.10	0.28	0.04	0.08	0.02	0.15	0.05	0.11	0.03	0.02	0.02
97211_40_A	0.05	29.1	1.06	0.45	0.19	0.38	0.33	0.05	0.13	0.03	0.19	0.05	0.08	0.04	0.09	0.06
97211_25_A	0.26	28.3	0.47	0.19	0.15	0.67	1.39	0.37	0.41	0.21	0.23	0.13	0.27	0.16	0.86	0.23
97211_100_B	0.01	26.2	0.38	0.30	0.06	0.13	0.07	0.01	0.02	0.00	0.03	0.01	0.01	0.01	0.02	0.01
97211_80_B	0.03	25.9	0.45	0.32	0.09	0.23	0.15	0.03	0.05	0.01	0.07	0.01	0.02	0.01	0.03	0.01
97211_55_B	0.03	27.1	0.78	0.40	0.12	0.39	0.12	0.03	0.07	0.03	0.10	0.03	0.07	0.02	0.08	0.03
97211_40_B	0.06	28.4	1.90	1.36	0.28	1.10	0.31	0.07	0.27	0.02	0.17	0.04	0.12	0.03	0.11	0.02
97211_25_B	0.16	32.3	6.98	3.72	1.45	4.66	1.25	0.25	0.55	0.11	0.58	0.08	0.42	0.03	0.39	0.15
97211_100_C	0.01	23.1	0.48	0.30	0.07	0.15	0.05	0.02	0.02	0.00	0.03	0.01	0.02	0.01	0.02	0.01
97211_80_C	0.01	23.2	0.57	0.30	0.08	0.36	0.12	0.02	0.06	0.01	0.06	0.02	0.05	0.01	0.07	0.01
97211_55_C	0.02	25.2	1.10	0.51	0.11	0.45	0.17	0.03	0.08	0.02	0.09	0.02	0.04	0.03	0.10	0.02
97211_40_C	0.04	25.5	1.96	0.95	0.35	0.63	0.51	0.04	0.16	0.04	0.20	0.06	0.10	0.03	0.20	0.04
97211_25_C	0.15	28.1	3.11	1.41	0.49	1.62	1.29	0.22	0.78	0.16	0.31	0.19	0.23	0.13	0.51	0.11
97211_100_D	0.01	23.2	0.76	0.38	0.11	0.40	0.11	0.01	0.03	0.00	0.03	0.01	0.02	0.01	0.02	0.01
97211_80_D	0.01	23.9	0.39	0.19	0.06	0.21	0.12	0.03	0.04	0.01	0.05	0.02	0.03	0.01	0.04	0.01
97211_55_D	0.04	26.0	1.44	0.72	0.20	0.77	0.26	0.04	0.08	0.02	0.09	0.02	0.05	0.02	0.04	0.03
97211_40_D	0.04	29.8	2.28	1.02	0.51	1.42	0.39	0.04	0.12	0.05	0.15	0.06	0.13	0.03	0.12	0.03
97211_25_D	0.24	33.6	6.87	6.91	0.96	3.91	1.25	0.19	0.58	0.14	0.19	0.14	0.18	0.02	0.22	0.12
97211_100_E	0.14	27.6	0.27	0.14	0.06	0.36	0.48	0.11	0.46	0.06	0.33	0.12	0.20	0.10	0.31	0.10
97211_80_E	0.24	35.4	5.16	2.97	1.26	4.82	1.88	0.17	0.76	0.09	0.80	0.13	0.42	0.17	0.20	0.18
97211_55_E	0.51	49.2	9.96	6.19	1.51	5.06	4.03	0.75	1.42	0.37	2.24	0.68	0.68	0.39	0.49	0.53
97211_40_E	0.82	46.2	9.84	8.43	2.60	11.0	4.54	0.79	1.73	0.37	1.93	0.64	0.82	0.54	2.58	0.41
97211_25_E	3.15	81.8	18.3	23.6	2.48	24.1	16.2	1.52	5.80	1.23	6.48	2.27	1.37	1.81	6.10	2.35
97211_100_F	0.05	33.1	3.90	1.91	0.81	2.70	0.57	0.13	0.25	0.06	0.20	0.05	0.09	0.04	0.14	0.06
97211_80_F	0.26	38.0	6.80	3.12	1.22	4.08	1.54	0.20	0.59	0.11	0.48	0.08	0.50	0.02	0.39	0.12
97211_55_F	0.34	39.0	12.3	4.90	2.28	7.68	1.69	0.42	1.03	0.20	1.71	0.25	0.52	0.21	1.17	0.23
97211_40_F	0.31	36.3	13.5	4.43	1.98	8.70	2.32	0.37	0.44	0.16	1.10	0.30	0.48	0.21	0.28	0.13
97211_25_F	0.42	38.6	16.0	4.56	2.37	9.83	2.70	0.33	1.26	0.27	1.62	0.57	0.60	0.28	1.04	0.36
97211_100_G	0.03	32.9	5.22	1.48	0.69	2.82	0.31	0.08	0.43	0.03	0.28	0.05	0.10	0.03	0.12	0.04
97211_80_G	0.06	32.0	9.71	2.42	1.52	6.63	0.67	0.20	0.64	0.08	0.24	0.06	0.18	0.05	0.31	0.04
97211_55_G	0.12	40.6	13.1	4.24	2.35	9.97	1.23	0.49	1.01	0.20	0.47	0.18	0.52	0.14	0.25	0.15
97211_40_G	0.23	34.9	10.1	3.46	1.81	4.67	2.69	0.28	0.93	0.11	0.85	0.16	0.36	0.07	0.98	0.07
97211_25_G	0.33	52.3	17.4	6.80	2.94	11.2	2.78	0.37	1.30	0.22	0.84	0.30	0.47	0.14	0.44	0.39
97211_100_H	0.05	34.3	3.87	2.89	0.55	2.39	0.34	0.09	0.22	0.05	0.20	0.05	0.14	0.02	0.13	0.04
97211_80_H	0.12	42.0	5.68	2.80	1.36	5.26	1.20	0.30	0.52	0.15	0.51	0.14	0.24	0.13	0.30	0.13
97211_55_H	0.25	53.9	10.9	8.85	1.86	5.20	1.26	0.31	1.01	0.15	1.07	0.13	0.40	0.19	0.99	0.28
97211_40_H	1.5	54.4	17.6	13.2	5.7	12.4	11.8	1.2	2.0	1.0	4.1	0.9	3.0	1.2	2.1	1.5
97211_25_H	2.4	178.6	64.7	31.8	14.8	55.4	13.9	2.2	8.2	1.5	4.6	1.6	5.6	0.9	2.3	2.4
97217_100_A	0.01	85.8	0.01	0.04	0.01	0.04	0.05	0.01	0.03	0.01	0.03	0.00	0.01	0.01	0.02	0.01
97217_80_A	0.02	78.5	0.01	0.02	0.01	0.09	0.19	0.02	0.02	0.00	0.07	0.01	0.03	0.00	0.05	0.01
97217_55_A	0.05	71.9	0.03	0.03	0.04	0.12	0.27	0.09	0.01	0.05	0.27	0.05	0.12	0.02	0.11	0.02
97217_40_A	0.09	73.4	0.05	0.05	0.05	0.32	0.93	0.07	0.32	0.04	0.17	0.07	0.13	0.04	0.34	0.04

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U
97211_100_A	0.02	0.01	0.03	0.02	0.03	0.02	0.34	0.01	0.01	0.03
97211_80_A	0.03	0.02	0.08	0.05	0.12	0.06	0.12	0.02	0.01	0.01
97211_55_A	0.03	0.05	0.10	0.04	0.30	0.10	0.09	0.04	0.05	0.01
97211_40_A	0.15	0.06	0.18	0.12	0.45	0.16	0.11	0.07	0.03	0.06
97211_25_A	0.70	0.18	0.84	0.39	1.32	0.77	0.67	0.38	0.12	0.21
97211_100_B	0.02	0.01	0.04	0.02	0.03	0.02	0.07	0.01	0.01	0.01
97211_80_B	0.04	0.01	0.04	0.05	0.11	0.05	0.05	0.02	0.01	0.01
97211_55_B	0.10	0.06	0.05	0.11	0.30	0.11	0.08	0.06	0.01	0.03
97211_40_B	0.13	0.05	0.17	0.11	0.56	0.14	0.12	0.06	0.03	0.03
97211_25_B	0.28	0.17	0.62	0.44	1.66	0.50	0.35	0.22	0.10	0.33
97211_100_C	0.02	0.01	0.03	0.01	0.04	0.02	0.06	0.01	0.01	0.01
97211_80_C	0.04	0.01	0.09	0.03	0.09	0.05	0.07	0.02	0.01	0.01
97211_55_C	0.04	0.03	0.07	0.07	0.13	0.10	0.09	0.04	0.02	0.02
97211_40_C	0.12	0.07	0.13	0.08	0.34	0.18	0.21	0.05	0.04	0.04
97211_25_C	0.26	0.02	0.41	0.42	0.41	0.51	0.48	0.26	0.13	0.06
97211_100_D	0.03	0.01	0.03	0.01	0.06	0.02	0.10	0.01	0.01	0.01
97211_80_D	0.03	0.02	0.02	0.04	0.09	0.05	0.04	0.02	0.02	0.00
97211_55_D	0.11	0.04	0.12	0.05	0.15	0.10	0.07	0.05	0.03	0.02
97211_40_D	0.09	0.07	0.31	0.07	0.25	0.18	0.13	0.08	0.04	0.04
97211_25_D	0.49	0.03	0.44	0.31	0.80	0.47	0.40	0.18	0.12	0.10
97211_100_E	0.28	0.09	0.35	0.22	0.63	0.29	0.19	0.06	0.04	0.03
97211_80_E	0.34	0.31	0.74	0.53	0.94	0.58	0.57	0.28	0.17	0.12
97211_55_E	1.54	0.39	1.19	0.85	1.52	1.59	1.25	0.85	0.38	0.32
97211_40_E	1.44	0.67	0.22	1.47	1.85	2.35	1.13	1.03	0.33	0.24
97211_25_E	11.7	4.5	13.7	4.3	15.1	9.9	5.0	2.8	3.1	0.7
97211_100_F	0.11	0.03	0.06	0.09	0.34	0.11	0.17	0.07	0.03	0.04
97211_80_F	0.29	0.24	0.25	0.27	0.97	0.44	0.60	0.27	0.10	0.07
97211_55_F	1.05	0.25	0.66	0.53	0.83	0.75	0.73	0.21	0.15	0.17
97211_40_F	0.42	0.30	0.91	0.52	0.81	0.82	0.77	0.37	0.14	0.17
97211_25_F	1.18	0.40	1.06	0.93	3.97	1.40	0.97	0.57	0.24	0.16
97211_100_G	0.12	0.05	0.08	0.05	0.17	0.10	0.05	0.05	0.02	0.04
97211_80_G	0.14	0.01	0.22	0.10	0.39	0.16	0.15	0.07	0.05	0.08
97211_55_G	0.28	0.23	0.28	0.51	0.93	0.45	0.39	0.15	0.10	0.15
97211_40_G	0.58	0.29	0.64	0.88	1.11	0.91	0.62	0.43	0.05	0.09
97211_25_G	0.71	0.09	1.73	0.83	2.75	0.83	0.95	0.31	0.24	0.12
97211_100_H	0.08	0.08	0.12	0.10	0.21	0.11	0.16	0.06	0.03	0.06
97211_80_H	0.31	0.20	0.58	0.21	0.92	0.41	0.26	0.17	0.07	0.19
97211_55_H	0.78	0.26	1.21	0.43	1.21	0.74	0.65	0.32	0.22	0.33
97211_40_H	4.23	1.42	2.33	4.06	7.97	4.53	4.30	1.53	0.83	0.79
97211_25_H	4.46	1.84	8.46	4.29	5.93	4.25	3.75	3.57	0.75	1.76
97217_100_A	0.02	0.01	0.01	0.01	0.03	0.02	0.04	0.01	0.01	0.00
97217_80_A	0.03	0.02	0.05	0.05	0.11	0.06	0.04	0.02	0.01	0.01
97217_55_A	0.21	0.06	0.02	0.08	0.33	0.12	0.09	0.06	0.01	0.02
97217_40_A	0.25	0.08	0.38	0.16	0.59	0.26	0.18	0.08	0.05	0.06

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Li	Be	B	Na	Al	Si	P	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Cu
97217_25_A	1.30	9.30	4.74	5416	4.69	445.3	79131	312387	2.45	21.3	1.88	13.6	3.1	97.9	0.80	2.14
97217_100_B	0.27	0.57	1.55	5165	4.97	119.2	75014	295279	0.08	0.88	0.90	1.27	2.1	74.7	0.03	0.78
97217_80_B	0.42	1.03	1.61	5246	5.00	134.6	79826	316606	0.18	1.58	1.00	1.63	1.3	73.8	0.05	0.32
97217_55_B	0.39	3.77	1.87	5330	13.1	119.8	80310	311098	0.38	2.95	0.84	2.30	2.4	58.9	0.22	0.47
97217_40_B	0.67	5.33	3.21	5352	8.40	122.1	81216	313227	0.59	6.23	0.60	3.35	1.2	61.3	0.40	1.09
97217_25_B	2.38	3.59	7.52	5516	6.80	425.5	84019	322510	2.05	13.8	2.09	11.4	2.7	108.3	0.53	2.56
97217_100_C	0.33	0.51	1.20	5361	7.60	101.6	72693	287984	0.10	0.69	0.98	1.31	1.5	67.5	0.05	0.14
97217_80_C	0.42	1.81	2.14	5489	21.4	103.2	80017	315531	0.20	1.83	1.33	2.01	3.0	72.6	0.12	0.19
97217_55_C	0.75	2.20	1.95	5539	27.0	160.3	79543	305732	0.40	3.86	1.25	1.94	2.8	54.6	0.11	0.49
97217_40_C	0.75	0.55	1.75	5788	42.7	177.4	84829	335817	0.63	6.61	1.40	3.62	6.1	97.0	0.23	0.67
97217_25_C	2.44	5.37	9.74	5344	70.3	491.6	83480	322326	1.82	24.7	1.82	11.2	12.0	64.6	0.74	2.35
97217_100_D	0.25	0.15	1.16	5928	17.5	147.3	77480	304196	0.10	0.94	1.47	1.31	2.2	62.8	0.05	0.17
97217_80_D	0.29	1.12	0.83	6053	17.3	121.2	82094	330689	0.18	1.46	1.51	1.76	2.2	67.8	0.09	0.32
97217_55_D	0.45	2.44	3.84	6359	49.1	153.0	84395	331942	0.41	4.45	1.85	2.50	4.0	97.9	0.13	0.48
97217_40_D	0.73	3.93	1.30	6339	43.1	177.0	83431	331381	0.58	8.74	1.78	3.22	4.6	93.6	0.22	2.99
97217_25_D	2.22	7.97	8.81	5876	25.4	554.2	80796	310825	1.88	15.2	1.55	9.78	4.3	55.4	0.31	1.91
97217_100_E	1.35	0.73	3.36	4875	1.95	157.6	74659	288323	0.85	7.20	0.84	4.14	1.0	64.5	0.39	1.05
97217_80_E	3.37	12.6	8.40	4940	4.08	385.7	66046	272802	1.79	15.9	1.75	11.1	2.5	80.0	0.83	2.72
97217_55_E	5.58	29.3	13.9	4384	8.34	716.3	62153	253802	3.52	22.6	3.24	20.0	4.6	102.3	1.12	5.22
97217_40_E	12.5	46.1	38.0	5118	18.5	1674.9	72107	255347	8.62	76.4	7.03	45.0	11.9	233.4	3.91	11.6
97217_25_E	29.4	341.0	89.2	6594	46.4	5197.1	73007	252952	29.5	268.9	24.4	141.7	30.0	750.5	7.1	45.1
97217_100_F	0.51	5.72	3.36	5447	1.32	131.5	61558	238079	0.76	7.09	0.89	3.55	0.9	23.2	0.22	0.90
97217_80_F	0.34	11.5	9.56	4987	8.92	344.7	56685	229623	1.68	17.4	1.59	9.32	2.2	51.4	0.61	1.92
97217_55_F	3.48	25.1	13.6	6080	96.2	594.8	62864	221898	3.43	21.8	2.40	22.4	3.8	100.1	1.33	8.17
97217_40_F	7.50	38.1	15.2	5934	15.4	1192.4	59770	229635	6.21	65.8	6.56	34.6	6.2	219.6	3.17	9.38
97217_25_F	25.4	90.6	53.9	6417	30.5	2850.36	54529	229070	15.1	145.7	12.4	76.6	17.4	403.7	5.81	22.2
97217_100_G	0.67	4.74	1.63	5205	1.22	112.1	61292	230307	0.70	2.87	0.62	3.12	0.7	21.4	0.20	0.87
97217_80_G	1.20	21.0	10.4	5310	5.06	431.0	63336	257117	1.91	30.5	1.87	11.3	2.3	72.1	0.77	3.09
97217_55_G	6.13	9.41	12.9	5368	7.75	701.6	63516	232397	3.02	31.5	2.97	19.4	4.1	98.5	2.23	5.71
97217_40_G	15.1	60.7	25.9	4478	19.2	1402.9	55760	209295	7.0	57.1	5.9	37.3	9.3	189.9	1.6	10.4
97217_25_G	11.7	185.8	112.5	5051	65.1	6015.0	71602	211325	27.5	291.2	18.7	167.0	34.6	847.8	9.5	49.0
97217_100_H	1.45	5.01	2.94	5566	1.24	145.5	62848	245832	0.76	6.60	1.14	4.02	0.9	39.0	0.26	1.20
97217_80_H	4.18	28.6	15.9	4953	8.03	654.9	64016	269741	3.04	33.5	2.67	17.6	3.9	82.8	1.03	5.71
97217_55_H	3.73	23.3	11.7	4308	6.13	752.3	56823	217050	3.64	33.3	3.20	20.4	4.5	99.0	1.67	7.16
97217_40_H	15.9	43.9	27.0	6458	16.5	1401.3	63018	239038	6.55	57.0	5.23	37.4	8.1	211.2	2.33	10.8
97217_25_H	15.8	49.9	73.0	5397	54.8	4588.98	56169	254953	19.8	203.7	16.2	128.9	25.4	710.1	7.25	42.1
97225_100_A	0.14	0.21	2.15	7010	11.7	236.1	118421	547999	0.20	2.50	2.63	2.29	22.6	164.7	0.27	0.54
97225_80_A	0.36	0.81	2.79	6991	5.80	203.4	117616	533001	0.33	3.72	1.90	1.42	19.5	92.3	0.20	0.41
97225_55_A	1.27	0.88	2.69	7209	11.5	115.6	115828	534020	0.64	8.39	1.45	2.84	30.7	79.3	0.29	0.74
97225_40_A	1.30	8.14	5.23	7091	23.0	406.3	116400	528097	1.06	15.8	2.51	5.28	51.5	105.6	0.34	1.62
97225_25_A	2.10	32.2	12.0	7299	30.4	969.6	115523	538233	3.77	49.6	3.75	19.6	70.6	115.7	0.91	6.09
97225_100_B	0.26	1.40	1.70	7111	11.3	188.0	105481	486559	0.23	3.32	1.52	2.09	72.1	89.8	0.36	0.40
97225_80_B	0.39	1.66	2.26	7102	27.7	173.4	107869	500983	0.46	4.60	1.73	1.84	116.7	101.4	0.57	0.67
97225_55_B	0.53	4.56	2.74	7213	2.87	221.8	103344	493218	0.61	6.87	1.37	3.04	41.4	72.5	0.24	0.72

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ag	Cd	In	Sn	Sb
97217_25_A	39.5	1.34	2.38	6.35	1.73	110.9	0.23	0.71	3.23	0.49	1.90	1.17	3.63	0.20	1.75	0.38
97217_100_B	80.9	0.55	0.07	0.25	0.08	120.1	0.02	0.03	0.12	0.01	0.09	0.03	0.05	0.01	0.22	0.03
97217_80_B	87.5	0.68	0.19	0.43	0.11	123.2	0.02	0.05	0.32	0.05	0.11	0.02	0.13	0.01	0.14	0.07
97217_55_B	109.4	0.84	0.35	0.89	0.22	122.1	0.06	0.11	0.50	0.13	0.33	0.12	0.07	0.04	0.26	0.16
97217_40_B	101.1	0.51	0.77	2.05	0.37	124.1	0.06	0.14	0.86	0.19	0.49	0.25	0.96	0.07	0.42	0.27
97217_25_B	124.5	1.31	2.43	6.35	1.49	121.9	0.12	0.47	3.04	0.33	1.66	1.10	1.37	0.19	1.49	1.14
97217_100_C	75.4	0.73	0.07	0.36	0.05	126.7	0.01	0.02	0.17	0.01	0.07	0.03	0.07	0.01	0.19	0.03
97217_80_C	128.6	0.78	0.15	0.38	0.11	129.0	0.02	0.05	0.29	0.03	0.12	0.05	0.19	0.00	0.21	0.05
97217_55_C	140.0	0.97	0.33	1.26	0.21	128.4	0.05	0.11	0.33	0.05	0.27	0.15	0.27	0.03	0.23	0.15
97217_40_C	162.0	1.38	0.61	1.89	0.43	138.3	0.11	0.02	0.65	0.07	0.50	0.33	0.61	0.10	0.61	0.28
97217_25_C	225.5	1.27	2.18	5.65	1.14	124.9	0.14	0.25	3.62	0.71	1.62	0.88	2.31	0.36	1.64	0.43
97217_100_D	89.7	1.24	0.10	0.33	0.10	142.7	0.01	0.03	0.09	0.00	0.13	0.04	0.07	0.01	0.23	0.05
97217_80_D	133.3	1.12	0.20	0.43	0.12	147.0	0.02	0.07	0.18	0.03	0.19	0.07	0.24	0.04	0.22	0.11
97217_55_D	161.5	1.21	0.46	1.43	0.22	150.1	0.02	0.14	0.10	0.02	0.41	0.20	0.34	0.06	0.27	0.16
97217_40_D	171.3	1.51	0.50	1.35	0.35	148.6	0.03	0.07	0.86	0.03	0.47	0.25	1.05	0.05	0.39	0.26
97217_25_D	213.6	1.11	1.98	5.93	1.00	141.2	0.26	0.11	3.15	0.28	2.00	0.54	2.82	0.31	1.11	0.55
97217_100_E	18.0	0.54	1.03	1.87	0.46	108.0	0.11	0.17	0.77	0.03	0.60	0.33	1.04	0.07	0.47	0.23
97217_80_E	15.4	1.13	2.54	5.05	1.02	99.0	0.12	0.42	1.45	0.50	2.96	0.57	2.08	0.43	1.22	0.36
97217_55_E	31.8	1.99	3.68	14.7	2.10	94.7	0.15	1.17	3.37	0.48	3.44	0.94	6.83	0.60	2.45	1.01
97217_40_E	44.9	4.95	11.7	22.4	4.47	84.1	1.22	1.53	6.92	0.77	10.8	3.60	9.24	1.46	7.33	4.14
97217_25_E	157.5	15.9	29.5	84.8	15.3	133.4	3.27	5.03	32.2	6.03	17.8	16.8	24.8	1.96	19.3	9.62
97217_100_F	30.0	0.77	0.80	2.13	0.32	121.7	0.09	0.22	0.60	0.16	0.46	0.18	0.65	0.10	0.48	0.36
97217_80_F	39.5	1.08	1.92	2.56	1.10	106.3	0.42	0.53	4.16	0.52	2.96	0.31	1.84	0.25	1.25	0.71
97217_55_F	30.3	2.71	3.94	8.82	1.64	109.1	0.53	5.20	6.15	0.69	4.56	0.76	2.83	0.39	3.50	0.97
97217_40_F	63.3	4.11	6.78	16.8	2.79	121.9	0.00	1.59	9.65	1.70	12.3	3.77	7.39	0.48	3.56	2.34
97217_25_F	77.9	8.42	18.1	44.2	8.29	131.0	1.34	1.59	13.2	0.83	17.8	3.27	10.1	1.61	10.9	1.60
97217_100_G	27.6	1.11	0.82	1.45	0.28	108.1	0.13	0.02	0.97	0.15	0.76	0.21	0.64	0.07	0.36	0.14
97217_80_G	16.2	1.36	2.12	4.51	0.98	127.4	0.38	0.47	2.13	0.46	1.67	0.65	2.82	0.18	1.62	0.63
97217_55_G	22.1	2.16	3.75	7.95	1.96	117.1	0.63	1.36	3.08	0.47	4.17	0.82	4.06	0.59	2.34	1.81
97217_40_G	41.3	3.50	7.68	20.3	3.52	103.0	0.40	2.70	10.6	1.32	6.76	3.22	9.28	0.91	5.16	1.79
97217_25_G	147.0	11.5	37.9	103.2	17.6	131.4	3.79	5.82	45.6	4.03	15.8	11.3	20.0	1.40	18.8	10.9
97217_100_H	25.6	1.35	0.67	2.45	0.35	118.9	0.14	0.31	1.41	0.03	0.55	0.22	0.76	0.15	0.39	0.29
97217_80_H	20.1	1.82	3.45	9.34	1.65	115.0	0.13	0.89	4.00	0.07	4.43	1.22	4.28	0.35	2.02	1.43
97217_55_H	24.3	1.87	3.82	7.56	2.13	95.3	0.47	1.61	4.60	0.99	4.41	1.72	3.47	0.40	2.39	2.12
97217_40_H	39.3	3.91	8.13	20.0	3.55	91.2	0.30	1.78	6.09	1.87	6.75	1.22	6.50	1.05	4.89	3.07
97217_25_H	127.9	12.8	22.5	74.2	12.3	100.2	0.70	4.39	39.8	2.63	15.6	8.62	13.0	2.98	12.7	10.0
97225_100_A	233.4	1.81	0.22	0.45	0.23	206.7	0.32	0.06	0.18	0.02	0.29	0.06	0.43	0.02	0.35	0.06
97225_80_A	197.7	1.53	0.27	0.76	0.34	196.2	0.14	0.14	0.34	0.03	0.52	0.76	0.26	0.01	0.33	0.14
97225_55_A	180.0	1.55	0.62	2.12	0.70	205.1	0.20	0.14	1.05	0.05	0.39	0.23	0.53	0.06	0.32	0.12
97225_40_A	148.6	1.63	1.00	2.64	1.15	198.4	0.61	0.37	0.20	0.16	0.84	0.23	1.31	0.16	0.59	0.30
97225_25_A	160.1	3.32	4.37	8.97	4.40	194.2	1.29	1.13	5.12	0.64	3.29	0.87	7.81	0.44	2.24	2.39
97225_100_B	110.5	1.40	0.13	0.30	0.16	193.9	0.18	0.04	0.23	0.02	0.39	0.06	0.25	0.01	0.32	0.04
97225_80_B	133.4	1.59	0.29	0.83	0.29	194.5	0.32	0.09	0.30	0.02	0.31	0.09	0.16	0.03	0.30	0.12
97225_55_B	136.7	1.09	0.60	1.36	0.55	189.4	0.06	0.18	0.58	0.14	0.53	0.18	0.74	0.07	0.46	0.15

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
97217_25_A	0.36	64.2	0.19	0.09	0.18	1.08	2.53	0.33	0.89	0.27	1.00	0.29	0.60	0.28	1.77	0.21
97217_100_B	0.01	87.3	0.03	0.03	0.01	0.02	0.08	0.01	0.00	0.01	0.02	0.01	0.03	0.01	0.02	0.01
97217_80_B	0.02	94.5	0.03	0.03	0.02	0.08	0.16	0.03	0.05	0.01	0.11	0.02	0.05	0.02	0.07	0.02
97217_55_B	0.06	101.7	0.03	0.04	0.03	0.12	0.39	0.05	0.07	0.01	0.18	0.04	0.03	0.02	0.18	0.04
97217_40_B	0.09	104.4	0.05	0.06	0.03	0.35	0.67	0.03	0.17	0.04	0.22	0.07	0.05	0.01	0.25	0.07
97217_25_B	0.28	99.1	0.12	0.10	0.21	0.10	1.79	0.44	1.32	0.10	1.33	0.30	0.57	0.05	0.25	0.24
97217_100_C	0.01	102.6	0.02	0.03	0.01	0.04	0.09	0.01	0.05	0.00	0.03	0.01	0.03	0.01	0.02	0.01
97217_80_C	0.03	123.1	0.07	0.06	0.01	0.06	0.17	0.01	0.04	0.01	0.09	0.02	0.04	0.01	0.07	0.01
97217_55_C	0.05	137.9	0.08	0.06	0.03	0.12	0.25	0.03	0.10	0.02	0.15	0.05	0.11	0.02	0.15	0.05
97217_40_C	0.05	177.4	0.16	0.07	0.05	0.21	0.47	0.09	0.25	0.01	0.33	0.04	0.11	0.04	0.19	0.07
97217_25_C	0.31	160.0	0.17	0.26	0.16	0.98	1.23	0.14	0.81	0.12	0.55	0.26	0.39	0.13	1.37	0.27
97217_100_D	0.01	154.6	0.01	0.02	0.00	0.04	0.08	0.01	0.03	0.00	0.05	0.01	0.03	0.01	0.02	0.01
97217_80_D	0.02	160.9	0.03	0.02	0.00	0.04	0.21	0.01	0.07	0.02	0.04	0.01	0.03	0.01	0.04	0.02
97217_55_D	0.06	179.7	0.05	0.04	0.04	0.18	0.47	0.05	0.10	0.04	0.16	0.05	0.07	0.02	0.16	0.02
97217_40_D	0.06	184.3	0.08	0.04	0.04	0.20	0.35	0.11	0.07	0.04	0.30	0.07	0.11	0.05	0.18	0.09
97217_25_D	0.30	191.4	0.15	0.13	0.07	0.60	1.50	0.19	0.27	0.06	0.64	0.30	0.09	0.03	1.18	0.02
97217_100_E	0.13	93.5	0.03	0.08	0.06	0.25	1.01	0.11	0.03	0.08	0.43	0.12	0.25	0.05	0.23	0.09
97217_80_E	0.24	82.7	0.22	0.13	0.04	0.63	2.08	0.10	0.73	0.11	0.83	0.12	0.18	0.12	0.56	0.17
97217_55_E	0.59	86.5	0.25	0.22	0.24	1.78	2.58	0.64	1.70	0.26	2.35	0.52	0.82	0.19	0.91	0.20
97217_40_E	1.08	90.6	1.23	0.97	0.38	2.27	8.57	0.99	1.88	0.40	4.59	0.61	2.57	0.60	1.09	0.45
97217_25_E	3.12	127.0	2.56	2.26	1.77	13.0	29.7	2.31	6.20	2.30	8.07	2.84	4.23	1.39	9.38	1.47
97217_100_F	0.09	140.7	0.05	0.02	0.03	0.10	0.61	0.09	0.16	0.08	0.37	0.05	0.22	0.06	0.25	0.07
97217_80_F	0.15	143.8	0.14	0.04	0.09	0.56	1.56	0.03	0.07	0.17	0.74	0.26	0.45	0.10	0.08	0.19
97217_55_F	0.36	376.5	0.21	0.25	0.35	1.21	2.64	0.37	0.29	0.13	1.13	0.23	0.13	0.23	1.32	0.45
97217_40_F	0.71	193.6	0.44	0.55	0.31	3.16	5.13	0.22	2.62	0.32	3.12	0.60	1.46	0.34	0.84	0.88
97217_25_F	1.80	195.5	1.04	2.99	1.02	1.77	10.8	1.33	5.05	0.31	3.49	0.98	3.45	1.61	2.62	1.70
97217_100_G	0.05	119.4	0.07	0.03	0.03	0.27	0.60	0.10	0.13	0.04	0.32	0.03	0.22	0.03	0.24	0.03
97217_80_G	0.38	152.9	0.17	0.26	0.17	0.28	1.24	0.30	1.00	0.07	0.79	0.33	0.40	0.18	0.25	0.20
97217_55_G	0.45	141.9	0.49	0.30	0.10	1.42	2.53	0.31	1.44	0.25	1.33	0.19	1.14	0.19	1.79	0.34
97217_40_G	0.77	124.8	0.48	0.43	0.58	2.82	3.55	0.30	1.65	0.35	3.05	0.66	2.26	0.53	1.78	0.39
97217_25_G	4.49	165.2	3.59	1.83	1.44	12.1	30.5	0.82	10.1	2.64	9.29	3.66	10.9	2.78	7.65	2.40
97217_100_H	0.07	157.4	0.08	0.05	0.07	0.32	0.71	0.07	0.27	0.04	0.30	0.08	0.19	0.02	0.35	0.06
97217_80_H	0.38	115.3	0.22	0.20	0.31	0.71	3.48	0.49	1.32	0.16	1.41	0.47	0.74	0.30	0.38	0.36
97217_55_H	0.41	105.0	0.36	0.04	0.22	1.06	3.52	0.65	0.88	0.27	1.40	0.45	0.85	0.20	0.94	0.51
97217_40_H	0.83	113.3	0.31	0.60	0.33	0.32	2.49	1.06	2.32	0.35	3.04	0.54	1.13	0.53	1.77	0.55
97217_25_H	3.05	88.9	2.43	1.38	2.16	12.9	16.1	2.00	5.35	1.19	8.57	2.14	3.67	2.71	9.98	1.81
97225_100_A	0.02	163.9	0.45	0.36	0.06	0.39	0.11	0.01	0.05	0.01	0.04	0.02	0.04	0.01	0.04	0.01
97225_80_A	0.04	148.6	0.27	0.18	0.05	0.18	0.21	0.02	0.04	0.02	0.07	0.03	0.04	0.01	0.08	0.02
97225_55_A	0.08	171.9	0.46	0.35	0.09	0.44	0.43	0.07	0.11	0.03	0.24	0.03	0.18	0.04	0.13	0.05
97225_40_A	0.15	165.0	0.71	0.50	0.13	0.54	0.62	0.08	0.21	0.05	0.46	0.10	0.20	0.07	0.06	0.07
97225_25_A	0.45	182.3	1.00	1.25	0.25	0.95	3.18	0.20	0.85	0.17	1.04	0.32	1.09	0.25	1.71	0.08
97225_100_B	0.12	142.5	0.28	0.34	0.05	0.19	0.13	0.02	0.04	0.01	0.05	0.01	0.02	0.00	0.03	0.01
97225_80_B	0.04	159.0	0.54	0.42	0.10	0.48	0.23	0.02	0.08	0.01	0.11	0.03	0.09	0.01	0.06	0.02
97225_55_B	0.05	136.6	0.09	0.17	0.02	0.23	0.44	0.09	0.17	0.02	0.30	0.06	0.13	0.03	0.21	0.00

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U
97217_25_A	0.84	0.53	0.41	0.60	1.56	0.68	0.57	0.37	0.16	0.07
97217_100_B	0.02	0.01	0.03	0.02	0.05	0.03	0.07	0.01	0.01	0.01
97217_80_B	0.06	0.01	0.06	0.02	0.07	0.04	0.03	0.03	0.02	0.02
97217_55_B	0.13	0.07	0.12	0.09	0.20	0.13	0.12	0.03	0.01	0.02
97217_40_B	0.07	0.01	0.11	0.14	0.53	0.21	0.14	0.10	0.07	0.03
97217_25_B	0.64	0.33	1.00	0.67	1.18	0.80	0.59	0.17	0.06	0.03
97217_100_C	0.03	0.01	0.03	0.02	0.01	0.03	0.06	0.01	0.00	0.01
97217_80_C	0.04	0.01	0.06	0.05	0.09	0.05	0.06	0.02	0.00	0.01
97217_55_C	0.09	0.04	0.28	0.06	0.13	0.10	0.07	0.03	0.02	0.02
97217_40_C	0.19	0.05	0.21	0.13	0.50	0.19	0.22	0.11	0.06	0.02
97217_25_C	0.44	0.37	0.68	0.65	1.79	0.56	0.57	0.36	0.21	0.14
97217_100_D	0.03	0.01	0.02	0.03	0.03	0.03	0.03	0.01	0.00	0.00
97217_80_D	0.06	0.03	0.08	0.04	0.09	0.05	0.05	0.03	0.01	0.01
97217_55_D	0.16	0.07	0.12	0.08	0.25	0.12	0.09	0.07	0.02	0.02
97217_40_D	0.18	0.07	0.28	0.14	0.28	0.22	0.12	0.03	0.06	0.04
97217_25_D	0.21	0.16	0.84	0.37	1.93	0.67	0.45	0.31	0.12	0.20
97217_100_E	0.33	0.07	0.36	0.18	0.41	0.28	0.24	0.07	0.09	0.08
97217_80_E	0.40	0.29	0.88	0.50	0.71	0.53	0.55	0.30	0.13	0.09
97217_55_E	0.66	0.21	1.02	0.63	2.33	1.14	1.08	0.68	0.30	0.25
97217_40_E	2.06	0.85	2.04	1.62	5.75	2.60	2.51	1.01	0.81	0.45
97217_25_E	9.59	1.98	7.42	4.61	11.9	9.24	7.05	4.44	1.54	1.79
97217_100_F	0.13	0.10	0.32	0.11	0.38	0.19	0.20	0.04	0.04	0.05
97217_80_F	0.62	0.15	0.78	0.34	1.40	0.56	0.28	0.33	0.11	0.17
97217_55_F	1.10	0.28	0.85	1.01	1.66	0.92	0.81	0.38	0.25	0.12
97217_40_F	2.03	0.44	1.81	1.45	1.32	2.03	1.56	0.88	0.37	0.35
97217_25_F	4.80	2.80	1.76	3.44	4.82	4.19	3.51	2.69	0.88	0.59
97217_100_G	0.14	0.05	0.22	0.13	0.35	0.19	0.11	0.09	0.03	0.02
97217_80_G	0.63	0.41	0.65	0.43	0.78	0.73	0.46	0.28	0.14	0.10
97217_55_G	1.29	0.38	2.24	0.67	1.93	0.98	1.00	0.49	0.35	0.19
97217_40_G	3.39	0.53	2.80	1.01	2.21	2.34	1.14	1.11	0.70	0.38
97217_25_G	7.80	3.22	8.54	7.51	13.4	9.52	9.85	4.48	3.48	1.17
97217_100_H	0.26	0.01	0.32	0.22	0.36	0.26	0.09	0.08	0.08	0.01
97217_80_H	0.59	0.35	1.83	0.57	1.76	1.02	0.61	0.28	0.26	0.13
97217_55_H	0.96	0.40	1.05	0.53	1.64	1.06	0.86	0.36	0.21	0.14
97217_40_H	2.21	0.74	2.57	1.00	4.35	2.13	1.60	0.87	0.13	0.46
97217_25_H	8.31	2.97	9.09	3.60	7.07	6.01	3.69	3.11	0.22	1.74
97225_100_A	0.04	0.01	0.03	0.03	0.09	0.03	0.09	0.02	0.01	0.02
97225_80_A	0.08	0.03	0.10	0.06	0.16	0.06	0.06	0.03	0.01	0.01
97225_55_A	0.20	0.08	0.14	0.12	0.15	0.14	0.15	0.09	0.04	0.02
97225_40_A	0.27	0.11	0.24	0.28	0.45	0.24	0.23	0.14	0.07	0.05
97225_25_A	0.87	0.44	0.38	0.45	2.29	1.14	0.77	0.46	0.19	0.13
97225_100_B	0.04	0.01	0.03	0.03	0.08	0.03	0.05	0.01	0.01	0.01
97225_80_B	0.08	0.04	0.10	0.07	0.13	0.07	0.07	0.04	0.02	0.01
97225_55_B	0.12	0.08	0.23	0.13	0.24	0.15	0.11	0.06	0.04	0.03

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Li	Be	B	Na	Al	Si	P	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Cu
97225_40_B	0.35	0.00	4.40	7263	50.8	334.5	102751	452288	0.89	22.0	1.63	4.32	139.2	129.4	0.36	1.29
97225_25_B	6.26	4.97	10.0	6867	144.9	1187.4	99077	433928	2.96	32.2	2.44	16.0	191.5	255.4	1.72	14.6
97225_100_C	0.21	0.76	2.66	6903	29.3	245.5	94365	429419	0.23	1.82	1.91	2.16	90.3	108.1	0.94	0.59
97225_80_C	0.14	2.50	3.65	6901	62.8	240.1	96928	447873	0.27	4.24	2.29	1.63	114.6	195.9	0.62	1.16
97225_55_C	0.82	3.33	2.59	7092	40.2	166.9	102026	446394	0.58	5.72	2.15	2.63	117.7	124.7	0.34	0.70
97225_40_C	0.94	5.58	3.44	6972	90.9	330.9	98885	439993	0.85	9.97	1.55	4.42	133.5	246.6	0.61	1.16
97225_25_C	5.34	21.3	14.5	6918	313.0	1007.4	110472	451093	3.48	40.8	3.03	17.0	165.9	284.8	1.11	3.99
97225_100_D	0.34	0.78	2.64	7044	45.8	252.4	87574	407171	0.28	2.47	1.75	2.08	66.2	155.0	1.71	0.56
97225_80_D	0.12	1.76	3.04	7369	61.5	193.1	95664	454880	0.31	2.81	1.48	1.38	71.3	104.7	0.43	0.53
97225_55_D	1.63	0.00	2.82	7250	97.8	324.9	95804	437473	0.56	5.18	1.56	2.79	96.5	162.9	0.82	0.63
97225_40_D	1.23	6.65	6.96	6012	1168.1	2203.63	81549	354900	0.65	199.4	3.84	3.44	198.5	1195.9	1.45	2.29
97225_25_D	1.83	15.0	13.5	6206	1193.8	1523.9	81773	382410	2.30	41.4	3.00	12.1	317.9	1467.9	4.88	4.52
97225_100_E	2.38	5.64	7.22	7142	154.0	717.1	86554	394904	1.44	67.7	2.46	6.60	25.1	183.5	0.69	24.2
97225_80_E	6.32	23.4	21.4	6579	124.8	729.2	80614	377898	3.66	32.6	3.34	17.9	56.0	122.7	2.54	12.7
97225_55_E	0.00	108.2	25.6	6919	315.6	1919.7	78710	390870	7.92	129.8	6.66	48.2	418.0	525.8	10.7	28.6
97225_40_E	54.4	241.3	81.3	7744	621.3	4511.08	102583	454515	20.1	287.9	17.2	112.7	47.3	554.8	7.48	49.3
97225_25_E	65.0	233.0	216.3	7593	1749.5	7438.72	84279	319535	35.1	436.9	26.8	185.5	252.2	1294.3	14.4	166.2
97225_100_F	2.36	8.36	10.2	6720	112.9	329.5	78546	347284	1.24	11.3	2.58	6.04	215.4	147.6	2.67	5.66
97225_80_F	5.63	19.7	14.9	8881	485.3	631.8	73909	324531	2.91	31.3	2.70	14.9	324.3	479.4	3.26	22.6
97225_55_F	14.0	48.2	35.3	7745	780.7	1512.0	85002	358737	7.42	134.2	5.78	36.9	5554	1667.2	111.1	34.7
97225_40_F	20.9	11.6	75.9	7111	855.3	2208.14	76997	312071	11.4	308.3	7.37	55.2	983.3	465.5	18.1	23.1
97225_25_F	41.9	0.00	104.4	13477	1660.2	7062.54	73522	303867	38.1	324.2	28.4	181.3	4584	3465	94.5	63.4
97225_100_G	2.66	1.36	24.1	6694	449.0	196.8	64490	288154	0.72	30.9	4.19	3.44	995.2	661.7	10.7	7.49
97225_80_G	6.55	21.5	18.5	6381	1021.3	1335.8	67508	292433	2.07	61.3	4.61	11.3	1122.0	1626.3	28.3	9.74
97225_55_G	22.5	51.6	27.7	6193	859.1	1466.1	70271	350032	8.38	77.0	5.45	36.0	146.3	811.2	3.06	7.50
97225_40_G	22.8	51.4	58.9	5364	1316.6	1545.3	53422	238861	7.78	75.2	5.16	39.9	587.9	1544.9	22.8	10.5
97225_25_G	97.5	306.8	192.1	7697	2135.23	6449.39	58507	299052	29.7	357.1	23.1	157.6	76.0	1325.5	11.1	31.2
97225_100_H	3.32	14.6	9.17	6894	1161.7	905.2	80839	352330	1.44	51.2	2.65	6.74	714.5	1753.7	15.3	5.73
97225_80_H	7.57	3.35	27.5	6837	1539.0	1612.1	87672	401447	3.35	61.6	4.48	17.0	2162	2539	76.2	8.44
97225_55_H	13.7	28.1	50.9	8865	1908.9	2008.06	96972	391857	5.97	110.9	16.2	30.0	7760	4277	141.9	11.8
97225_40_H	13.9	41.0	26.4	5652	3108.64	3307.72	65683	304643	5.25	211.5	18.9	32.3	11867	5616	249.4	26.8
97225_25_H	13.3	88.8	70.6	5005	5094.67	9918.99	75494	264446	10.1	224.3	10.3	61.1	4544	8638	238.8	16.5
98355_100_A	0.54	1.24	5.76	5716	47.5	160.4	76667	416773	0.22	1.21	8.08	2.16	30.8	96.5	0.34	0.73
98355_80_A	1.01	1.92	5.56	5623	73.4	147.5	78834	431454	0.24	2.12	7.73	1.35	27.1	65.6	0.15	0.38
98355_55_A	2.44	4.42	4.37	5664	32.1	171.8	77085	409924	0.51	3.64	7.25	2.52	20.2	74.6	0.18	0.81
98355_40_A	2.97	2.14	5.01	5670	26.4	237.2	80196	426649	0.84	6.64	7.12	4.53	15.8	48.7	0.18	0.96
98355_25_A	14.2	3.61	15.1	4686	28.9	588.8	75902	387291	2.92	29.5	5.07	15.5	13.3	85.7	0.88	3.70
98355_100_B	1.19	0.91	3.20	5657	3.01	148.0	68497	364693	0.11	0.94	5.11	1.96	10.5	48.7	0.12	0.50
98355_80_B	0.98	1.25	3.23	5615	0.49	126.5	68329	369037	0.22	1.51	4.19	1.97	5.3	34.5	0.08	0.25
98355_55_B	1.47	5.58	2.88	5372	1.08	191.9	65910	343271	0.44	4.07	3.48	2.24	3.4	45.3	0.09	0.45
98355_40_B	3.55	6.75	5.29	5249	1.60	142.1	68870	350840	0.68	6.01	3.06	3.78	4.1	43.2	0.31	0.68
98355_25_B	1.27	25.4	10.2	6174	7.56	527.6	72705	368006	2.38	22.6	4.81	14.0	4.2	64.7	0.58	3.20
98355_100_C	0.60	1.03	2.48	5582	1.09	105.9	62837	323982	0.11	0.91	2.82	1.58	2.9	58.5	0.06	0.21
98355_80_C	0.90	1.71	2.96	5446	0.45	57.2	64233	333070	0.16	0.81	2.62	1.57	3.2	30.3	0.10	0.16

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ag	Cd	In	Sn	Sb
97225_40_B	137.3	1.66	1.02	1.95	0.83	178.9	0.68	0.34	0.97	0.15	0.22	0.37	0.41	0.12	0.44	0.28
97225_25_B	121.9	2.33	2.53	5.66	2.98	161.1	1.67	1.15	4.01	0.50	1.83	1.78	1.15	0.45	1.70	0.65
97225_100_C	63.1	1.44	0.12	0.35	0.14	186.1	0.53	0.05	0.10	0.01	0.24	0.04	0.65	0.02	0.26	0.04
97225_80_C	83.9	1.45	0.21	0.62	0.23	184.6	1.09	0.15	0.22	0.05	0.32	0.07	0.16	0.02	0.31	0.09
97225_55_C	100.1	1.76	0.58	1.47	0.43	180.4	0.57	0.09	0.41	0.03	0.61	0.02	0.43	0.07	0.27	0.23
97225_40_C	127.3	1.93	0.99	1.92	0.76	181.4	0.83	0.22	1.19	0.15	0.77	0.20	0.87	0.10	0.55	0.38
97225_25_C	159.7	2.50	3.47	9.58	2.67	180.8	1.82	1.00	5.19	0.40	2.90	0.82	1.90	0.32	2.07	1.45
97225_100_D	50.9	1.09	0.13	0.34	0.85	177.9	0.64	0.03	0.10	0.01	0.22	0.06	0.07	0.02	0.38	0.03
97225_80_D	82.2	1.06	0.28	0.47	0.22	186.8	0.73	0.11	0.21	0.03	0.17	0.13	0.27	0.04	0.44	0.10
97225_55_D	110.0	1.47	0.48	1.13	0.44	185.4	0.60	0.19	0.76	0.05	0.32	0.14	0.45	0.10	0.32	0.21
97225_40_D	147.1	2.10	0.61	1.98	0.83	159.8	1.90	0.21	0.79	0.17	1.17	0.25	0.86	0.08	0.47	0.22
97225_25_D	209.4	3.04	2.31	6.26	1.72	160.6	6.99	0.88	1.78	0.27	1.73	0.98	1.83	0.22	1.26	0.70
97225_100_E	44.2	1.41	1.14	2.89	0.94	162.0	1.08	1.80	2.10	0.16	0.83	1.27	1.79	0.13	1.91	0.11
97225_80_E	43.2	2.54	3.87	9.25	2.57	154.0	2.06	1.40	1.59	0.31	3.07	0.87	11.0	0.24	2.01	1.52
97225_55_E	46.1	6.74	9.46	20.0	6.25	167.7	6.31	3.23	7.28	1.58	8.15	3.28	9.13	1.41	5.16	2.01
97225_40_E	191.9	12.2	22.2	49.4	15.9	193.6	9.23	5.85	28.0	1.72	18.1	4.46	23.3	2.43	14.8	7.72
97225_25_E	175.6	25.3	43.1	97.0	24.6	199.9	15.1	23.8	46.5	3.81	21.3	14.9	33.6	5.21	23.5	10.5
97225_100_F	32.9	2.36	1.09	2.77	0.85	151.3	2.82	0.37	0.96	0.21	0.76	0.33	0.98	0.14	0.71	0.26
97225_80_F	38.3	2.66	3.31	6.48	1.89	157.1	9.13	1.22	3.17	0.49	1.78	1.02	0.84	0.44	1.42	0.87
97225_55_F	45.0	12.2	7.50	15.7	4.86	173.8	12.6	2.60	10.9	1.45	6.12	3.03	6.80	1.06	4.46	2.99
97225_40_F	58.9	7.62	10.4	28.8	6.98	155.5	12.2	2.52	9.16	2.47	6.38	2.99	8.67	1.40	6.23	3.81
97225_25_F	166.3	20.7	35.4	69.0	24.4	152.5	16.0	6.04	54.5	8.38	30.6	15.2	33.9	2.75	18.6	7.45
97225_100_G	49.9	2.93	0.58	1.56	0.57	155.8	10.7	0.82	0.70	0.17	0.42	0.32	0.76	0.10	0.48	0.13
97225_80_G	52.6	2.72	2.42	4.80	1.45	156.4	11.0	1.16	2.91	0.27	2.31	1.08	2.94	0.15	1.35	0.13
97225_55_G	48.9	4.08	6.68	20.9	4.56	181.9	15.1	1.78	6.10	1.23	4.50	3.66	4.05	1.10	4.39	1.54
97225_40_G	34.0	4.71	7.50	14.1	4.63	132.6	14.2	2.63	9.72	1.49	4.46	2.56	8.01	1.20	4.69	1.53
97225_25_G	128.1	15.0	32.3	80.4	19.1	148.6	21.7	9.03	23.5	6.27	18.7	6.59	16.8	4.10	17.2	7.74
97225_100_H	112.8	3.09	1.56	2.57	0.85	186.2	12.9	0.95	1.11	0.24	1.53	0.95	1.12	0.22	0.70	0.30
97225_80_H	174.0	6.39	3.66	8.10	1.88	201.3	21.8	0.95	3.50	0.38	1.97	1.39	3.05	0.37	2.26	1.50
97225_55_H	386.1	12.6	5.16	14.9	3.39	208.0	18.2	1.92	6.19	1.73	3.48	2.01	5.39	0.38	3.19	1.67
97225_40_H	181.6	18.5	4.94	10.8	3.50	208.2	44.5	5.02	7.52	0.76	3.46	2.00	3.08	0.93	3.07	1.17
97225_25_H	194.8	11.9	9.31	19.6	6.67	222.2	55.3	5.62	10.8	1.66	7.44	3.04	6.62	1.41	7.80	5.63
98355_100_A	112.5	2.32	0.11	0.25	0.09	164.3	0.04	0.04	0.14	0.02	0.15	0.04	0.25	0.01	0.25	0.04
98355_80_A	85.2	2.47	0.21	0.59	0.18	168.3	0.04	0.10	0.26	0.05	0.19	0.09	0.20	0.02	0.16	0.04
98355_55_A	67.6	2.78	0.51	0.98	0.38	168.1	0.07	0.13	0.41	0.09	0.13	0.17	0.17	0.07	0.29	0.18
98355_40_A	56.6	1.71	0.89	1.88	0.59	170.1	0.08	0.23	1.29	0.23	0.31	0.21	0.80	0.12	0.40	0.12
98355_25_A	45.5	1.46	3.10	5.17	2.26	155.8	0.14	0.54	3.54	0.53	0.78	1.00	2.21	0.20	1.64	0.87
98355_100_B	32.0	2.03	0.09	0.24	0.07	167.1	0.01	0.05	0.19	0.01	0.10	0.01	0.08	0.01	0.16	0.04
98355_80_B	25.2	1.99	0.21	0.41	0.16	160.3	0.02	0.08	0.34	0.02	0.19	0.09	0.15	0.04	0.13	0.06
98355_55_B	22.5	2.11	0.47	1.24	0.26	152.2	0.05	0.08	0.36	0.08	0.56	0.18	0.32	0.03	0.30	0.13
98355_40_B	22.8	1.60	0.75	1.76	0.52	151.9	0.09	0.13	0.62	0.04	0.48	0.14	0.39	0.07	0.32	0.15
98355_25_B	19.4	2.01	3.59	4.46	2.10	160.8	0.23	1.13	2.33	0.61	1.80	0.67	1.46	0.20	1.54	0.81
98355_100_C	30.3	1.69	0.07	0.20	0.05	146.8	0.01	0.01	0.15	0.01	0.09	0.03	0.06	0.00	0.24	0.03
98355_80_C	35.1	1.80	0.22	0.40	0.11	145.8	0.02	0.06	0.35	0.02	0.12	0.09	0.14	0.01	0.15	0.08

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
97225_40_B	0.06	156.8	1.15	1.05	0.07	0.74	0.67	0.12	0.32	0.06	0.30	0.10	0.22	0.06	0.19	0.06
97225_25_B	0.23	160.3	2.37	2.81	0.41	1.67	1.62	0.33	0.87	0.13	0.93	0.25	0.43	0.24	0.67	0.21
97225_100_C	0.01	163.4	0.83	0.93	0.17	0.65	0.14	0.02	0.09	0.01	0.06	0.02	0.06	0.01	0.06	0.01
97225_80_C	0.02	174.7	1.94	1.40	0.40	1.36	0.29	0.04	0.26	0.02	0.20	0.03	0.08	0.02	0.11	0.02
97225_55_C	0.06	166.8	0.98	1.03	0.23	0.60	0.47	0.07	0.13	0.03	0.18	0.07	0.13	0.05	0.12	0.05
97225_40_C	0.13	180.6	1.63	1.49	0.30	1.12	0.55	0.12	0.26	0.10	0.45	0.07	0.31	0.04	0.03	0.04
97225_25_C	0.37	179.2	3.14	2.86	0.71	2.79	3.14	0.26	0.69	0.21	0.91	0.23	0.32	0.22	0.75	0.24
97225_100_D	0.01	123.5	0.78	1.74	0.18	0.64	0.13	0.03	0.10	0.01	0.08	0.01	0.04	0.01	0.04	0.00
97225_80_D	0.02	126.0	1.03	0.70	0.17	0.71	0.26	0.04	0.11	0.02	0.08	0.04	0.06	0.01	0.06	0.01
97225_55_D	0.06	131.0	0.72	0.97	0.20	0.43	0.46	0.06	0.12	0.03	0.24	0.03	0.11	0.03	0.13	0.06
97225_40_D	0.07	159.8	4.38	3.84	0.78	3.30	0.64	0.10	0.52	0.05	0.34	0.07	0.15	0.03	0.23	0.05
97225_25_D	0.27	264.1	12.9	13.3	2.72	10.0	1.76	0.32	1.01	0.27	1.08	0.30	0.75	0.15	0.87	0.20
97225_100_E	0.16	190.4	1.40	1.23	0.20	1.30	0.84	0.18	0.28	0.10	0.37	0.09	0.27	0.06	0.30	0.10
97225_80_E	0.51	192.4	2.40	2.20	0.62	1.74	2.47	0.47	1.03	0.07	1.35	0.38	0.87	0.07	0.79	0.18
97225_55_E	0.89	217.4	6.41	5.17	1.57	5.90	5.85	0.72	3.33	0.72	1.79	1.00	2.66	0.76	2.09	0.80
97225_40_E	2.28	268.6	9.73	9.64	2.00	11.7	19.4	1.59	3.68	1.84	5.81	1.72	4.17	1.38	10.4	1.45
97225_25_E	1.89	375.6	18.3	16.7	4.18	19.6	26.4	1.22	7.07	2.16	11.4	4.66	4.52	2.29	7.71	3.42
97225_100_F	0.15	177.8	2.25	2.75	0.71	2.39	0.87	0.15	0.53	0.08	0.48	0.12	0.32	0.12	0.30	0.09
97225_80_F	0.22	227.8	6.31	9.10	2.13	7.60	2.20	0.57	1.70	0.26	1.46	0.34	0.58	0.14	1.33	0.32
97225_55_F	0.81	737.8	9.57	56.1	2.05	5.05	7.57	0.54	2.48	0.31	3.28	0.67	2.30	0.47	1.45	0.60
97225_40_F	1.44	276.5	7.38	14.3	2.86	6.30	8.51	0.64	4.72	1.21	4.84	0.85	2.93	1.08	4.61	0.33
97225_25_F	3.03	742.6	13.7	104.2	6.49	14.9	24.7	3.79	10.1	1.34	13.4	2.89	8.60	1.64	1.13	2.45
97225_100_G	0.07	307.1	10.3	10.9	2.51	10.6	1.21	0.52	1.61	0.23	1.10	0.31	0.84	0.11	0.54	0.10
97225_80_G	0.22	354.2	13.4	25.8	3.47	9.99	3.60	0.39	1.81	0.25	1.07	0.40	0.73	0.15	0.77	0.15
97225_55_G	0.60	250.4	12.1	5.77	2.63	12.6	4.52	0.79	2.10	0.64	2.35	0.75	1.43	0.32	2.30	0.62
97225_40_G	0.96	256.6	15.9	10.8	3.54	17.1	5.48	1.35	2.08	0.42	3.37	0.77	1.00	0.76	3.67	0.50
97225_25_G	4.04	274.7	14.4	16.7	5.86	20.5	23.0	4.61	6.16	1.33	9.99	2.49	3.71	1.42	11.7	1.49
97225_100_H	0.13	249.6	18.4	19.0	3.55	13.9	3.01	0.58	1.84	0.36	1.62	0.26	1.07	0.11	0.76	0.12
97225_80_H	0.25	437.4	26.9	52.4	6.68	21.2	2.97	0.88	3.83	0.31	2.48	0.72	2.74	0.30	1.64	0.27
97225_55_H	0.43	1199.3	26.8	163.6	6.77	25.1	6.02	1.41	2.23	0.52	2.40	0.61	1.38	0.36	1.37	0.28
97225_40_H	0.71	1671.1	58.0	186.6	12.4	42.9	9.13	1.33	9.46	0.89	6.25	0.68	2.99	0.39	2.88	0.48
97225_25_H	1.13	1419.9	72.0	301.3	17.5	57.2	9.83	3.70	9.75	0.91	5.92	2.11	4.15	0.65	3.78	0.86
98355_100_A	0.01	250.4	0.43	0.21	0.04	0.13	0.10	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.02	0.01
98355_80_A	0.02	262.7	0.52	0.11	0.02	0.13	0.12	0.02	0.07	0.01	0.11	0.02	0.03	0.01	0.07	0.02
98355_55_A	0.07	252.2	0.11	0.03	0.03	0.18	0.36	0.06	0.09	0.02	0.14	0.04	0.11	0.02	0.02	0.04
98355_40_A	0.10	245.6	0.14	0.05	0.04	0.32	0.76	0.12	0.08	0.04	0.26	0.12	0.24	0.05	0.09	0.05
98355_25_A	0.32	224.0	0.26	0.16	0.18	1.51	2.38	0.41	1.13	0.09	0.86	0.43	0.65	0.21	0.73	0.23
98355_100_B	0.01	238.7	0.05	0.43	0.02	0.04	0.09	0.01	0.01	0.01	0.04	0.01	0.02	0.01	0.00	0.01
98355_80_B	0.02	230.6	0.02	0.01	0.02	0.05	0.12	0.02	0.06	0.01	0.08	0.01	0.03	0.01	0.05	0.02
98355_55_B	0.02	216.9	0.03	0.02	0.03	0.11	0.35	0.02	0.19	0.04	0.09	0.03	0.07	0.02	0.11	0.02
98355_40_B	0.08	215.0	0.06	0.04	0.06	0.19	0.59	0.08	0.32	0.05	0.26	0.07	0.16	0.05	0.18	0.04
98355_25_B	0.36	221.3	0.17	0.26	0.12	1.00	2.02	0.31	0.61	0.23	0.80	0.20	0.29	0.04	0.46	0.02
98355_100_C	0.01	202.4	0.04	0.20	0.01	0.02	0.06	0.01	0.00	0.00	0.03	0.00	0.01	0.01	0.03	0.01
98355_80_C	0.02	200.0	0.03	0.03	0.01	0.07	0.16	0.01	0.04	0.02	0.07	0.02	0.05	0.02	0.06	0.01

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U
97225_40_B	0.20	0.10	0.22	0.16	0.33	0.16	0.22	0.06	0.06	0.04
97225_25_B	0.48	0.44	1.05	0.53	0.79	0.75	1.17	0.58	0.25	0.17
97225_100_C	0.03	0.01	0.03	0.03	0.05	0.03	0.13	0.01	0.01	0.03
97225_80_C	0.06	0.04	0.07	0.04	0.02	0.05	0.14	0.02	0.01	0.07
97225_55_C	0.12	0.08	0.26	0.07	0.24	0.11	0.11	0.06	0.03	0.03
97225_40_C	0.25	0.10	0.12	0.19	0.61	0.21	1.13	0.10	0.06	0.05
97225_25_C	0.76	0.54	0.83	0.42	0.82	0.63	0.77	0.51	0.23	0.16
97225_100_D	0.01	0.01	0.04	0.02	0.04	0.03	0.12	0.01	0.01	0.03
97225_80_D	0.09	0.04	0.10	0.02	0.12	0.06	0.06	0.03	0.01	0.04
97225_55_D	0.13	0.06	0.14	0.07	0.29	0.12	0.10	0.05	0.06	0.03
97225_40_D	0.12	0.11	0.18	0.20	0.26	0.22	0.20	0.09	0.12	0.08
97225_25_D	0.64	0.21	1.14	0.61	0.59	0.48	0.54	0.29	0.10	0.37
97225_100_E	0.31	0.13	0.13	0.30	0.26	0.31	1.79	0.09	0.13	0.06
97225_80_E	1.13	0.33	0.88	0.45	1.29	0.88	0.70	0.34	0.17	0.18
97225_55_E	0.00	0.88	3.29	1.87	3.13	2.15	1.49	0.83	0.32	0.63
97225_40_E	4.71	1.94	7.28	4.14	13.0	6.29	5.01	2.24	0.99	0.92
97225_25_E	13.6	2.46	8.56	8.14	17.7	10.5	10.0	6.14	1.64	2.20
97225_100_F	0.20	0.12	0.12	0.22	0.21	0.28	0.31	0.12	0.02	0.13
97225_80_F	0.58	0.27	1.24	0.51	2.20	0.66	1.24	0.37	0.24	0.52
97225_55_F	1.12	0.93	1.74	1.25	4.72	2.02	1.38	0.67	0.47	1.09
97225_40_F	1.65	1.36	2.56	2.60	3.70	2.64	2.19	1.65	0.49	0.96
97225_25_F	9.72	3.27	12.3	6.97	19.8	9.51	7.93	2.38	1.65	1.56
97225_100_G	0.18	0.06	0.17	0.18	0.23	0.21	0.34	0.05	0.04	0.57
97225_80_G	0.35	0.14	0.75	0.38	0.54	0.31	0.84	0.23	0.14	0.72
97225_55_G	2.02	0.48	2.55	1.45	1.41	1.79	1.70	0.70	0.34	0.67
97225_40_G	1.15	1.06	3.09	1.43	1.81	1.77	1.72	0.69	0.48	0.99
97225_25_G	11.8	3.45	12.9	5.37	18.6	5.95	8.68	4.09	1.41	0.98
97225_100_H	0.32	0.16	0.28	0.25	0.50	0.43	0.79	0.12	0.13	0.76
97225_80_H	0.51	0.36	0.79	0.89	1.78	0.72	1.10	0.50	0.26	1.08
97225_55_H	0.90	0.35	2.41	1.32	3.13	1.38	3.57	0.38	0.37	0.89
97225_40_H	1.78	0.52	2.75	0.86	3.67	1.50	1.43	0.53	0.59	2.24
97225_25_H	1.94	1.12	0.86	1.51	6.65	2.48	3.15	1.40	0.95	3.39
98355_100_A	0.05	0.02	0.03	0.02	0.03	0.02	0.06	0.01	0.00	0.00
98355_80_A	0.05	0.01	0.06	0.04	0.06	0.04	0.04	0.02	0.01	0.02
98355_55_A	0.09	0.06	0.13	0.12	0.13	0.10	0.10	0.06	0.04	0.02
98355_40_A	0.22	0.13	0.03	0.27	0.25	0.20	0.20	0.16	0.01	0.08
98355_25_A	0.75	0.37	0.00	0.40	1.57	0.78	0.77	0.33	0.15	0.10
98355_100_B	0.03	0.01	0.03	0.02	0.05	0.03	0.11	0.01	0.01	0.00
98355_80_B	0.07	0.03	0.08	0.03	0.09	0.04	0.05	0.02	0.01	0.00
98355_55_B	0.11	0.03	0.12	0.05	0.16	0.13	0.09	0.04	0.01	0.01
98355_40_B	0.23	0.08	0.11	0.14	0.28	0.16	0.14	0.07	0.07	0.04
98355_25_B	0.49	0.28	0.76	0.42	1.28	0.72	0.72	0.18	0.14	0.09
98355_100_C	0.02	0.01	0.03	0.01	0.04	0.02	0.04	0.01	0.00	0.00
98355_80_C	0.03	0.02	0.05	0.04	0.12	0.04	0.04	0.01	0.01	0.01

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Li	Be	B	Na	Al	Si	P	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Cu
98355_55_C	1.93	6.37	3.75	5575	1.44	191.6	63542	319095	0.35	1.88	2.20	1.99	2.7	39.5	0.13	0.34
98355_40_C	2.61	6.53	2.63	5515	3.48	132.9	65849	335529	0.61	6.21	3.02	3.56	3.1	36.1	0.30	0.55
98355_25_C	2.72	0.00	10.4	5779	7.16	483.1	71633	355946	2.04	16.0	3.83	13.3	4.1	67.8	1.51	2.37
98355_100_D	0.95	0.98	1.91	6429	237.5	1193.9	59014	323913	0.09	10.9	4.06	3.30	28.2	245.8	0.46	10.2
98355_80_D	1.58	0.75	2.22	6421	323.4	1267.4	60991	341152	0.14	16.1	3.78	4.59	54.9	370.0	0.72	11.7
98355_55_D	1.29	1.07	2.31	6820	273.3	1211.9	62857	344754	0.30	8.05	4.16	3.56	30.3	306.3	0.19	12.2
98355_40_D	3.25	12.4	3.08	7765	729.3	943.4	70267	347507	0.77	23.8	3.95	5.72	23.0	456.2	0.39	1.86
98355_25_D	7.48	28.6	10.1	7227	816.4	1445.2	60617	327555	2.04	34.5	3.85	11.1	15.7	523.3	0.78	1.78
98355_100_E	2.65	7.15	7.09	7003	451.6	304.9	73560	387677	0.65	7.17	7.29	3.96	281.8	159.9	3.34	1.23
98355_80_E	8.41	12.2	9.70	6643	164.1	450.8	72134	389539	1.99	22.8	6.89	11.8	187.6	70.3	1.95	2.24
98355_55_E	5.53	7.48	27.8	6572	110.8	1095.8	77796	403901	5.13	39.2	8.59	29.6	783.7	138.1	13.7	4.13
98355_40_E	45.6	123.5	43.7	6222	51.5	1935.4	73094	390653	7.73	81.4	9.83	52.7	376.9	244.4	5.11	6.48
98355_25_E	135.4	518.4	106.1	7630	80.3	7652.89	67619	390670	32.8	223.3	25.2	204.9	328.1	907.7	8.08	33.3
98355_100_F	2.76	2.74	4.80	6357	17.8	183.2	65251	346685	0.60	4.91	4.88	3.35	20.6	39.9	0.48	0.52
98355_80_F	0.00	34.5	10.3	6531	31.9	370.0	69648	371499	1.82	8.55	4.90	9.88	3.8	56.9	0.85	1.80
98355_55_F	14.9	57.0	26.2	6483	29.8	899.1	75103	386510	4.56	44.5	4.45	24.3	6.0	112.0	2.16	3.64
98355_40_F	35.1	67.4	43.9	5455	49.3	1417.6	57715	302612	5.73	52.6	5.27	37.6	9.2	217.8	2.08	6.08
98355_25_F	116.6	206.3	159.8	10722	100.7	6978.81	79516	406200	37.1	220.3	16.2	181.6	44.8	844.3	12.0	30.8
98355_100_G	0.32	1.72	4.20	6637	9.56	145.9	62605	323536	0.70	3.14	3.57	3.23	2.0	32.8	0.14	0.52
98355_80_G	8.75	16.8	9.83	6358	14.6	327.3	62026	320332	1.38	13.0	3.90	8.88	2.9	46.4	0.36	1.07
98355_55_G	17.4	33.4	21.9	6489	12.4	688.1	59559	312781	3.14	30.6	3.25	18.3	5.7	81.6	1.77	3.46
98355_40_G	14.4	55.6	23.0	6861	16.2	852.4	67327	279489	3.21	30.3	3.39	22.4	5.1	129.1	1.47	3.21
98355_25_G	68.3	0.00	44.6	6310	74.9	2313.80	61648	272751	9.56	110.9	8.52	60.6	15.5	283.9	3.27	10.4
98355_100_H	2.35	6.39	3.47	6866	233.9	124.1	60993	314304	0.54	6.67	2.68	3.34	8.3	188.0	0.34	0.70
98355_80_H	2.86	27.3	8.03	6626	472.4	370.9	61651	316834	1.46	13.2	2.72	9.55	47.3	383.1	0.92	1.33
98355_55_H	4.17	23.3	18.1	6972	577.8	1629.4	56880	281299	2.29	27.1	2.87	13.2	642.7	736.9	18.4	2.57
98355_40_H	12.3	21.9	8.09	5529	2086.60	2253.96	48220	201172	3.38	79.2	5.01	19.4	35.1	1438.3	1.24	2.73
98355_25_H	13.1	0.00	90.9	5899	9426.62	16379.57	28832	120601	9.06	438.6	20.4	63.9	3839	7596	127.5	12.6
98359_100_A	0.89	0.28	1.97	5156	83.9	295.1	71508	375569	0.11	1.96	3.85	2.30	7.4	87.1	0.16	0.39
98359_80_A	0.64	3.05	2.62	5219	41.3	134.2	73028	389421	0.20	2.63	3.50	1.70	8.2	53.1	0.16	2.34
98359_55_A	2.01	6.43	2.34	5112	1.61	152.6	69484	366453	0.45	4.35	3.32	2.34	2.9	27.4	0.24	1.96
98359_40_A	5.07	5.39	5.68	5250	1.49	148.7	70842	372659	0.62	6.05	2.29	3.91	1.4	26.5	0.14	3.33
98359_25_A	14.4	7.48	18.5	4524	5.66	532.8	69691	341600	2.70	21.0	3.02	13.7	3.3	69.3	0.58	8.10
98359_100_B	0.87	0.28	1.78	4936	24.0	152.4	61189	321110	0.10	2.07	3.65	1.80	1.8	73.7	0.04	0.21
98359_80_B	0.74	2.87	1.58	5005	2.60	97.7	64118	331139	0.33	1.52	3.04	1.19	1.0	28.8	0.06	0.38
98359_55_B	0.85	6.15	1.84	4997	0.90	193.7	62666	320117	0.40	3.85	2.83	2.30	1.1	21.0	0.16	0.52
98359_40_B	2.72	1.00	2.62	5108	1.48	138.3	65434	336027	0.70	6.11	2.60	3.71	1.1	41.7	0.13	0.65
98359_25_B	9.34	36.3	17.2	4932	4.83	536.5	65241	323575	1.89	19.1	3.12	12.4	3.0	57.8	0.75	2.23
98359_100_C	0.35	0.97	1.70	4903	1.42	131.9	57372	297025	0.08	9.34	2.68	1.44	5.6	25.1	0.03	0.14
98359_80_C	0.28	0.76	1.93	4943	0.40	75.5	59334	307362	0.21	1.40	2.65	0.96	0.7	28.2	0.08	0.28
98359_55_C	2.13	4.14	2.50	4978	0.78	174.1	60394	307603	0.35	1.94	2.83	2.03	0.9	27.2	0.05	0.60
98359_40_C	2.44	9.48	4.40	4940	1.26	160.2	60888	308997	0.49	5.86	2.47	3.95	0.9	27.8	0.07	1.06
98359_25_C	8.56	40.8	7.12	4686	4.62	424.1	60645	302051	1.90	15.5	2.84	12.1	2.6	48.3	0.68	2.76
98359_100_D	0.85	0.87	1.82	5349	0.37	108.9	56438	289110	0.07	0.40	2.44	1.68	0.5	26.3	0.04	0.15

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ag	Cd	In	Sn	Sb
98355_55_C	48.5	1.60	0.25	0.76	0.26	137.4	0.05	0.10	0.88	0.01	0.26	0.14	0.30	0.03	0.24	0.03
98355_40_C	72.3	1.83	0.67	1.53	0.70	137.3	0.08	0.13	0.40	0.09	0.92	0.17	0.64	0.12	0.43	0.15
98355_25_C	78.2	2.53	2.52	3.90	1.44	139.5	0.29	0.44	2.85	0.31	0.26	0.82	2.19	0.28	1.37	0.87
98355_100_D	35.9	1.84	0.07	0.20	0.62	210.6	0.45	0.29	0.20	0.02	0.08	0.04	0.10	0.01	0.17	0.03
98355_80_D	49.3	1.75	0.16	0.32	1.50	221.7	0.43	0.40	0.28	0.08	0.16	0.05	0.10	0.02	0.32	0.08
98355_55_D	58.8	1.55	0.36	0.77	0.69	217.3	0.44	0.48	0.48	0.05	0.26	0.16	0.34	0.06	0.20	0.14
98355_40_D	74.3	1.43	0.89	1.18	0.42	165.4	0.77	0.37	0.78	0.15	0.75	0.23	0.78	0.08	0.37	0.11
98355_25_D	82.6	1.84	3.00	4.17	1.12	145.4	0.75	0.39	2.06	0.39	1.40	0.90	1.60	0.25	1.44	0.63
98355_100_E	36.0	2.73	0.72	1.93	0.43	192.1	1.05	0.24	1.27	0.04	0.40	0.26	0.80	0.09	0.45	0.16
98355_80_E	30.4	2.44	1.62	6.13	1.18	194.3	0.20	0.45	0.27	0.16	1.57	0.82	0.34	0.28	1.42	0.41
98355_55_E	26.0	3.09	6.52	9.67	3.32	214.2	0.49	2.37	6.91	1.05	3.82	2.83	4.35	0.69	3.13	1.74
98355_40_E	50.5	5.39	11.0	29.6	5.97	195.3	0.77	4.07	10.8	1.65	6.00	0.72	10.8	0.88	6.57	2.20
98355_25_E	124.6	16.6	43.9	90.1	25.0	186.2	3.23	12.1	32.0	0.71	10.9	22.8	20.2	2.60	21.3	8.07
98355_100_F	19.6	2.30	0.57	1.48	0.38	183.4	0.08	0.11	0.46	0.04	0.89	0.19	0.41	0.07	0.37	0.23
98355_80_F	19.1	3.29	2.01	4.83	1.16	201.3	0.15	0.16	1.50	0.23	1.18	0.97	1.34	0.24	1.12	0.38
98355_55_F	23.8	2.46	4.15	10.8	2.70	206.1	0.50	1.52	6.04	0.75	2.74	1.44	4.41	0.49	3.23	1.25
98355_40_F	36.4	4.01	6.70	13.8	3.98	161.8	0.15	3.10	8.22	1.25	4.15	2.40	2.86	0.82	4.36	1.47
98355_25_F	159.2	21.0	38.4	73.5	23.5	257.5	3.88	10.3	47.2	5.87	21.5	7.94	24.3	3.60	20.8	12.0
98355_100_G	25.1	2.01	0.74	1.98	0.42	192.0	0.06	0.12	0.29	0.12	0.43	0.16	0.49	0.06	0.34	0.28
98355_80_G	28.3	2.13	1.26	2.66	0.85	199.7	0.25	0.31	1.44	0.03	1.14	0.94	0.91	0.17	0.93	0.37
98355_55_G	21.3	2.48	3.84	10.0	1.83	172.2	0.17	0.62	4.03	0.38	3.18	1.18	2.55	0.33	2.19	1.03
98355_40_G	21.6	2.37	3.58	8.03	2.23	173.5	0.48	1.45	8.17	0.08	0.41	0.98	3.66	0.54	2.48	1.20
98355_25_G	58.7	5.64	10.9	26.2	6.47	170.8	1.30	3.96	12.9	1.96	10.2	4.61	9.98	1.28	7.01	4.64
98355_100_H	28.2	2.15	0.58	1.56	0.35	147.3	0.89	0.12	0.76	0.04	0.43	0.22	0.59	0.06	0.34	0.20
98355_80_H	40.5	2.78	2.08	2.58	1.13	153.5	1.85	0.61	1.62	0.35	1.82	0.95	2.06	0.26	1.28	0.11
98355_55_H	33.4	3.18	2.90	5.67	1.40	138.4	0.97	0.74	1.95	0.19	2.19	0.37	2.47	0.23	1.59	0.87
98355_40_H	29.2	2.05	4.79	8.97	2.43	110.6	2.69	1.30	4.58	0.35	0.73	1.43	1.78	0.46	2.12	1.25
98355_25_H	63.1	12.5	7.97	20.0	7.77	116.7	4.21	4.87	9.68	0.46	15.4	2.85	8.69	0.79	7.67	4.31
98359_100_A	99.1	1.40	0.08	0.25	0.09	110.0	0.34	0.04	0.09	0.01	0.12	0.04	0.08	0.01	0.19	0.03
98359_80_A	64.8	1.48	0.19	0.49	0.11	113.4	0.14	0.04	0.18	0.04	0.17	0.05	0.16	0.03	0.22	0.05
98359_55_A	50.9	1.06	0.44	0.92	0.27	110.5	0.05	0.16	0.53	0.06	0.42	0.25	0.19	0.05	0.31	0.10
98359_40_A	41.5	0.90	1.01	1.50	0.40	111.1	0.07	0.14	1.14	0.10	0.74	0.20	0.84	0.08	0.50	0.24
98359_25_A	29.9	1.56	1.89	3.69	1.57	103.0	0.06	0.07	1.84	1.55	1.82	0.95	2.90	0.19	1.53	0.59
98359_100_B	54.9	1.18	0.12	0.21	0.10	100.0	0.02	0.04	0.12	0.03	0.13	0.03	0.06	0.01	0.23	0.01
98359_80_B	42.4	1.10	0.24	0.41	0.10	99.3	0.03	0.04	0.23	0.02	0.13	0.05	0.11	0.01	0.14	0.04
98359_55_B	37.5	0.94	0.40	1.15	0.23	99.1	0.05	0.03	0.10	0.08	0.40	0.13	0.23	0.02	0.25	0.16
98359_40_B	38.1	1.22	0.80	0.99	0.34	104.1	0.06	0.09	0.85	0.13	0.84	0.05	0.54	0.06	0.53	0.27
98359_25_B	32.9	1.45	1.95	5.88	1.49	95.8	0.21	0.45	3.58	0.21	1.66	1.38	1.32	0.34	1.44	0.54
98359_100_C	32.6	1.04	0.11	0.22	0.16	99.4	0.01	0.03	0.08	0.01	0.09	0.02	0.09	0.01	0.18	0.03
98359_80_C	30.9	1.07	0.17	0.35	0.08	98.4	0.00	0.03	0.21	0.00	0.12	0.06	0.08	0.02	0.24	0.06
98359_55_C	33.5	1.22	0.33	0.89	0.17	100.8	0.03	0.15	0.33	0.05	0.38	0.17	0.09	0.03	0.25	0.09
98359_40_C	34.8	1.03	0.63	1.02	0.33	98.4	0.05	0.17	0.53	0.06	0.35	0.23	0.28	0.06	0.48	0.08
98359_25_C	46.7	1.95	2.21	3.11	1.23	95.3	0.19	0.66	1.87	0.29	1.22	0.79	1.20	0.46	1.22	0.98
98359_100_D	39.8	0.91	0.06	0.19	0.04	97.5	0.00	0.02	0.07	0.00	0.10	0.04	0.09	0.01	0.22	0.04

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
98355_55_C	0.05	183.5	0.05	0.03	0.02	0.14	0.26	0.05	0.12	0.02	0.14	0.02	0.14	0.04	0.10	0.02
98355_40_C	0.08	192.4	0.06	0.04	0.03	0.25	0.40	0.06	0.15	0.03	0.38	0.07	0.11	0.05	0.07	0.07
98355_25_C	0.32	199.1	0.21	0.20	0.10	1.05	1.56	0.28	0.09	0.20	1.47	0.17	0.83	0.12	0.58	0.18
98355_100_D	0.03	197.2	0.66	0.60	0.14	0.53	0.11	0.03	0.06	0.01	0.06	0.01	0.03	0.01	0.04	0.01
98355_80_D	0.04	199.4	1.02	1.15	0.19	0.65	0.11	0.02	0.08	0.01	0.06	0.02	0.04	0.01	0.07	0.01
98355_55_D	0.03	182.8	0.77	0.79	0.14	0.73	0.36	0.04	0.12	0.02	0.11	0.03	0.08	0.01	0.06	0.03
98355_40_D	0.08	211.5	1.55	1.48	0.41	1.13	0.44	0.05	0.19	0.03	0.25	0.08	0.12	0.05	0.19	0.04
98355_25_D	0.28	198.7	1.76	1.98	0.39	2.10	1.39	0.30	0.47	0.14	0.62	0.11	0.47	0.11	0.30	0.16
98355_100_E	0.07	369.4	6.69	1.81	0.45	1.54	0.55	0.09	0.31	0.02	0.38	0.06	0.17	0.03	0.18	0.06
98355_80_E	0.22	348.9	0.21	0.18	0.04	0.08	2.05	0.43	0.52	0.11	0.84	0.17	0.64	0.12	0.16	0.26
98355_55_E	0.82	399.6	0.62	0.45	0.13	0.20	4.23	0.46	0.17	0.04	2.91	0.52	0.48	0.29	0.19	0.29
98355_40_E	1.24	358.2	0.56	1.00	0.77	2.32	5.13	0.73	1.30	0.43	3.72	0.54	3.44	1.13	0.72	1.20
98355_25_E	3.12	328.9	2.33	2.08	3.24	4.21	32.8	5.28	2.42	2.53	15.6	4.78	3.40	1.92	4.03	2.04
98355_100_F	0.06	276.0	0.05	0.03	0.02	0.24	0.56	0.08	0.21	0.03	0.22	0.08	0.19	0.03	0.19	0.03
98355_80_F	0.27	296.1	0.15	0.02	0.13	0.91	1.30	0.20	0.68	0.07	0.73	0.26	0.55	0.09	0.43	0.10
98355_55_F	0.48	325.8	0.16	0.39	0.25	1.06	3.02	0.33	0.91	0.48	0.85	0.43	0.64	0.16	0.62	0.22
98355_40_F	0.70	250.6	0.42	0.69	0.29	0.46	3.90	1.11	2.62	0.29	2.45	0.87	1.07	0.35	1.68	0.52
98355_25_F	3.52	302.2	2.80	0.58	1.38	11.7	21.1	3.66	7.09	2.63	17.5	3.32	7.05	2.31	6.42	2.26
98355_100_G	0.10	279.2	0.06	0.05	0.03	0.23	0.56	0.02	0.14	0.05	0.27	0.03	0.10	0.05	0.04	0.06
98355_80_G	0.17	292.0	0.11	0.16	0.07	0.44	0.96	0.14	0.53	0.08	0.18	0.15	0.26	0.09	0.32	0.13
98355_55_G	0.37	273.5	0.21	0.19	0.20	0.86	2.91	0.47	1.48	0.16	1.39	0.49	0.74	0.10	1.43	0.03
98355_40_G	0.46	267.9	0.22	0.23	0.24	0.93	2.88	0.55	1.23	0.32	1.99	0.20	0.56	0.40	1.93	0.30
98355_25_G	1.41	299.0	2.16	1.06	0.22	3.89	8.61	1.22	3.35	1.13	2.56	0.96	2.88	1.09	2.14	1.16
98355_100_H	0.08	217.4	1.27	0.95	0.37	1.61	0.63	0.04	0.24	0.05	0.29	0.07	0.14	0.05	0.17	0.01
98355_80_H	0.21	244.3	2.30	1.75	0.55	1.30	1.40	0.22	0.44	0.09	0.79	0.14	0.42	0.10	0.47	0.10
98355_55_H	0.29	323.0	2.29	6.69	0.53	1.95	2.38	0.41	0.72	0.19	0.95	0.20	0.62	0.29	0.37	0.12
98355_40_H	0.44	289.2	3.85	3.44	0.95	5.68	3.26	0.31	1.04	0.22	1.37	0.30	0.51	0.24	1.15	0.18
98355_25_H	1.17	941.3	10.7	57.3	2.63	10.8	9.16	1.42	5.64	0.54	3.26	1.18	1.77	1.01	1.29	0.62
98359_100_A	0.02	149.3	1.34	0.95	0.24	1.02	0.16	0.02	0.10	0.01	0.06	0.01	0.05	0.01	0.03	0.01
98359_80_A	0.03	157.5	0.73	0.29	0.06	0.31	0.12	0.02	0.05	0.01	0.09	0.02	0.05	0.02	0.07	0.01
98359_55_A	0.05	157.7	0.04	0.04	0.00	0.16	0.21	0.01	0.20	0.04	0.13	0.03	0.10	0.00	0.03	0.04
98359_40_A	0.08	160.4	0.04	0.06	0.03	0.28	0.72	0.11	0.17	0.04	0.28	0.08	0.17	0.06	0.05	0.04
98359_25_A	0.23	140.3	0.37	0.15	0.20	0.46	1.52	0.31	0.59	0.13	1.11	0.20	0.42	0.14	0.66	0.15
98359_100_B	0.01	136.6	0.01	0.04	0.00	0.02	0.05	0.01	0.02	0.01	0.04	0.01	0.02	0.01	0.02	0.01
98359_80_B	0.01	134.5	0.01	0.01	0.01	0.05	0.18	0.02	0.04	0.01	0.09	0.02	0.06	0.01	0.02	0.03
98359_55_B	0.04	139.1	0.05	0.01	0.03	0.07	0.36	0.03	0.09	0.03	0.15	0.02	0.06	0.00	0.10	0.02
98359_40_B	0.10	142.2	0.04	0.04	0.03	0.18	0.23	0.02	0.02	0.03	0.26	0.06	0.05	0.01	0.25	0.05
98359_25_B	0.29	137.8	0.15	0.02	0.10	0.89	1.38	0.11	0.29	0.16	0.50	0.10	0.53	0.18	0.08	0.19
98359_100_C	0.01	131.5	0.02	0.04	0.00	0.03	0.05	0.01	0.02	0.00	0.00	0.01	0.01	0.00	0.01	0.01
98359_80_C	0.02	131.7	0.02	0.02	0.01	0.02	0.17	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.04	0.01
98359_55_C	0.05	140.1	0.06	0.00	0.02	0.00	0.22	0.01	0.09	0.01	0.11	0.03	0.09	0.03	0.06	0.02
98359_40_C	0.03	132.4	0.06	0.02	0.04	0.09	0.68	0.01	0.02	0.03	0.18	0.05	0.10	0.02	0.15	0.03
98359_25_C	0.29	127.1	0.14	0.12	0.09	0.98	1.25	0.36	0.49	0.15	0.46	0.11	0.48	0.11	0.00	0.27
98359_100_D	0.01	108.4	0.01	0.00	0.00	0.04	0.05	0.01	0.02	0.00	0.02	0.01	0.00	0.01	0.02	0.01

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U
98355_55_C	0.10	0.05	0.11	0.08	0.11	0.10	0.09	0.04	0.01	0.01
98355_40_C	0.13	0.07	0.33	0.10	0.15	0.11	0.12	0.05	0.07	0.04
98355_25_C	0.60	0.30	0.66	0.39	0.11	0.50	0.65	0.40	0.20	0.05
98355_100_D	0.01	0.01	0.03	0.01	0.04	0.02	0.30	0.01	0.03	0.01
98355_80_D	0.02	0.01	0.07	0.02	0.04	0.04	0.24	0.02	0.03	0.02
98355_55_D	0.06	0.03	0.10	0.09	0.03	0.09	0.21	0.04	0.02	0.02
98355_40_D	0.12	0.09	0.26	0.14	0.18	0.18	0.17	0.05	0.06	0.03
98355_25_D	0.38	0.27	0.59	0.35	0.82	0.58	0.37	0.19	0.10	0.10
98355_100_E	0.23	0.05	0.21	0.18	0.35	0.14	0.17	0.08	0.05	0.02
98355_80_E	0.42	0.34	0.66	0.46	1.12	0.58	0.62	0.27	0.12	0.08
98355_55_E	2.06	0.93	0.65	0.80	0.64	1.57	1.33	0.77	0.12	0.27
98355_40_E	2.10	0.65	2.51	1.78	2.88	2.46	1.77	0.91	0.45	0.05
98355_25_E	11.7	2.73	10.7	5.39	20.8	9.60	8.75	4.27	0.54	1.80
98355_100_F	0.14	0.04	0.15	0.14	0.21	0.14	0.13	0.07	0.03	0.03
98355_80_F	0.32	0.22	0.73	0.58	0.98	0.47	0.35	0.18	0.09	0.06
98355_55_F	1.27	0.30	1.15	0.81	2.28	0.77	1.08	0.29	0.20	0.14
98355_40_F	1.11	0.86	3.32	1.35	4.26	1.87	1.34	0.49	0.89	0.23
98355_25_F	0.93	5.18	8.97	4.13	17.9	10.4	6.29	3.25	1.58	2.42
98355_100_G	0.16	0.02	0.26	0.06	0.31	0.15	0.16	0.07	0.05	0.02
98355_80_G	0.23	0.03	0.18	0.29	0.82	0.32	0.30	0.15	0.03	0.01
98355_55_G	1.04	0.34	0.94	0.66	1.33	0.89	0.59	0.45	0.17	0.05
98355_40_G	1.57	0.28	1.69	0.87	1.10	1.39	0.98	0.56	0.19	0.06
98355_25_G	1.87	1.09	5.20	2.38	2.94	2.39	1.63	1.63	0.91	0.51
98355_100_H	0.16	0.07	0.25	0.11	0.18	0.09	0.11	0.09	0.03	0.07
98355_80_H	0.68	0.24	0.14	0.38	0.76	0.41	0.34	0.22	0.19	0.09
98355_55_H	0.82	0.17	1.12	0.45	0.86	0.49	0.53	0.39	0.13	0.19
98355_40_H	0.59	0.48	0.93	0.74	1.87	0.74	0.71	0.34	0.23	0.13
98355_25_H	2.03	1.17	4.54	1.61	2.98	2.91	3.01	1.42	0.77	0.59
98359_100_A	0.03	0.01	0.04	0.01	0.01	0.03	0.14	0.02	0.00	0.01
98359_80_A	0.07	0.01	0.02	0.04	0.03	0.05	0.05	0.02	0.01	0.01
98359_55_A	0.14	0.03	0.25	0.12	0.36	0.10	0.10	0.04	0.01	0.02
98359_40_A	0.28	0.08	0.03	0.16	0.31	0.20	0.15	0.13	0.04	0.03
98359_25_A	0.39	0.05	0.76	0.66	1.33	0.83	0.58	0.19	0.02	0.03
98359_100_B	0.03	0.01	0.03	0.01	0.03	0.02	0.05	0.01	0.00	0.00
98359_80_B	0.04	0.02	0.08	0.03	0.08	0.05	0.04	0.02	0.01	0.00
98359_55_B	0.18	0.00	0.12	0.10	0.21	0.08	0.05	0.05	0.04	0.01
98359_40_B	0.18	0.07	0.20	0.12	0.24	0.13	0.09	0.06	0.05	0.02
98359_25_B	0.43	0.18	1.19	0.49	0.70	0.55	0.43	0.33	0.02	0.22
98359_100_C	0.02	0.01	0.05	0.02	0.06	0.02	0.02	0.01	0.01	0.00
98359_80_C	0.07	0.03	0.03	0.03	0.05	0.05	0.05	0.02	0.01	0.01
98359_55_C	0.14	0.03	0.16	0.07	0.16	0.07	0.11	0.05	0.03	0.01
98359_40_C	0.11	0.05	0.36	0.14	0.18	0.15	0.06	0.07	0.03	0.03
98359_25_C	0.68	0.16	0.51	0.31	1.11	0.54	0.55	0.28	0.11	0.05
98359_100_D	0.01	0.01	0.02	0.01	0.03	0.02	0.04	0.01	0.00	0.00

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Li	Be	B	Na	Al	Si	P	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Cu
98359_80_D	0.96	2.60	2.04	5499	0.41	74.4	59836	313634	0.14	1.35	2.76	2.29	0.7	26.0	0.04	0.20
98359_55_D	1.37	3.78	2.29	5397	0.83	138.8	57692	298639	0.32	2.48	2.76	2.41	0.7	16.7	0.11	0.35
98359_40_D	1.94	6.63	3.11	5637	2.74	119.2	62416	315019	0.48	3.42	2.13	3.43	1.6	18.0	0.27	0.62
98359_25_D	1.06	5.84	13.2	5009	8.41	385.3	60288	296061	1.41	10.0	3.11	12.0	2.6	51.9	0.62	2.15
98359_100_E	2.28	6.70	4.99	5694	1.73	120.8	61014	294052	0.60	5.77	0.87	3.19	0.8	22.7	0.24	0.97
98359_80_E	2.68	26.0	7.94	5704	3.71	359.4	59934	293452	1.48	8.44	1.07	8.70	2.0	37.9	0.64	2.48
98359_55_E	27.7	44.3	19.6	6336	8.38	845.0	65397	319324	2.87	24.9	2.47	22.6	4.7	85.3	2.19	4.88
98359_40_E	4.03	91.1	34.2	5890	12.7	1292.6	58709	274252	5.54	46.6	3.59	35.7	8.5	184.3	1.29	5.93
98359_25_E	88.6	0.00	199.4	6135	52.5	4619.15	51783	220297	19.9	209.5	12.5	125.2	28.9	612.7	6.96	26.9
98359_100_F	0.34	6.06	11.2	5376	2.45	117.3	54855	270489	0.56	3.38	1.33	4.39	0.7	22.6	0.17	0.56
98359_80_F	10.4	20.5	10.9	5545	4.28	369.2	56081	283891	1.75	11.4	1.43	9.97	2.2	49.1	0.41	1.87
98359_55_F	12.9	4.96	16.2	5018	7.04	777.7	56913	285266	2.89	25.7	2.92	19.0	4.5	74.0	1.43	4.11
98359_40_F	36.3	71.3	38.2	5155	18.9	1514.0	61955	298125	7.33	39.5	4.40	41.9	9.4	169.8	2.83	8.52
98359_25_F	132.9	261.1	213.9	4990	54.4	5214.77	88965	299013	20.1	128.2	24.2	140.9	34.7	693.7	10.3	24.9
98359_100_G	0.99	1.84	7.84	6065	1.48	122.6	58370	283877	0.62	5.77	2.29	3.19	0.9	35.1	0.11	0.67
98359_80_G	5.82	22.9	7.43	6486	3.49	306.4	61152	304762	1.24	11.5	2.48	8.59	1.7	60.0	0.11	5.64
98359_55_G	16.3	8.32	21.1	6367	8.73	607.2	64143	284996	2.74	22.8	3.24	16.2	3.5	69.3	0.25	4.12
98359_40_G	13.0	36.2	25.2	7365	11.4	721.1	68626	258390	2.63	32.4	3.48	19.7	4.1	99.6	1.00	5.21
98359_25_G	26.6	20.5	23.1	6517	14.1	1466.4	54682	183067	6.14	46.8	3.69	39.6	9.2	167.0	2.90	9.47
98359_100_H	3.75	2.99	4.01	6225	12.5	207.9	58702	285997	0.60	6.59	2.59	3.50	1.7	45.4	0.20	3.00
98359_80_H	2.82	0.00	9.87	6295	7.55	238.6	61310	263536	0.98	9.00	1.89	6.58	1.4	32.4	0.50	1.61
98359_55_H	6.31	38.2	16.9	6217	47.8	711.1	59535	281567	3.06	59.0	2.67	18.7	4.3	83.3	1.28	5.50
98359_40_H	22.0	43.5	20.4	12534	79.0	857.8	71561	280557	3.93	27.2	5.46	86.3	5.8	109.7	1.69	17.2
98359_25_H	0.00	74.3	23.4	7189	52.0	1536.6	42253	179132	6.78	51.9	4.79	41.2	10.3	199.9	3.52	10.1
SRM612 Avg.	42.38	38.18	35.81	105192	11276	336656	60.70	85519	41.36	48.13	39.59	40.27	38.75	56.69	32.42	37.16

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Zn	Ga	Ge	As	Rb	Sr	Y	Zr90	Zr91	Nb	Mo	Ag	Cd	In	Sn	Sb
98359_80_D	54.8	0.83	0.15	0.42	0.10	97.7	0.01	0.03	0.15	0.02	0.12	0.04	0.09	0.02	0.12	0.05
98359_55_D	68.8	0.72	0.43	0.95	0.16	92.0	0.03	0.07	0.42	0.08	0.42	0.15	0.19	0.02	0.25	0.08
98359_40_D	95.4	0.99	0.70	1.59	0.34	95.9	0.08	0.11	1.47	0.03	0.17	0.22	0.47	0.04	0.27	0.14
98359_25_D	143.8	1.16	1.86	4.03	0.91	87.4	0.21	0.37	0.91	0.26	1.94	0.14	1.02	0.14	1.32	0.77
98359_100_E	18.4	1.26	0.55	1.97	0.31	114.7	0.02	0.08	0.74	0.11	0.60	0.22	0.47	0.06	0.31	0.04
98359_80_E	23.4	1.97	1.43	3.11	0.97	114.1	0.25	0.31	2.47	0.24	1.16	0.43	0.91	0.17	0.97	0.53
98359_55_E	28.2	2.12	4.50	7.50	2.29	123.1	0.30	1.06	4.84	0.75	2.79	2.06	4.40	0.63	2.16	0.91
98359_40_E	24.8	2.95	6.90	17.6	2.91	109.5	0.26	2.18	9.93	0.77	4.04	1.50	3.19	0.71	3.48	2.28
98359_25_E	78.4	11.2	24.8	41.5	11.2	102.3	3.83	5.85	32.6	5.77	21.7	9.85	17.1	2.20	16.5	7.08
98359_100_F	23.3	1.33	0.59	1.12	0.32	113.2	0.08	0.08	0.46	0.07	0.93	0.20	0.09	0.08	0.35	0.21
98359_80_F	16.4	0.97	1.65	4.63	0.88	120.1	0.09	0.19	2.70	0.24	1.27	0.67	1.42	0.26	1.02	0.59
98359_55_F	35.5	2.32	4.86	5.40	2.10	126.3	0.55	1.20	2.73	0.42	4.45	1.43	3.04	0.50	1.97	1.26
98359_40_F	35.4	3.56	7.75	14.2	3.57	130.9	0.53	1.68	12.1	0.84	7.66	3.66	4.93	0.45	3.80	1.11
98359_25_F	110.4	13.0	26.1	39.3	13.2	102.0	2.01	4.34	19.7	3.05	16.2	8.47	9.78	3.26	18.7	6.50
98359_100_G	24.7	1.43	0.60	1.15	0.35	111.3	0.01	0.12	0.73	0.04	0.60	0.22	0.33	0.07	0.38	0.09
98359_80_G	25.5	0.83	1.83	3.65	0.86	112.5	0.02	0.46	1.22	0.33	1.00	0.37	1.36	0.30	0.91	0.46
98359_55_G	26.7	1.49	2.68	4.83	1.51	103.1	0.35	0.34	1.87	0.37	2.79	1.03	2.20	0.21	1.85	0.65
98359_40_G	36.1	1.52	3.79	10.5	1.75	101.6	0.48	0.84	4.67	0.72	0.92	1.84	1.21	0.39	1.65	1.03
98359_25_G	62.6	3.65	9.72	20.0	3.66	63.2	1.12	2.10	5.51	1.48	9.06	2.38	7.12	1.02	4.23	2.57
98359_100_H	60.1	0.76	0.59	1.57	0.25	91.2	0.08	0.28	0.86	0.15	0.36	0.17	0.50	0.05	0.41	0.15
98359_80_H	104.3	1.15	1.33	1.92	0.64	84.6	0.10	0.83	1.02	0.15	0.24	0.29	0.61	0.09	0.62	0.44
98359_55_H	133.6	1.87	3.52	7.56	1.85	88.8	0.57	4.86	4.87	0.07	3.28	1.49	2.57	0.23	2.11	0.76
98359_40_H	239.3	1.99	4.00	9.20	1.97	83.5	0.14	8.82	6.39	0.99	4.56	2.19	0.57	0.46	5.73	0.86
98359_25_H	117.3	3.50	9.31	11.1	3.98	65.7	0.78	70.2	10.9	0.52	4.49	2.88	6.10	0.64	5.17	2.55
SRM612 Avg.	38.37	36.36	34.87	38.29	31.96	76.54	38.61	36.66	36.22	38.14	35.90	22.06	28.72	43.09	38.26	38.52

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
98359_80_D	0.01	105.3	0.01	0.01	0.01	0.04	0.18	0.02	0.03	0.00	0.05	0.02	0.05	0.00	0.04	0.01
98359_55_D	0.04	101.3	0.03	0.00	0.02	0.09	0.23	0.04	0.11	0.02	0.07	0.04	0.02	0.02	0.04	0.02
98359_40_D	0.07	106.2	0.05	0.08	0.02	0.06	0.35	0.01	0.19	0.05	0.31	0.08	0.10	0.00	0.21	0.06
98359_25_D	0.22	95.9	0.12	0.11	0.15	0.51	1.46	0.11	0.88	0.13	0.92	0.21	0.31	0.10	0.20	0.15
98359_100_E	0.06	168.9	0.03	0.03	0.05	0.22	0.35	0.03	0.19	0.01	0.18	0.03	0.10	0.03	0.15	0.07
98359_80_E	0.13	186.3	0.15	0.03	0.14	0.43	0.78	0.36	0.53	0.11	0.60	0.15	0.37	0.15	0.71	0.09
98359_55_E	0.54	189.5	0.50	0.03	0.30	0.15	4.18	0.24	0.13	0.19	0.85	0.21	0.27	0.06	2.20	0.22
98359_40_E	0.36	174.4	0.72	0.06	0.22	1.50	6.35	0.67	1.83	0.39	0.63	0.74	1.28	0.16	2.86	0.45
98359_25_E	2.11	135.5	1.38	2.14	1.90	9.89	10.3	1.79	4.92	1.05	7.96	1.15	3.44	0.62	2.22	2.40
98359_100_F	0.04	177.4	0.02	0.06	0.03	0.14	0.40	0.04	0.24	0.04	0.20	0.05	0.12	0.04	0.13	0.04
98359_80_F	0.21	177.5	0.23	0.07	0.08	0.47	1.20	0.26	0.71	0.15	0.15	0.05	0.49	0.16	0.45	0.14
98359_55_F	0.27	209.4	0.28	0.10	0.20	1.17	2.97	0.37	0.71	0.34	0.67	0.33	0.50	0.16	1.57	0.30
98359_40_F	0.94	189.6	0.56	0.71	0.61	2.84	5.11	0.30	2.00	0.60	3.23	0.74	2.20	0.46	2.69	0.69
98359_25_F	3.83	190.9	1.33	1.30	1.41	3.68	18.6	1.88	5.16	1.10	4.82	1.30	9.51	2.37	8.02	1.77
98359_100_G	0.05	147.2	0.03	0.03	0.04	0.16	0.28	0.07	0.14	0.03	0.22	0.03	0.09	0.00	0.21	0.06
98359_80_G	0.11	155.1	0.04	0.11	0.09	0.64	1.24	0.23	0.00	0.07	0.51	0.06	0.31	0.01	0.12	0.08
98359_55_G	0.34	143.3	0.25	0.22	0.17	0.73	2.27	0.46	1.09	0.04	0.59	0.29	0.88	0.14	0.98	0.19
98359_40_G	0.38	144.5	0.34	0.18	0.19	0.82	1.80	0.57	1.00	0.26	1.47	0.37	0.98	0.16	1.10	0.17
98359_25_G	0.78	109.5	0.40	0.63	0.39	1.67	2.13	0.52	1.44	0.43	1.90	0.48	1.74	0.66	1.58	0.50
98359_100_H	0.08	94.6	0.10	0.21	0.03	0.13	0.52	0.10	0.14	0.02	0.19	0.03	0.04	0.02	0.16	0.02
98359_80_H	0.13	93.2	0.27	0.09	0.07	0.29	0.89	0.09	0.08	0.12	0.23	0.10	0.17	0.01	0.38	0.12
98359_55_H	0.37	81.3	0.16	0.19	0.14	1.21	3.07	0.04	1.04	0.41	0.97	0.17	0.72	0.17	0.25	0.36
98359_40_H	0.53	86.5	0.10	0.30	0.23	0.13	2.46	0.30	1.18	0.18	1.56	0.39	0.16	0.16	1.83	0.20
98359_25_H	0.78	51.0	0.56	0.62	0.48	0.34	4.19	0.52	2.46	0.61	1.88	0.37	1.71	0.46	2.70	0.85
SRM612 Avg.	42.00	37.87	35.98	38.36	37.34	35.32	37.14	34.59	37.22	36.13	36.24	38.15	37.85	37.81	40.22	38.00

Appendix B: Laser ablation elemental data for KN XIV teeth (Sample ID_Laser Spot Size_Sample Group).

Sample ID	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U
98359_80_D	0.05	0.01	0.05	0.03	0.07	0.04	0.03	0.01	0.01	0.00
98359_55_D	0.09	0.01	0.20	0.05	0.18	0.07	0.06	0.03	0.02	0.01
98359_40_D	0.11	0.06	0.07	0.06	0.25	0.12	0.14	0.06	0.04	0.01
98359_25_D	0.61	0.25	0.57	0.35	1.01	0.45	0.25	0.15	0.10	0.04
98359_100_E	0.11	0.05	0.30	0.12	0.31	0.13	0.13	0.08	0.00	0.02
98359_80_E	0.42	0.21	0.83	0.42	0.70	0.45	0.21	0.19	0.12	0.08
98359_55_E	0.10	0.41	0.17	0.41	1.68	0.81	0.51	0.29	0.28	0.20
98359_40_E	1.80	0.42	1.67	0.84	2.44	1.55	1.16	0.43	0.28	0.35
98359_25_E	6.83	3.21	6.35	6.76	16.0	3.86	3.41	3.24	1.87	1.32
98359_100_F	0.12	0.06	0.22	0.14	0.32	0.11	0.12	0.08	0.02	0.04
98359_80_F	0.33	0.11	0.14	0.37	0.77	0.37	0.33	0.21	0.13	0.06
98359_55_F	0.81	0.33	0.92	0.57	1.65	0.91	0.81	0.33	0.16	0.16
98359_40_F	3.20	1.30	3.16	1.30	2.69	1.57	1.70	0.49	0.30	0.38
98359_25_F	10.1	1.03	6.67	4.10	12.0	5.72	5.06	3.80	1.96	1.38
98359_100_G	0.15	0.02	0.30	0.09	0.19	0.12	0.11	0.10	0.00	0.02
98359_80_G	0.25	0.10	0.41	0.29	0.74	0.27	0.31	0.15	0.14	0.07
98359_55_G	0.87	0.35	0.32	0.71	0.85	0.83	0.71	0.36	0.14	0.14
98359_40_G	0.98	0.40	1.29	0.56	1.90	0.70	0.85	0.23	0.31	0.11
98359_25_G	1.99	0.47	1.87	1.48	3.37	2.06	1.21	0.83	0.32	0.39
98359_100_H	0.16	0.03	0.19	0.13	0.19	0.13	0.40	0.08	0.04	0.02
98359_80_H	0.28	0.11	0.15	0.16	0.75	0.31	0.30	0.10	0.05	0.05
98359_55_H	1.02	0.26	0.59	0.59	1.00	0.53	1.77	0.34	0.10	0.20
98359_40_H	0.94	0.77	1.08	0.86	1.61	0.75	2.30	0.44	0.18	0.13
98359_25_H	1.60	0.80	1.85	1.97	3.87	1.88	2.64	0.74	0.54	0.22
SRM612 Avg.	35.08	40.09	0.00	8.26	5.21	14.08	39.72	30.70	37.56	37.79

Appendix C: Laser ablation 87Sr/86Sr ratio data for KN XIV teeth (Sample ID_Sample Group).

Sample ID	total Sr (V)	88Sr (V)	85Rb (V)	87Sr/86Sr	2σ error	84Sr/86Sr	2σ error
97.211_A1	0.51551	0.45867	2.89E-04	0.712374	0.000181	0.05592	0.000181
97.211_A2	0.51609	0.45335	2.41E-04	0.712508	0.000168	0.05652	0.000202
97.211_A3	0.49531	0.42887	2.70E-04	0.712539	0.000204	0.05615	0.000192
97.211_B1	0.52372	0.43622	2.80E-04	0.712277	0.000198	0.05598	0.000182
97.211_B2	0.50026	0.41559	1.92E-04	0.712029	0.000162	0.05665	0.000115
97.211_B3	0.48724	0.40481	2.08E-04	0.712610	0.000141	0.05542	0.000272
97.211_C1	0.50601	0.42038	1.77E-04	0.711635	0.000157	0.05709	0.000112
97.211_C2	0.43079	0.35789	1.41E-04	0.711531	0.000202	0.05717	0.000116
97.211_C3	0.50637	0.42081	1.77E-04	0.711771	0.000164	0.05518	0.000191
97.211_D1	0.49949	0.41508	2.26E-04	0.712428	0.000172	0.05474	0.000404
97.211_D2	0.46193	0.38379	1.12E-04	0.711917	0.000189	0.05678	0.000109
97.211_D3	0.54054	0.44921	1.67E-04	0.711483	0.000214	0.05620	0.000262
97.217_A1	0.41158	0.34178	3.00E-04	0.715898	0.000197	0.05696	0.000175
97.217_A2	0.40418	0.33555	3.99E-04	0.717021	0.000274	0.05822	0.000114
97.217_A3	0.40042	0.33247	4.29E-04	0.717213	0.000200	0.05708	0.000112
97.217_B1	0.33228	0.27592	2.38E-04	0.716345	0.000320	0.05777	0.000196
97.217_B2	0.34036	0.28257	2.91E-04	0.716882	0.000130	0.05858	0.000147
97.217_B3	0.36801	0.30552	3.38E-04	0.717450	0.000204	0.05726	0.000129
97.217_C1	0.29886	0.24818	2.15E-04	0.715361	0.000214	0.05796	0.000155
97.217_C2	0.43354	0.36000	2.94E-04	0.715857	0.000240	0.05738	0.000145
97.217_C3	0.42691	0.35448	2.86E-04	0.715117	0.000204	0.05758	0.000102
97.217_D1	0.36271	0.30120	1.91E-04	0.715128	0.000234	0.05827	0.000167
97.217_D2	0.37763	0.31354	2.07E-04	0.715732	0.000195	0.05777	0.000131
97.217_D3	0.37921	0.31475	2.35E-04	0.716022	0.000236	0.05895	0.000150
97.225_A1	0.25591	0.21245	3.16E-04	0.714416	0.000294	0.05955	0.000222
97.225_A2	0.23264	0.19311	2.65E-04	0.716152	0.000312	0.05906	0.000190
97.225_A3	0.26784	0.22227	3.13E-04	0.716326	0.000208	0.05988	0.000232
97.225_B1	0.22018	0.18276	3.03E-04	0.715584	0.000296	0.05915	0.000166
97.225_B2	0.23487	0.19493	3.21E-04	0.716525	0.000252	0.05998	0.000208
97.225_B3	0.24834	0.20608	3.51E-04	0.716107	0.000300	0.05992	0.000216
97.225_C1	0.21049	0.17468	3.30E-04	0.715738	0.000300	0.06010	0.000246
97.225_C2	0.25908	0.21497	3.62E-04	0.715356	0.000252	0.06026	0.000159
97.225_C3	0.25338	0.21027	3.90E-04	0.715987	0.000280	0.05950	0.000169
97.225_D1	0.18731	0.15546	2.53E-04	0.715001	0.000320	0.06019	0.000260
97.225_D2	0.21800	0.18086	3.44E-04	0.716650	0.000348	0.06077	0.000230
97.225_D3	0.13213	0.10972	1.64E-04	0.715232	0.000672	0.05441	0.000842
98.355_A1	0.20930	0.17431	5.31E-05	0.713216	0.000366	0.03779	0.001754
98.355_A2	0.19146	0.15974	5.37E-05	0.715299	0.000420	0.02282	0.001328
98.355_B1	0.17089	0.14191	5.08E-05	0.712612	0.000450	0.06042	0.000360
98.355_B2	0.19550	0.16235	5.24E-05	0.712071	0.000302	0.05999	0.000192
98.355_B3	0.22082	0.18339	6.25E-05	0.711960	0.000278	0.05934	0.000240
98.355_C1	0.17003	0.14126	4.84E-05	0.711643	0.000414	0.05909	0.000240
98.355_C2	0.16434	0.13654	6.00E-05	0.712180	0.000448	0.05918	0.000226
98.355_C3	0.17493	0.14530	6.72E-05	0.712650	0.000346	0.05840	0.000288
98.355_D1	0.14176	0.11771	5.70E-05	0.713514	0.000632	0.05988	0.000342
98.355_D2	0.17101	0.14200	1.05E-04	0.713680	0.000390	0.05869	0.000278
98.355_D3	0.15444	0.12822	6.71E-05	0.714696	0.000464	0.05890	0.000240

Appendix C: Laser ablation 87Sr/86Sr ratio data for KN XIV teeth (Sample ID_Sample Group).

Sample ID	total Sr (V)	88Sr (V)	85Rb (V)	87Sr/86Sr	2σ error	84Sr/86Sr	2σ error
98.359_A1	0.08856	0.07353	3.41E-05	0.711740	0.000690	0.06180	0.000490
98.359_A2	0.09535	0.07919	3.17E-05	0.712716	0.000660	0.05925	0.000470
98.359_A3	0.09603	0.07978	3.54E-05	0.711875	0.000672	0.05881	0.000402
98.359_B1	0.07894	0.06555	2.82E-05	0.711754	0.000710	0.06094	0.000444
98.359_B2	0.08500	0.07059	2.74E-05	0.712941	0.000916	0.06025	0.000504
98.359_B3	0.09881	0.08204	2.92E-05	0.712905	0.000712	0.06003	0.000440
98.359_C1	0.07775	0.06455	2.07E-05	0.714185	0.001052	0.05964	0.000504
98.359_C2	0.09139	0.07587	1.97E-05	0.713401	0.000680	0.05945	0.000456
98.359_C3	0.09690	0.08046	2.68E-05	0.713736	0.000610	0.05919	0.000352
98.359_D1	0.07844	0.06514	1.65E-05	0.713330	0.000860	0.06142	0.000484
98.359_D2	0.08522	0.07079	2.26E-05	0.712387	0.000880	0.06143	0.000472
98.359_D3	0.08934	0.07420	3.15E-05	0.712620	0.000800	0.06016	0.000414
NBS-987	3.09790		3.82E-05	0.710253	0.000027	0.05648	0.000021

Appendix D: Laser ablation 87Sr/86Sr ratio data for KN XIV teeth with correction results.

Sample ID	87Sr/86Sr	Zr Corrected #	Zr Corrected #	Sr Corrected	2σ error
97.211_A1	0.71237430	0.70821408	0.71108833	0.71056915	0.0001806
97.211_A2	0.71250770	0.70823243	0.71122170	0.71071835	0.0001684
97.211_A3	0.71253930	0.70824821	0.71140698	0.71075663	0.0002040
97.211_B1	0.71227740	0.70816728	0.71100795	0.71048493	0.0001980
97.211_B2	0.71202850	0.70810714	0.71077471	0.71024595	0.0001622
97.211_B3	0.71261000	0.70825984	0.71136671	0.71082603	0.0001414
97.211_C1	0.71163530	0.70799253	0.71036271	0.70978755	0.0001572
97.211_C2	0.71153080	0.70796321	0.71026708	0.70966876	0.0002020
97.211_C3	0.71177110	0.70803503	0.71055889	0.70985657	0.0001640
97.211_D1	0.71242800	0.70821164	0.71115754	0.71058669	0.0001718
97.211_D2	0.71191690	0.70807137	0.71069914	0.71011702	0.0001888
97.211_D3	0.71148250	0.70796882	0.71028614	0.70963369	0.0002140
Standard Deviation		0.00011341	0.00041561	0.00044487	
97.217_A1	0.71589830	0.70916331	0.71462579	0.71425862	0.0001974
97.217_A2	0.71702070	0.70946692	0.71577390	0.71538276	0.0002740
97.217_A3	0.71721260	0.70953035	0.71603309	0.71557575	0.0002000
97.217_B1	0.71634480	0.70928272	0.71507506	0.71476320	0.0003200
97.217_B2	0.71688150	0.70943396	0.71564234	0.71532475	0.0001302
97.217_B3	0.71744970	0.70959904	0.71623286	0.71588370	0.0002040
97.217_C1	0.71536060	0.70901162	0.71409974	0.71383020	0.0002140
97.217_C2	0.71585720	0.70915276	0.71461090	0.71434325	0.0002400
97.217_C3	0.71511730	0.70895875	0.71386866	0.71359879	0.0002040
97.217_D1	0.71512840	0.70894867	0.71385162	0.71370219	0.0002340
97.217_D2	0.71573200	0.70911950	0.71446194	0.71433012	0.0001950
97.217_D3	0.71602160	0.70920874	0.71472953	0.71463623	0.0002360
Standard Deviation		0.00022346	0.00083040	0.00076318	
97.225_A1	0.71441630	0.70875527	0.71314311	0.71324599	0.0002940
97.225_A2	0.71615180	0.70923948	0.71488803	0.71495085	0.0003120
97.225_A3	0.71632610	0.70928631	0.71513680	0.71515129	0.0002080
97.225_B1	0.71558430	0.70907414	0.71432001	0.71437625	0.0002960
97.225_B2	0.71652500	0.70933733	0.71526199	0.71531867	0.0002520
97.225_B3	0.71610680	0.70923198	0.71486652	0.71488428	0.0003000
97.225_C1	0.71573800	0.70911716	0.71445760	0.71450444	0.0003000
97.225_C2	0.71535630	0.70902323	0.71407876	0.71411776	0.0002520
97.225_C3	0.71598720	0.70919037	0.71473958	0.71473358	0.0002800
97.225_D1	0.71500120	0.70891396	0.71372276	0.71373858	0.0003200
97.225_D2	0.71665020	0.70937318	0.71537663	0.71541911	0.0003480
97.225_D3	0.71523210	0.70899393	0.71401245	0.71399631	0.0006720
Standard Deviation		0.00018410	0.00067363	0.00066716	
NBS-987	0.7102531				0.0000268

Appendix D: Laser ablation 87Sr/86Sr ratio data for KN XIV teeth with correction results.

Sample ID	87Sr/86Sr	Zr Corrected #	Zr Corrected #	Sr Corrected	2σ error
98.355_A1	0.71321610	0.70842549	0.71194423	0.71189847	0.0003660
98.355_A2	0.71529940	0.70900309	0.71403402	0.71399903	0.0004200
98.355_B1	0.71261160	0.70826177	0.71134340	0.71130582	0.0004500
98.355_B2	0.71207140	0.70811765	0.71082020	0.71073572	0.0003020
98.355_B3	0.71196010	0.70808717	0.71071416	0.71058561	0.0002780
98.355_C1	0.71164310	0.70799212	0.71037700	0.71023980	0.0004140
98.355_C2	0.71218040	0.70814531	0.71093771	0.71077170	0.0004480
98.355_C3	0.71265020	0.70828057	0.71148712	0.71119181	0.0003460
98.355_D1	0.71351400	0.70852977	0.71221852	0.71235422	0.0006320
98.355_D2	0.71368010	0.70858320	0.71238294	0.71254837	0.0003900
98.355_D3	0.71469610	0.70886989	0.71341020	0.71355363	0.0004640
Standard Deviation		0.00032814	0.00115463	0.00124365	
98.359_A1	0.71173970	0.70802341	0.71046317	0.71006817	0.0006900
98.359_A2	0.71271620	0.70829094	0.71145679	0.71107688	0.0006600
98.359_A3	0.71187540	0.70808271	0.71066127	0.71020853	0.0006720
98.359_B1	0.71175440	0.70802811	0.71048662	0.70997575	0.0007100
98.359_B2	0.71294070	0.70835282	0.71169777	0.71115279	0.0009160
98.359_B3	0.71290470	0.70834199	0.71163271	0.71111523	0.0007120
98.359_C1	0.71418450	0.70869238	0.71290906	0.71239862	0.0010520
98.359_C2	0.71340080	0.70847836	0.71215470	0.71160299	0.0006800
98.359_C3	0.71373560	0.70859164	0.71248943	0.71196584	0.0006100
98.359_D1	0.71332960	0.70845532	0.71205540	0.71152037	0.0008600
98.359_D2	0.71238730	0.70820050	0.71112639	0.71058079	0.0008800
98.359_D3	0.71262010	0.70827165	0.71141785	0.71073830	0.0008000
Standard Deviation		0.00021411	0.00077966	0.00075921	

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

Analysis ID	Li	Be	B	Na	Al	Si	P	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	Ga	Ge
K14_1998.027.01 (Sample: 1998.304)																					
98304_a1	7.17	3.64	30.45	2447	846.7	2510	65514	60.55	3E+05	10.69	110.5	29.71	72.74	211.1	419.6	16.24	13.13	8.26	118	7.81	11.84
98304_a2	4.28	26.7	22.11	2499	751.9	4643	63889	45.35	3E+05	5.24	46.31	22.4	46.08	141.8	203.2	13.61	6.44	8.45	73.47	8.27	5.44
98304_a3	1.37	79.6	46.55	2146	806.9	8174	62300	37.21	3E+05	10.14	84.8	28.65	65.72	118.2	372.4	16.36	19.44	11.26	93.98	7.81	11.44
98304_a4	3.28	20.73	9.89	2119	678.4	2841	61756	40.33	3E+05	5.39	25.33	21.84	37.6	102.4	374	14.42	5.12	7.76	107.2	6.12	6.43
98304_a5	12	4.38	36.17	2268	607.7	3162	64471	37.04	3E+05	16.44	21.37	25.3	94.76	92.09	407.4	13.61	13.44	15.18	62.83	6.54	8.89
98304_b1	7.41	46.95	22.33	2607	1239	3580	68111	79.46	3E+05	8.78	94.08	14.03	83.18	385.4	633.1	20.57	11.72	14.82	77.01	8.65	10.97
98304_b2	1.55	32.01	26.33	2653	1183	5193	70526	24.55	3E+05	7.7	54.95	17.43	69.2	433.6	553.6	16.7	15.18	9.03	120.8	6.42	9.14
98304_b3	1.55	9.86	38.01	2563	955.9	2329	67839	51.83	3E+05	6.81	77.66	20.32	67.47	356.5	356	24.16	10.41	12.63	72.63	10.76	12.77
98304_b4	5.09	12.34	26.64	2814	1188	5689	74332	72.37	3E+05	9.39	55.51	25.19	55.63	347.1	795.8	17.32	13.45	9.15	92.44	5.74	6.54
98304_b5	9.86	14.52	21.08	2712	1619	2567	76107	59.57	3E+05	9.84	53.76	17.52	72.44	460.2	1188	17.89	16.42	12.55	93.63	11.78	8.95
98304_c1	0	30.16	14.25	2053	421.3	2199	56142	25.23	3E+05	5.1	51.35	26.97	44.34	86.52	383.4	10.68	8.15	3.26	50.57	3.61	7.41
98304_c2	9.38	33.08	9.76	2191	417.9	4035	64016	27.75	3E+05	9.9	19.87	13.9	64.02	87.07	277.6	15.04	14.28	5.98	57.02	10.26	13.92
98304_c3	1.07	44.54	11.3	2157	386.9	2302	64696	26.65	3E+05	8.21	8.22	24.49	61.85	100.2	309.8	15.71	8.75	6.26	73.52	4.97	5.14
98304_c4	2.26	7.26	3.42	2133	380.1	2752	62770	39.1	3E+05	8.33	69.29	22.8	51.71	88.92	251.3	15.57	13.32	8.13	47.85	6.47	4.72
98304_c5	8.31	37.91	3.43	2100	348.7	1958	61933	31.24	3E+05	6.03	45.27	24.96	50	97.56	318.2	11.53	13.27	250.1	78.25	4.87	9.75
98304_d1	7.44	16.28	15.96	1102	20.32	3968	39041	36.74	2E+05	5.4	40.54	10.9	58.65	7.74	299.2	22.32	12.04	8.26	47.56	7.26	8.29
98304_d2	6.19	4.8	11.25	1368	20.25	2435	62416	47.71	2E+05	9.94	47.71	18.82	63.34	10.6	150.3	22.2	8.35	7.95	43.94	7.5	8.61
98304_d3	7	11.53	26.03	1040	26.72	1954	50623	23.53	2E+05	8.47	38.11	9.22	52.3	8.82	190	14.84	6.78	8.07	26.35	9.5	7.8
98304_d4	5.64	36.7	34.3	1409	23.94	4216	61353	25.87	3E+05	7.09	68.71	9.06	51.56	7.25	256.6	15	7.87	9.6	27.3	9.11	7.26
98304_d5	0	31.14	25.17	3412	14.86	4893	63174	23.15	3E+05	6.74	18.12	12.99	53	12.3	246.6	17.13	9.59	7.54	21.5	11.73	10.36
K14_1998.035.01 (Sample: 1998.312)																					
98312_a1	9.17	4.81	2.18	2020	72.1	6236	57206	25.04	3E+05	9.93	27.13	18.44	61.65	9.25	322.2	29.43	4.87	1.32	35.02	9.83	6.87
98312_a2	0.47	9.69	11.86	1952	74.96	3755	55348	30.57	3E+05	5.58	29.55	19.4	43.92	7.58	224	9.75	18.2	7.2	29.82	4.42	5.39
98312_a3	0	4013	0	0	1819	0	0	804.6	2E+05	0	0	0	1665	0	0	0	953.1	0	2617	0	0
98312_a3	0.98	25.82	11.64	1952	65.92	1881	54416	22.08	3E+05	5.76	28.95	24.51	43.39	6.54	178.3	10.46	9.46	3.54	22.64	6.41	6.31
98312_a4	1.65	30.7	27.64	1942	53.8	1657	49715	22.41	2E+05	5.07	48.58	18.28	46.21	7.58	222.8	11.33	5.34	8.41	20.54	4.21	9.17
98312_a5	4.19	28.85	25.94	2162	64.14	2418	55440	34.09	3E+05	6.57	45.56	18.27	44.8	13.37	181.1	12.58	7.24	5.53	20.27	5.57	3.85
98312_b1	7.02	9.41	15.37	2100	70.47	2962	51962	393.1	2E+05	6.01	38.15	22.27	40.8	7.64	151.8	11.94	23.73	6.62	19.04	8.01	4.16
98312_b2	1.5	13.82	30.19	2179	83.07	6815	55897	24.78	3E+05	8.17	19.21	24.19	68.81	9.01	344.4	19.15	48.19	9.2	20.15	4.92	10.34
98312_b3	1.75	12.15	29.46	2072	82.52	6844	51426	22.88	3E+05	7.27	13.48	20.95	62.38	9.5	336.2	15.24	28.08	8.99	28.93	5.67	8.74
98312_b4	0.97	34.66	18.98	2219	95.52	2460	53905	27.55	3E+05	6.04	29.69	16.98	39.99	7.77	187.6	13.88	7.4	5.79	30.65	6.88	7.73
98312_b5	3	36.2	5.74	2057	90.88	1829	52009	29.69	3E+05	4.83	51.64	19.47	35.86	6.1	176.6	12.76	16.55	4.93	14.24	5.25	5.29
98312_c1	2.88	39.09	11.92	2200	98.89	3225	54855	35.67	2E+05	6.37	86.21	23.09	48.01	6.84	222.5	12.73	6.34	9.22	27.71	5.03	6.66
98312_c2	0.51	44.39	27.94	2399	128.9	3822	55119	41.98	3E+05	8.7	69.07	21.61	56.6	13.38	148	12.49	5.31	3.42	8.93	5.37	6.76
98312_c3	3.71	36.76	11.55	2454	146.9	3150	51979	37.54	2E+05	6.61	57.08	18.11	41.29	14.53	228.7	9.42	23.06	5	17.64	4.16	4.42
98312_c4	2.88	16.86	24.76	2255	136.3	2631	50243	30.08	2E+05	6.39	61.13	16.17	48.54	24.68	245.1	11.68	7.2	9.29	15.23	4.45	8.46
98312_c5	10.8	7.79	6.9	2297	163.6	6827	52629	40.5	3E+05	9.07	83.14	16.75	61.6	17.89	236	19.42	8.68	12.65	29.45	7.26	8.14
98312_d1	0.8	26.27	8.76	1614	363.8	1740	53430	27.87	2E+05	4.24	57.32	14.8	38.9	25.49	247.5	8.34	15.32	6.17	38.19	4.18	6.28
98312_d2	8.14	6.24	35.9	2037	400.5	3272	55372	20.09	2E+05	8.81	16.98	14.68	58.31	40.59	324.7	18.48	60.85	5.5	27.67	7.64	7.51
98312_d3	3.58	30.96	11.16	1817	344	1094	49471	30.79	2E+05	3.24	38.84	17.88	29.43	53.9	215.3	9.07	22.99	2.42	15.83	6.18	4.66
98312_d4	8.05	8.77	7.73	1980	395.6	2805	53466	28.99	2E+05	9.54	61.82	10.53	53.32	45.11	287.7	20.42	7.93	7.72	22.41	6.39	8.57
98312_d5	3.73	18.72	8.24	1967	368.5	1148	54678	47.13	2E+05	4.33	35.07	13.22	31.12	60.39	141.5	8.98	30	8	21.71	7.4	3.97

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

Analysis ID	Li	Be	B	Na	Al	Si	P	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	Ga	Ge
K14_1998.035.02 (Sample: 2003.597)																					
03597_a1	0.7	4.02	18.68	3023	1749	5710	52780	390.1	3E+05	7.58	49.48	18.75	53.65	159.4	1005	19.69	4.25	10.78	51.99	9.52	5.71
03597_a2	3.72	3.87	23.43	2433	1625	17599	63194	106.3	3E+05	7.64	41.35	15.06	46.99	145.5	766.3	15.77	6.61	7.41	61.02	8.14	7.18
03597_a3	3.21	32.2	31.75	2292	1491	3659	59916	107.3	3E+05	7.68	42.97	16.7	43.38	137.6	593.9	12.04	4.35	8.99	47.48	8.16	5.96
03597_a4	4.51	26.18	18.66	2296	1441	2904	59072	82.04	3E+05	6.63	24.65	19.62	41.75	112.4	462.2	12.16	4.69	7.63	39.32	6.76	6.57
03597_a5	9.96	2.7	20.86	2371	1472	8191	56486	113	3E+05	11.04	94.35	16.77	54.58	107.9	449.1	13.81	3.21	11.93	28.74	5.69	8.9
03597_b1	0	17.16	23.89	1879	292.6	4114	49097	22.84	3E+05	5.61	39.43	28.76	37.63	110.2	159.3	11.05	4.42	7.06	26.82	4.25	6.26
03597_b2	2.27	13.25	24.46	1972	269.2	7176	50142	26.48	2E+05	6.99	91.22	28.2	59.27	113.6	333.6	12.84	4.15	10.02	52.74	5.32	8.61
03597_b3	1.49	26.68	18.92	2070	314.6	4974	50825	22.91	3E+05	7.48	61.05	20.47	48.87	136	247.1	15.48	4.58	9.49	40.46	6.96	5.26
03597_b4	6.62	5.03	19.43	2206	323.1	7442	52408	27.82	3E+05	7.84	51.16	23.94	56.5	187.3	242.1	14.98	4	11.27	29.18	8.25	5.92
03597_b5	2.21	5.2	18.3	2036	300.9	7095	47215	27.11	2E+05	7.38	17.1	17.5	55.71	169.2	306	17.53	7.81	7.51	16.13	6.08	9.1
03597_c1	9.31	0	25.28	1956	464.7	10318	56764	72.01	3E+05	9.56	72	12.71	67.1	49.9	305.4	27.91	9.63	11.24	42.96	9.99	13.62
03597_c2	5.2	30.67	21.63	1999	442.3	6137	56631	36.32	3E+05	8.15	37.09	18.7	58.51	53.72	225.6	11.77	7.68	9.93	32.42	7.47	8.5
03597_c3	0	68.68	23.92	1994	483.1	4863	54995	53.4	3E+05	9.32	89.79	25.68	59.91	62.68	357	14.11	10.62	9.94	25.58	6.23	8.5
03597_c4	4.62	8.33	23.56	1952	450.5	3328	52939	60.08	3E+05	4.47	50.45	19.59	38.83	52.77	178	9.78	6.03	6.25	33.16	5.84	5.07
03597_c5	8.15	4.46	25.5	1882	495.3	5835	54473	48.28	3E+05	8.81	26.15	18.9	61.03	52.27	245.4	20.63	6.2	12.1	33.18	8.24	5.96
03597_d1	7.12	77.8	61.03	1822	2308	3237	53579	96.5	3E+05	13.8	21.99	18.74	90.45	586.7	1313	28.2	21.35	22.47	43.61	10.02	11.73
03597_d2	4.06	42	34.4	1957	2108	6101	55266	78.11	3E+05	8.69	44.38	13.27	49.35	672.4	1329	20.49	17.21	4.95	60.45	12.41	7.87
03597_d3	8.25	34.91	34.51	2254	2312	2014	59564	106.1	3E+05	6.92	45.09	14.6	57.9	653.4	1285	18.98	17.11	10.06	45.43	8.95	6.76
03597_d4	5.22	22.14	31.2	2123	2243	4540	55760	91.05	3E+05	6.45	49.43	15.65	39.55	736	1401	13.23	16.97	6.38	33.46	10.18	6.35
03597_d5	5.67	34.08	30.67	2439	2227	1753	54096	155.7	3E+05	7.52	43.83	17.23	48.76	629.5	993.9	14.37	19.26	8.5	26.13	8.78	7.21
K14_1999.039 (Sample: 2003.591)																					
03591_a1	1.52	4.57	25.84	1800	89.97	1996	50942	47.01	3E+05	7.61	67.37	12.85	53.58	24.36	144.5	17.11	0.62	10.68	39.19	7.65	9.05
03591_a2	8.32	2.89	24.67	1791	92.94	10087	52547	62.36	3E+05	9	64.27	13.14	61.49	16.04	239	16.33	1.99	7.21	38.89	7.47	9.66
03591_a3	0.93	2.82	24.35	1768	93.19	1543	48311	49.42	3E+05	7.03	49.32	12.02	43.2	18.16	173.1	15.63	3.09	6.4	19.87	4	4.69
03591_a4	4.8	29.03	16.52	1849	87.59	3266	48696	61.28	3E+05	5.44	45.36	10.35	41.78	17.84	149.1	9.41	1.97	7.22	32.43	5.35	6.35
03591_a5	2.34	0	21.6	1724	102.8	2385	46971	56.52	2E+05	6.44	30.08	9.31	41.68	19.06	305.6	9.08	4.86	6.04	28.69	7.2	4.66
03591_b1	0.57	0	36.65	1946	208.5	6797	53355	45.85	3E+05	5.97	67.32	14.68	64.87	40.02	251.4	26.13	1	7.01	26.5	10.41	14.33
03591_b2	1.31	73.27	19.47	1973	186.9	8681	54370	62.76	3E+05	8.73	65.69	7.21	64.67	37.85	347.2	16.69	1.53	3.04	26.84	5.8	8.85
03591_b3	1.06	33.1	19.32	1871	167.4	1454	52767	49.73	3E+05	6.56	51.29	11.36	40.58	37.25	171.3	11.5	2.2	7.49	33.13	8.19	5.64
03591_b4	2.71	20.9	16.49	1881	201.7	2722	52165	54.37	3E+05	7.12	26.39	10.17	38.68	32.4	189.3	9.49	0.7	4.23	27.27	6.3	5.62
03591_b5	1.56	43.87	21.34	1886	195.1	4075	51057	51.21	3E+05	7.75	15.03	11.35	51.78	39.37	119.7	11.47	2.12	6.27	81.79	5.75	3.73
03591_c1	3.65	33.5	13.89	1875	1393	2779	55641	29.07	3E+05	6.05	51.59	11.81	47	787.2	401.8	16.87	15.37	8.95	53.24	7.99	6.35
03591_c2	11.3	69.68	29.65	1915	1406	8599	52958	67.27	3E+05	15.98	123.7	16.34	87.94	785	424.1	25.67	20.11	6.88	44.31	8.04	16.69
03591_c3	0.76	13.97	34.22	2040	1456	9628	53035	65.39	3E+05	10.38	88.44	12.47	79.79	811.5	451.6	18.36	15.27	10.07	41.96	12.27	8.44
03591_c4	15.5	7.37	32.84	2056	1351	2917	50683	63.66	3E+05	13.03	50.65	9.91	84.6	734.2	319.3	21.57	23.33	9.67	20.14	7.9	9.33
03591_c5	6.23	4.56	18.64	1827	1324	2664	49180	59.91	3E+05	7.07	83.29	7.4	58.42	782.7	344.3	9.99	15.67	9.51	31.11	10.4	11.26
03591_d1	2.18	13.5	28.83	2140	3383	2261	71306	69.35	3E+05	8.3	42.91	22.94	64.67	1183	1072	15.44	26.02	10.97	89.37	9.8	7.1
03591_d2	2.18	54.51	30.18	2302	3479	4229	71258	69.51	3E+05	7.36	100.2	21.11	54.88	1378	1077	41.68	37.36	10.01	61.46	7.97	6.99
03591_d3	3.36	12.54	29.11	2088	3697	5181	67094	39.11	3E+05	8.15	31.07	22.73	62.11	1656	1303	41.18	41.76	8.59	57.83	10.54	9.71
03591_d3	81	505.4	971.8	2938	1891	1E+06	18171	3086	2E+05	1196	8125	213.6	7468	1463	25106	1688	1514	1319	1938	530.6	777.6
03591_d4	6.97	43.54	28.77	2041	3505	5714	70168	70.12	3E+05	7.54	75.99	20.63	63.87	1616	1271	39.37	60.08	6.18	62.95	12.01	8.13
03591_d5	2.17	54.2	25.99	1930	3233	5259	64675	66.57	3E+05	7.65	41.86	13.13	48.25	1688	1350	23.98	46.08	4.44	66.69	7.32	9.04

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

Analysis ID	Li	Be	B	Na	Al	Si	P	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	Ga	Ge
K14_1999.045 (Sample: 2003.623)																					
03623_a1	55.8	156.8	87.08	1963	43.37	3162	49949	155.5	3E+05	18.27	143.7	36.28	81.52	22.27	451.1	94.41	4.19	23.34	143.2	10.53	18.15
03623_a2	48.1	135.3	115	3560	32.47	2559	75275	700.7	4E+05	12.92	154.3	26.15	66.58	16.41	367.5	25.25	3.42	19.6	119.1	11.26	8.84
03623_a3	68.4	64.18	52.74	4203	35.94	2868	76885	90.25	4E+05	15.33	111.5	23.97	71.07	19.83	388.5	23.14	6.16	16.31	118.8	7.97	15.11
03623_a4	23.2	87.17	101.5	4382	34.45	3116	76534	528	4E+05	16.29	143.3	24.21	82.41	23.17	394	35.37	4.17	17.29	62.86	8.25	18.8
03623_a5	34.4	137.3	44.34	4004	22.86	1906	71707	59.54	4E+05	10.26	124.7	33.67	69.24	13.79	220.2	18.14	3.63	12.01	78.93	5.31	8.91
03623_b1	15.5	21.9	50.67	2972	25.46	2191	69540	72.84	4E+05	13.38	94.61	27.05	54.22	14.69	289.4	44.18	3.58	12.66	86.92	6.17	12.15
03623_b2	53.3	56.61	39.84	2824	20.67	1679	69952	57.21	4E+05	9.21	82.83	22.65	43.68	21.98	277.6	14.69	2.8	7.01	70.1	7.62	10.5
03623_b3	4.18	85.26	27.7	3670	19.7	1635	73904	51.49	4E+05	8.4	67.85	24.01	43.59	11.06	241.9	13.45	2.74	9.71	49.09	4.53	8.24
03623_b4	29.2	12.68	65.69	3526	16.06	1575	69427	56.98	4E+05	7.61	60.58	23.58	38.71	11.28	251.1	17.13	3.05	9.37	40.97	4.27	8.78
03623_b5	83	148.5	12.64	3899	21.23	1900	69570	60.67	4E+05	10.12	94.3	14.24	47.46	13.41	204.2	16.67	2.03	8.43	59.91	5.67	8.06
03623_b6	30.5	86.4	48.89	3864	16.73	1640	72921	53.74	4E+05	8.31	68.29	22.11	41.75	11.13	201.6	13.28	2.76	8.48	35.85	7.23	7.94
03623_b7	0	36.81	42.71	3988	14.61	1426	72002	50.92	4E+05	7.3	55.01	24.06	37.27	10.35	200.6	14.73	1.96	7.38	43.97	5	6.13
03623_b8	39.5	25.79	25.96	3831	17.61	1498	67730	46.84	4E+05	7.58	52.64	24.5	37.62	15.63	209.6	13.54	1.45	5.16	36.36	6.36	8.17
03623_b9	40.1	80.36	45.74	3698	15.53	1507	70689	47.45	4E+05	7.48	92.37	26.44	37.51	10.3	186.4	15.03	2.55	7.4	32.19	7.55	8.66
03623_b10	41.2	67.5	31.43	3036	16.48	1336	54812	41.84	3E+05	6.93	52.88	21.16	33.99	9.37	167.8	54.97	1.74	6.2	30.89	5.55	5.24
03623_b11	31.9	128.3	73.3	3705	18.82	1692	62797	93.91	4E+05	9.01	53.61	30.9	44.21	11.95	217.5	56.63	2.86	11.04	38.86	4.03	9.52
03623_b12	12	163.5	54.04	4000	15.08	1515	65659	104	4E+05	7.12	83.47	23.91	37.85	9.47	221.7	22.12	3.93	8.78	39.06	4.79	7.52
03623_c1	9.54	88.17	29.2	2476	37.5	1674	55171	142.2	3E+05	9.46	73.35	31.07	42.15	13.14	225	90.28	3.19	13.59	53.97	5.7	9.81
03623_c2	10.3	19.62	33.24	2985	18.8	1324	67868	130.6	4E+05	6.52	47.01	30.1	33.97	13.07	174.7	51.81	1.81	7.77	63.31	4.06	5.89
03623_c3	30.8	152.1	58.41	3331	16.8	1543	71907	120.9	4E+05	6.85	72.73	25.38	39.64	11.19	223.3	32.23	2.74	9.8	37.95	4.53	7.78
03623_c4	30.5	123.1	41	3514	17.27	1602	71546	128.4	4E+05	8.41	62.27	22.48	40.19	16.89	183.1	13.07	3.13	8.02	46.38	3.78	9.02
03623_c5	25.8	73.52	54.88	3407	14.57	1432	70492	47.15	4E+05	7.2	47.92	23.29	37.5	21.37	191.9	14.05	2.28	7.07	31.66	5.98	7.07
03623_c6	30.7	123.9	50.76	3630	13.75	1606	69785	104.5	4E+05	8.42	76.42	23.56	40.63	20.25	183.5	15.91	2.22	10.12	73.88	6.52	7.86
03623_c7	52.9	26.83	29.23	3714	15.18	1589	74873	173.5	4E+05	6.66	50.59	32.56	40.07	16.33	245.8	12.17	1.92	8.36	83.21	4.82	7.65
03623_c8	31.5	127.3	90.67	4047	19.61	1631	72528	173.8	4E+05	7.21	68.92	20.89	41.11	22.46	211.8	14.59	2.27	7.6	53.75	4.74	5.91
03623_c9	40.7	22.8	61.98	3785	14.29	1483	66303	160.9	4E+05	6.96	67.27	26.21	38.42	17	200.2	13.32	2.53	9.46	38.16	6.22	6.97
03623_c10	44.1	154.6	60.21	3739	18.79	1609	70866	102.2	4E+05	7.92	68.05	19.88	41.16	12.98	237.3	12.8	3.16	8.52	48.42	6.08	5.84
03623_c11	64.4	92.22	62.34	4375	15.57	1656	79648	135	4E+05	7.76	64.95	27.98	43.45	10.98	182.4	16.71	2.82	9.26	75.09	4.81	7.77
03623_c12	122	246.2	166.8	4567	45.44	4408	83821	140.5	3E+05	19.78	157.9	15.64	111	26.89	669.7	35.14	6.14	19.11	122	8.37	22.02
03623_d1	17.4	192.7	130.8	4290	32.41	3287	72942	110.7	3E+05	16.49	165.5	29.45	81.54	22.62	398	24.54	1.76	18.29	194	7.16	17.19
03623_d2	45.2	129.7	76.41	3803	23.35	2318	74159	76.72	3E+05	10.49	104.8	20.16	59.04	15.25	301.6	15.78	3.22	15.86	76.1	5	10.1
03623_d3	38.5	110.6	7.54	5195	22.77	2426	74342	83.83	3E+05	12.59	86.54	19.91	62.09	14.39	315.3	21.67	4.12	9.38	127.5	5.02	10.95
03623_d4	49.2	141.2	68.23	6317	23.63	2510	104742	191.5	4E+05	11.63	80.3	22.7	65.77	16.74	410.1	22.48	0.4	10.89	163.8	10.29	13.91
03623_d5	53.6	154	74.55	5018	29.89	2714	85749	151.9	3E+05	10.72	97.66	21.81	69.34	15.86	456.2	24.45	2.68	6.84	93.61	6.12	11.9
03623_d6	26.1	106	36.36	4874	10.82	1317	57488	124.4	2E+05	6.84	63.62	12.84	33.58	13.71	184.8	10.55	1.84	6.65	56.82	4.31	5.78
03623_d7	37.5	62.2	64.32	5127	14.77	1342	58823	282.8	2E+05	6.64	21.56	10.65	34.43	8.09	175.8	11.07	2.65	6.76	78.54	2.91	7.29
03623_d8	15.2	0.001	15.13	3632	8.93	768	58187	57.82	2E+05	3.62	32.72	13.47	20.15	4.86	157.2	7.46	1.52	4.75	95.43	2.16	2.64
03623_e1	55.9	80.55	73.6	3832	16.63	1549	71887	50.68	4E+05	7.74	59.89	22.79	38.16	12.37	231.5	15.41	1.39	7.54	33.75	4.15	5.93
03623_e2	56.4	81.3	13.67	4110	17.29	1520	72547	136.6	4E+05	7.09	50.98	22.05	38.79	13.54	253.5	17.68	2.42	6.2	35.38	3.72	9.28
03623_e3	0	70.39	54.98	4680	20.29	1604	75534	56.87	4E+05	8.82	88.68	20.9	40.47	10.3	209	13.55	2.22	6.97	58	6.63	6.55
03623_e4	44	89.82	44.16	4101	18.45	1575	68471	51.05	4E+05	7.8	61.41	28.9	40.34	11.67	256.6	12.04	1.54	7.37	65.3	8.44	8.26
03623_e5	44.6	91.14	55.01	4133	18.39	1590	67441	113.7	4E+05	7.2	50.76	24.65	41.53	9.76	175.2	13.43	1.88	8.92	40.81	4.35	7.43
03623_e6	14.6	91.2	71.23	4033	15	1589	68328	153.2	4E+05	8.03	56.66	31.66	39.8	10.28	247.4	12.6	2.69	10.16	35.84	4.02	8.34
03623_f1	56	19.85	56.77	3271	35.45	2008	78817	119	4E+05	8.27	89.92	29.42	49.64	12.95	268.8	17.78	5.51	7.08	126.3	6.49	8.96
03623_f2	32.5	94	32.98	3430	17.22	1616	68435	57.59	4E+05	8.46	58.13	24.51	39.99	9.82	260.2	17.09	2.25	7.09	84.05	6.26	7.35

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

Analysis ID	**Li**	**Be**	**B**	**Na**	**Al**	**Si**	**P**	**K**	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Ni**	**Co**	**Cu**	**Zn**	**Ga**	**Ge**
03623_f3	49.2	142.5	35.43	4252	17.67	1731	73756	59.1	4E+05	8.73	68.09	20.71	42.87	10.89	227.2	13.82	1.7	10.27	62.16	6.27	6.64
03623_f4	39.3	114.1	56.89	4075	19.09	1943	74711	348.5	4E+05	9.11	83.12	22.12	49.83	12.66	343.3	15.61	1.92	9.91	48.3	5.06	10.61
03623_f5	39.9	115.9	91.56	3875	20.26	1971	75179	69.99	4E+05	10	63.66	30.72	51.32	11.82	278.3	16.4	2.76	12.3	42.41	5.05	11.01
03623_f6	61.6	126.4	48.22	3601	23.45	2157	75760	73.64	4E+05	9.71	97.99	42.89	54.81	13.14	303	21.13	2.12	9.47	111.4	9.76	13.34
K14_1999.057.02 (Sample: 1999.175)																					
99175_a1	2.45	50.49	33.28	2181	15.79	1694	43147	21.72	2E+05	4.95	72.92	6.74	44.65	8.71	210.5	12.4	3.54	7.05	17.79	4.25	4.98
99175_a2	5.25	7.94	22.63	2293	31.79	1617	44699	31.82	2E+05	3.74	70.08	8.26	42.59	6.21	271.7	10.32	2.38	6.78	22.01	6.19	4.89
99175_a3	0.42	2.72	19.79	2372	19.39	1550	45652	27.13	2E+05	5.44	35.35	13.09	42.13	8.01	158.4	9.02	2.49	5.94	17.49	4.55	5.92
99175_a4	1.4	13.04	7.41	2394	21.98	732.9	45359	32.53	2E+05	3.29	10.81	10.66	19.91	3.08	80.69	5.74	1.44	1.76	16.25	3.49	3.62
99175_a5	4.07	15.47	10.14	2341	21.72	1933	44620	20.7	2E+05	3.11	36.18	9.93	26.41	5.12	99.47	8.83	3	3.73	28.73	2.63	4.1
99175_b1	3.44	30.09	24.12	2388	143.7	1948	47591	41.61	2E+05	7.96	35.11	13.01	49.3	6.07	249.5	16.35	3.12	4.18	57.89	7.96	7.6
99175_b2	9.69	3.11	10.07	2310	34.29	6939	49374	29.28	2E+05	10.49	74.58	7.19	71.12	11.43	290.6	26.91	15.69	4.76	32.54	7.22	8.84
99175_b3	2.8	32.1	14.82	2199	26.9	1170	45035	23.55	2E+05	4.06	30.46	11.75	34.88	4.43	168	8.97	6.54	4.46	25.11	2.86	4.17
99175_b4	1.49	18.76	14.98	2228	69.12	2933	43810	26.45	2E+05	3.75	43.51	13.02	31.17	4.49	155.1	8.48	6.74	5.21	13.07	6.02	5.58
99175_b5	2.44	16.2	21.09	2212	79.89	1979	44378	25.08	2E+05	4	49.61	10.55	30.1	3.35	126.9	8.29	5.94	5.5	29.22	4.55	4.45
99175_c1	2	0	6.11	2117	241.9	3286	45905	39.05	2E+05	4.45	50	6.12	38.07	667.8	178.6	11.5	8.09	2.46	40.11	5.8	4.2
99175_c2	0.34	4.49	4.12	2296	198	3229	46486	29.41	2E+05	5.29	23.28	9.32	36.78	1071	164.6	12.39	3.63	3.42	28.64	7.75	7.06
99175_c3	2.13	4.07	2.8	2333	189.8	3050	48564	27.86	2E+05	4.14	11.7	9.55	33.73	1021	149	13.79	9.09	6.47	29.38	5.49	6.9
99175_c4	0.26	22.33	10.22	2270	186.9	1669	44579	30.3	2E+05	3.02	7.89	5.11	26.53	222.4	116.1	6.54	6.27	3.09	22.35	6.37	5.56
99175_c5	0.8	7.17	13.56	2443	233.4	2013	45777	27.89	2E+05	4.66	24.02	3.72	28.79	229.6	163.4	10.01	10.41	4.1	30.89	6.07	6.17
99175_d1	5.96	12.84	5.86	2222	246.7	1387	46769	50.8	2E+05	5	45.86	10.42	37.13	53.66	293.1	7.87	4.51	6.03	41.01	6.01	4.46
99175_d2	3.14	21.19	16.73	2406	38.45	1217	45547	40.06	2E+05	4.56	41.85	9.61	34.02	4.98	164.7	10.08	10.99	5.06	29.51	5.56	5.25
99175_d3	2.18	14.71	11.6	2295	15.02	951.1	44775	32.01	2E+05	3.49	19.87	8.85	31.63	3.7	113.8	7.81	7.81	4.97	23.3	6.41	3.45
99175_d4	2.94	4.87	12.8	2252	19.74	1433	45299	41.58	2E+05	3.7	15.98	8.41	25.9	2.95	102.9	8.5	6.25	4.36	21.84	3.77	2.91
99175_d5	2.04	11.09	20.07	2593	15.22	1540	47351	76.5	2E+05	4.45	28.93	12.11	35.89	4.62	197.8	12.28	8.2	4.26	19.85	6.69	7.18
99175_d5	32.9	0	0	1874	160.2	0	30885	0	1E+05	59.09	1075	0	102.7	55.35	0	0	0	0	203.9	51.28	26.11
SRM612 Avg.	42.38	38.181	35.814	105192	11276	3E+05	60.697	76.54	85519	41.36	48.13	39.59	40.27	38.75	56.6	38.72	32.42	37.16	38.37	36.36	34.87

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**As**	**Rb**	**Sr**	**Y**	**^{90}Zr**	**^{91}Zr**	**Nb**	**Mo**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Cs**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**
1998.304 Burial 27-1																					
98304_a1	16.9	0.69	374.8	1.39	0.52	14.06	3.71	9.63	0.61	6.25	1.04	7.92	4.08	0.53	556.1	2.8	0.9	0.96	4.04	5.07	1.67
98304_a2	8.65	1.27	398.4	0.57	0.32	11.78	1.79	9.59	1.51	7.4	0.62	4.34	1.71	0.35	549.6	0.87	0.64	0.47	2.41	3	1.21
98304_a3	23.5	1.89	404.9	1.79	0.31	2.69	1.03	2.35	4.72	1.8	0.5	9.5	0.28	0.34	703.3	1.84	1.2	0.59	1.55	6.31	0.34
98304_a4	9.46	0.85	371.2	1.14	0.53	3.46	1.39	11.38	2.45	1.03	0.68	3.82	1.87	0.55	588.4	1.82	0.52	0.33	2.62	4.02	0.94
98304_a5	7.33	3.59	396.2	0.97	0.94	23.51	0	7.31	6.34	1.81	1.75	11.19	4.83	1.41	667.3	2.47	0.69	1.14	6.76	8.48	1.97
98304_b1	17.4	1.56	386.5	6.56	1.27	7.35	2.21	26.44	5.53	9.13	0.68	10.24	2.98	1.07	697	14.26	3.81	1.92	13.73	12.8	1.22
98304_b2	17.8	1.68	376.8	6.19	1.39	7.58	1.5	31.63	1.23	6.21	0.68	7.27	2.03	1.02	651.3	11.71	3.86	0.95	5.67	6.15	1.02
98304_b3	16.6	0.94	374.4	2.32	0.7	12.31	0.69	17.11	1.63	5.48	0.79	6.93	4.39	0.52	555.2	7.31	1.74	1.03	3.54	7.68	2.53
98304_b4	18	0.76	400.6	5.47	2.28	14.08	1.15	32.96	4.65	4.43	1.28	5.99	2.05	0.94	638.4	13.35	3.98	1.74	9.06	5.07	1.18
98304_b5	9.96	1.47	447.3	6.34	4.42	13.63	0.45	70.07	5.2	13.58	2.26	6.48	3.97	1	754.2	18.68	3.77	1.79	9.01	8.5	1.98
98304_c1	9.61	0	353.2	1.51	0.81	9.2	1.4	0	0	0	1.18	4.79	0	0.39	464	0.53	0.59	0	2.65	4.69	0.77
98304_c2	17.5	2.61	383.8	1.15	2.97	22.43	1.97	26.02	4.94	5.77	1.92	6.18	3.78	1.23	500.6	0.96	0.82	0.63	3.72	6.8	0.63
98304_c3	21.6	1.03	364.4	1.59	0.24	6.24	0.32	27.63	0.28	0.46	1	8.14	0.86	0.57	544.8	1.42	0.93	0.65	1.79	4.87	0.26
98304_c4	8.65	1.09	386.2	1.03	2.32	10.13	2.18	21.05	0.3	6.39	0.75	6.46	2.09	1.13	527.8	0.75	0.91	0.21	1.26	3.65	0.37
98304_c5	12	0.87	343.3	0.67	2.62	2.2	1.74	34.27	0.89	5.11	0.57	5.45	2.37	1.08	485.7	0.85	0.28	0.78	3.29	3.57	0.96
98304_d1	17.5	0.78	329.1	0.25	0.84	2.45	0.75	18.5	2.77	4.57	0.46	6.17	2.12	0.75	659.1	0.76	0.078	0.18	2.95	4.16	1.22
98304_d2	16.3	1.84	459.1	1.23	0.66	4.33	0.88	52.9	6.52	5.38	0.89	8.31	2.49	1.02	962	0.86	1.08	1.17	1.25	9.71	1.01
98304_d3	8.25	1.04	369	0.98	0.4	9.63	0.79	37.26	2.6	0.77	0.71	5.42	1.99	0.58	649.4	1.24	0.61	0.81	0.5	4.9	0.81
98304_d4	9.77	0.59	434.3	0.79	1.23	7.76	1.67	24.98	2.97	0.6	0.81	6.18	2.27	0.46	779.5	0.58	1.1	0.38	1.93	7.39	1.13
98304_d5	14.9	0.35	411	0.78	1.04	4.58	1.99	37.32	4.35	4.15	0.69	6.25	1.92	0.68	814	1.19	0.19	0.63	3.78	6.69	1.35
1998.312 Burial 35-1																					
98312_a1	21.7	1.35	235.2	1.8	0.92	4.08	4.62	21.32	0.37	7.93	1.85	9.19	0.28	0.23	435.7	1.31	0.34	0.2	5.09	6.35	1.48
98312_a2	7.88	0.57	250.5	0.75	0.41	19.58	1.12	29.93	4.01	5.76	1.23	5.77	1.55	0.31	485	0.34	0.47	0.132	1.31	5.31	0.88
98312_a3	2082	0	0	0	0	376.3	170.47	7858	0	845	0	282.3	0	0	0	0	95.23	0	0	0	0
98312_a3	11.8	0.78	261	1.47	1.48	14.49	1.09	44.23	1.97	1.69	0.42	4.74	1.52	0.43	481.7	0.54	0.46	0.35	0.81	6.37	0.86
98312_a4	11.8	0.24	247.3	0.56	0.89	2.38	1.3	31.88	1.51	3.86	0.64	5.47	2.55	0.51	459.1	1.27	0.77	0.59	3.5	4.36	0.2
98312_a5	11.1	1.07	281.7	0.44	0.59	4.34	1.72	37.26	0.24	5.12	0.84	5.41	1.69	0.75	500.5	1.03	0.88	0.39	0.25	2.49	0.58
98312_b1	8.31	0.89	250.6	0.69	2.15	2.62	0.26	64.67	0	3.03	0.87	4.96	0	0.63	488.7	0.5	0.43	0.33	0.25	4.84	0.57
98312_b2	20	0.51	282.9	0.098	0.43	0.96	0.43	47.79	5.08	3.02	0.071	9.31	0.61	0.78	505.8	0.28	0.24	0.093	0.28	6.72	1.57
98312_b3	27.6	1.4	272.7	1.86	0.76	1.68	4.77	8.72	0.91	8.21	2.34	5.47	0.53	0.141	518	0.31	0.106	0.163	0.97	11.34	1.53
98312_b4	9.36	0.73	266.7	0.19	1.53	9.58	1.45	51.66	2.6	4.31	0.5	4.31	1.43	0.49	527	0.5	0.43	0.33	3.38	3.44	0.81
98312_b5	8.72	1.17	272.8	0.59	1.3	12.89	0.87	32.41	2.71	5.8	0.43	4.81	1.72	0.48	516.9	0.74	0.36	0.39	2.35	2.92	0.68
98312_c1	6.65	1.65	227.9	1.09	3.42	10.76	0.28	109.4	2.92	4.84	0.41	6.65	0.77	0.27	369.7	0.068	0.35	0.73	0	7.72	0.9
98312_c2	19.9	0.93	243	0.4	3.87	17.23	1.84	48.51	0.54	5.48	0.37	42.46	1.45	0.41	437.4	0.37	1.33	0.83	0.85	6.18	0.41
98312_c3	5.87	0.77	249.8	1.02	2.26	1.46	1.07	64.89	1.19	3.2	0.75	4.89	0.62	0.66	451.6	0.75	0.46	0.34	2.05	3.61	0.85
98312_c4	14.9	1.43	232.8	0.28	0.21	9.21	0.42	103.3	2.93	6.86	0.8	4.57	2.27	0.78	429.2	0.2	0.058	0.52	3.1	6.69	0.54
98312_c5	20.3	1.95	264.2	0.22	3.29	14.65	0.16	60.61	8.9	6.6	1.09	7.61	5.35	0.44	490.9	1.54	0.93	0	1.83	9.1	2.46
98312_d1	10.8	0.55	259.9	0.7	2.78	7.14	0.69	107.8	0.21	4.55	1.18	3.86	1.51	0.51	560.4	0.23	0.29	0.34	0.89	4.43	0.85
98312_d2	9.66	0.58	267.7	3.17	5.88	6.77	0.76	176.2	0.23	0.38	1.15	6.6	3.29	0.28	507.3	1.63	0.98	0.122	0.24	5.58	0.21
98312_d3	6.71	0.98	243.3	0.85	1.08	2.98	1.03	58.19	0.4	1.34	0.36	4.58	2.04	0.45	476.4	0.36	0.33	0.144	1.97	4.24	0.7
98312_d4	9.55	1.67	280.6	0.16	0.71	1.58	3.28	71.71	0	1.07	1.14	4.61	0.83	0.64	572	1.14	0.97	0.038	4.43	5.51	0.33
98312_d5	7	1.16	265.5	0.72	1.13	8.73	0.63	85.07	0.95	3.21	0.75	3.69	0	0.47	516.5	0.53	0.55	0.42	1.45	2.64	0.18

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**As**	**Rb**	**Sr**	**Y**	**^{90}Zr**	**^{91}Zr**	**Nb**	**Mo**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Cs**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**
2003.597 Burial 35-2																					
03597_a1	11.8	0.69	360	0.93	3.02	9.05	2.41	9.3	3.42	1.22	1.17	4.74	4.05	0.78	955.8	5.79	0.82	0.44	1.6	7.34	1.07
03597_a2	8.69	0.8	353.8	1.32	1.75	12.9	0.41	7.73	3.98	3.28	0.3	5.03	1.49	0.46	821	4.96	0.69	0.45	1.15	5.4	0.63
03597_a3	7.49	1.09	312.4	0.66	2.32	6.41	0.99	3.1	2.97	4.89	0.48	3.87	2.57	0.73	727.3	4.98	0.95	0.48	1.13	2.32	0.76
03597_a4	11.2	0.68	312.5	0.92	1.5	1.65	0.63	2.62	2.41	5.61	0.67	4.08	2.21	0.39	650.2	5.19	0.67	0.46	4.09	5.16	1.2
03597_a5	20.2	1.07	287.8	1.44	3.31	14.07	0.29	21.28	3.77	6.19	0.21	5.2	0.74	1.05	565.8	3.81	0.91	0.18	2.4	1.34	1.18
03597_b1	9.73	0.63	271.2	0	0.49	8.31	0.32	6.35	3.52	3.66	0.62	5.4	1.67	0.67	558.1	0.62	0	0.4	2.92	3.69	0.7
03597_b2	13.8	1.55	268.2	1.2	0.64	16.64	1.11	12.85	3.15	5.18	0.4	8.34	2.36	0.86	536.4	0.87	0.76	0.57	3.38	6.03	0.38
03597_b3	9.23	0.69	299.5	1.31	0.93	1.97	0.61	3.27	1.32	8.01	1.79	4.34	1.83	0.68	607.2	1.17	0.58	0.76	2.61	4.66	0.76
03597_b4	10.9	1	292.3	1.35	3.09	13.19	0.13	2.86	5	8.22	0.32	6.9	3.75	0.147	653.1	0.38	0.055	0.124	0.49	8.27	1.11
03597_b5	7.28	0.33	264	0.09	0.83	0.88	0.14	13.98	0	0.39	0.2	4.96	2.5	0.53	633.1	0.46	0.17	0.6	0.51	6.35	0
03597_c1	15.4	0.31	312.7	0.51	0.94	18.55	0	21.12	4.97	8.18	1.38	6.86	3.73	0.43	659	1.38	1.68	0.9	5.32	6.71	1.56
03597_c2	17.2	0.79	321.2	0	2.42	10.35	1.59	11.9	1.46	2.41	0.2	4.94	2.08	0.77	646.6	0.77	0.66	0.71	5.14	5.3	0.87
03597_c3	16.6	0.41	299.3	0	5.41	0	2.51	19.01	1.73	0.48	1.72	6.53	3.29	0.7	626.5	3.84	0.41	1.58	0.62	2.34	1.37
03597_c4	10.8	1.63	302.4	0.66	1.52	6.49	1	7.63	3.89	4.05	0.84	5.79	1.31	0.48	595.3	0.31	0.27	0.44	2.63	5.25	0.77
03597_c5	3.96	0.28	306.6	2.87	1.05	2.24	0.46	4.44	0.8	3.63	0.33	4.89	0.15	0.225	635.5	0.166	0.144	0.072	0.21	0.54	1.36
03597_d1	26.5	0.32	355.1	1.88	0	2.83	2.82	38.26	1.52	0.62	0.21	7.84	0.29	0.79	998.5	7.03	1.9	0.82	5.28	0.51	1.54
03597_d2	6.72	0.61	376	1.43	3.26	10.05	1.75	14.01	3.06	5.04	1.04	5.57	2.82	0.77	1060	8.76	1.38	0.68	3.6	2.92	0.68
03597_d3	13.7	0.99	357.1	1.33	1.39	7.12	0.36	1.48	1.59	7.23	1.22	5.79	2.34	1.11	979.8	7.76	1.9	0.46	3.32	5.92	1.37
03597_d4	7.49	0.53	351.3	1.3	1.71	10.02	1.94	9.21	1.97	1.16	0.77	4.55	1.24	0.31	925.5	10.61	2.21	0.61	2.1	2.65	0.074
03597_d5	6.65	1.48	367.2	0.94	4.54	3.69	2.43	14.3	3.02	2.04	0.27	5.62	0.75	0.84	979.5	10.7	1.2	0.94	1.59	9.09	1.34
2003.591 Burial 39																					
03591_a1	16.2	2.08	339.2	0.31	1.05	12.22	0.69	0	2.02	5.4	0.45	6.64	2.48	0.52	527.9	0.91	0.58	0.84	3.51	9.88	0.63
03591_a2	13.8	1.77	346.2	1.68	1.33	16.48	0.15	2.48	6.26	2.1	0.21	6.09	0.58	0.204	527.3	0.28	1.05	0.184	4.73	3.09	1.96
03591_a3	8.06	0.55	336.1	0.76	0.43	7.3	0.85	3.65	2.77	4.57	0.77	4.92	0.75	0.44	508	0.34	0.47	0.134	2.1	3.73	0.39
03591_a4	11.2	1.14	356.9	0.37	2.08	6.71	2.51	12.65	1.8	2.97	0.41	4.29	2.72	0.41	533.9	0.5	0.059	0.46	1.93	3.43	1.38
03591_a5	12.4	0.59	324.4	0.39	0.36	7.93	1.21	3.12	2.13	0	0.29	5.21	2.28	0.68	483.3	0.83	0.049	0.186	2.28	3.29	0.67
03591_b1	2.7	1.85	342.3	0.23	0.53	24.37	3.72	23.54	1.22	2.01	1.28	9.72	3.5	0.74	546.7	1.28	0.22	1.18	4.95	1.64	1.45
03591_b2	9.98	0.131	350.1	1.72	1.8	1.72	0	2.38	4.52	7.44	0.26	7.6	6.83	1.02	542.5	0.19	0.28	0.25	2.23	8.59	0.22
03591_b3	7.79	1	342.5	0.21	1.76	10.71	0.11	10.61	0.75	3.35	0.56	4.42	1.54	0.65	508.7	0.31	0.48	0.37	2.18	6.12	0.64
03591_b4	10.6	0.89	362.3	0.69	2.21	6.75	0.35	3.25	0.41	2.99	0.5	4.31	0.62	0.41	521.3	0.114	0.098	0.33	1.94	1.38	0.98
03591_b5	13.3	0.76	357.5	1.02	2.32	9.99	1.53	14.35	0.62	4.43	0.171	5.63	2.03	0.74	547	0.74	0.9	0.41	2.87	5.1	0.84
03591_c1	9.06	1.16	351.9	2.5	1.34	1.44	1.4	6.29	2.05	4.77	0.57	4.73	2.68	0.65	730.9	0.53	0.49	0.28	2.19	6.14	0.64
03591_c2	23	0.78	397.5	1.05	1.67	22.33	0.16	10.63	1.94	1.83	1.66	8.9	0.84	1.35	833.1	1.66	0.59	0.45	0.59	11.4	0.69
03591_c3	19	3.84	438.2	0.91	2.07	22.57	3.45	2.22	2	0	1.68	10.75	0.3	0.63	875.3	1.68	1.44	0.22	6.49	2.15	0.75
03591_c4	18.3	0.36	409.6	0.96	2.72	21.64	0.54	32.74	1.58	1.56	0.44	7.98	0.48	1.6	868.6	1.61	0.22	0.23	6.22	7.81	0.3
03591_c5	22	0.93	406.2	0.59	4.91	12.27	1.87	32.58	1.17	1.93	1.82	6.4	0.89	1.38	853.9	0.91	0.093	0.84	0.83	4.43	1.03
03591_d1	16	1.18	368.3	8.18	3.58	15.47	0.65	29.46	2.94	0.95	1.41	6.17	3.16	0.73	604.7	20.28	2.5	1.44	4.45	5.58	1.3
03591_d2	11.9	1.31	426	6.42	1.65	9.96	0.44	27.18	2.68	4.42	1.05	6.71	4.07	0.6	780.2	20.8	3.35	1.1	8.51	3.59	0.84
03591_d3	17.4	2.06	430.1	6.25	3.6	15.59	0.8	2.11	4.2	1.17	1.16	9.09	3.19	0.66	920.8	22.11	3.94	0.92	10.24	1.9	1.85
03591_d3	2144	72.75	25.94	16.24	146.9	159.2	48.52	3353	557.2	353.5	153.6	763.2	65.14	124.5	10.61	0	20.3	15.39	91.49	746.4	173.7
03591_d4	18.3	1.04	411.9	6.44	3.15	13.68	2.95	31.79	1.79	2.95	2.03	7.13	2.8	0.52	907.4	18.51	3.98	1.18	5.16	4.93	1.15
03591_d5	11.8	1.49	396.9	4.38	2.99	7.46	1.49	8.88	0.86	2.84	0.73	5.91	2.01	0.42	854.8	10.29	2.58	0.67	4.29	7.91	0.82

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**As**	**Rb**	**Sr**	**Y**	**^{90}Zr**	**^{91}Zr**	**Nb**	**Mo**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Cs**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**
2003.623 Burial 45																					
03623_a1	36.8	14.58	410.7	2.09	7.76	11.12	1.2	9.26	3.44	12.52	1.31	9.25	5.28	1.69	922.6	0.81	1.27	1.12	2.34	12.11	1.5
03623_a2	41.4	11.96	436.4	1.38	5.17	9.9	0.33	7.97	5.12	8.8	1.13	8.32	2.35	1.28	667.3	0.99	0.63	0.22	2.9	8.14	0.2
03623_a3	32.1	12.33	415.4	1.18	4.42	16.33	1.41	9.63	1.4	10.63	1.93	8.7	2.49	1.17	583.6	0.85	1.08	0.83	0.69	11.77	1.56
03623_a4	40.3	13.43	420.2	1.6	4.88	27.07	2.98	7.67	4.84	12.47	0.92	7.86	1.69	1.68	615.6	1.98	1.03	0.15	3.35	13.16	2.11
03623_a5	25.9	8.29	403.9	1.2	3	11.77	1.06	9.84	3.65	6.26	0.8	6.04	3.75	0.98	630	0.7	0.83	0.34	1.9	5.85	1.29
03623_b1	28.3	8.73	442.8	0.79	2.96	7.72	0.95	2.56	4.27	7.12	0.91	6.87	3.69	1.47	801	0.45	0.88	0.42	1.39	7.87	0.74
03623_b2	24	6.53	425.9	0.62	3.78	6.04	0.94	7.16	2.79	7.88	0.51	4.69	2.36	1.07	663.9	0.63	0.69	0.099	0.3	8.39	1.15
03623_b3	21.8	6.16	454.6	0.85	3.46	5.91	0.92	7.01	1.02	8.62	0.86	3.33	3.27	0.43	662.8	0.18	0.55	0.73	3.11	5.09	0.56
03623_b4	18.2	6.14	413.8	0.18	2.82	8.05	0.89	11.7	4.34	3.72	0.83	4.18	2.73	1.01	593.6	0.72	0.38	0.58	1.73	6.58	0.17
03623_b5	25.6	6.76	423.9	0.74	2.77	10.23	1.96	8.58	3.9	4.72	0.86	5.31	2.22	1.04	603	0.92	0.24	0.52	1.08	9.23	1.54
03623_b6	16.8	6.12	412.1	0.61	2.63	5.93	0.17	4.98	3.2	3.88	1.22	5.18	2.85	0.74	621.5	0.87	0.96	0.52	1.8	4.57	0.98
03623_b7	15.7	5.1	441.9	0.6	1.61	8.93	1.4	1.41	2.1	3.37	0.97	4.01	1.43	0.83	615.1	0.38	0.056	0.45	2.21	4.44	0.49
03623_b8	15.4	5.45	427.9	0.55	2.67	12.08	0.55	6.43	1.37	7.06	1.01	5.19	1.5	0.63	636.1	0.129	0.36	0.61	2.32	6.9	1.15
03623_b9	16.7	5.5	460.3	1.09	1.21	5.47	1.48	4.6	2.42	7.15	0.79	4.36	1.52	0.79	679.5	0.57	0.36	0.39	2.87	5.57	0.52
03623_b10	16.4	4.67	374.8	0.36	1.43	4.58	0.14	5.46	1.1	1.15	0.38	3.47	1.81	0.7	661.9	0.47	0.3	0.4	0.53	4.66	0.87
03623_b11	17.6	6.46	469.8	0.89	1.5	9.15	1.66	2.86	0.53	9.83	1.36	4.38	2.42	0.94	796.5	0.78	0.23	0.54	2.63	4.17	1.17
03623_b12	18.9	5.55	432.1	0.98	2.16	5.34	0.24	6.58	1.73	5.1	1.03	3.83	1.54	0.63	745.9	0.7	0.73	0.39	2.37	3.67	1.17
03623_c1	25.8	5.95	420.9	1.05	2.02	8.37	0.93	11.19	2.63	5.49	0.99	5.08	2.87	0.68	891.8	0.43	0.39	0.52	1.8	6.84	0.56
03623_c2	16.4	4.92	439.9	0.49	2.35	4.74	0.31	4.01	1.49	4.39	0.69	3.89	1.43	0.54	720.8	0.35	0.44	0.48	4.55	5.47	0.64
03623_c3	18.2	5.09	445.6	0.6	2.25	10.15	1.3	1.29	1.84	3.84	0.85	5.03	1.64	0.85	702.7	0.43	0.55	0.73	0.46	5.52	0.56
03623_c4	14.2	5.89	432.3	0.84	0.89	5.79	0.91	0.85	1.58	6.57	0.93	5.49	1.41	0.89	601.2	0.74	0.54	0.29	1.76	5.46	0.55
03623_c5	20.1	4.96	403	0.71	1.87	6.89	1.08	5.84	2.17	4.52	0.71	3.6	0.22	0.79	560.4	0.36	0.46	0.55	1.48	5.63	1.04
03623_c6	20.2	5.79	428.6	0.84	2.39	5.79	1.28	2.15	3.65	3.8	0.69	4.76	3.99	0.77	601	0.6	0.54	0.41	3.05	4.98	0.78
03623_c7	18	4.88	460.8	0.36	1.76	8.12	2.21	2.25	1.81	3.77	0.97	5.74	2.29	0.83	601.6	0.6	0.54	0.5	1.74	5.85	0.55
03623_c8	20.7	5.38	454.1	0.25	2.93	5.91	0.93	2.09	1.86	6.72	0.5	4.62	1.39	0.74	600.3	0.97	0.39	0.3	1.8	5.08	0.8
03623_c9	15.8	5.19	423.2	0.46	1.2	7.62	1.2	6.48	0.71	5.01	0.64	4.33	2.15	0.78	606.2	0.109	0.51	0.54	1.64	3.59	0.73
03623_c10	22.5	4.76	454.4	0.84	2.59	8.24	1.29	1.53	3.68	3.83	0.69	4.91	2.33	0.52	644.7	0.43	0.119	0.29	1.77	4.48	0.55
03623_c11	21.2	5.41	478.4	0.87	0.87	6	1.33	5.11	0.62	6.83	0.88	5.9	1.7	0.81	613.9	0.62	0.065	0.3	3.16	4	0.093
03623_c12	61.9	12.68	397.2	0.001	3.55	31.92	3.55	19.25	11.3	18.19	3.3	14.06	6.4	2.18	608.7	2.34	1.06	0.81	0.75	13.73	0.47
03623_d1	36.9	10.49	446.6	1.28	4.79	39.38	1.96	10.63	5.58	23.19	1.05	11.42	0.92	1.7	735.1	1.83	0.83	0.63	3.78	9.58	1.19
03623_d2	35.1	7.23	326	0.86	4.91	8.35	1.45	12.36	1.47	14.56	0.71	6.89	2.37	0.87	468.9	0.61	0.79	0.6	2.54	5.57	0.8
03623_d3	34	6.62	325.7	1.55	1.94	21.37	0.89	12.91	1.8	9.95	1.47	6.47	3.51	1.01	539	0.64	1	0.76	3.75	8.22	0.81
03623_d4	22.8	7.94	427.4	1.51	2.66	18.08	2.46	7.73	1.4	8.43	1.08	7.46	4.46	1.14	662.4	0.66	0.6	0.65	4.76	6.95	1.49
03623_d5	24.9	8.64	331.9	1.75	4.37	17.02	1.55	16.82	4.42	11.22	1.86	9.53	3.96	1.68	499.3	0.72	1.13	0.081	4.22	8.45	1.32
03623_d6	21.6	4.27	190.6	0.49	1.06	11.68	0.001	4.08	2.15	5.45	0.7	4.03	3.33	0.7	773.9	0.49	0.32	0.24	2.51	3.67	0.64
03623_d7	17.4	3.46	295.8	1.11	2.15	6.85	1.08	7.19	2.18	1.56	0.82	3.9	1.38	0.97	467.9	0.62	0.31	0.42	1.47	4.16	0.65
03623_d8	11	2.32	246.8	0.49	1.38	2.77	0.44	4.12	0.88	1.83	0.41	2.65	1.59	0.25	496.7	0.29	0.26	0.106	1.19	3.37	0.37
03623_e1	19.2	4.59	404	0.9	1.96	10.15	0.8	7.55	0.59	3.35	1.14	4.76	2.52	0.91	531.3	0.75	0.34	0.36	1.54	5.85	0.88
03623_e2	23.4	4.48	406.4	0.74	1.61	10.21	0.8	3.55	2.31	3.37	1.3	4.79	1.46	0.92	598.4	0.65	0.34	0.258	0.001	5.89	0.24
03623_e3	26.3	4.52	441.8	1.02	2.16	5.73	1.56	8.53	2.59	6.56	0.84	4.27	4.35	0.79	656.3	0.59	0.54	0.58	1.74	6.96	0.17
03623_e4	18.2	4.7	430.4	0.81	2.16	7.93	0.14	6.82	2.54	3.71	0.82	5.26	2.28	0.71	641.6	0.71	0.122	0.4	2.41	6.09	0.53
03623_e5	18.5	4.76	440.9	1.01	2.19	5.67	1.26	0.85	2.57	7.5	0.68	5.32	2.83	0.93	638	0.93	0.53	0.57	1.72	5.34	0.94
03623_e6	27	4.22	442.1	0.18	1.26	13.85	0.89	9.75	0.001	2.3	1.27	4.22	2.3	0.83	621.7	0.42	0.53	0.64	2.43	5.32	0.54
03623_f1	26	6.28	484.3	0.73	3.87	15.85	1.12	6.11	3.21	8.13	1.04	137.1	2.04	0.97	731.9	0.52	0.33	0.062	0.37	6.09	1.35
03623_f2	23.3	4.63	423.2	0.84	2.24	5.79	1.58	0.001	3.22	3.83	1.3	5.13	3.34	0.74	620.2	0.43	0.55	0.45	2.49	5.45	0.96

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**As**	**Rb**	**Sr**	**Y**	**^{90}Zr**	**^{91}Zr**	**Nb**	**Mo**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Cs**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**
03623_f3	19.1	5.63	430.8	0.64	1.95	6.19	1.38	5.35	2.81	5.8	0.74	5.82	2.53	0.64	623.9	0.25	0.41	0.173	3.26	3.36	1.02
03623_f4	18.2	6.71	438.1	0.72	3.82	9.88	0.32	8.54	3.18	9.26	0.84	4.2	4.04	1.15	623	1.03	0.34	0.61	3	7.1	0.94
03623_f5	23.4	5.84	461.7	0.73	2.73	7.83	1.12	6.12	3.94	4.69	1.59	7.02	2.05	1.04	642.7	0.52	0.47	0.148	3.73	6.08	1.35
03623_f6	32.5	6.02	476.3	1.37	2.43	13.32	2.43	9.42	3.5	7.21	1.6	6.54	3.15	0.98	708.9	1.13	1.03	1.1	5.23	7.82	1.04
1999.175 Burial 57-2																					
99175_a1	11.2	1.41	216.7	1.08	0.27	10.63	2.28	25.12	2.87	0.53	0.18	6.19	2.2	0.63	421.6	0	0.95	0.29	4.32	3.42	0.89
99175_a2	10.7	1.1	228.2	1.04	0.72	10.21	1.55	24.61	4.78	4.56	0.76	4.6	3.67	0.75	423	0.058	0.05	0.038	2.94	6.36	0.2
99175_a3	13.3	0.68	248.9	0.91	0.37	3.23	0.24	31.01	0.44	1.44	1.15	4.83	3.2	0.238	448.6	0.66	0	0.078	3.63	3.21	0.136
99175_a4	4.68	0.42	236.4	0.48	1.08	0.91	0.72	6.84	1.47	1.72	0.53	2.24	0.8	0.199	440	0.35	0.24	0.132	0.78	1.7	0.4
99175_a5	4.8	0.35	229.9	0.66	0.28	4.56	1.69	28.61	2.47	2.88	0.76	3.06	1.64	0.33	438.3	0.59	0.5	0.151	1.31	4.02	0.157
99175_b1	10.8	0.68	263.8	0.39	4.03	8.85	0.58	32.73	2.39	1.28	0.93	5.64	2.6	0.74	513.4	1.14	0.18	0.74	2.55	6.36	1.04
99175_b2	19.8	1.44	242.1	0.37	4.27	1.83	2.85	12.2	0.74	0	0.2	7.98	1.14	1.12	457.9	0.135	0.23	0.044	0.53	2.63	0.54
99175_b3	8.09	0.83	257.1	0.78	0.28	5.42	1.16	13.26	1.47	4.85	0.8	3.74	0	0.32	464.8	0.7	0.34	0.37	2.21	4.78	0.79
99175_b4	8.83	0.84	242.8	0.29	2.49	5.48	0.73	15.29	2.96	0.43	0.7	4.03	1.14	0.4	463.5	0.29	0.35	0.53	1.58	3.41	0.46
99175_b5	5.75	1.25	243.4	0.48	1.52	6.67	0.71	13.48	2.21	2.99	0.49	3.25	0.98	0.28	497.8	0.49	0.21	0.079	1.36	2.94	0.56
99175_c1	7.67	1.18	232.6	0.52	0.88	1.93	1.35	36.77	2.41	3.98	0.095	5	1.85	0.53	558	0.81	0.6	0.155	0.93	1.16	1.06
99175_c2	11.2	0.81	233.6	0.4	1.33	3.9	1.6	11.68	2.86	0.87	0.78	4.49	2.2	0.77	621.6	0.39	0.67	0.72	0.75	5.37	0.164
99175_c3	5.84	0.73	243.2	0.97	0.53	2.94	0.44	29.31	0.16	1.32	0.174	4.06	0.37	0.57	569.8	0.71	0.41	0.46	0.68	0.85	0.099
99175_c4	3.94	0.98	206.2	0.101	1.46	3.47	1.38	7.79	1.74	2.88	0.83	2.9	0.72	0.27	481.4	0.48	0.251	0.167	1.85	2.31	0.125
99175_c5	7.38	0.65	238.1	0.87	0.7	8.53	0.47	19.45	1.63	0.46	0.153	2.22	0.54	0.36	523.6	0.89	0.38	0.05	0.3	3.07	0.043
99175_d1	7.05	1.08	237.5	0.22	0.33	16.28	0.56	26.94	3.12	0.66	1.05	3.67	0.31	0.68	473.6	0.49	0.73	0.56	2.34	6.54	0.68
99175_d2	9.1	0.8	219.3	0.62	1.94	6.06	0.46	35.69	1.64	2.72	0.45	4.07	0.16	0.44	432.9	0.64	0.146	0.41	2.47	3.08	0.72
99175_d3	3.64	0.72	220.9	0.085	0.95	5.94	0.64	25.41	1.61	1.12	0.62	2.44	2.48	0.3	419	0.123	0.266	0.203	2.7	3.37	0.21
99175_d4	6.95	0.61	224.6	0.41	0.91	4.01	0.1	14.39	1.88	3.11	0.3	3.24	1.45	0.29	420.3	0.3	0.44	0.034	0.2	2.74	0.67
99175_d5	2.9	1.11	228.5	0.24	2.84	3.15	1.9	26.79	3.4	0.35	0	3.61	3.03	0.43	418.2	0.76	0.8	0.61	0.23	4.51	0.86
99175_d5	233	0	124.7	0	0	0	0	0	17.18	0	0	0	0	0	109.7	0	0	0.77	0	0	5.32
SRM612 Avg	38.3	31.96	76.54	38.61	36.66	36.22	38.137	35.9	22.06	28.72	43.09	38.26	38.52	42	37.87	35.98	38.36	37.34	35.32	37.14	34.59

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**Re**	**Au**	**Tl**	**Pb**	**Bi**	**Th**	**U**
1998.304 Burial 27-1																	
98304_a1	4.89	0.7	4.19	0.48	1.23	0.71	3.33	0.71	2.37	1.05	0.61	4.08	1.95	2.65	0.9	0.82	0.47
98304_a2	3.55	0.72	2.48	0.15	1.82	0.73	1.97	0.14	1.4	0.62	0.75	4.18	2.03	1.28	0.38	0.15	0.047
98304_a3	0.66	0.87	3.69	0.071	2.71	0.89	4.14	0.89	0.45	0.1	2.71	1.17	0.38	1.34	0.79	0.075	0.58
98304_a4	1.58	0.115	1.36	0.48	0.99	0.46	2.15	0.117	0	0.83	0.81	2.63	1.86	0.62	0.65	0	0.116
98304_a5	5.78	0.34	0.86	1.23	0.21	0.137	5.56	0.138	0.46	0.2	0.24	1.57	4.89	2.54	1.06	0.15	0.41
98304_b1	3.57	1.02	2.71	1.32	3.17	0.73	0.87	0.74	0.92	1.53	0.33	4.19	3.06	1.11	0.75	0.3	0.68
98304_b2	3.43	0.3	2.94	0.9	2.64	0.86	4.03	0.077	1.65	0.73	1.52	2.85	2.11	1.06	1	0.54	0.35
98304_b3	1.49	0.61	4.49	0.91	1.9	0.88	1.07	0.077	0.76	1.83	0.14	3.56	3.79	1.88	0.62	0.68	0.41
98304_b4	2.45	0.19	3.63	0.33	2.17	0.71	1.79	0.5	1.67	0.37	0.89	4.97	2.69	1.06	0.78	0.42	0.29
98304_b5	1.46	0.29	4.06	1.24	1.6	0.15	3.22	0.3	0.5	1.43	1.21	3.93	3.75	1.04	1.23	0.75	0.59
98304_c1	0	0.35	2.74	0.84	2.46	0	2.17	0.47	2.67	0.68	1.16	0	4.2	0.99	0.41	0	0.12
98304_c2	0.93	0.19	2.12	0.68	0.39	0.93	0.89	0.66	2.17	1.36	0.22	3.73	3	1.96	1.17	0.71	0.43
98304_c3	3.32	0.67	1.53	1	0.48	0.68	0.98	0.47	2.26	0.31	0.18	6.74	0.52	1.02	0.86	0.115	0.034
98304_c4	2.49	0.87	3.69	0.35	2.21	0.22	0.52	0.51	0.18	0.33	0.9	2.91	3.43	1.88	1.02	0.18	0.146
98304_c5	3.98	0.22	1.85	0.115	1.77	0.39	0.52	0.58	1.91	0.85	1.02	3.29	4.42	1.22	0.89	0.63	0.38
98304_d1	0.9	0.51	2.16	0.26	1.58	0.73	0.29	0.73	1.71	1.07	1.29	4.17	1.8	1.34	0.8	0.57	0.081
98304_d2	2.96	0.85	1.22	0.63	0.45	0.86	2.84	0.61	2.85	0.43	0.51	2.07	4.81	1.57	0.77	0.94	0.56
98304_d3	0.85	0.086	0.73	0.87	0.53	0.69	2.27	0.49	2.27	1.01	1.21	4.79	2.48	1.26	0.43	0.53	0.32
98304_d4	2.7	0.38	2.83	0.35	1.69	0.39	1.26	0.39	1.83	0.57	0.69	4.45	2.87	0.91	0.7	0.44	0.26
98304_d5	2.28	0.46	2.77	0.97	2.03	0.94	3.79	0.66	2.68	0.69	1.42	4.61	2.33	0.82	0.93	1.14	0.2
1998.312 Burial 35-1																	
98312_a1	0.33	0.87	0.86	0.21	0.42	1.26	0.64	0.55	0.9	0.4	1.54	0	9.54	1.29	0.78	0.074	0.58
98312_a2	1.81	0.135	0.38	0.86	1.61	0.37	2.45	0.37	0.45	0.54	0.64	5.54	6.28	0.54	0.73	0.149	0.03
98312_a3	92.2	0	0	0	173.5	94.82	0	94.66	61.92	0	0	0	124.5	0	0	0	0
98312_a3	1.77	0.093	2.15	0.53	0	0.37	1.69	0.63	1.19	0.75	0.63	2.9	2.47	1.06	0.78	0.79	0.33
98312_a4	2.1	0.42	0.67	0.45	0.37	0.61	2.01	0.43	3.74	0.116	0.75	3.43	3.03	1.08	0.54	0.47	0.39
98312_a5	1.97	0.043	2.39	0.42	1.24	0.41	1.88	0.57	2.29	0.44	1.21	4.55	4.15	1.02	0.5	0.88	0.52
98312_b1	2.33	0.043	3.17	0.182	1.04	0.68	1.57	0.68	0.57	0.49	0.59	1.9	5.68	0.69	0.59	0.37	0.057
98312_b2	0.23	0.24	3.93	0.1	0.74	0.097	4.37	1.33	4.35	0.35	0.25	1.62	1.5	0.42	0.82	0.26	0.062
98312_b3	6.32	1.27	5.42	0.22	3.96	1.3	6.02	0.212	0.69	0.31	0.073	1.42	1.7	0.37	0.8	1	0.59
98312_b4	1.66	0.23	1.42	0.5	1.8	0.34	1.58	0.14	2.22	0.5	0.56	0.52	4.93	1.1	0.79	0.37	0.38
98312_b5	2	0.28	1.71	0.3	1.25	0.58	1.9	0.29	1.34	0.26	0.5	2.3	3.56	0.59	0.51	0.31	0.187
98312_c1	0.67	0.53	3.19	0.79	0.56	0.139	0	0.54	0	1.11	0.93	3.03	3.76	0.53	0.47	0.83	0.089
98312_c2	0.24	0.6	3.61	0.9	1.87	0.3	2.84	0.099	2	1.26	0.34	1.11	8.17	1.24	0.48	0.108	0.39
98312_c3	1.74	0.35	2.59	0.076	1.54	0.59	1.02	0.62	1.17	0.52	0.87	2.83	3.53	0.51	0.7	0.67	0.047
98312_c4	0.23	0.92	3.2	0.79	0.57	0.23	2.51	0.185	2.49	0.2	0.32	5.25	7.9	1.34	0.47	0.59	0.35
98312_c5	2.08	1.02	3.07	0.055	0	0.107	7.63	0.74	0.35	0.23	1.26	0.89	7.97	1.05	0.186	0.17	0.67
98312_d1	3.49	0.152	2.12	0.2	1.55	0.36	1.66	0.36	0.38	0.52	0.2	2.84	7.07	1.26	0.44	0.042	0.33
98312_d2	0.21	0.084	4.62	0.088	0.52	0.78	0.79	0.042	0.14	0.062	0.073	0.95	9.38	1.94	0.185	0.85	0.136
98312_d3	0.55	0.58	1.01	0.5	0.34	0.112	1.12	0.242	1.37	0.35	0.93	1.36	5.33	0.49	0.47	0.26	0.22
98312_d4	0.96	0.76	1.49	0.164	2.36	0.079	0.92	0.77	0.64	1.94	1.32	1.55	14.69	0.23	1.16	0.129	0.5
98312_d5	0.85	0.249	1.49	0.64	1.34	0.36	0	0.36	1.16	0.52	0.87	0.59	5.12	0.36	0.49	0.55	0.281

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**Re**	**Au**	**Tl**	**Pb**	**Bi**	**Th**	**U**
2003.597 Burial 35-2																	
03597_a1	0	0.28	1.92	0.22	1.41	0.65	2.17	0.29	1.56	1.19	0	2.7	1.33	0.74	0.85	0.72	0
03597_a2	1.84	0.53	2.23	0.49	1.16	0.66	0.64	0.66	2.57	0.1	0.69	3.14	1.11	0.86	0.61	0.42	0.26
03597_a3	1.59	0.098	2.35	0.48	1.41	0.73	1.42	0.57	1.91	1.38	0.84	2.7	1.11	1.28	0.52	0.33	0.221
03597_a4	1.57	0.32	1.35	0.82	0.26	0.32	0	0.127	1.1	0.5	0.59	2.68	1.12	1.16	0.52	0.36	0.057
03597_a5	0	0.23	2.98	0.147	0	0.72	3.37	0.72	0.48	0.07	2.25	4.18	1.76	1.98	0.26	0.104	0.223
03597_b1	0.51	0.29	1.76	0.44	1.58	0.42	0.99	0.43	0.71	0.77	0.19	1.75	1.17	1.06	0.73	0.33	0.14
03597_b2	2.91	0.83	1.15	0.62	0.56	0.6	0.65	1.05	2.02	0.89	1.08	1.61	1.5	1.65	0.95	0.051	0.57
03597_b3	0.73	0.45	1.88	1.27	1.41	0.101	0.24	0	1.56	0.97	0	2.7	2.03	1.04	0.42	0.111	0.31
03597_b4	4.61	0.66	3.95	0.99	0.53	0.67	3.15	0.96	3.92	0.065	2.1	0.76	2.1	0.62	0.28	0.24	0.059
03597_b5	0	0.62	1.12	0.093	1.93	0.045	0.21	0.9	3.69	0.2	1.14	3.68	0.16	1.41	0.205	0.197	0.121
03597_c1	0.25	0.151	1.28	0.98	0.16	1.89	0.72	0.21	0.17	0.15	2.41	1.19	1.74	1.49	1.5	1.04	0.069
03597_c2	0.67	0.27	0.87	0.55	2.27	0.21	0.33	0.49	1.77	1.11	0.13	6.12	1.04	1.18	0.83	0.58	0.14
03597_c3	0.53	0.107	3.46	0.114	0.33	0.165	0.51	0.055	2.8	0.16	1.5	1.59	0.31	1.85	1.52	0.121	0.56
03597_c4	2.27	0.32	1.94	0.34	1.75	0.33	0.67	0.58	1.92	0.69	0.59	3.83	0.89	0.73	0.6	0.36	0.38
03597_c5	0.74	0.34	0.32	0.85	3.56	0.82	0.71	0.27	0.77	1.73	0.21	1.54	3.18	1.08	1.06	0.91	0.102
03597_d1	6.41	1.29	3.59	0.6	0.88	0.22	4.38	0.94	4.44	1.96	0.39	5.42	5.16	2.54	1.21	0.79	0.144
03597_d2	1.99	0.57	1.7	0.6	0.49	0.58	2.72	0.41	0.89	1.36	0.74	3.36	2.16	0.97	0.83	0.35	0.32
03597_d3	4.95	0.58	2.45	0.61	1.8	0.59	2.76	0.59	0.2	0.87	0.32	4.82	2.06	1.3	1.31	0.2	0.68
03597_d4	1.81	0.26	1.93	0.55	0.68	0.37	1.75	0.179	1.25	0.55	0.94	2.16	1.32	0.82	0.34	0.098	0.43
03597_d5	0.46	0.79	0.19	0.59	0.43	0.57	0.44	0.047	0.47	0.85	0.25	3.31	1.06	0.59	0.52	0.63	0.38
2003.591 Burial 39																	
03591_a1	4.26	0.86	0.95	0.64	1.89	0.23	0	0.88	0.26	1.3	1.57	0.44	1.3	1.37	0.98	0.68	0.41
03591_a2	0.7	0.047	3.48	1.23	2.56	0.24	0.23	0.146	0.16	0.36	1.5	1.12	1.77	1.3	0.76	0.159	0.161
03591_a3	2.54	0.046	2.18	0.77	1.13	0.83	3.01	0.65	1.24	0.42	0.25	3.71	1.12	0.63	0.67	0.41	0.247
03591_a4	2.34	0.137	2.83	0.5	0.28	0.23	0.87	0.59	1.14	0.5	1.22	1.97	1.04	0.53	0.62	0.37	0.23
03591_a5	1.95	0.192	0.65	0.32	0.24	0.078	1.89	0.7	0.26	1.03	0.14	3.29	2.33	0.61	0.52	0.44	0.46
03591_b1	1.12	0.28	0.24	0.91	2.67	1.52	1.08	0.88	0.19	0	0.41	1.66	1.28	1.35	0.21	0.96	0.82
03591_b2	0.21	0.214	0.91	0.27	2.6	0.85	0.2	0.86	2.85	0.129	1.52	6.96	1.91	1.87	1.34	0.94	0.57
03591_b3	1.87	0.38	0.44	0.56	1.17	0.071	2.54	0.55	0.59	0.105	0.97	2.22	0.87	0.33	0.49	0.233	0.36
03591_b4	2.35	0.27	1.13	0.5	0.36	0.69	0.54	0.49	1.98	0.51	0.21	1.79	1.93	0.53	0.82	0.128	0.228
03591_b5	0.76	0.5	4.71	0.53	1.19	0.234	2.37	0.51	1.69	1.06	0.9	5.05	1.67	0.78	0.79	0.56	0.155
03591_c1	1.87	0.76	1.61	0.4	1.67	0.39	2.55	0.55	1.29	0.57	0.97	3.85	2.41	1.33	0.92	0.51	0.36
03591_c2	5.5	0.2	4.71	1.66	4.89	0.052	1.47	0.21	0.35	0.23	2.01	1.2	1.75	1.74	1.02	0.23	0.75
03591_c3	2.57	1.59	4.76	1.19	0.23	0.23	0.71	1.15	5.4	0.33	2.88	6.58	2.77	1.76	1.79	1.25	0.45
03591_c4	0.58	1.08	1.49	0.25	1.27	1.1	1.39	0.12	0.2	0.26	0.42	3.42	4.66	1.68	0.43	1.2	0.28
03591_c5	1.07	0.14	1.84	0.31	0.45	1.08	0	0.074	0.74	0.92	1.1	5.05	1.55	1.65	0.79	0.081	0.41
03591_d1	2.64	0.54	3.26	1.15	0.99	0.96	2.59	0.79	1.85	0.82	1.39	6.37	2.42	0.66	0.86	0.86	0.92
03591_d2	3.52	0.99	2.1	0.53	1.54	0.51	2.36	0.88	2.38	0.74	1.55	4.1	2.23	1.89	1.2	0.55	0.9
03591_d3	2.71	0.55	4.03	0.82	1.84	0.56	2.61	0.97	2.63	1.43	1.4	5.55	3.23	1.48	0.5	0.37	0.7
03591_d3	509	102.8	201.4	25.09	0	8.07	489.93	16.2	53.65	154.5	185.8	1041	275.1	12.29	133.2	35.29	15.99
03591_d4	1.64	0.5	4.08	0.72	4.23	0.168	4.58	1.2	2.3	1.44	1.74	2.89	3.19	1.02	1.08	0.76	0.74
03591_d5	4.83	0.32	2.92	0.89	1.32	0.7	2.32	0.5	1.65	0.73	0.88	2.85	2.32	1.07	0.63	0.24	0.64

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**Re**	**Au**	**Tl**	**Pb**	**Bi**	**Th**	**U**
2003.623 Burial 45																	
03623_a1	1.34	0.29	4.71	1.36	2.02	0.94	3.19	1.22	2.32	1.34	2.34	4.02	2.95	3.89	2.82	0.29	0.79
03623_a2	3.54	0.53	5.23	0.58	3.89	0.99	2.74	0.27	1.99	0.81	2.31	6	2.27	2.25	1.44	0.12	0.55
03623_a3	3.02	0.91	2.82	0.28	2.1	0.98	8.1	1.04	2.41	2.2	2.43	3.28	3.49	1.72	0.56	0.66	0.001
03623_a4	2.89	0.62	4.68	2.24	2.84	0.94	1.31	0.99	3.26	2.1	3.3	5.68	2.78	2.02	1.67	1.09	0.64
03623_a5	2.52	0.76	4.07	0.83	1.23	0.71	3.37	0.96	3.74	0.58	1.66	3.49	2.13	1.54	0.94	0.39	0.28
03623_b1	2.86	0.75	3.78	1.25	2.43	0.8	3.13	0.49	2.28	1.14	2.11	4.87	2.43	2	0.95	0.17	0.55
03623_b2	3.88	0.75	2.09	0.37	1.55	0.63	1.73	0.125	0.41	0.89	1.65	3.82	1.6	1.28	1.12	0.69	0.35
03623_b3	2.19	0.57	2.89	1.14	1.52	0.5	0.23	0.84	0.34	0.87	1.91	4.32	1.57	1.53	1.59	0.58	0.24
03623_b4	2.11	0.32	3.11	0.6	0.95	0.001	1.63	0.51	2.9	1.19	1.71	4.17	1.51	1.04	0.93	0.32	0.23
03623_b5	1.89	0.4	3.06	0.76	2.27	0.75	2.07	0.46	2.13	0.87	2.5	2.77	1.82	1.87	0.63	0.41	0.42
03623_b6	2.2	0.47	1.45	0.42	1.08	0.066	1.7	0.65	3.02	1.01	1.62	4.35	1.58	1.4	0.64	0.48	0.54
03623_b7	2.34	0.29	3.99	0.7	0.61	0.001	2.55	0.57	2.15	0.29	1.26	2.68	1.73	1.34	0.71	0.29	0.3
03623_b8	2	0.74	3.96	0.47	0.98	0.56	2.18	0.112	2.25	1.12	0.94	1.99	1.88	0.99	0.75	0.001	0.22
03623_b9	2.02	0.61	2.32	0.58	1.98	0.46	0.51	0.6	0.56	0.46	1.64	2.85	2	1.16	0.83	0.051	0.32
03623_b10	1.7	0.44	1.58	0.48	2.35	0.053	0.5	0.29	1.65	0.55	1.48	2.93	1.39	1.88	0.69	0.45	0.145
03623_b11	2.78	0.142	2.12	0.65	0.92	0.37	2.48	0.67	2.55	0.52	2.26	3.93	2.12	2.05	0.85	0.6	0.44
03623_b12	1.44	0.43	2.69	0.48	1	0.183	1.57	0.34	2.56	0.81	1.17	2.88	1.13	0.82	1.02	0.31	0.227
03623_c1	2.19	0.33	2.51	0.51	1.52	0.5	1.56	0.53	2.13	0.87	1.45	6.59	1.32	1.25	1.04	0.34	0.34
03623_c2	3.04	0.46	1.45	0.5	1.49	0.49	0.19	0.52	1.97	0.4	1.01	2.49	1.59	1.1	0.88	0.38	0.35
03623_c3	2.17	0.46	2.03	0.62	1.06	0.182	0.43	0.98	1.72	0.5	1.25	3.78	1.84	1.39	0.63	0.043	0.34
03623_c4	2.63	0.112	0.74	0.61	1.05	0.78	2.34	0.52	0.83	0.98	1.74	3.73	1.09	1.23	1.02	0.33	0.41
03623_c5	1.28	0.132	2.39	0.6	1.53	0.65	1.39	0.44	1.43	1.1	1.7	4.07	1.3	1.27	0.68	0.276	0.4
03623_c6	1.52	0.56	1.42	0.5	0.61	0.35	1.65	0.73	2.41	0.7	2.14	3.75	1.76	1.5	1.08	0.57	0.239
03623_c7	2.13	0.32	3.14	0.5	1.47	0.49	0.76	0.52	3.16	1.46	1.73	3.72	1.37	1.06	0.51	0.15	0.24
03623_c8	2.68	0.33	1.45	0.2	1.52	0.35	1.69	0.75	2.13	0.5	1.46	3.83	2.17	1.25	0.9	0.33	0.24
03623_c9	0.59	0.52	1.87	0.57	0.54	0.32	1.54	0.59	1.58	0.79	1.49	4.52	1.5	1.62	1.01	0.43	0.39
03623_c10	1.53	0.32	2.02	0.8	1.83	0.35	2.35	0.52	1.71	0.7	1.76	4.38	1.55	1.24	0.81	0.66	0.34
03623_c11	1.57	0.22	2.08	0.9	0.89	0.62	2.42	0.54	1.76	0.88	1.05	3.91	1.13	2.3	0.92	0.59	0.35
03623_c12	5.92	0.68	3.91	1.95	4.09	1.35	9.11	0.78	3.31	2.35	3.95	10.42	3.55	2.94	1.72	0.9	0.66
03623_d1	7.3	0.69	6.1	1.32	2.26	0.58	0.001	1.37	3.66	1.06	3.45	10.51	3.63	1.89	1.74	1	0.52
03623_d2	2.19	0.52	3.54	1.35	1.51	0.71	2.38	0.92	2.45	0.66	1.46	7.74	2.11	2.18	1.12	0.67	0.35
03623_d3	3.23	0.97	3.7	1.19	3.16	0.34	2.49	0.55	3.14	1.05	2.86	4.3	2.54	2.07	1.33	0.7	0.41
03623_d4	2.37	0.5	6.64	0.78	2.84	0.54	3.65	0.47	3.25	0.5	1.28	2.23	2.64	2.72	1.38	0.001	0.37
03623_d5	1.26	1.22	4.17	1.59	2.52	0.19	3.96	1.25	5	0.83	3.22	3.04	2.74	3.47	0.87	0.78	0.58
03623_d6	2.17	0.38	2.02	0.58	0.86	0.29	1.92	0.3	1.98	0.81	1.32	4.05	1.27	1.13	0.67	0.269	0.34
03623_d7	1.27	0.27	2.37	0.66	0.57	0.29	1.38	0.53	1	0.41	1.2	3.19	1.22	1.03	0.61	0.045	0.2
03623_d8	0.73	0.154	0.68	0.24	0.5	0.166	0.79	0.249	1.41	0.119	0.69	1.06	0.66	0.81	0.35	0.158	0.115
03623_e1	3.26	0.28	3.04	0.44	0.92	0.53	2.05	0.46	2.35	0.75	1.55	2.74	1.6	1.95	0.84	0.4	0.229
03623_e2	0.87	0.57	1.77	0.62	1.85	0.31	1.46	0.37	2.12	0.43	0.95	2.56	1.29	0.89	0.64	0.23	0.37
03623_e3	3.01	0.32	3.14	0.93	1.47	0.158	3.27	0.51	2.66	0.49	1.24	4.39	1.18	1.36	0.72	0.46	0.037
03623_e4	1.47	0.62	2.38	0.34	1.76	0.34	0.26	0.058	1.16	0.82	1.56	4.3	1.64	1.03	0.86	0.71	0.4
03623_e5	2.1	0.32	1.5	0.85	0.71	0.41	2.8	0.36	1.66	0.83	2	3.08	1.51	1.28	1.12	0.45	0.41
03623_e6	1.48	0.31	3.1	0.77	1.02	0.83	1.61	0.72	2.03	0.48	1.22	3.08	1.85	1.04	0.71	0.32	0.24
03623_f1	3.22	0.39	2.46	0.75	1.81	0.95	2.86	0.78	1.47	0.6	1.53	5.46	2.15	1.85	1.26	0.56	0.29
03623_f2	1.52	0.32	1.18	0.94	2.1	0.49	1.65	0.73	1.33	0.27	1.91	2.23	1.69	1.51	0.63	0.33	0.48

Appendix E: Raw elemental data for individual osteons (i.e., ‘1’ Haversian canal —> ‘5’ cement line).

continued	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hf**	**Ta**	**Re**	**Au**	**Tl**	**Pb**	**Bi**	**Th**	**U**
03623_f3	2.81	0.34	1.84	0.26	3.36	0.37	2.49	0.39	1.81	0.74	1.55	3.38	2.09	2.09	0.87	0.35	0.36
03623_f4	1.83	0.67	3.43	0.74	1.26	0.59	0.87	0.19	1.27	1.03	2.14	2.36	1.41	1.67	0.76	0.39	0.41
03623_f5	1.86	0.68	1.73	0.61	1.28	0.73	0.84	0.45	2.07	0.85	2.34	4.74	1.79	1.51	0.88	0.4	0.29
03623_f6	2.02	0.18	3.77	0.94	2.41	0.65	2.19	0.84	3.19	0.92	1.36	5.17	1.84	1.16	0.84	0.42	0.32
<u>1999.175 Burial 57-2</u>																	
99175_a1	2.61	0.059	2.24	0.062	2.32	0.54	0.56	0.93	0.79	0.26	0.94	4.31	0.68	0.18	0.95	0.065	0.118
99175_a2	0.77	0.039	0.66	0	1.57	0.52	2.4	0.44	0.39	0.058	0.9	5.85	4.47	0.82	0.46	0.086	0.026
99175_a3	2.19	0.44	1.88	0.042	1.37	0.45	0.38	0.64	0.27	0.93	0.071	2.55	3.08	0.67	0.56	0.044	0.133
99175_a4	1.16	0.23	1.52	0.247	0.73	0.39	0.91	0.19	0.64	0.28	0.42	1.74	1.66	0.5	0.4	0.34	0.155
99175_a5	1.12	0.226	1.36	0.36	0.99	0.126	1.07	0.063	1.07	0.34	0.98	1.84	1.64	0.59	0.35	0.251	0.021
99175_b1	2.17	0.094	3.22	0.46	1.93	0.63	3.6	0.89	0.32	0.141	1.56	2.53	3.75	0.66	0.56	0.49	0.031
99175_b2	6.52	0.23	3.95	1.39	0.28	0.95	0.43	0.138	0.76	1.96	1.65	5.36	5.74	2.42	0.84	0.15	0.15
99175_b3	1.33	0.27	0.77	0.127	1.18	0.061	0.85	0.27	0.4	0.4	0.48	3.46	2.39	0.9	0.48	0.133	0.199
99175_b4	0	0.38	1.99	0.29	0.84	0.097	2.23	0.39	0.8	0.071	0.96	2.21	1.36	0.7	0.42	0.3	0.311
99175_b5	1.16	0.28	0.99	0.49	1.03	0.53	1.11	0.24	1.35	0.12	0.41	0.93	1.54	0.35	0.59	0.09	0.219
99175_c1	0.47	0.44	1.87	0.46	1.37	0.065	2.09	0.032	0.21	0.93	0	2.53	3.63	0.66	0.69	0.49	0.148
99175_c2	0	0.129	2.22	0.78	0.3	0.131	0.61	0.75	2.47	0.24	1.31	0.56	2.55	0.29	0.66	0.107	0.107
99175_c3	0.14	0.47	0	0.5	0	0.48	0.28	0.48	1.58	0.13	1.18	3.84	4.71	0.71	0.74	0.52	0.135
99175_c4	0.49	0.025	1.35	0.052	0.076	0.65	0.12	0.32	0.49	0.219	0.043	0.14	1	0.146	0.11	0.35	0.298
99175_c5	1.48	0.026	0.43	0.45	0.079	0.3	0	0.3	1.73	0.63	0.75	2.42	1.56	0.63	0.27	0.113	0.118
99175_d1	0.18	0.4	0.31	0.115	1.77	0.41	1.91	0.41	1.35	0.162	0.32	3.27	2.16	0.85	0.72	0.45	0.266
99175_d2	0.56	0.3	1.27	0.45	0	0.53	2.01	0.31	1.73	0.45	1.5	3.44	2.33	0.23	0.54	0.47	0.198
99175_d3	1.03	0.29	1.53	0.22	1.58	0.126	0.98	0.042	1.2	0.62	0.44	1.69	2.62	0.53	0.32	0.33	0.054
99175_d4	0.98	0.034	0.84	0.209	0.87	0.29	0.94	0.202	0.66	0.29	0.121	0.79	1.63	0.51	0.35	0.076	0.185
99175_d5	2.51	0.36	2.15	0.54	1.11	0	2.4	0.52	1.2	0.75	0.63	1.79	5.23	0.52	0.56	0.043	0
99175_d5	0	0	0	0	0	0.8	44.46	0	0	0	0	0	0	1.16	0	0	0
SRM612 Avg	37.2	36.13	36.24	38.15	37.85	37.81	40.218	38	35.08	40.09	8.263	5.206	14.08	39.72	30.7	37.56	37.79

Appendix F: Raw strontium isotope results for individual osteons.

Burial	Total Sr (V)	^{87}Sr/^{86}Sr	2σ error	^{84}Sr/^{86}Sr	2σ error
K14_1998.027.01					
Intact-1	1.03	0.710664	0.00057	0.056743	0.00014
Intact-2	1.36	0.710550	0.00025	0.056652	0.00010
Intact-3	1.44	0.710515	0.00026	0.056803	0.00005
Intact-4	1.12	0.709436	0.00045	0.056275	0.00015
Intact-5	1.01	0.710160	0.00037	0.056376	0.00012
Intact-6	1.30	0.710140	0.00032	0.056274	0.00009
Intact-7	1.38	0.710461	0.00034	0.056267	0.00006
Intact-8	1.30	0.710390	0.00026	0.056302	0.00007
Intact-9	1.50	0.710141	0.00031	0.056493	0.00007
Diagenetic-1	1.41	0.711112	0.00020	0.056815	0.00006
Diagenetic-2	1.23	0.711441	0.00024	0.056856	0.00008
Diagenetic-3	1.69	0.710975	0.00023	0.056624	0.00005
Diagenetic-4	1.42	0.710920	0.00020	0.056449	0.00008
Diagenetic-5	1.45	0.710674	0.00023	0.056500	0.00008
K14_1998.035.01					
Intact-1	0.92	0.710227	0.00028	0.055419	0.00015
Intact-2	0.79	0.710674	0.00032	0.054155	0.00023
Intact-3	0.63	0.710653	0.00043	0.053240	0.00059
Intact-4	0.70	0.711823	0.00058	0.056539	0.00016
Intact-5	0.61	0.712002	0.00072	0.056230	0.00019
Intact-6	0.75	0.710928	0.00040	0.056326	0.00014
Intact-7	0.73	0.710549	0.00040	0.056439	0.00014
Intact-8	0.71	0.710233	0.00037	0.056640	0.00014
Intact-9	0.60	0.710852	0.00055	0.056722	0.00020
Diagenetic-1	0.26	0.717124	0.00394	0.057195	0.00072
Diagenetic-2	0.50	0.713042	0.00166	0.056344	0.00038
Diagenetic-3	0.43	0.713551	0.00175	0.056118	0.00043
Diagenetic-4	0.76	0.709987	0.00047	0.056970	0.00015
Diagenetic-5	0.72	0.709661	0.00057	0.057015	0.00018

Appendix F: Raw strontium isotope results for individual osteons.

Burial	**Total Sr (V)**	**^{87}Sr/^{86}Sr**	**2σ error**	**^{84}Sr/^{86}Sr**	**2σ error**
K14_1998.035.02					
Intact-1	0.44	0.711867	0.00127	0.053728	0.00100
Intact-2	0.47	0.710200	0.00151	0.054214	0.00084
Intact-3	0.47	0.710127	0.00103	0.053236	0.00108
Intact-4	0.50	0.709541	0.00102	0.056439	0.00027
Intact-5	0.51	0.708952	0.00104	0.056749	0.00025
Intact-6	0.55	0.709380	0.00063	0.056916	0.00038
Intact-7	0.60	0.711022	0.00039	0.056745	0.00025
Intact-8	0.44	0.710124	0.00130	0.055967	0.00055
Intact-9	0.42	0.710383	0.00081	0.055754	0.00058
Diagenetic-1	0.51	0.706062	0.00194	0.057846	0.00079
Diagenetic-2	0.50	0.707067	0.00129	0.057923	0.00052
Diagenetic-3	0.48	0.703660	0.00332	0.058432	0.00114
Diagenetic-4	0.57	0.709698	0.00094	0.058219	0.00068
Diagenetic-5	0.39	0.707243	0.00226	0.058927	0.00092
K14_1999.039					
Intact-1	0.82	0.710023	0.00036	0.057456	0.00023
Intact-2	0.83	0.709940	0.00035	0.057370	0.00014
Intact-3	0.98	0.710684	0.00030	0.056128	0.00009
Intact-4	0.90	0.710015	0.00031	0.056579	0.00016
Intact-5	0.93	0.709531	0.00039	0.056671	0.00009
Intact-6	0.94	0.710463	0.00041	0.056273	0.00012
Intact-7	0.92	0.711014	0.00039	0.056112	0.00014
Intact-8	0.84	0.709833	0.00041	0.057040	0.00024
Intact-9	0.98	0.711244	0.00053	0.056170	0.00014
Diagenetic-1	0.78	0.712520	0.00090	0.056108	0.00021
Diagenetic-2	0.64	0.712921	0.00104	0.056217	0.00022
Diagenetic-3	0.61	0.714094	0.00172	0.057733	0.00054
Diagenetic-4	0.71	0.712651	0.00088	0.057027	0.00019
Diagenetic-5	0.75	0.712178	0.00061	0.056626	0.00026

Appendix F: Raw strontium isotope results for individual osteons.

Burial	**Total Sr (V)**	**^{87}Sr/^{86}Sr**	**2σ error**	**^{84}Sr/^{86}Sr**	**2σ error**
K14_1999.045					
Intact-1	1.02	0.710794	0.00069	0.057295	0.00032
Intact-2	0.58	0.711944	0.00140	0.057212	0.00042
Intact-3	0.71	0.711907	0.00085	0.057173	0.00030
Intact-4	0.66	0.710800	0.00034	0.055969	0.00014
Intact-5	1.19	0.710754	0.00049	0.056357	0.00010
Intact-6	1.10	0.710465	0.00052	0.056178	0.00013
Intact-7	0.63	0.711429	0.00074	0.055748	0.00024
Intact-8	0.63	0.710353	0.00086	0.055476	0.00036
Intact-9	0.60	0.710083	0.00078	0.055501	0.00033
Diagenetic-1	0.65	0.707400	0.00108	0.056776	0.00032
Diagenetic-2	0.89	0.709474	0.00053	0.056587	0.00012
Diagenetic-3	0.69	0.707060	0.00172	0.056476	0.00030
Diagenetic-4	0.78	0.710675	0.00086	0.057410	0.00034
Diagenetic-5	0.79	0.711184	0.00047	0.057102	0.00030
K14_1999.057.02					
Intact-1	0.78	0.710234	0.00048	0.055832	0.00016
Intact-2	0.87	0.710433	0.00044	0.055905	0.00016
Intact-3	0.75	0.710328	0.00058	0.055377	0.00033
Intact-4	0.58	0.711643	0.00098	0.056602	0.00042
Intact-5	0.90	0.711309	0.00041	0.056475	0.00014
Intact-6	0.74	0.711146	0.00047	0.056469	0.00013
Intact-7	0.83	0.711812	0.00032	0.056063	0.00015
Intact-8	0.71	0.712509	0.00066	0.055552	0.00029
Intact-9	0.73	0.712036	0.00040	0.055360	0.00033
Diagenetic-1	0.53	0.714669	0.00182	0.055312	0.00051
Diagenetic-2	0.46	0.714494	0.00127	0.056269	0.00048
Diagenetic-3	0.51	0.714701	0.00156	0.056303	0.00026
Diagenetic-4	0.45	0.712510	0.00135	0.055570	0.00045
Diagenetic-5	0.07	0.716986	0.00292	0.054349	0.00154
NBS-987	3.10	0.710253	0.00003	0.056476	0.00002

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2008.008	Arshan	Martes zibellina	sable	sobol	tooth	51°53'52"	102°26'08"
E 2008.013	Arshan	Apodemus peninsulae	mouse	mysh	tooth	51°54'54"	102°23'23"
E 2008.014	Tunka Valley	Citelius parryi	ground squirrel	suslik	longbone	51°42'23"	102°35'50"
E 2008.015	Tunka Valley	Bos taurus	cow	korova	tooth	51°45'32"	102°33'41"
E 2008.016	Tunka Valley	Bos taurus	cow	korova	longbone	51°54'91"	102°23'37"
E 2008.017	Tunka Valley	Bos taurus	cow	korova	tooth	51°41'56"	102°33'49"
E 2008.018	Tunka Valley	Bos taurus	cow	korova	tooth	51°41'57"	102°25'34"
E 2008.019	Tunka Valley	Bos taurus	cow	korova	tooth	51°41'57"	102°25'34"
E 2008.020	Tunka Valley	Bos taurus	cow	korova	tooth	51°41'57"	102°25'34"
E 2008.021	Tunka Valley	Bos taurus	cow	korova	tooth	51°41'57"	102°25'34"
E 2008.030	Tunka Valley	Equus callabus	horse	loshad	tooth	51°41'57"	102°25'34"
E 2008.035	Tunka Valley	Equus callabus	horse	loshad	longbone	51°41'57"	102°25'34"
E 2008.039	Tunka Valley	Equus callabus	horse	loshad	longbone	51°41'57"	102°25'34"
E 2008.040	Tunka Valley	Equus callabus	horse	loshad	tooth	51°41'57"	102°25'34"
E 2008.051	Little Sea	Cervidae	deer	olen	pedal element	53°05'54"	106°48'09"
E 2008.056	Little Sea	Citelius parryi	ground squirrel	suslik	tooth	53°04'98"	106°46'62"
E 2008.057	Little Sea	Citelius parryi	ground squirrel	suslik	vertebra	53°04'29"	106°46'62"
E 2008.061	Ol'khon Island	Lepus	hare	zajac	longbone	53°00'87"	106°56'20"
E 2008.065	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°00'92"	106°56'14"
E 2008.068	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'74"	106°56'28"
E 2008.069	Ol'khon Island	Citelius parryi	ground squirrel	suslik	longbone	53°01'75"	106°56'30"
E 2008.070	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'75"	106°56'30"
E 2008.071	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'76"	106°56'30"
E 2008.072	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'77"	106°56'32"
E 2008.074	Ol'khon Island	Citelius parryi	ground squirrel	suslik	inominate	53°01'78"	106°56'35"
E 2008.075	Ol'khon Island	Citelius parryi	ground squirrel	suslik	longbone	53°01'80"	106°56'36"
E 2008.076	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'80"	106°56'36"
E 2008.080	Ol'khon Island	Citelius parryi	ground squirrel	suslik	tooth	53°01'56"	106°56'40"
E 2008.082	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°41'60"	106°27'76"
E 2008.085	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	pedal element	52°41'32"	106°29'21"
E 2008.086	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°41'29"	106°29'18"
E 2008.088	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°41'39"	106°29'26"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2008.089	Sagan-Zaba	Cervus elaphus	red deer	blagorodnii olen	tooth	52°41'40"	106°29'15"
E 2008.091	Sagan-Zaba	Cervidae	deer	olen	longbone	52°41'46"	106°29'10"
E 2008.092	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°41'47"	106°29'10"
E 2008.094	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°41'48"	106°29'06"
E 2008.095	Sagan-Zaba	Phoca sibirica	baikal seal	Baikalskaya nerpa	rib	52°38'82"	106°26'06"
E 2008.105	Sagan-Zaba	Cervus elaphus	red deer	blagorodnii olen	longbone	52°40'89"	106°25'48"
E 2008.112	Sagan-Zaba	Citelius parryi	ground squirrel	suslik	longbone	52°43'56"	106°31'62"
E 2008.115	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°43'56"	106°31'24"
E 2008.117	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°43'54"	106°31'18"
E 2008.118	Sagan-Zaba	Citelius parryi	ground squirrel	suslik	tooth	52°43'49"	106°31'05"
E 2008.122	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°43'48"	106°30'96"
E 2008.126	Sagan-Zaba	Capreolus pygargus	roe deer	kosulya	tooth	52°42'51"	106°29'33"
E 2008.128	Sagan-Zaba	Citelius parryi	ground squirrel	suslik	tooth	52°41'33"	106°29'07"
E 2008.129	Sagan-Zaba	Apodemus peninsulae	mouse	mysh	tooth	52°41'53"	106°28'00"
E 2008.130	Sagan-Zaba	Citelius parryi	ground squirrel	suslik	tooth	52°41'37"	106°28'26"
E 2008.131	Sagan-Zaba	Citelius parryi	ground squirrel	suslik	tooth	52°41'32"	106°26'36"
E 2009.001	Baiandai	Betula sp.	birch	bereza	leaves	53°07'13"	105°38'31"
E 2009.002	Baiandai	Betula sp.	birch	bereza	leaves	53°07'13"	105°38'31"
E 2009.007	Khogot	Picea sp.	spruce	el'	needles	53°13'40"	105°51'04"
E 2009.008	Khogot	Picea sp.	spruce	el'	needles	53°13'40"	105°51'04"
E 2009.018	Khogot	Betula sp.	birch	bereza	leaves	53°16'56"	105°54'18"
E 2009.019	Khogot	Abies sp.	larch	listvennitsa	needles	53°16'56"	105°54'18"
E 2009.023	Khodontsa R.	n/a	n/a	n/a	water	53°22'33"	106°00'24"
E 2009.029	Manzurka	Betula sp.	birch	bereza	leaves	53°30'26"	106°01'37"
E 2009.030	Manzurka	Abies sp.	larch	listvennitsa	needles	53°30'26"	106°01'37"
E 2009.034	Manzurka R.	n/a	n/a	n/a	water	53°43'24"	105°59'37"
E 2009.040	Kharbatovo	Betula sp.	birch	bereza	leaves	53°48'31"	105°58'47"
E 2009.041	Kharbatovo	Pinus sp.	pine	sosna	needles	53°48'31"	105°58'47"
E 2009.050	Ilikta	Betula sp.	birch	bereza	leaves	53°49'25"	106°24'54"
E 2009.051	Ilikta	Picea sp.	spruce	el'	needles	53°49'25"	106°24'54"
E 2009.055	Ilikta R.	n/a	n/a	n/a	water	53°49'25"	106°24'54"
E 2009.056	Lena R.	n/a	n/a	n/a	water	53°50'22"	106°20'41"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.057	Biriulka R.	n/a	n/a	n/a	water	53°51'54"	106°20'18"
E 2009.061	Makrushina	Betula sp.	birch	bereza	leaves	53°52'50"	106°15'40"
E 2009.062	Makrushina	Pinus sp.	pine	sosna	needles	53°52'50"	106°15'40"
E 2009.073	Malye Goly	Betula sp.	birch	bereza	leaves	53°54'38"	106°09'29"
E 2009.074	Malye Goly	Pinus sp.	pine	sosna	needles	53°54'38"	106°09'29"
E 2009.078	Anga R.	n/a	n/a	n/a	water	53°56'14"	106°02'49"
E 2009.079	Tutura R.	n/a	n/a	n/a	water	54°47'23"	105°14'06"
E 2009.082	Zhigalovo	Betula sp.	birch	bereza	leaves	54°46'07"	105°08'39"
E 2009.083	Zhigalovo	Pinus sp.	pine	sosna	needles	54°46'07"	105°08'39"
E 2009.086	Lena R.	n/a	n/a	n/a	water	54°39'54"	105°13'05"
E 2009.088	Vorob'eva	Betula sp.	birch	bereza	leaves	54°34'38"	105°14'48"
E 2009.089	Vorob'eva	Pinus sp.	pine	sosna	needles	54°34'38"	105°14'48"
E 2009.094	Zapleskino	Betula sp.	birch	bereza	leaves	54°21'58"	105°15'00"
E 2009.095	Zapleskino	Pinus sp.	pine	sosna	needles	54°21'58"	105°15'00"
E 2009.099	Gul'ma R.	n/a	n/a	n/a	water	54°12'53"	105°27'08"
E 2009.101	Verkholensk	Betula sp.	birch	bereza	leaves	54°06'44"	105°34'06"
E 2009.102	Verkholensk	Pinus sp.	pine	sosna	needles	54°06'44"	105°34'06"
E 2009.108	Magdan	Betula sp.	birch	bereza	leaves	53°37'34"	105°17'56"
E 2009.109	Magdan	Abies sp.	larch	listvennitsa	needles	53°37'34"	105°17'56"
E 2009.112	Magdan R.	n/a	n/a	n/a	water	53°37'34"	105°17'56"
E 2009.114	Magdan	Betula sp.	birch	bereza	leaves	53°37'41"	105°17'21"
E 2009.115	Magdan	Pinus sp.	pine	sosna	needles	53°37'41"	105°17'21"
E 2009.119	Kulenga R.	n/a	n/a	n/a	water	53°40'41"	105°19'16"
E 2009.120	Inei R.	n/a	n/a	n/a	water	53°43'12"	105°20'03"
E 2009.123	Ikhinagui	Betula sp.	birch	bereza	leaves	53°44'32"	105°19'53"
E 2009.124	Ikhinagui	Abies sp.	larch	listvennitsa	needles	53°44'32"	105°19'53"
E 2009.128	Obkhoi	Betula sp.	birch	bereza	leaves	53°58'34"	105°26'47"
E 2009.129	Obkhoi	Pinus sp.	pine	sosna	needles	53°58'34"	105°26'47"
E 2009.134	Shemetovo	Betula sp.	birch	bereza	leaves	54°01'03"	105°26'47"
E 2009.135	Shemetovo	Pinus sp.	pine	sosna	needles	54°01'03"	105°26'47"
E 2009.139	Shemetovo	Bos taurus	cow	korova	molar	54°01'03"	105°26'47"
E 2009.140	Shemetovo	Bos taurus	cow	korova	molar	54°01'03"	105°26'47"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.141	Tal'ma R.	n/a	n/a	n/a	water	54°01'12"	105°29'57"
E 2009.142	Kulenga R.	n/a	n/a	n/a	water	54°06'01"	105°35'05"
E 2009.145	Kartukhai	Betula sp.	birch	bereza	leaves	54°02'17"	105°37'17"
E 2009.146	Kartukhai	Pinus sp.	pine	sosna	needles	54°02'17"	105°37'17"
E 2009.150	Shyshkino	Betula sp.	birch	bereza	leaves	54°00'07"	105°43'48"
E 2009.151	Shyshkino	Pinus sp.	pine	sosna	needles	54°00'07"	105°43'48"
E 2009.155	Mys	Betula sp.	birch	bereza	leaves	54°01'55"	106°24'15"
E 2009.157	Mys	Picea sp.	spruce	el'	needles	54°01'55"	106°24'15"
E 2009.161	Anga R.	n/a	n/a	n/a	water	53°58'41"	106°11'15"
E 2009.163	Kachug	Betula sp.	birch	bereza	leaves	53°58'53"	105°51'41"
E 2009.164	Kachug	Abies sp.	larch	listvennitsa	needles	53°58'53"	105°51'41"
E 2009.168	Lena R.	n/a	n/a	n/a	water	53°56'38"	105°53'04"
E 2009.169	Polovinka	Betula sp.	birch	bereza	leaves	53°07'07"	105°40'44"
E 2009.170	Polovinka	Betula sp.	birch	bereza	leaves	53°07'07"	105°40'44"
E 2009.172	Oloi	Betula sp.	birch	bereza	leaves	52°55'09"	105°10'37"
E 2009.173	Oloi	Betula sp.	birch	bereza	leaves	52°55'09"	105°10'37"
E 2009.175	Kuda R.	n/a	n/a	n/a	water	52°55'56"	104°51'25"
E 2009.176	Sosnovyi Bor	Betula sp.	birch	bereza	leaves	52°39'01"	104°30'59"
E 2009.177	Sosnovyi Bor	Betula sp.	birch	bereza	leaves	52°39'01"	104°30'59"
E 2009.182	Irkut R.	n/a	n/a	n/a	water	52°04'34"	103°53'34"
E 2009.185	Moty	Betula sp.	birch	bereza	leaves	52°04'24"	103°54'14"
E 2009.186	Moty	Pinus sp.	pine	sosna	needles	52°04'24"	103°54'14"
E 2009.191	Andrianovskaia	Betula sp.	birch	bereza	leaves	51°48'34"	103°47'18"
E 2009.192	Andrianovskaia	Pinus sp.	pine	sosna (kedr)	needles	51°48'34"	103°47'18"
E 2009.197	Angaselka	Betula sp.	birch	bereza	leaves	51°43'21"	103°42'02"
E 2009.198	Angaselka	Pinus sp.	pine	sosna	needles	51°43'21"	103°42'02"
E 2009.203	Kultuk	Betula sp.	birch	bereza	leaves	51°44'04"	103°38'12"
E 2009.204	Kultuk	Betula sp.	birch	bereza	leaves	51°44'04"	103°38'12"
E 2009.207	Kultuchnaia R	n/a	n/a	n/a	water	51°44'04"	103°38'12"
E 2009.208	Bol'shaia Bystraia R.	n/a	n/a	n/a	water	51°43'51"	103°23'13"
E 2009.211	Bystroe	Betula sp.	birch	bereza	leaves	51°43'56"	103°25'57"
E 2009.212	Bystroe	Pinus sp.	pine	sosna (kedr)	needles	51°43'56"	103°25'57"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.215	Sredniaia Tibelti R.	n/a	n/a	n/a	water	51°45'41"	103°15'17"
E 2009.216	Irkut R.	n/a	n/a	n/a	water	51°46'39"	103°14'41"
E 2009.219	Tibelti	Betula sp.	birch	bereza	leaves	51°46'45"	103°13'19"
E 2009.220	Tibelti	Pinus sp.	pine	sosna	needles	51°46'45"	103°13'19"
E 2009.225	Zun-Murino	Betula sp.	birch	bereza	leaves	51°44'07"	102°52'41"
E 2009.226	Zun-Murino	Pinus sp.	pine	sosna	needles	51°44'07"	102°52'41"
E 2009.229	Zun-Murino R.	n/a	n/a	n/a	water	51°43'56"	102°51'40"
E 2009.232	Shabartaika	Betula sp.	birch	bereza	leaves	51°43'01"	102°43'43"
E 2009.233	Shabartaika	Pinus sp.	pine	sosna	needles	51°43'01"	102°43'43"
E 2009.236	Irkut R.	n/a	n/a	n/a	water	51°43'03"	102°35'13"
E 2009.239	Guzhiry	Betula sp.	birch	bereza	leaves	51°47'42"	102° 4' 3"
E 2009.240	Guzhiry	Pinus sp.	pine	sosna	needles	51°47'42"	102° 4' 3"
E 2009.245	Dalakhai	Betula sp.	birch	bereza	leaves	51°48'01"	102°58'31"
E 2009.246	Dalakhai	Betula sp.	birch	bereza	leaves	51°48'01"	102°58'31"
E 2009.248	Tsagan-Ugun R.	n/a	n/a	n/a	water	51°48'01"	102°58'31"
E 2009.251	Nikol'sk	Picea sp.	spruce	el'	needles	51°43'06"	102°35'23"
E 2009.252	Nikol'sk	Pinus sp.	pine	sosna	needles	51°43'06"	102°35'23"
E 2009.257	Tagarkhai	Betula sp.	birch	bereza	leaves	51°52'32"	102°26'41"
E 2009.258	Tagarkhai	Abies sp.	larch	listvennitsa	needles	51°52'32"	102°26'41"
E 2009.261	Kitoi R.	n/a	n/a	n/a	water	52°02'56"	101°05'53"
E 2009.262	Il'chir Lake	Abies sp.	larch	listvennitsa	needles	52° 0' 2"	101°01'17"
E 2009.263	Il'chir Lake	Abies sp.	larch	listvennitsa	needles	52° 0' 2"	101°01'17"
E 2009.265	Ch. Irkut R.	n/a	n/a	n/a	water	51°57'23"	100°56'35"
E 2009.266	Il'chir Lake	Abies sp.	larch	listvennitsa	needles	51°57'39"	100°57'05"
E 2009.267	Il'chir Lake	Abies sp.	larch	listvennitsa	needles	51°57'39"	100°57'05"
E 2009.269	Suser R.	n/a	n/a	n/a	water	51°54'20"	100°45'27"
E 2009.270	Ch. Irkut	Abies sp.	larch	listvennitsa	needles	51°54'04"	100°45'30"
E 2009.271	Ch. Irkut	Abies sp.	larch	listvennitsa	needles	51°54'04"	100°45'30"
E 2009.273	Ch. Irkut R.	n/a	n/a	n/a	water	51°54'04"	100°45'30"
E 2009.274	Ch. Irkut	Betula sp.	birch	bereza	leaves	51°47'54"	100°42'32"
E 2009.275	Ch. Irkut	Betula sp.	birch	bereza	leaves	51°47'54"	100°42'32"
E 2009.277	B. Irkut	Betula sp.	birch	bereza	leaves	51°46'12"	100°42'33"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.278	B. Irkut	Betula sp.	birch	bereza	leaves	51°46'12"	100°42'33"
E 2009.280	B. Irkut R.	n/a	n/a	n/a	water	51°46'12"	100°42'33"
E 2009.281	Irkut	Abies sp.	larch	listvennitsa	needles	51°44'58"	100°43'56"
E 2009.282	Irkut	Abies sp.	larch	listvennitsa	needles	51°44'58"	100°43'56"
E 2009.284	Irkut R.	n/a	n/a	n/a	water	51°44'58"	100°43'56"
E 2009.286	Aerkhan	Abies sp.	larch	listvennitsa	needles	51°41'50"	100°52'18"
E 2009.287	Aerkhan	Pinus sp.	pine	sosna	needles	51°41'50"	100°52'18"
E 2009.289	Aerkhan R.	n/a	n/a	n/a	water	51°41'50"	100°52'18"
E 2009.290	Irkut R.	n/a	n/a	n/a	water	51°40'26"	101°01'06"
E 2009.293	B. Khara-Gol	Betula sp.	birch	bereza	leaves	51°39'16"	101°15'05"
E 2009.294	B. Khara-Gol	Pinus sp.	pine	sosna (kedr)	needles	51°39'16"	101°15'05"
E 2009.297	B. Khara-Gol R.	n/a	n/a	n/a	water	51°39'16"	101°15'05"
E 2009.300	Khalagan	Betula sp.	birch	bereza	leaves	51°37'56"	101°33'23"
E 2009.301	Khalagan	Abies sp.	larch	listvennitsa	needles	51°37'56"	101°33'23"
E 2009.304	Khalagan R.	n/a	n/a	n/a	water	51°37'56"	101°33'23"
E 2009.307	Nilovka	Betula sp.	birch	bereza	leaves	51°40'45"	101°40'46"
E 2009.308	Nilovka	Pinus sp.	pine	sosna	needles	51°40'45"	101°40'46"
E 2009.311	Ekhe-Ukhgun' R.	n/a	n/a	n/a	water	51°40'45"	101°40'46"
E 2009.314	Turan	Betula sp.	birch	bereza	leaves	51°38'55"	101°41'12"
E 2009.315	Turan	Pinus sp.	pine	sosna	needles	51°38'55"	101°41'12"
E 2009.318	Irkut R.	n/a	n/a	n/a	water	51°38'55"	101°41'12"
E 2009.321	B. Zangisan	Betula sp.	birch	bereza	leaves	51°40'00"	101°49'43"
E 2009.322	B. Zangisan	Pinus sp.	pine	sosna	needles	51°40'00"	101°49'43"
E 2009.325	B. Zangisan R.	n/a	n/a	n/a	water	51°40'00"	101°49'43"
E 2009.326	Arshan	Pinus sp.	pine	sosna	needles	51°55'02"	102°25'34"
E 2009.327	Arshan	Pinus sp.	pine	sosna	needles	51°55'02"	102°25'34"
E 2009.329	Kyngarga R.	n/a	n/a	n/a	water	51°55'02"	102°25'34"
E 2009.330	Arshan	Abies sp.	larch	listvennitsa	needles	51°55'06"	102°25'25"
E 2009.331	Arshan	Abies sp.	larch	listvennitsa	needles	51°55'06"	102°25'25"
E 2009.335	Arshan	Betula sp.	birch	bereza	leaves	51°52'06"	102°30'14"
E 2009.336	Arshan	Pinus sp.	pine	sosna	needles	51°52'06"	102°30'14"
E 2009.339	Tunka R.	n/a	n/a	n/a	water	51°44'24"	102°31'53"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.342	Tunka	Betula sp.	birch	bereza	leaves	51°44'20"	102°30'11"
E 2009.343	Tunka	Pinus sp.	pine	sosna	needles	51°44'20"	102°30'11"
E 2009.346	Ulan-Gorkhon	Betula sp.	birch	bereza	leaves	51°41'23"	102°30'41"
E 2009.347	Ulan-Gorkhon	Betula sp.	birch	bereza	leaves	51°41'23"	102°30'41"
E 2009.349	Ulan-Gorkhon R.	n/a	n/a	n/a	water	51°41'23"	102°30'41"
E 2009.352	Okhor-Shibir	Betula sp.	birch	bereza	leaves	51°37'55"	102°21'50"
E 2009.353	Okhor-Shibir	Larix sp.	larch	listvennitsa	needles	51°37'55"	102°21'50"
E 2009.356	Okhor-Shibir R.	n/a	n/a	n/a	water	51°37'55"	102°21'50"
E 2009.357	Irkut R.	n/a	n/a	n/a	water	51°42'49"	102°25'50"
E 2009.360	Kiren	Betula sp.	birch	bereza	leaves	51°40'34"	102°08'49"
E 2009.361	Kiren	Pinus sp.	pine	sosna	needles	51°40'34"	102°08'49"
E 2009.364	Kultuk	Betula sp.	birch	bereza	leaves	51°41'15"	103°41'37"
E 2009.365	Kultuk	Betula sp.	birch	bereza	leaves	51°41'15"	103°41'37"
E 2009.367	Bezymiannaia	Betula sp.	birch	bereza	leaves	51°35'42"	103°54'34"
E 2009.368	Bezymiannaia	Betula sp.	birch	bereza	leaves	51°35'42"	103°54'34"
E 2009.370	Bezymiannaia R.	n/a	n/a	n/a	water	51°35'42"	103°54'34"
E 2009.373	Sukhoi Ruchei	Betula sp.	birch	bereza	leaves	51°37'37"	103°47'45"
E 2009.374	Sukhoi Ruchei	Pinus sp.	pine	sosna	needles	51°37'37"	103°47'45"
E 2009.379	Gramatukha	Pinus sp.	pine	sosna	needles	51°56'46"	103°48'42"
E 2009.380	Gramatukha	Abies sp.	fir	pikhta	needles	51°56'46"	103°48'42"
E 2009.385	Bulga	Betula sp.	birch	bereza	leaves	52°58'04"	105°44'18"
E 2009.386	Bulga	Larix sp.	larch	listvennitsa	needles	52°58'04"	105°44'18"
E 2009.391	Kosaia Step	Betula sp.	birch	bereza	leaves	52°52'03"	106°01'55"
E 2009.392	Kosaia Step	Larix sp.	larch	listvennitsa	needles	52°52'03"	106°01'55"
E 2009.395	Bugul'deika R.	n/a	n/a	n/a	water	52°50'27"	106°04'58"
E 2009.396	Bugul'deika R.	n/a	n/a	n/a	water	52°32'52"	106°03'49"
E 2009.399	Dolon-Bogot	Betula sp.	birch	bereza	leaves	52°36'23"	106°08'42"
E 2009.400	Dolon-Bogot	Pinus sp.	pine	sosna	needles	52°36'23"	106°08'42"
E 2009.403	Dolon-Bogot R.	n/a	n/a	n/a	water	52°36'23"	106°08'42"
E 2009.406	Popovo	Betula sp.	birch	bereza	leaves	52°43'49"	106°17'28"
E 2009.407	Popovo	Larix sp.	larch	listvennitsa	needles	52°43'49"	106°17'28"
E 2009.412	Petrovo	Betula sp.	birch	bereza	leaves	52°44'59"	106°21'01"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.413	Petrovo	Pinus sp.	pine	sosna	needles	52°44'59"	106°21'01"
E 2009.416	Anga R.	n/a	n/a	n/a	water	52°47'57"	106°30'59"
E 2009.419	Khotoruk	Larix sp.	larch	listvennitsa	needles	52°47'50"	106°30'50"
E 2009.420	Khotoruk	Pinus sp.	pine	sosna	needles	52°47'50"	106°30'50"
E 2009.423	Gorkhon R.	n/a	n/a	n/a	water	52°51'01"	106°28'51"
E 2009.426	Narim-Kurei	Larix sp.	larch	listvennitsa	needles	52°50'43"	106°29'16"
E 2009.427	Narim-Kurei	Pinus sp.	pine	sosna	needles	52°50'43"	106°29'16"
E 2009.432	Shamanskii Mys	Larix sp.	larch	listvennitsa	needles	53°12'11"	107°20'36"
E 2009.433	Shamanskii Mys	Larix sp.	larch	listvennitsa	needles	53°12'11"	107°20'36"
E 2009.436	Baikal Lake	n/a	n/a	n/a	water	53°12'11"	107°20'36"
E 2009.437	Khuzhir	Larix sp.	larch	listvennitsa	needles	53°10'40"	107°20'03"
E 2009.438	Khuzhir	Larix sp.	larch	listvennitsa	needles	53°10'40"	107°20'03"
E 2009.440	Khadai	Larix sp.	larch	listvennitsa	needles	53°03'52"	107°03'54"
E 2009.441	Khadai	Larix sp.	larch	listvennitsa	needles	53°03'52"	107°03'54"
E 2009.443	Baikal Lake	n/a	n/a	n/a	water	53°01'05"	106°53'47"
E 2009.444	Kurkut Bay	Larix sp.	larch	listvennitsa	needles	53°00'39"	106°48'15"
E 2009.445	Kurkut Bay	Larix sp.	larch	listvennitsa	needles	53°00'39"	106°48'15"
E 2009.447	Kurma	Larix sp.	larch	listvennitsa	needles	53°10'59"	106°58'27"
E 2009.448	Kurma	Larix sp.	larch	listvennitsa	needles	53°10'59"	106°58'27"
E 2009.450	Kurma Lake	n/a	n/a	n/a	water	53°10'59"	106°58'27"
E 2009.451	Sarma	Pinus sp.	pine	sosna	needles	53°08'28"	106°53'32"
E 2009.452	Sarma	Pinus sp.	pine	sosna	needles	53°08'28"	106°53'32"
E 2009.454	Baikal Lake	n/a	n/a	n/a	water	53°08'28"	106°53'32"
E 2009.455	Sarma	Pinus sp.	pine	sosna	needles	53°08'36"	106°53'27"
E 2009.456	Sarma	Pinus sp.	pine	sosna	needles	53°08'36"	106°53'27"
E 2009.460	Sarma	Betula sp.	birch	bereza	leaves	53°06'48"	106°50'21"
E 2009.461	Sarma	Larix sp.	larch	listvennitsa	needles	53°06'48"	106°50'21"
E 2009.464	Sarma R.	n/a	n/a	n/a	water	53°06'48"	106°50'21"
E 2009.467	Khuzhir-Nuge	Betula sp.	birch	bereza	leaves	53°05'09"	106°47'24"
E 2009.468	Khuzhir-Nuge	Larix sp.	larch	listvennitsa	needles	53°05'09"	106°47'24"
E 2009.473	Kulura	Larix sp.	larch	listvennitsa	needles	53°01'01"	106°44'25"
E 2009.474	Kulura	Larix sp.	larch	listvennitsa	needles	53°01'01"	106°44'25"

Appendix G: Environmental samples used in the study.

Sample ID	Site	Latin Name	English Name	Russian Name	Element	Latitude	Longitude
E 2009.477	Kulura	n/a	n/a	n/a	water	53°01'01"	106°44'25"
E 2009.478	Tazhyren' Steppe	Pinus sp.	pine	sosna	needles	52°53'42"	106°37'10"
E 2009.479	Tazhyren' Steppe	Pinus sp.	pine	sosna	needles	52°53'42"	106°37'10"
E 2009.483	Listvianka	Betula sp.	birch	bereza	leaves	51°51'38"	104°51'11"
E 2009.484	Listvianka	Larix sp.	larch	listvennitsa	needles	51°51'38"	104°51'11"
E 2009.487	Listvianka	n/a	n/a	n/a	water	51°51'38"	104°51'11"
E 2009.490	Bol'shaia Rechka	Betula sp.	birch	bereza	leaves	51°57'06"	104°44'50"
E 2009.491	Bol'shaia Rechka	Pinus sp.	pine	sosna	needles	51°57'06"	104°44'50"
E 2009.494	Bol'shaia Rechka	n/a	n/a	n/a	water	51°57'06"	104°44'50"
E 2009.495	Karolok R.	n/a	n/a	n/a	water	52°08'08"	104°34'42"
E 2009.498	Karolok	Betula sp.	birch	bereza	leaves	52°08'18"	104°34'14"
E 2009.499	Karolok	Pinus sp.	pine	sosna	needles	52°08'18"	104°34'14"
E 2009.504	Central Park	Betula sp.	birch	bereza	leaves	52°16'25"	104°17'40"
E 2009.505	Central Park	Larix sp.	larch	listvennitsa	needles	52°16'25"	104°17'40"
E 2009.508	Ushakovka R.	n/a	n/a	n/a	water	52°17'48"	104°17'43"
E 2009.511	Lokomotiv	Betula sp.	birch	bereza	leaves	52°17'15"	104°15'13"
E 2009.512	Lokomotiv	Betula sp.	birch	bereza	leaves	52°17'15"	104°15'13"
E 2009.515	Irkut R.	n/a	n/a	n/a	water	52°17'46"	104°14'23"
E 2009.518	Ershi	Betula sp.	birch	bereza	leaves	52°13'22"	104°19'27"
E 2009.519	Ershi	Pinus sp.	pine	sosna	needles	52°13'22"	104°19'27"
E 2009.523	Tunka	Betula sp.	birch	bereza	leaves	51°44'33"	102°26'01"
E 2009.524	Tunka	Betula sp.	birch	bereza	leaves	51°44'33"	102°26'01"
E 2009.525	Tunka	Pinus sp.	pine	sosna	needles	51°44'33"	102°26'01"
E 2009.526	Tunka	Pinus sp.	pine	sosna	needles	51°44'33"	102°26'01"
E 2009.527	Tunka	Pinus sp.	pine	sosna	needles	51°44'33"	102°26'01"
E 2009.528	Mondy	Betula sp.	birch	bereza	leaves	51°41'53"	100°52'28"
E 2009.529	Mondy	Betula sp.	birch	bereza	leaves	51°41'53"	100°52'28"
E 2009.530	Mondy	Betula sp.	birch	bereza	leaves	51°41'53"	100°52'28"
E 2009.531	Mondy	Larix sp.	larch	listvennitsa	needles	51°41'53"	100°52'28"
E 2009.536	Zun-Murino	Betula sp.	birch	bereza	leaves	51°44'30"	102°47'14"
E 2009.537	Zun-Murino	Pinus sp.	pine	sosna (kedr)	needles	51°44'30"	102°47'14"
E 2009.542	Tory	Betula sp.	birch	bereza	leaves	51°46'30"	103°01'25"
E 2009.543	Tory	Pinus sp.	pine	sosna	needles	51°46'30"	103°01'25"

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Plants

Sample ID	$^{87}Sr/^{86}Sr$	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
E2009.001	0.709952	25.422	5158.4	122560.4	391.720	35396.7	250105.2	22.554	2.739	4.891	2989.2
E2009.002	0.710224	48.688	6468.7	64575.5	479.768	19957.5	267427.8	38.221	2.336	7.771	3852.9
E2009.007	0.709011	52.315	4704.2	26995.1	2131.997	23141.5	232334.9	171.684	8.535	15.510	5227.2
E2009.008	0.708929	69.472	6407.4	30292.3	1911.524	27396.0	226075.4	154.387	6.559	13.167	4563.7
E2009.018	0.708891	14.377	2200.7	29962.1	258.679	18705.2	157236.7	29.573	1.569	3.460	2873.2
E2009.019	0.708960	207.888	16631.4	49253.2	2677.871	62123.3	110816.1	117.629	10.216	18.695	4411.1
E2009.029	0.709780	162.091	5476.5	72640.9	775.508	53789.1	206581.5	64.849	2.908	4.621	3086.9
E2009.030	0.709945	284.893	25114.8	56912.8	2410.230	81673.6	98445.8	52.432	4.045	15.902	2675.2
E2009.040	0.710573	33.448	3783.2	67865.7	697.571	48828.8	227172.8	40.820	1.882	4.996	3006.9
E2009.041	0.709897	73.930	6567.7	39219.7	5514.541	36402.5	296074.7	173.782	7.881	14.106	5348.1
E2009.050	0.711422	40.438	6148.4	93486.6	2697.950	42985.2	293334.7	174.210	6.652	9.156	6052.2
E2009.051	0.711192	72.998	10242.7	33688.6	3057.300	56939.3	211605.9	176.121	7.957	11.971	4532.3
E2009.061	0.710731	28.239	4628.4	63704.2	1086.776	52101.0	330820.9	65.328	2.942	7.649	4329.8
E2009.062	0.711043	67.231	7687.6	32035.8	6948.570	37942.7	286097.0	300.090	15.960	26.260	9781.1
E2009.073	0.710312	11.707	1607.7	41658.1	874.138	24040.6	241653.3	60.765	2.593	3.919	3593.4
E2009.074	0.710546	95.192	5240.8	36869.8	12957.964	31457.5	243340.7	348.978	31.157	37.603	18651.6
E2009.082	0.711487	70.667	14554.6	189334.5	760.985	115665.6	408702.1	39.658	4.326	2.918	4657.3
E2009.083	0.711883	384.224	57674.0	142007.5	6709.369	148001.9	259975.9	228.169	9.530	11.428	7080.5
E2009.088	0.709874	100.645	18723.2	152088.4	6186.425	111522.5	495276.1	418.717	13.881	14.356	9167.7
E2009.089	0.710792	451.104	45138.3	80752.4	21088.247	107726.5	449428.0	671.046	46.958	51.216	20629.9
E2009.094	0.710142	60.644	14017.6	195505.2	2454.587	110844.2	553549.1	121.492	6.440	6.560	6968.2
E2009.095	0.710459	206.806	15655.5	32696.5	12865.650	35811.7	255983.6	402.377	31.904	29.369	15520.2
E2009.101	0.709100	49.709	7702.9	102081.5	1905.723	37155.2	298021.8	114.067	5.018	5.096	4198.6
E2009.102	0.710748	216.808	19451.3	52742.1	5082.179	58967.4	253391.7	202.751	12.986	13.375	6959.6
E2009.108	0.709258	72.579	13735.8	61575.2	873.355	77610.2	221051.5	51.746	2.734	2.301	3187.9
E2009.109	0.708889	223.399	15674.2	56913.5	682.590	53835.3	133196.1	17.640	2.552	2.504	2311.5
E2009.114	0.709252	45.140	8252.2	75521.9	268.573	116629.2	159701.0	18.177	1.344	1.009	1985.7
E2009.115	0.708751	186.021	19213.4	38831.2	3661.567	60690.5	342961.2	138.748	8.346	10.258	5819.6
E2009.123	0.709809	42.888	9317.3	46928.3	286.103	84189.2	200832.9	18.270	1.501	0.947	2511.4
E2009.124	0.709184	315.273	25329.3	23666.1	608.153	90431.6	90394.1	13.377	2.116	11.521	1884.3
E2009.128	0.710131	33.291	8126.3	63809.9	770.101	35419.5	251134.1	51.032	1.782	2.175	2996.6
E2009.129	0.709934	78.647	6910.4	32766.4	4349.621	33073.0	390479.3	204.805	11.130	11.169	6813.1
E2009.134	0.709883	16.129	3487.0	73459.5	402.350	44906.2	298725.2	25.584	1.175	1.368	3512.3
E2009.135	0.709992	132.362	15473.0	48593.6	5966.786	53402.7	311227.4	299.646	15.118	18.073	8185.6
E2009.145	0.710993	53.314	9156.2	81018.4	6718.672	44663.7	240305.1	337.854	15.467	12.996	9364.3
E2009.146	0.711913	27.215	3084.6	14822.8	5795.085	13482.4	77694.8	205.303	13.406	12.976	7385.7
E2009.150	0.710488	23.114	4712.9	84236.0	616.576	52216.9	227086.1	31.651	2.091	1.856	2880.9
E2009.151	0.710735	60.756	8224.3	33021.0	10896.616	35069.5	256910.4	372.107	26.831	25.054	16002.9
E2009.155	0.711096	542.427	11907.7	63167.4	1261.089	55896.8	255890.7	70.895	3.263	4.815	4049.1
E2009.157	0.711151	66.413	8527.1	39412.1	2358.769	39840.9	227856.1	80.658	5.165	6.122	4539.9
E2009.163	0.709212	30.878	7467.5	61760.9	953.808	48822.5	253664.5	57.297	2.751	2.869	3623.5

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
E2009.001	2232.314	1.128	17.279	94.834	289.097	0.401	1.830	6.517	59.154	1492.768	0.237
E2009.002	5214.006	1.976	22.078	98.419	180.806	0.527	0.934	2.701	74.269	1760.337	0.411
E2009.007	761.818	2.002	14.726	78.642	2186.604	1.893	2.142	3.172	42.734	2475.973	1.937
E2009.008	858.275	1.716	11.519	85.850	1745.890	1.425	1.446	1.530	47.350	2570.193	1.562
E2009.018	1847.358	1.484	25.844	76.389	173.515	0.396	0.569	1.763	176.309	2436.609	0.230
E2009.019	1433.432	2.707	29.284	193.114	466.644	1.462	2.835	6.513	127.046	2320.278	1.270
E2009.029	4943.575	2.904	49.678	86.939	2602.232	0.874	1.328	2.907	73.699	796.089	1.310
E2009.030	17511.472	4.813	38.319	121.531	234.808	1.154	1.300	2.555	139.454	456.274	0.734
E2009.040	8218.702	2.394	49.653	71.084	170.452	0.700	0.785	1.508	64.678	660.298	0.470
E2009.041	9991.575	3.087	17.833	73.612	2105.897	1.478	2.147	4.121	38.777	498.978	1.281
E2009.050	5831.437	6.071	14.387	99.512	973.074	1.144	1.171	2.505	65.048	244.386	1.137
E2009.051	1181.560	1.738	9.614	58.480	1663.341	1.213	1.454	3.537	86.757	365.862	1.161
E2009.061	940.851	1.711	21.245	84.979	892.923	0.784	0.619	1.132	26.296	667.563	0.588
E2009.062	1022.417	3.390	18.141	75.368	1144.901	2.482	2.150	1.497	37.131	448.053	2.819
E2009.073	2599.706	2.026	12.542	38.194	91.156	0.587	0.541	0.928	48.586	725.031	0.601
E2009.074	1933.509	7.048	29.563	79.762	495.007	4.617	3.283	1.347	79.737	605.037	5.771
E2009.082	8558.649	4.437	162.200	210.630	1807.832	0.925	6.426	10.068	112.098	387.914	0.583
E2009.083	14441.983	3.183	70.070	420.528	4836.300	2.597	1.788	3.600	183.812	101.287	1.610
E2009.088	8801.453	5.939	35.354	205.263	1867.373	2.476	2.343	4.327	54.383	718.845	3.226
E2009.089	19693.252	11.830	45.805	369.461	4167.721	7.505	7.179	12.708	77.113	477.795	11.562
E2009.094	2923.491	2.784	22.356	196.856	3520.620	1.381	1.833	4.851	81.637	1164.595	1.677
E2009.095	1366.447	5.617	20.877	123.365	952.023	4.106	4.178	3.678	28.954	343.378	8.010
E2009.101	637.287	1.922	27.651	125.415	1630.456	0.738	1.578	4.163	38.575	2159.010	0.830
E2009.102	3372.983	2.512	8.898	138.514	1932.895	1.922	2.829	5.863	29.397	364.222	2.079
E2009.108	5456.274	2.112	61.997	189.805	1511.189	0.714	0.883	2.689	99.569	528.417	0.343
E2009.109	12422.427	1.901	8.596	155.819	338.724	0.696	1.012	3.428	105.168	952.083	0.268
E2009.114	4609.011	0.868	72.195	96.745	2248.697	0.762	0.679	2.232	36.390	272.071	0.227
E2009.115	5556.530	1.353	7.586	147.334	2050.670	1.489	2.469	5.327	30.635	271.704	1.468
E2009.123	7158.792	1.742	10.192	134.856	1659.924	0.636	0.870	2.575	41.931	373.275	0.320
E2009.124	9848.243	1.588	11.352	163.105	184.732	0.776	1.131	2.644	35.493	263.784	0.182
E2009.128	3265.831	1.437	19.334	82.009	135.824	0.464	0.497	1.430	74.885	617.632	0.385
E2009.129	1932.007	1.866	9.118	101.491	1206.959	1.541	2.838	6.720	11.585	739.196	1.795
E2009.134	1980.860	0.985	10.064	86.574	194.334	0.402	0.655	1.489	23.801	741.929	0.221
E2009.135	3102.471	2.898	12.828	121.482	1494.447	2.270	3.258	4.903	42.997	414.918	2.487
E2009.145	1468.884	3.845	20.369	130.199	430.503	2.045	2.023	1.493	25.789	375.829	3.573
E2009.146	473.205	2.588	9.055	31.482	424.954	1.785	1.499	0.412	9.669	66.626	2.565
E2009.150	1346.600	1.206	16.085	83.664	331.771	0.522	0.973	2.019	20.826	404.576	0.427
E2009.151	1144.133	5.034	19.350	61.706	1025.586	3.635	4.847	5.444	31.989	375.420	5.984
E2009.155	3678.940	2.315	28.018	236.723	1215.721	0.716	0.971	2.400	66.418	623.343	0.776
E2009.157	2375.185	1.713	12.172	66.168	519.163	1.024	0.803	0.515	87.256	1239.782	1.224
E2009.163	912.695	1.519	20.266	125.978	2909.779	0.602	0.917	2.063	39.672	723.889	0.531

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
E2009.001	0.001	0.056	1.064	0.890	0.081	0.157	0.560	0.370	0.129	0.270	709.636
E2009.002	0.001	0.081	2.177	1.256	0.068	0.078	0.808	1.420	0.162	0.495	525.230
E2009.007	0.001	0.115	1.869	1.445	0.114	0.161	0.150	1.059	0.499	0.573	2828.832
E2009.008	0.001	0.095	2.277	1.126	0.091	0.145	0.001	0.604	0.317	0.583	1623.147
E2009.018	0.001	0.065	1.272	0.962	0.048	0.110	0.264	0.177	0.107	0.749	486.234
E2009.019	0.001	0.138	1.758	0.654	0.094	0.474	0.317	0.375	0.283	1.235	1035.162
E2009.029	0.001	0.149	11.110	0.803	0.073	0.319	1.061	0.362	0.103	1.215	803.041
E2009.030	0.001	0.121	1.097	0.148	0.080	0.345	0.281	0.374	0.128	1.447	335.767
E2009.040	0.001	0.101	1.325	0.752	0.055	0.085	0.895	0.177	0.072	0.334	449.978
E2009.041	0.001	0.193	1.285	0.761	0.097	0.300	0.526	0.388	0.185	0.392	202.340
E2009.050	0.001	0.181	1.617	0.847	0.065	0.084	0.922	0.332	0.125	0.269	367.911
E2009.051	0.001	0.109	1.081	0.569	0.062	0.095	0.092	0.256	0.098	0.467	1051.612
E2009.061	0.001	0.112	1.523	1.012	0.056	0.055	0.181	0.198	0.102	0.222	771.921
E2009.062	0.001	0.194	1.279	1.017	0.079	0.322	0.154	0.611	0.339	0.532	125.850
E2009.073	0.001	0.071	2.266	0.834	0.039	0.032	0.231	0.118	0.055	0.277	588.510
E2009.074	0.202	0.153	2.313	0.999	0.106	0.270	1.382	0.732	0.267	1.713	246.071
E2009.082	0.128	0.221	3.061	0.730	0.194	0.422	0.559	0.418	0.112	1.034	1439.055
E2009.083	0.138	0.413	5.379	0.576	0.133	1.378	0.780	0.864	0.352	0.840	129.818
E2009.088	0.472	0.439	2.826	1.180	0.133	0.367	0.883	0.453	0.134	0.783	2247.290
E2009.089	0.133	0.183	3.090	0.981	0.255	1.688	0.521	2.428	0.420	1.318	375.692
E2009.094	0.199	0.169	2.430	1.236	0.106	0.180	0.598	0.189	0.081	0.754	1153.260
E2009.095	0.091	0.189	1.613	0.453	0.234	0.520	0.205	1.411	0.219	0.840	269.776
E2009.101	0.086	0.160	11.077	0.894	0.107	0.258	0.114	0.190	0.085	0.416	666.997
E2009.102	0.397	0.075	1.878	0.555	0.142	0.383	0.157	0.481	0.210	0.508	123.089
E2009.108	0.097	0.070	2.038	0.556	0.065	0.189	0.262	0.076	0.096	0.329	844.754
E2009.109	0.126	0.001	0.800	0.367	0.048	0.542	0.285	0.094	0.012	1.146	1323.047
E2009.114	0.065	0.026	1.132	0.302	0.050	0.117	0.433	0.067	0.042	0.381	880.117
E2009.115	0.075	0.065	4.241	1.015	0.100	0.293	0.558	0.399	0.204	0.289	232.077
E2009.123	0.042	0.011	1.614	0.351	0.042	0.108	0.548	0.085	0.044	0.225	580.039
E2009.124	0.070	0.001	1.005	0.028	0.037	0.141	0.370	0.084	0.018	0.542	353.565
E2009.128	0.057	0.050	1.209	0.485	0.028	0.120	0.154	0.062	0.045	0.488	976.827
E2009.129	0.099	0.072	1.038	0.940	0.089	0.786	0.124	0.395	0.150	0.313	241.405
E2009.134	0.123	0.128	0.858	0.687	0.075	0.098	0.152	0.146	0.045	0.311	1489.149
E2009.135	0.099	0.365	1.382	0.684	0.168	0.259	0.563	0.712	0.310	0.564	227.193
E2009.145	0.173	0.200	5.133	0.522	0.071	0.106	0.084	0.448	0.100	0.338	675.368
E2009.146	0.038	0.064	0.935	0.181	0.041	0.070	0.070	0.399	0.096	0.370	60.053
E2009.150	0.029	0.076	2.484	0.459	0.040	0.080	0.124	0.098	0.050	0.231	980.211
E2009.151	0.072	0.168	1.868	0.822	0.119	0.295	0.270	0.865	0.313	0.869	183.310
E2009.155	0.065	0.095	1.491	0.657	0.049	1.735	0.811	0.155	0.054	0.142	1029.648
E2009.157	0.158	0.037	0.619	0.666	0.043	0.184	0.044	0.217	0.080	0.936	1161.377
E2009.163	0.120	0.095	1.371	0.684	0.064	0.084	0.091	0.120	0.064	0.268	964.152

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
E2009.001	0.379	0.658	0.074	0.291	0.064	0.320	0.064	0.001	0.046	0.001	0.001
E2009.002	0.748	1.272	0.145	0.558	0.117	0.262	0.112	0.001	0.081	0.001	0.047
E2009.007	3.254	5.994	0.691	2.660	0.586	1.457	0.462	0.061	0.359	0.072	0.207
E2009.008	2.472	4.604	0.537	2.076	0.414	0.832	0.388	0.049	0.299	0.059	0.161
E2009.018	0.447	0.832	0.094	0.360	0.073	0.237	0.064	0.001	0.044	0.001	0.001
E2009.019	2.218	4.095	0.484	1.913	0.364	0.535	0.337	0.043	0.242	0.046	0.129
E2009.029	2.148	2.815	0.469	1.771	0.348	0.422	0.389	0.045	0.254	0.048	0.113
E2009.030	1.046	1.756	0.230	0.868	0.166	0.173	0.190	0.001	0.135	0.028	0.074
E2009.040	0.773	1.270	0.151	0.550	0.102	0.220	0.139	0.001	0.085	0.001	0.047
E2009.041	2.033	3.645	0.442	1.682	0.326	0.147	0.324	0.041	0.235	0.049	0.137
E2009.050	1.751	3.486	0.417	1.591	0.310	0.220	0.316	0.038	0.241	0.046	0.130
E2009.051	1.936	3.750	0.428	1.564	0.313	0.508	0.333	0.043	0.240	0.047	0.140
E2009.061	0.896	1.745	0.207	0.777	0.159	0.377	0.189	0.001	0.128	0.026	0.071
E2009.062	5.096	10.017	1.176	4.418	0.863	0.236	0.819	0.099	0.575	0.111	0.297
E2009.073	0.936	1.893	0.221	0.869	0.179	0.304	0.198	0.001	0.131	0.026	0.071
E2009.074	10.503	20.764	2.458	9.212	1.792	0.496	1.700	0.206	1.188	0.224	0.608
E2009.082	0.920	1.410	0.179	0.671	0.145	0.522	0.151	0.020	0.106	0.025	0.056
E2009.083	2.691	5.078	0.578	2.142	0.436	0.123	0.438	0.056	0.334	0.070	0.171
E2009.088	4.341	8.634	1.053	4.144	0.841	0.925	0.867	0.111	0.657	0.127	0.338
E2009.089	15.570	31.139	3.869	14.794	3.020	0.826	2.943	0.391	2.203	0.420	1.157
E2009.094	2.182	4.429	0.557	2.130	0.426	0.505	0.459	0.057	0.352	0.066	0.177
E2009.095	10.441	21.697	2.737	10.837	2.217	0.611	1.926	0.271	1.554	0.301	0.749
E2009.101	1.124	2.216	0.264	1.036	0.191	0.264	0.194	0.026	0.164	0.031	0.081
E2009.102	3.388	6.613	0.794	3.033	0.580	0.166	0.512	0.066	0.399	0.072	0.210
E2009.108	0.549	1.016	0.121	0.418	0.103	0.292	0.079	0.011	0.064	0.012	0.037
E2009.109	0.419	0.781	0.095	0.350	0.070	0.454	0.058	0.007	0.041	0.008	0.024
E2009.114	0.391	0.549	0.077	0.280	0.054	0.304	0.050	0.006	0.036	0.006	0.015
E2009.115	2.223	4.444	0.526	1.976	0.369	0.168	0.359	0.046	0.281	0.053	0.136
E2009.123	0.323	0.501	0.088	0.367	0.075	0.222	0.078	0.009	0.053	0.011	0.031
E2009.124	0.307	0.532	0.061	0.250	0.054	0.125	0.044	0.006	0.030	0.006	0.021
E2009.128	0.535	1.022	0.118	0.454	0.094	0.369	0.080	0.011	0.066	0.013	0.036
E2009.129	2.574	5.000	0.586	2.277	0.456	0.172	0.431	0.056	0.333	0.064	0.185
E2009.134	0.312	0.576	0.073	0.265	0.073	0.585	0.062	0.011	0.043	0.012	0.029
E2009.135	4.170	7.812	0.928	3.634	0.683	0.236	0.645	0.090	0.520	0.100	0.281
E2009.145	5.179	10.462	1.263	4.949	1.007	0.459	1.050	0.134	0.795	0.155	0.426
E2009.146	4.539	9.008	1.073	4.058	0.794	0.188	0.744	0.092	0.551	0.105	0.272
E2009.150	0.616	1.205	0.142	0.545	0.120	0.388	0.115	0.014	0.091	0.018	0.048
E2009.151	9.918	19.817	2.358	8.694	1.673	0.431	1.640	0.198	1.217	0.229	0.652
E2009.155	1.040	2.097	0.253	0.976	0.191	0.438	0.198	0.024	0.152	0.028	0.081
E2009.157	1.801	3.751	0.430	1.682	0.358	0.508	0.323	0.042	0.251	0.046	0.121
E2009.163	0.843	1.649	0.187	0.706	0.141	0.393	0.148	0.020	0.109	0.021	0.063

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
E2009.001	0.001	0.001	0.001	0.001	0.161	0.475	5.834	0.051	0.001
E2009.002	0.007	0.001	0.001	0.001	0.078	0.258	5.262	0.118	0.057
E2009.007	0.027	0.185	0.001	0.001	0.129	0.553	8.938	0.569	0.345
E2009.008	0.024	0.148	0.001	0.001	0.071	0.591	8.085	0.511	0.263
E2009.018	0.001	0.001	0.001	0.001	0.055	0.233	3.006	0.081	0.001
E2009.019	0.017	0.113	0.001	0.001	0.199	0.129	17.385	0.410	0.419
E2009.029	0.013	0.078	0.001	0.001	0.100	0.619	5.078	0.164	0.058
E2009.030	0.011	0.059	0.001	0.052	0.365	0.127	11.654	0.327	0.079
E2009.040	0.006	0.001	0.001	0.027	0.129	0.420	3.672	0.148	0.001
E2009.041	0.018	0.112	0.001	0.030	0.206	0.400	5.916	0.442	0.110
E2009.050	0.019	0.107	0.001	0.001	0.111	0.494	7.697	0.450	0.108
E2009.051	0.019	0.125	0.001	0.001	0.123	0.363	4.379	0.533	0.115
E2009.061	0.010	0.062	0.001	0.001	0.046	0.320	5.421	0.212	0.049
E2009.062	0.041	0.249	0.001	0.001	0.048	0.608	10.846	0.997	0.227
E2009.073	0.010	0.061	0.001	0.001	0.025	0.194	2.694	0.198	0.042
E2009.074	0.078	0.482	0.066	0.001	0.027	0.588	17.072	1.843	0.359
E2009.082	0.012	0.049	0.012	0.092	1.383	0.718	7.592	0.294	0.044
E2009.083	0.034	0.165	0.028	0.125	0.652	1.086	18.049	0.717	0.199
E2009.088	0.049	0.296	0.045	0.027	0.335	0.769	14.620	0.889	0.275
E2009.089	0.151	0.961	0.130	0.001	0.827	1.053	34.018	2.485	0.851
E2009.094	0.026	0.140	0.023	0.006	0.184	0.555	12.097	0.375	0.123
E2009.095	0.110	0.674	0.096	0.029	1.193	0.671	16.336	2.031	0.513
E2009.101	0.011	0.077	0.013	0.001	0.478	0.445	7.179	0.302	0.091
E2009.102	0.031	0.185	0.023	0.001	0.535	0.617	10.701	0.646	0.207
E2009.108	0.006	0.033	0.004	0.001	0.184	0.476	4.402	0.131	0.033
E2009.109	0.002	0.022	0.004	0.001	0.246	0.071	4.756	0.057	0.022
E2009.114	0.002	0.014	0.002	0.001	0.094	0.173	3.077	0.060	0.016
E2009.115	0.017	0.118	0.016	0.001	0.499	0.688	10.333	0.267	0.139
E2009.123	0.004	0.024	0.004	0.001	0.103	0.283	2.299	0.048	0.019
E2009.124	0.002	0.014	0.002	0.001	0.088	0.017	3.502	0.050	0.015
E2009.128	0.006	0.037	0.005	0.001	0.025	0.370	3.806	0.078	0.031
E2009.129	0.025	0.157	0.022	0.001	0.342	0.662	7.072	0.380	0.159
E2009.134	0.009	0.026	0.007	0.059	0.403	0.285	3.476	0.231	0.024
E2009.135	0.036	0.229	0.031	0.066	0.863	0.657	9.899	0.845	0.244
E2009.145	0.054	0.354	0.049	0.031	0.170	0.380	9.018	1.211	0.269
E2009.146	0.037	0.236	0.033	0.001	0.065	0.151	4.592	1.025	0.216
E2009.150	0.007	0.045	0.006	0.017	0.192	0.192	5.323	0.164	0.034
E2009.151	0.081	0.518	0.068	0.001	0.388	0.562	10.938	2.160	0.494
E2009.155	0.011	0.068	0.010	0.001	0.124	1.190	7.565	0.211	0.056
E2009.157	0.016	0.093	0.013	0.001	0.023	0.370	4.489	0.337	0.082
E2009.163	0.008	0.056	0.009	0.001	0.121	0.474	6.687	0.188	0.054

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**^{87}Sr/^{86}Sr**	**Li**	**Na**	**Mg**	**Al**	**P**	**Ca**	**Ti**	**V**	**Cr**	**Fe**
E2009.164	0.709836	185.084	16960.5	54734.2	2241.292	47150.9	179359.7	80.352	7.027	6.669	4580.9
E2009.169	0.710089	26.427	5020.3	85879.8	320.991	56470.2	250131.0	20.380	1.439	1.115	3706.6
E2009.170	0.709924	28.734	5133.4	74796.0	447.835	52394.2	284831.4	27.946	1.771	1.254	3443.9
E2009.172	0.709744	29.247	4641.9	77034.9	531.472	29726.4	265887.4	31.744	1.647	21.832	3536.9
E2009.173	0.709818	35.175	4403.8	71746.7	1069.152	32942.8	251994.1	65.350	2.470	13.978	4000.8
E2009.176	0.709648	33.118	6176.7	74256.6	1863.507	39354.1	188051.3	136.019	3.887	5.033	3910.8
E2009.177	0.709514	55.441	7679.4	74649.8	2963.794	30478.5	262909.5	171.117	5.815	6.815	6473.5
E2009.185	0.710747	23.265	4330.8	80503.9	1793.111	39033.4	181485.6	98.898	3.799	5.368	3832.6
E2009.186	0.712200	254.554	26769.3	56463.5	13938.094	73536.5	168253.3	523.108	19.251	36.529	11545.1
E2009.191	0.714414	53.585	8219.4	76790.7	1413.850	41900.7	214183.3	116.638	3.460	6.572	4524.3
E2009.192	0.713661	155.031	17042.2	71355.6	10915.198	56850.2	215483.3	411.722	13.432	19.865	8808.4
E2009.197	0.711874	24.547	4725.3	49960.2	775.029	37713.0	157332.1	70.180	3.154	6.124	6014.0
E2009.198	0.716004	392.620	35240.1	44613.9	19448.077	72339.0	74446.3	404.905	21.232	31.730	20407.7
E2009.203	0.711531	31.725	6323.4	86329.2	1898.186	27321.4	212012.8	140.921	5.410	7.332	6217.2
E2009.204	0.710690	36.319	5113.3	91059.6	1114.249	43982.4	251212.0	81.332	3.342	4.585	4950.3
E2009.211	0.711031	27.720	5385.2	71110.8	1420.464	43097.3	176757.2	113.517	3.508	5.428	3944.9
E2009.212	0.710951	131.358	11022.8	59289.4	12154.697	60833.9	198179.7	68.996	3.051	6.954	3853.7
E2009.219	0.709721	49.253	7483.4	64743.2	1122.866	55693.2	190846.6	73.699	2.731	3.794	4166.2
E2009.220	0.709569	225.584	23925.4	57685.7	10335.835	78483.6	183568.2	115.475	4.958	7.557	4327.8
E2009.225	0.709737	17.729	3412.1	61934.4	2224.713	50774.2	124775.3	85.376	6.031	5.944	5489.6
E2009.226	0.709855	127.170	16049.2	62179.5	8090.773	76226.3	114487.6	193.109	6.005	8.247	4498.0
E2009.232	0.710365	19.442	4700.6	71895.3	718.950	33018.6	283122.1	64.744	2.004	2.931	4501.6
E2009.233	0.709700	65.081	7365.9	48152.1	13073.742	51337.4	218482.7	245.333	10.555	15.853	7465.9
E2009.239	0.710190	14.530	2247.6	26675.2	429.990	24171.5	124712.7	30.738	1.287	2.723	2120.9
E2009.240	0.711257	207.814	22730.4	53716.6	12514.657	67966.8	110044.5	154.256	4.465	13.162	3979.2
E2009.245	0.710757	27.132	6343.5	60109.2	748.971	55174.1	186340.8	57.523	2.421	2.685	3373.5
E2009.246	0.710669	65.082	12232.2	53476.3	3336.987	85941.3	168513.0	238.216	8.449	12.783	5946.7
E2009.251	0.708958	72.875	11754.6	29960.9	4415.541	47014.1	159833.6	426.908	12.062	14.663	9128.6
E2009.252	0.708475	171.450	20344.3	42015.5	11484.081	51270.3	72563.3	1004.37	25.481	33.561	15333.9
E2009.257	0.709891	29.913	5638.1	73035.1	1126.266	17177.1	252339.0	92.463	3.953	5.163	4364.6
E2009.258	0.709719	168.536	23848.4	40900.6	3113.674	40635.5	85960.8	216.289	9.360	18.642	4897.0
E2009.262	0.713761	249.207	21682.8	81374.5	5984.986	50275.7	115489.3	185.150	17.039	40.525	10455.9
E2009.263	0.713422	166.425	22917.9	61253.9	5452.080	54669.8	138294.0	221.671	15.663	35.585	9426.2
E2009.266	0.717476	202.227	16545.2	40648.9	12682.338	44246.4	67168.9	296.174	35.775	61.817	22160.1
E2009.267	0.718116	170.725	12451.6	44802.8	9045.970	38612.1	83099.7	249.019	27.382	47.710	17696.2
E2009.270	0.709765	122.989	12225.0	46265.6	10737.397	69247.6	79588.4	342.930	23.257	40.571	17381.0
E2009.271	0.709778	84.020	10721.9	30184.1	14331.971	47374.0	51662.7	578.925	35.205	59.970	21094.2
E2009.274	0.706728	25.400	4950.8	35479.1	1128.635	12945.3	265841.0	127.932	4.429	4.815	4011.4
E2009.275	0.706904	200.720	8556.1	24618.1	881.595	12263.3	258122.4	113.179	3.796	6.570	3842.6
E2009.277	0.709739	20.165	4555.2	62750.7	1102.032	38659.6	190003.9	106.247	4.931	8.117	3910.5
E2009.278	0.710665	26.747	4653.1	69305.5	1416.106	31656.0	242154.2	133.990	5.725	9.258	4620.0

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**Mn**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**As**	**Se**	**Rb**	**Sr**	**Y**
E2009.164	392.873	1.389	7.303	192.773	358.888	0.971	1.791	3.885	37.858	1034.632	1.027
E2009.169	5718.033	1.487	20.574	97.663	368.373	0.578	0.794	2.264	58.863	1854.485	0.280
E2009.170	2882.486	1.290	22.503	90.688	592.778	0.525	1.119	3.337	46.286	1765.065	0.321
E2009.172	9580.138	5.946	38.716	104.206	1451.759	0.528	0.717	2.504	257.570	1475.142	0.330
E2009.173	14069.783	4.460	60.743	111.037	1136.686	0.803	0.584	1.614	255.418	1124.525	0.514
E2009.176	25763.757	15.815	82.353	93.635	1765.180	1.355	0.908	1.612	76.953	896.857	1.170
E2009.177	27305.412	9.765	45.221	115.084	3275.656	1.751	1.326	2.621	40.613	1347.538	1.502
E2009.185	10197.965	5.155	86.271	86.003	1782.770	1.206	0.782	1.765	116.670	1148.936	0.933
E2009.186	11158.309	6.202	98.609	201.129	1053.427	5.508	2.120	2.543	56.409	378.149	4.257
E2009.191	17024.547	6.596	29.963	128.582	3482.162	1.094	0.769	1.404	58.097	930.098	0.723
E2009.192	8073.706	12.567	38.845	166.754	1447.974	3.266	3.882	2.005	31.156	347.319	2.634
E2009.197	15500.144	7.765	63.101	103.412	929.627	0.845	0.548	1.048	75.507	1225.636	0.514
E2009.198	9241.271	9.613	106.615	226.912	1345.899	3.454	2.703	2.375	153.615	315.316	3.883
E2009.203	3857.841	4.170	30.708	126.821	831.980	0.985	0.923	2.068	113.451	1060.355	0.985
E2009.204	13338.599	18.293	121.798	187.898	2558.789	0.930	0.925	2.618	264.520	1572.386	0.767
E2009.211	11102.972	3.996	31.809	104.808	4912.401	1.033	0.696	1.616	171.837	1142.189	0.660
E2009.212	S	3.836	38.334	144.121	2903.543	1.777	0.841	2.526	157.643	502.543	0.600
E2009.219	27371.777	4.242	52.424	120.499	947.986	1.261	0.678	1.570	169.881	1217.451	0.556
E2009.220	13971.956	4.623	57.788	238.091	1540.483	1.513	1.028	2.677	87.516	595.588	0.930
E2009.225	11845.912	11.682	71.733	107.807	2133.333	1.370	0.438	0.892	150.749	796.431	0.868
E2009.226	35284.223	4.255	69.240	133.241	1563.217	2.085	0.699	1.740	202.520	207.109	0.900
E2009.232	5035.259	8.664	39.126	113.865	1531.063	0.608	0.474	1.752	52.288	1102.356	0.501
E2009.233	29722.613	9.570	39.487	108.484	1133.228	2.642	1.888	3.315	33.709	339.350	2.112
E2009.239	8896.967	8.133	45.925	66.445	363.931	0.458	0.423	1.268	96.998	389.157	0.271
E2009.240	16992.019	3.605	95.032	172.177	1044.020	1.604	0.666	1.417	126.198	98.612	1.008
E2009.245	1351.456	1.766	14.151	105.984	2181.850	0.748	0.612	1.764	56.249	763.544	0.355
E2009.246	748.165	4.470	21.786	145.312	1603.126	1.986	0.873	1.222	70.747	755.617	1.298
E2009.251	12702.143	5.809	21.331	88.122	1255.164	2.150	0.971	2.192	112.629	941.577	2.045
E2009.252	1746.638	7.361	30.301	181.150	1036.221	3.726	1.466	2.992	72.517	194.946	4.343
E2009.257	1156.459	2.919	75.955	98.994	2862.692	0.553	1.180	3.693	102.212	976.188	0.511
E2009.258	2392.163	1.817	16.770	193.313	428.007	1.307	1.701	4.419	138.702	924.948	1.253
E2009.262	12641.322	8.722	77.819	153.883	391.820	1.697	1.591	2.320	78.080	659.283	1.230
E2009.263	7919.103	7.392	116.834	174.289	412.400	1.602	1.259	1.763	72.854	974.617	1.511
E2009.266	12881.723	13.918	63.014	106.433	321.177	3.262	3.789	1.590	44.090	979.257	4.278
E2009.267	8190.526	10.087	40.404	70.196	467.080	2.547	3.056	1.290	37.621	474.045	2.967
E2009.270	6984.935	10.421	53.852	97.685	429.982	3.185	1.208	1.716	208.342	339.684	2.070
E2009.271	2703.951	12.945	62.436	102.394	331.568	5.556	2.138	2.773	97.122	408.601	3.530
E2009.274	758.819	1.368	5.671	100.993	1223.035	0.654	1.102	3.060	82.688	1085.709	1.202
E2009.275	885.509	1.471	7.363	136.163	857.949	0.590	0.857	2.188	103.362	975.087	1.115
E2009.277	2816.689	7.130	50.047	183.305	2136.902	0.910	1.278	3.859	118.104	488.911	0.968
E2009.278	6217.957	8.127	50.395	107.488	527.967	1.088	1.476	4.084	50.773	717.098	1.137

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
E2009.164	0.041	0.016	0.530	0.394	0.047	0.291	0.053	0.678	0.077	0.653	1076.671
E2009.169	0.063	0.142	1.137	0.797	0.092	0.217	0.298	0.172	0.055	0.286	978.684
E2009.170	0.053	0.094	1.335	0.656	0.065	0.289	0.199	0.153	0.038	0.213	474.418
E2009.172	0.030	0.084	2.119	0.781	0.055	0.148	0.361	0.127	0.051	0.850	242.667
E2009.173	0.020	0.123	2.164	0.717	0.055	0.149	0.803	0.126	0.067	0.491	586.190
E2009.176	0.113	0.179	2.322	0.562	0.055	0.084	1.188	0.247	0.106	0.467	710.892
E2009.177	0.923	0.434	1.511	0.665	0.129	0.277	1.031	0.320	0.177	0.438	239.943
E2009.185	0.362	0.261	1.252	0.521	0.063	0.102	1.167	0.347	0.196	0.503	322.364
E2009.186	0.215	0.484	2.295	0.385	0.118	0.944	0.584	1.878	1.051	0.919	253.452
E2009.191	0.137	0.154	1.265	0.568	0.099	0.247	1.303	0.406	0.173	0.328	980.873
E2009.192	0.215	0.370	1.937	0.617	0.101	0.605	0.452	1.305	12.305	0.412	286.464
E2009.197	0.177	0.127	2.234	0.389	0.057	0.113	0.577	0.475	0.573	0.473	244.400
E2009.198	0.433	0.413	2.625	0.193	0.101	0.702	0.331	1.837	1.661	1.054	293.370
E2009.203	0.103	0.131	1.646	0.558	0.048	0.181	0.385	0.398	0.198	0.504	342.271
E2009.204	0.150	0.156	5.112	0.733	0.079	0.183	0.952	0.348	0.213	0.474	1152.232
E2009.211	0.137	0.174	1.596	0.444	0.098	0.342	1.945	0.405	0.133	0.597	815.462
E2009.212	0.164	0.160	2.055	0.395	0.083	0.329	2.098	0.353	0.139	0.507	300.123
E2009.219	0.198	0.162	1.983	0.589	0.077	0.267	1.256	0.306	0.124	0.418	361.191
E2009.220	0.451	0.230	1.996	0.451	0.101	0.579	0.690	0.602	0.203	0.397	202.798
E2009.225	0.238	0.130	1.961	0.343	0.053	0.093	1.011	0.179	0.041	0.720	355.954
E2009.226	0.468	0.483	2.068	0.184	0.080	0.464	0.439	0.453	0.148	0.598	126.393
E2009.232	0.082	0.175	6.209	0.889	0.093	0.132	0.479	0.239	0.079	0.334	773.541
E2009.233	0.169	0.335	1.708	0.362	0.101	0.831	1.868	0.805	0.476	0.947	277.710
E2009.239	0.131	0.068	1.029	0.310	0.041	0.102	0.648	0.162	0.040	0.317	789.640
E2009.240	0.402	0.321	1.601	0.247	0.135	0.620	0.486	0.607	0.155	0.590	80.003
E2009.245	0.227	0.129	10.048	0.541	0.082	0.107	0.155	0.187	0.057	0.366	907.348
E2009.246	0.397	0.325	37.206	0.448	0.063	0.273	0.668	0.330	0.106	0.491	598.052
E2009.251	0.355	0.431	2.437	0.436	0.069	0.275	0.229	0.406	0.128	0.869	790.064
E2009.252	0.507	0.745	20.819	0.185	0.106	0.604	0.389	0.718	0.247	0.821	122.893
E2009.257	0.257	0.182	21.505	0.624	0.095	0.129	0.207	0.232	0.082	0.495	471.101
E2009.258	1.835	0.103	2.735	0.322	0.119	0.831	0.630	0.375	0.143	0.921	573.985
E2009.262	0.261	0.220	1.019	0.318	0.115	0.763	0.571	0.355	0.322	1.181	487.545
E2009.263	0.150	0.169	0.900	0.527	0.062	0.572	0.767	0.242	0.222	0.660	672.119
E2009.266	0.828	0.299	1.891	0.179	0.086	0.358	0.436	0.324	0.282	0.808	223.385
E2009.267	0.502	0.193	1.237	0.224	0.055	0.228	0.177	0.259	0.250	0.768	114.514
E2009.270	0.439	0.256	0.771	0.133	0.044	0.200	0.375	0.250	0.122	2.128	645.358
E2009.271	2.413	0.379	2.019	0.160	0.110	0.191	0.165	0.412	0.152	1.473	414.675
E2009.274	0.001	0.151	4.274	1.212	0.066	0.436	0.090	0.293	0.114	0.575	1112.025
E2009.275	0.001	0.155	5.048	1.187	0.049	1.160	0.121	0.337	0.112	0.640	1581.158
E2009.277	0.094	0.183	5.351	0.973	0.064	0.137	0.317	0.259	0.353	0.654	1210.957
E2009.278	0.001	0.195	2.094	1.074	0.051	0.120	1.375	0.265	0.375	0.462	1241.926

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
E2009.164	1.612	3.357	0.386	1.490	0.292	0.487	0.274	0.035	0.204	0.038	0.122
E2009.169	0.363	0.611	0.078	0.286	0.070	0.401	0.077	0.011	0.050	0.013	0.030
E2009.170	0.417	0.752	0.091	0.370	0.075	0.210	0.081	0.011	0.061	0.012	0.035
E2009.172	0.505	0.914	0.104	0.408	0.083	0.111	0.093	0.011	0.064	0.011	0.033
E2009.173	0.830	1.505	0.182	0.640	0.132	0.275	0.140	0.018	0.106	0.020	0.059
E2009.176	2.027	3.639	0.412	1.465	0.283	0.345	0.308	0.037	0.231	0.044	0.119
E2009.177	2.379	4.497	0.509	1.903	0.352	0.171	0.414	0.048	0.296	0.061	0.166
E2009.185	2.096	4.346	0.401	1.420	0.277	0.181	0.293	0.033	0.200	0.036	0.102
E2009.186	9.112	16.096	1.929	7.032	1.302	0.318	1.260	0.158	0.900	0.170	0.446
E2009.191	1.579	2.732	0.288	1.028	0.189	0.451	0.218	0.027	0.140	0.031	0.088
E2009.192	4.885	9.123	0.993	3.673	0.672	0.231	0.689	0.096	0.521	0.113	0.306
E2009.197	1.199	1.928	0.232	0.795	0.145	0.130	0.154	0.024	0.108	0.025	0.057
E2009.198	5.572	10.263	1.234	4.544	0.927	0.290	0.961	0.121	0.749	0.167	0.429
E2009.203	1.858	3.317	0.383	1.397	0.266	0.194	0.288	0.038	0.218	0.048	0.121
E2009.204	1.363	2.347	0.260	0.971	0.182	0.543	0.203	0.030	0.149	0.031	0.085
E2009.211	1.225	2.240	0.252	0.921	0.172	0.371	0.191	0.025	0.136	0.030	0.076
E2009.212	0.921	1.635	0.187	0.669	0.138	0.150	0.148	0.024	0.110	0.028	0.067
E2009.219	1.006	1.862	0.199	0.738	0.149	0.188	0.164	0.023	0.118	0.025	0.063
E2009.220	1.477	2.718	0.309	1.119	0.237	0.133	0.240	0.039	0.198	0.047	0.092
E2009.225	2.003	3.880	0.438	1.671	0.321	0.207	0.324	0.040	0.210	0.041	0.103
E2009.226	1.669	3.086	0.344	1.284	0.237	0.106	0.272	0.043	0.192	0.047	0.121
E2009.232	1.482	2.430	0.262	0.914	0.166	0.375	0.171	0.025	0.105	0.027	0.056
E2009.233	4.831	8.088	0.944	3.446	0.611	0.228	0.684	0.091	0.462	0.104	0.261
E2009.239	0.540	0.812	0.096	0.354	0.072	0.354	0.078	0.012	0.055	0.013	0.029
E2009.240	1.682	2.825	0.345	1.269	0.240	0.084	0.256	0.041	0.202	0.051	0.122
E2009.245	0.732	1.340	0.147	0.548	0.109	0.409	0.113	0.017	0.076	0.016	0.046
E2009.246	3.303	6.058	0.694	2.508	0.443	0.345	0.465	0.055	0.308	0.058	0.154
E2009.251	4.530	8.606	1.011	3.801	0.709	0.488	0.782	0.091	0.514	0.096	0.242
E2009.252	8.581	15.975	1.846	7.072	1.372	0.348	1.638	0.201	1.073	0.202	0.544
E2009.257	0.799	1.453	0.170	0.600	0.124	0.233	0.131	0.022	0.106	0.026	0.063
E2009.258	1.885	3.311	0.394	1.453	0.285	0.313	0.375	0.060	0.297	0.067	0.152
E2009.262	2.379	4.455	0.516	1.885	0.361	0.256	0.407	0.053	0.286	0.059	0.159
E2009.263	2.715	5.255	0.594	2.243	0.429	0.347	0.489	0.057	0.343	0.067	0.188
E2009.266	5.933	11.495	1.366	5.175	1.043	0.286	1.207	0.158	0.940	0.186	0.520
E2009.267	4.156	8.174	0.964	3.697	0.734	0.190	0.812	0.105	0.610	0.120	0.335
E2009.270	8.417	15.007	1.798	6.589	1.175	0.461	1.025	0.102	0.501	0.089	0.250
E2009.271	14.191	27.409	2.940	10.639	1.914	0.521	1.890	0.181	0.936	0.160	0.442
E2009.274	1.626	2.886	0.349	1.333	0.271	0.448	0.315	0.040	0.244	0.050	0.135
E2009.275	1.603	2.745	0.343	1.289	0.276	0.651	0.290	0.036	0.213	0.044	0.121
E2009.277	1.569	2.863	0.331	1.228	0.265	0.479	0.265	0.033	0.194	0.037	0.108
E2009.278	2.220	4.044	0.480	1.727	0.350	0.528	0.358	0.041	0.244	0.049	0.122

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**Tm**	**Yb**	**Lu**	**Ta**	**Au**	**Tl**	**Pb**	**Th**	**U**
E2009.164	0.014	0.088	0.015	0.001	0.195	0.112	7.870	0.355	0.104
E2009.169	0.007	0.028	0.008	0.053	0.514	0.357	3.263	0.272	0.029
E2009.170	0.005	0.036	0.006	0.026	0.209	0.244	2.778	0.154	0.028
E2009.172	0.005	0.030	0.005	0.021	0.112	0.301	3.122	0.145	0.033
E2009.173	0.008	0.056	0.007	0.001	0.187	0.410	2.141	0.218	0.063
E2009.176	0.018	0.112	0.017	0.001	0.113	0.364	5.221	0.419	0.126
E2009.177	0.025	0.162	0.021	0.034	0.140	0.424	6.610	0.638	0.166
E2009.185	0.014	0.084	0.013	0.023	0.084	0.242	4.596	0.425	0.120
E2009.186	0.070	0.395	0.060	0.001	0.258	0.588	18.486	2.335	0.760
E2009.191	0.014	0.071	0.013	0.001	0.239	0.668	8.360	0.487	0.110
E2009.192	0.052	0.282	0.054	0.007	0.257	0.917	18.344	1.556	0.379
E2009.197	0.011	0.051	0.010	0.004	0.108	0.342	3.494	0.322	0.061
E2009.198	0.068	0.396	0.066	0.001	0.215	0.435	13.486	1.848	0.461
E2009.203	0.020	0.122	0.020	0.001	0.118	0.551	10.791	0.570	0.131
E2009.204	0.017	0.079	0.016	0.024	0.118	0.506	7.871	0.450	0.083
E2009.211	0.014	0.058	0.013	0.001	0.085	0.471	5.568	0.432	0.083
E2009.212	0.017	0.067	0.015	0.001	0.152	0.348	5.166	0.459	0.062
E2009.219	0.012	0.052	0.009	0.007	0.182	0.528	6.672	0.383	0.072
E2009.220	0.026	0.095	0.025	0.001	0.228	0.887	11.703	0.749	0.118
E2009.225	0.014	0.087	0.015	0.002	0.054	0.253	2.679	0.657	0.114
E2009.226	0.022	0.093	0.022	0.014	0.141	0.578	5.043	0.745	0.107
E2009.232	0.015	0.046	0.013	0.016	0.255	0.552	4.732	0.433	0.062
E2009.233	0.048	0.210	0.042	0.001	0.391	0.367	15.232	1.401	0.270
E2009.239	0.007	0.033	0.008	0.001	0.112	0.285	2.682	0.284	0.026
E2009.240	0.026	0.120	0.028	0.019	0.185	0.661	4.448	0.856	0.109
E2009.245	0.009	0.039	0.009	0.021	0.133	0.490	5.320	0.451	0.058
E2009.246	0.027	0.138	0.025	0.001	0.101	0.504	10.696	1.330	0.219
E2009.251	0.035	0.184	0.030	0.001	0.133	0.550	6.225	1.197	0.176
E2009.252	0.076	0.448	0.063	0.001	0.199	0.509	8.825	2.001	0.340
E2009.257	0.015	0.058	0.013	0.009	0.143	0.625	7.226	0.356	0.071
E2009.258	0.036	0.153	0.035	0.001	0.217	0.483	12.846	0.862	0.183
E2009.262	0.024	0.141	0.001	0.001	0.516	0.382	12.325	0.820	0.163
E2009.263	0.026	0.172	0.001	0.001	0.233	0.329	13.926	0.596	0.150
E2009.266	0.074	0.480	0.075	0.001	0.112	0.099	8.449	2.288	0.666
E2009.267	0.050	0.314	0.050	0.001	0.087	0.077	7.575	1.439	0.408
E2009.270	0.034	0.228	0.001	0.001	0.094	0.125	6.648	2.049	0.265
E2009.271	0.060	0.382	0.056	0.001	0.129	0.162	8.573	3.425	0.420
E2009.274	0.019	0.113	0.001	0.001	0.064	0.467	10.265	0.386	0.104
E2009.275	0.016	0.106	0.001	0.001	0.044	1.032	12.979	0.335	0.101
E2009.277	0.016	0.089	0.001	0.001	0.083	0.782	7.136	0.357	0.079
E2009.278	0.017	0.103	0.001	0.001	0.073	0.452	10.282	0.434	0.109

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**^{87}Sr/^{86}Sr**	**Li**	**Na**	**Mg**	**Al**	**P**	**Ca**	**Ti**	**V**	**Cr**	**Fe**
E2009.281	0.709765	133.988	10525.2	60929.6	6200.337	29262.3	145297.4	218.788	15.359	20.654	11302.9
E2009.282	0.710119	167.415	15038.3	65158.9	5654.371	35525.6	125878.7	244.061	14.494	16.595	10514.5
E2009.286	0.708671	15.898	2940.7	74173.6	1259.756	26483.4	245927.4	107.085	3.927	5.725	3838.9
E2009.287	0.708716	66.398	9700.8	52120.0	6961.077	29062.8	139335.3	392.461	18.647	27.548	13028.8
E2009.293	0.710034	296.588	8211.8	52563.2	546.085	24728.1	220835.1	42.151	1.959	2.523	2745.7
E2009.294	0.710003	181.263	20066.2	74714.6	2389.943	64340.4	152473.0	96.311	4.739	9.560	3366.9
E2009.300	0.709494	36.819	4943.0	83472.1	1035.469	31396.3	260262.0	73.455	3.142	8.525	3549.4
E2009.301	0.709476	121.336	11934.3	31585.0	892.962	39831.6	57404.6	47.726	3.430	25.368	2140.5
E2009.307	0.709600	50.808	8798.1	67663.8	6063.035	49100.8	245473.3	527.858	15.276	20.142	10990.7
E2009.308	0.709358	317.045	26687.0	63378.0	9821.442	71507.4	166940.1	607.704	16.214	26.089	9341.3
E2009.314	0.708391	24.738	4643.2	74884.7	1199.578	27466.0	259486.6	107.819	3.701	4.344	3342.8
E2009.315	0.708264	110.035	9354.3	60407.4	4780.857	20034.7	344671.1	378.529	11.560	23.532	7714.7
E2009.321	0.709353	39.274	8000.3	58979.9	8011.087	22753.3	203438.0	388.939	19.520	21.819	11584.5
E2009.322	0.709570	217.493	17872.9	60267.1	13612.992	47449.2	219522.4	944.742	26.896	35.187	16135.8
E2009.326	0.709551	253.005	24777.1	60421.9	3259.051	73609.1	171769.9	228.930	7.374	13.226	4349.8
E2009.327	0.709587	263.934	33647.7	41547.6	2690.707	61062.9	151311.7	198.030	6.491	13.641	3896.2
E2009.330	0.709368	114.366	13373.5	31954.9	6089.217	63916.9	110971.8	336.074	11.520	14.178	6049.0
E2009.331	0.709424	250.167	21239.2	56187.6	4586.006	62904.4	163155.1	263.284	10.293	12.803	5825.3
E2009.335	0.709167	12.581	2643.1	39718.6	336.158	25086.7	300737.7	30.959	1.648	2.198	2881.8
E2009.336	0.707136	143.613	12102.0	51081.5	3779.867	55412.3	218901.6	185.175	8.493	11.120	5014.7
E2009.342	0.708471	211.082	11560.2	82913.9	1495.189	51641.8	247532.1	152.603	3.650	4.519	3677.6
E2009.343	0.708951	373.280	31138.9	67996.1	8968.130	84308.1	159858.3	593.158	16.650	25.679	9638.1
E2009.346	0.712028	34.051	6494.6	76655.7	721.456	35138.5	268757.1	46.178	2.595	6.046	2996.9
E2009.347	0.712059	24.335	3817.2	64486.4	554.000	43114.4	233564.1	43.985	2.375	4.813	2976.2
E2009.352	0.711535	19.871	3626.2	55864.9	2087.177	24245.6	238130.9	180.343	5.038	6.240	3984.5
E2009.353	0.714250	134.289	13459.6	35023.9	1507.106	60448.0	115986.1	81.833	3.718	5.795	2689.9
E2009.360	0.708765	19.174	3986.2	63898.6	706.802	36106.7	292870.0	59.488	2.406	3.102	3211.6
E2009.361	0.708986	125.573	12810.5	66164.0	8669.027	68854.4	209061.3	585.248	18.457	30.042	10128.9
E2009.364	0.707739	29.367	4753.2	90020.5	1136.074	55116.4	220833.5	76.394	3.873	8.776	5925.9
E2009.365	0.707639	48.420	4864.5	121482.8	995.758	32659.8	317164.1	67.055	3.857	9.913	5642.6
E2009.367	0.711125	42.517	5797.8	77533.0	1355.123	46087.5	242573.2	91.567	3.482	6.888	4236.2
E2009.368	0.710069	27.573	4890.5	68333.2	896.427	58921.8	196168.8	58.868	2.092	5.615	3679.8
E2009.373	0.708605	31.092	4495.4	89134.2	1455.383	33834.8	248416.4	124.741	5.150	12.243	6145.4
E2009.374	0.711905	166.063	17729.4	49675.3	18782.117	64723.3	108797.9	258.064	14.848	22.045	10939.6
E2009.379	0.714123	59.977	9626.2	44805.0	10723.777	55681.8	268582.1	410.705	12.674	17.385	7800.1
E2009.380	0.714298	233.963	16605.6	41864.5	12046.666	61696.2	129418.7	126.828	4.252	12.191	3610.1
E2009.385	0.710596	163.358	8369.6	64109.4	261.904	41955.5	237389.1	21.045	0.946	2.291	5222.0
E2009.386	0.710573	96.250	9741.3	41661.3	1282.210	48774.6	129561.3	39.926	2.558	13.852	3672.4
E2009.391	0.712669	22.962	3393.0	91371.9	459.322	38247.3	260801.8	34.498	2.071	5.852	3174.2
E2009.392	0.709140	167.866	19078.0	49141.1	2000.530	52857.4	98250.2	86.612	5.332	6.816	3433.5
E2009.399	0.712124	11.915	2204.7	48705.8	551.123	29811.3	224807.6	48.899	2.032	2.634	4755.8

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
E2009.281	3255.134	5.629	28.623	119.210	321.547	2.087	2.207	3.199	39.323	466.483	3.784
E2009.282	2801.451	4.593	23.298	155.235	322.111	1.946	1.907	2.795	52.973	407.379	3.526
E2009.286	2431.815	1.884	9.812	87.377	809.842	0.640	0.916	2.699	53.701	465.899	0.761
E2009.287	6976.376	6.265	24.906	72.199	243.937	2.715	1.482	3.169	96.411	358.709	4.096
E2009.293	5008.384	1.724	8.725	124.536	3098.270	0.424	0.703	2.162	234.068	485.478	0.261
E2009.294	7013.660	0.970	6.249	176.289	970.748	1.186	1.103	2.222	220.271	94.958	0.612
E2009.300	5284.454	3.399	32.572	113.166	1347.360	0.611	1.104	3.223	54.226	851.344	0.443
E2009.301	3161.141	1.987	29.329	60.799	195.784	0.562	0.813	2.572	120.513	519.549	0.323
E2009.307	9335.226	9.420	82.950	154.209	2127.963	2.364	1.088	1.923	63.938	1143.416	3.011
E2009.308	6881.836	7.198	47.582	215.211	2026.358	2.490	1.398	2.687	62.720	416.962	2.765
E2009.314	829.534	2.054	25.316	94.650	2222.084	0.593	1.278	3.130	72.259	590.990	0.629
E2009.315	2239.148	3.114	28.268	91.414	3425.547	1.845	1.978	2.658	43.744	1033.769	2.354
E2009.321	1266.757	5.434	39.635	99.178	900.045	2.678	1.865	5.218	54.704	878.787	4.018
E2009.322	10978.509	6.602	27.542	145.938	464.345	4.159	1.768	4.868	58.415	296.467	5.151
E2009.326	798.445	1.991	13.696	196.627	2421.737	1.769	2.342	1.983	109.582	437.658	1.853
E2009.327	381.946	1.712	8.871	187.237	1063.633	1.387	4.554	2.364	87.672	279.181	1.669
E2009.330	8931.881	7.322	36.595	145.063	707.063	2.547	1.994	1.950	80.193	1102.121	3.491
E2009.331	9263.357	3.540	17.609	177.853	587.860	2.174	2.026	2.614	54.402	1460.562	2.693
E2009.335	1828.703	1.307	41.100	81.840	422.470	0.353	1.012	3.358	45.371	1139.233	0.245
E2009.336	7046.962	3.084	18.254	154.661	2417.157	1.585	1.744	4.023	66.718	801.034	1.082
E2009.342	1505.246	5.136	7.047	95.322	2671.367	0.744	0.830	0.819	83.891	854.822	0.728
E2009.343	5676.054	3.805	14.517	195.812	1489.465	2.852	2.127	3.170	127.528	217.960	2.707
E2009.346	3277.118	2.668	15.403	136.374	1274.632	0.466	1.027	3.378	50.779	914.068	0.437
E2009.347	1907.404	2.572	16.362	107.278	1617.426	0.465	0.926	2.839	51.420	562.719	0.308
E2009.352	5704.118	2.666	139.021	93.103	1138.530	0.913	1.098	2.652	99.913	834.979	1.329
E2009.353	21620.612	2.726	15.619	120.327	401.882	1.024	0.833	2.145	86.890	1573.452	0.557
E2009.360	1653.299	1.245	13.634	103.366	374.721	0.486	0.815	2.486	56.599	785.872	0.315
E2009.361	1660.936	4.283	14.945	128.408	1303.008	3.546	2.874	3.172	68.615	323.293	3.184
E2009.364	9515.760	10.161	82.833	149.248	1099.043	0.921	0.875	1.546	95.302	1025.818	0.767
E2009.365	8624.134	10.212	53.144	140.803	2527.689	0.783	1.239	3.019	83.979	1560.357	0.738
E2009.367	9491.173	8.197	50.055	126.516	3576.825	0.878	0.830	1.223	164.237	887.402	0.764
E2009.368	14481.710	8.116	58.353	133.895	3380.786	0.855	0.602	0.878	195.049	834.494	0.571
E2009.373	7291.915	17.409	68.323	107.654	2408.973	0.995	0.892	0.901	88.538	547.310	1.184
E2009.374	11943.628	16.893	318.456	201.435	952.642	2.384	2.215	0.508	595.073	55.239	2.172
E2009.379	60308.752	8.385	52.900	190.240	3145.491	3.855	2.251	2.924	250.799	983.304	3.560
E2009.380	73334.346	3.423	28.554	123.820	2030.486	2.122	0.999	1.881	148.821	134.201	0.835
E2009.385	12050.335	2.497	26.951	137.533	2244.672	0.583	0.436	1.189	99.265	492.999	0.227
E2009.386	23723.488	4.635	16.691	89.719	364.012	0.985	0.860	2.193	88.619	491.414	0.401
E2009.391	7106.679	6.373	7.641	88.030	3518.711	0.549	1.075	2.696	39.831	1023.526	0.298
E2009.392	29400.321	6.134	9.108	327.589	472.646	1.507	1.563	3.361	105.502	1081.448	1.060
E2009.399	11591.271	4.374	26.930	76.216	1630.263	0.632	0.487	0.899	117.532	1298.925	0.742

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
E2009.281	0.155	0.138	1.644	0.426	0.097	0.289	0.566	0.304	0.171	1.609	425.036
E2009.282	0.109	0.121	1.828	0.431	0.060	0.247	0.230	0.290	0.120	1.509	469.631
E2009.286	0.001	0.182	3.547	0.769	0.045	0.062	0.266	0.128	0.101	0.412	386.402
E2009.287	0.092	0.270	1.391	0.422	0.059	0.260	0.415	0.325	0.111	2.576	1019.976
E2009.293	0.001	0.087	5.043	0.663	0.059	0.599	0.469	0.179	0.096	0.959	588.311
E2009.294	0.001	0.212	3.274	0.646	0.039	0.316	0.295	0.338	0.261	0.700	58.509
E2009.300	0.001	0.129	4.739	1.086	0.049	0.077	1.124	0.148	0.133	0.400	1686.822
E2009.301	0.661	0.115	2.177	0.097	0.029	0.073	0.459	0.103	0.055	1.541	781.421
E2009.307	0.168	0.725	2.364	0.836	0.074	0.182	1.435	0.354	0.190	0.474	861.907
E2009.308	0.001	1.005	8.009	0.434	0.066	0.320	0.598	0.439	0.302	0.624	168.088
E2009.314	0.001	0.269	10.204	0.999	0.092	0.181	0.202	0.208	0.153	0.497	840.165
E2009.315	0.142	0.518	13.892	1.396	0.121	0.354	0.495	0.525	0.303	0.622	411.397
E2009.321	0.158	0.065	7.007	0.680	0.082	0.096	0.301	0.250	0.139	0.603	381.888
E2009.322	0.238	1.586	3.306	0.590	0.071	0.273	0.676	0.625	0.240	0.893	193.096
E2009.326	0.001	0.384	17.294	0.374	0.060	0.533	0.361	0.788	0.382	0.417	195.753
E2009.327	0.001	0.216	15.272	0.334	0.043	0.373	0.147	0.560	0.243	0.652	149.671
E2009.330	0.291	0.293	2.441	0.231	0.054	0.395	0.360	0.777	0.376	0.511	256.538
E2009.331	0.001	0.175	2.025	0.469	0.049	0.497	0.458	0.706	0.196	0.773	458.438
E2009.335	0.001	0.074	4.098	0.997	0.041	0.046	0.298	0.084	0.136	0.359	1179.066
E2009.336	0.001	0.298	4.588	0.637	0.055	0.334	0.935	0.396	0.341	0.795	112.565
E2009.342	0.001	0.314	3.214	0.817	0.078	0.524	0.191	0.260	0.107	0.853	1012.043
E2009.343	0.102	0.810	3.270	0.401	0.077	0.649	0.424	1.017	0.507	0.620	109.308
E2009.346	0.001	0.121	1.776	0.845	0.054	0.107	0.479	0.166	0.109	0.348	1723.519
E2009.347	0.001	0.111	3.312	0.719	0.049	0.057	0.277	0.087	0.109	0.237	1104.251
E2009.352	0.001	0.243	2.399	0.743	0.049	0.124	0.734	0.270	0.183	0.383	1982.137
E2009.353	0.001	0.064	2.695	0.271	0.030	0.320	0.833	0.168	0.083	0.751	655.570
E2009.360	0.001	0.138	5.492	0.880	0.046	0.046	0.190	0.112	0.079	0.364	984.140
E2009.361	0.097	0.609	19.597	0.512	0.053	0.514	0.280	1.049	0.562	0.884	162.852
E2009.364	0.001	0.184	2.252	0.662	0.047	0.238	0.697	0.406	0.474	0.319	561.529
E2009.365	0.001	0.157	1.644	1.185	0.071	0.242	0.543	0.524	0.481	0.393	1014.936
E2009.367	0.001	0.316	0.935	0.719	0.125	0.543	1.644	0.801	0.508	0.477	392.853
E2009.368	0.001	0.200	1.264	0.570	0.073	0.234	3.019	0.273	0.270	0.414	279.776
E2009.373	0.105	0.255	1.597	0.758	0.079	0.225	1.201	0.590	0.728	0.303	284.229
E2009.374	0.541	0.590	2.244	0.244	0.062	0.511	0.723	1.355	1.530	1.191	164.728
E2009.379	0.260	0.464	2.244	0.492	0.107	0.273	1.424	1.324	1.272	0.895	1652.300
E2009.380	0.001	0.299	2.167	0.217	0.046	0.340	1.318	0.673	0.795	0.556	143.961
E2009.385	0.318	0.072	1.214	0.720	0.060	0.550	3.547	0.189	0.108	1.188	863.362
E2009.386	0.130	0.059	1.657	0.346	0.037	0.194	0.785	0.223	0.132	1.215	255.205
E2009.391	0.001	0.093	1.604	0.913	0.073	0.116	1.369	0.144	0.255	0.332	977.487
E2009.392	0.001	0.123	1.414	0.267	0.031	0.763	0.244	0.243	0.145	0.456	340.031
E2009.399	0.103	0.162	2.219	0.715	0.068	0.166	0.920	0.218	0.140	0.384	296.123

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
E2009.281	6.025	11.140	1.298	4.938	0.981	0.356	1.192	0.151	0.869	0.172	0.467
E2009.282	5.976	11.086	1.291	4.844	0.973	0.371	1.157	0.140	0.843	0.152	0.430
E2009.286	1.638	3.014	0.344	1.278	0.244	0.191	0.254	0.030	0.176	0.032	0.089
E2009.287	10.621	18.973	2.127	7.722	1.403	0.649	1.487	0.170	0.981	0.179	0.487
E2009.293	0.502	0.830	0.096	0.366	0.069	0.251	0.078	0.001	0.058	0.001	0.001
E2009.294	1.180	2.054	0.239	0.891	0.161	0.050	0.167	0.001	0.136	0.025	0.071
E2009.300	0.821	1.441	0.161	0.575	0.129	0.718	0.133	0.001	0.085	0.001	0.046
E2009.301	0.871	1.594	0.182	0.678	0.126	0.311	0.099	0.001	0.064	0.001	0.001
E2009.307	6.846	12.333	1.418	5.334	1.020	0.538	1.127	0.132	0.731	0.133	0.370
E2009.308	5.893	10.780	1.238	4.576	0.884	0.232	0.977	0.118	0.661	0.122	0.324
E2009.314	1.186	2.213	0.257	0.962	0.190	0.356	0.211	0.001	0.143	0.030	0.082
E2009.315	4.765	8.854	1.011	3.761	0.719	0.291	0.748	0.089	0.501	0.096	0.270
E2009.321	9.137	17.233	1.913	6.948	1.282	0.386	1.434	0.168	0.958	0.180	0.494
E2009.322	13.362	24.344	2.625	9.292	1.671	0.375	1.763	0.205	1.183	0.222	0.616
E2009.326	2.354	4.386	0.502	1.851	0.363	0.123	0.428	0.062	0.389	0.075	0.222
E2009.327	2.023	3.810	0.430	1.641	0.312	0.103	0.370	0.052	0.333	0.070	0.194
E2009.330	3.451	7.097	0.897	3.454	0.702	0.201	0.828	0.111	0.701	0.142	0.432
E2009.331	3.465	6.563	0.798	3.043	0.595	0.264	0.660	0.091	0.552	0.111	0.332
E2009.335	0.545	0.761	0.093	0.354	0.075	0.465	0.078	0.001	0.047	0.001	0.023
E2009.336	2.167	3.846	0.483	1.718	0.312	0.101	0.296	0.038	0.225	0.044	0.124
E2009.342	1.231	2.293	0.259	0.958	0.198	0.430	0.237	0.001	0.168	0.033	0.089
E2009.343	5.066	9.310	1.091	4.095	0.772	0.186	0.837	0.101	0.592	0.112	0.319
E2009.346	0.749	1.032	0.124	0.448	0.103	0.670	0.110	0.001	0.078	0.001	0.055
E2009.347	0.497	0.836	0.097	0.347	0.074	0.421	0.086	0.001	0.062	0.001	0.001
E2009.352	2.446	4.241	0.476	1.761	0.356	0.835	0.382	0.048	0.277	0.052	0.136
E2009.353	1.280	2.058	0.246	0.896	0.161	0.269	0.169	0.001	0.114	0.001	0.057
E2009.360	0.587	1.057	0.122	0.441	0.087	0.401	0.093	0.001	0.062	0.001	0.001
E2009.361	6.546	12.068	1.388	5.079	0.942	0.238	0.965	0.122	0.696	0.135	0.371
E2009.364	1.069	1.967	0.219	0.839	0.169	0.237	0.192	0.001	0.162	0.031	0.093
E2009.365	1.087	1.879	0.223	0.812	0.175	0.427	0.192	0.001	0.144	0.027	0.076
E2009.367	1.337	2.324	0.265	0.981	0.181	0.160	0.182	0.001	0.155	0.030	0.083
E2009.368	0.858	1.531	0.185	0.686	0.123	0.111	0.139	0.001	0.107	0.020	0.060
E2009.373	1.590	3.068	0.357	1.369	0.256	0.140	0.293	0.038	0.240	0.048	0.132
E2009.374	2.881	5.413	0.633	2.400	0.472	0.139	0.469	0.066	0.407	0.082	0.233
E2009.379	6.164	10.585	1.209	4.520	0.837	0.669	0.811	0.105	0.643	0.124	0.348
E2009.380	1.654	2.925	0.339	1.208	0.232	0.079	0.187	0.001	0.145	0.027	0.078
E2009.385	0.334	0.556	0.071	0.261	0.054	0.288	0.053	0.001	0.001	0.001	0.001
E2009.386	0.620	1.206	0.141	0.539	0.097	0.097	0.106	0.001	0.085	0.001	0.043
E2009.391	0.507	0.948	0.105	0.407	0.082	0.341	0.084	0.001	0.058	0.001	0.001
E2009.392	2.052	4.055	0.458	1.686	0.314	0.162	0.310	0.038	0.218	0.043	0.117
E2009.399	1.571	2.405	0.286	0.996	0.165	0.133	0.193	0.001	0.131	0.028	0.076

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
E2009.281	0.063	0.394	0.058	0.001	0.298	0.184	9.250	1.810	0.444
E2009.282	0.057	0.358	0.051	0.001	0.154	0.229	14.214	1.680	0.424
E2009.286	0.012	0.076	0.001	0.001	0.073	0.305	4.204	0.440	0.081
E2009.287	0.063	0.403	0.055	0.001	0.108	0.239	11.504	3.060	0.431
E2009.293	0.001	0.001	0.001	0.001	0.060	0.796	7.625	0.140	0.030
E2009.294	0.010	0.066	0.001	0.001	0.083	0.783	11.926	0.347	0.088
E2009.300	0.007	0.001	0.001	0.001	0.071	0.543	8.704	0.189	0.051
E2009.301	0.001	0.001	0.001	0.001	0.058	0.070	4.280	0.204	0.056
E2009.307	0.049	0.306	0.041	0.001	0.050	0.561	10.457	1.249	0.294
E2009.308	0.044	0.266	0.001	0.001	0.102	0.412	13.845	1.416	0.284
E2009.314	0.013	0.073	0.001	0.001	0.361	0.603	8.310	0.341	0.090
E2009.315	0.034	0.233	0.001	0.001	0.207	1.072	17.594	0.982	0.328
E2009.321	0.064	0.413	0.057	0.001	0.141	0.612	7.892	2.162	0.381
E2009.322	0.079	0.507	0.071	0.001	0.157	0.809	18.613	3.933	0.633
E2009.326	0.031	0.193	0.001	0.001	0.086	0.764	15.012	0.863	0.324
E2009.327	0.031	0.194	0.001	0.001	0.089	0.175	10.095	0.700	0.260
E2009.330	0.064	0.418	0.062	0.001	0.073	0.101	10.110	1.014	0.547
E2009.331	0.044	0.301	0.045	0.001	0.088	0.137	17.561	0.987	0.425
E2009.335	0.004	0.001	0.001	0.001	0.038	0.239	3.411	0.100	0.021
E2009.336	0.015	0.105	0.001	0.001	0.101	0.434	16.632	0.463	0.155
E2009.342	0.013	0.077	0.001	0.001	0.225	0.935	8.261	0.387	0.064
E2009.343	0.042	0.275	0.001	0.001	0.402	0.756	23.177	1.320	0.309
E2009.346	0.008	0.053	0.001	0.001	0.172	0.618	6.413	0.152	0.040
E2009.347	0.001	0.001	0.001	0.001	0.104	0.354	4.828	0.132	0.035
E2009.352	0.017	0.116	0.001	0.001	0.084	0.424	7.540	0.527	0.119
E2009.353	0.009	0.053	0.001	0.001	0.089	0.122	7.863	0.294	0.073
E2009.360	0.001	0.001	0.001	0.001	0.051	0.392	3.991	0.165	0.040
E2009.361	0.049	0.325	0.052	0.001	0.088	0.783	19.511	1.706	0.491
E2009.364	0.013	0.082	0.001	0.001	0.043	0.537	10.157	0.289	0.087
E2009.365	0.013	0.073	0.001	0.001	0.059	0.522	10.897	0.269	0.076
E2009.367	0.013	0.073	0.001	0.074	0.361	0.660	6.915	0.413	0.090
E2009.368	0.009	0.001	0.001	0.037	0.138	0.341	3.487	0.221	0.053
E2009.373	0.019	0.123	0.001	0.028	0.101	0.434	6.146	0.398	0.140
E2009.374	0.034	0.210	0.001	0.025	0.055	0.402	13.162	1.030	0.270
E2009.379	0.049	0.314	0.048	0.027	0.202	0.863	28.571	1.311	0.525
E2009.380	0.011	0.069	0.001	0.021	0.121	0.216	8.508	0.409	0.197
E2009.385	0.001	0.001	0.001	0.001	0.058	0.591	5.389	0.083	0.001
E2009.386	0.006	0.001	0.001	0.001	0.097	0.001	4.817	0.143	0.046
E2009.391	0.001	0.001	0.001	0.001	0.083	0.418	7.314	0.104	0.001
E2009.392	0.017	0.103	0.001	0.001	0.095	0.061	8.224	0.379	0.125
E2009.399	0.011	0.064	0.001	0.028	0.139	0.270	2.409	0.251	0.055

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	$^{87}Sr/^{86}Sr$	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
E2009.400	0.709535	92.117	10677.9	41707.8	4972.934	55299.8	167987.3	244.008	11.641	13.513	5542.9
E2009.406	0.716746	25.906	4453.6	46633.7	4520.792	44740.3	167257.2	316.081	9.279	10.676	7469.2
E2009.407	0.717134	71.844	8047.4	19502.9	12281.169	37062.1	58746.8	290.668	25.617	26.033	18188.7
E2009.412	0.707832	20.184	3821.5	65228.1	601.394	38065.5	230977.7	44.098	2.000	3.894	3160.2
E2009.413	0.709014	68.777	7061.2	43779.8	3960.814	31226.6	276740.6	220.332	9.774	14.856	6465.6
E2009.419	0.712528	287.057	29838.1	78869.4	7331.625	75468.3	157035.4	115.358	6.611	6.451	4224.4
E2009.420	0.716140	196.591	17870.6	53916.9	4560.860	58989.7	284148.6	166.485	9.803	9.168	6048.6
E2009.426	0.715368	520.161	31137.5	99749.6	9376.350	54599.2	100680.2	454.878	21.979	19.011	10823.9
E2009.427	0.716263	189.874	14095.9	66333.4	22279.947	49626.1	150058.8	829.402	41.041	39.763	16809.3
E2009.432	0.710569	172.877	8541.4	56915.8	29680.364	40175.4	104369.0	234.260	64.752	49.857	26716.0
E2009.433	0.712683	167.547	10127.3	57260.4	20456.951	48060.6	91051.5	672.786	40.927	32.514	19489.0
E2009.437	0.713666	1170.70	33709.0	54601.1	12900.600	53089.7	155593.8	399.187	13.157	15.856	6545.8
E2009.438	0.713234	32.703	2073.0	59552.2	13081.267	12125.4	315161.8	409.421	21.519	22.839	12155.3
E2009.440	0.713131	330.268	18088.0	56187.0	2419.506	67229.9	135783.6	69.382	5.061	5.817	3359.3
E2009.441	0.715448	218.215	15990.9	42061.8	2502.448	55233.2	205120.0	84.816	5.705	7.946	3724.3
E2009.444	0.715100	214.760	16705.9	62281.7	16140.501	47237.2	110497.2	481.106	31.346	42.475	13582.3
E2009.445	0.716693	117.454	12091.5	60426.3	10381.117	43564.9	127184.7	442.721	23.330	27.064	11101.3
E2009.447	0.712968	38.620	1989.7	39085.9	3574.348	42550.8	118495.7	199.985	11.599	11.285	5796.1
E2009.448	0.712076	320.105	20666.4	32939.0	3815.168	52718.6	106952.6	156.544	11.169	14.093	5218.1
E2009.451	0.712026	333.713	22678.6	67199.4	12978.982	62252.1	151502.3	662.809	27.018	23.625	14363.7
E2009.452	0.712385	356.397	31899.1	48590.8	9823.439	63167.3	195538.8	579.039	23.462	24.689	12008.8
E2009.455	0.714079	475.485	46174.0	72452.7	7057.178	81315.7	98048.9	287.686	11.095	23.499	5854.3
E2009.456	0.716878	235.264	27440.3	56533.9	6831.559	66184.8	120022.1	393.872	14.782	15.497	7261.2
E2009.460	0.748496	70.962	8170.7	103411.8	1252.320	52197.2	238556.3	89.795	4.285	5.721	3750.9
E2009.461	0.750199	89.419	8216.9	68456.2	2184.961	52653.9	209541.0	116.297	6.035	9.836	4533.4
E2009.467	0.726098	79.030	8658.2	77135.0	2640.146	71807.8	216817.1	32.970	6.374	8.660	5149.0
E2009.468	0.730220	183.543	21582.8	91792.3	7462.415	50624.9	130861.0	322.603	15.349	18.152	9559.6
E2009.473	0.722925	312.932	9938.8	39817.5	13051.999	26986.9	64864.6	280.909	18.450	46.270	9185.7
E2009.474	0.717705	236.395	19925.8	47151.8	19179.206	41090.5	94997.4	579.810	30.940	52.069	15011.2
E2009.478	0.711935	174.231	19781.8	58311.2	23238.013	48728.4	138599.4	899.286	45.096	40.309	22127.1
E2009.479	0.711699	182.019	17150.0	63501.2	12708.481	49465.2	204821.6	608.830	24.579	33.310	12368.2
E2009.483	0.732844	183.723	15940.2	105806.5	1967.506	61295.2	234623.6	128.469	5.591	9.975	4667.0
E2009.484	0.752254	484.599	36206.9	64516.7	8606.575	55830.6	114160.5	504.343	22.976	28.533	10963.6
E2009.490	0.712507	147.603	16531.4	79955.6	2014.697	66968.6	185247.8	126.558	5.763	9.863	4008.0
E2009.491	0.712047	266.281	24109.8	52309.0	12428.613	56483.8	202853.3	299.766	14.470	34.349	7314.9
E2009.498	0.710242	80.945	9404.9	58519.0	1030.744	45156.9	204305.5	76.780	3.457	5.681	3664.8
E2009.499	0.710399	559.668	49409.8	56356.6	16059.301	76804.8	111616.9	236.331	9.925	28.278	5049.1
E2009.504	0.709915	336.987	25113.1	55466.7	18032.235	34495.4	130824.6	234.988	53.677	44.083	22060.7
E2009.505	0.709861	197.569	14201.4	47289.8	7308.027	29498.3	199462.1	242.613	20.579	22.443	10533.3
E2009.511	0.709930	342.556	18631.5	79222.7	6156.735	44179.6	262748.5	132.051	16.322	21.266	10752.5
E2009.512	0.710209	235.723	19104.8	70629.7	3144.487	53113.3	264941.1	235.207	9.853	15.865	6504.0

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
E2009.400	3043.288	2.885	21.705	104.905	1862.310	1.796	1.563	2.297	78.217	978.912	2.428
E2009.406	22951.731	5.836	104.839	81.436	1965.847	2.899	1.115	2.462	69.183	878.639	4.855
E2009.407	18995.760	8.864	34.820	45.915	320.435	7.102	1.753	2.021	85.269	501.580	16.710
E2009.412	9585.022	6.195	33.904	124.205	297.538	0.684	0.929	1.452	107.154	2045.099	0.433
E2009.413	4829.442	3.147	15.809	99.024	899.412	1.792	1.600	1.874	68.295	1694.370	2.131
E2009.419	1879.449	1.973	5.423	399.603	357.933	1.658	1.771	3.945	51.915	1733.520	0.802
E2009.420	6617.150	2.735	10.140	231.040	1642.501	1.695	2.432	2.158	22.455	636.645	1.473
E2009.426	3937.095	5.563	25.665	434.318	349.953	3.011	2.154	3.672	49.727	1113.082	3.261
E2009.427	1965.899	7.837	37.652	168.778	1053.304	5.788	1.803	2.117	52.717	249.299	6.271
E2009.432	4035.639	17.563	54.496	234.958	461.923	7.604	2.684	3.106	109.457	854.205	19.538
E2009.433	7450.211	22.172	64.437	143.136	348.716	5.722	2.201	2.885	77.249	1099.292	11.604
E2009.437	20170.055	8.814	57.444	274.097	1390.951	2.567	1.560	3.460	149.440	678.913	3.211
E2009.438	21117.772	11.331	31.336	105.838	1471.943	3.762	2.481	3.348	19.969	1101.555	6.812
E2009.440	5825.581	6.145	36.753	251.785	339.709	1.250	1.144	2.742	35.430	1898.601	2.040
E2009.441	4515.214	9.611	25.271	392.384	291.780	1.018	1.265	3.794	33.092	1714.364	1.503
E2009.444	9752.703	13.632	68.464	214.941	355.639	3.493	1.522	3.164	46.620	1021.829	3.298
E2009.445	8794.368	13.434	71.657	158.086	301.727	2.767	1.488	3.253	37.411	1188.702	3.056
E2009.447	52364.141	15.993	68.688	94.091	238.433	2.403	1.539	4.855	49.828	3003.874	2.667
E2009.448	14599.056	14.821	130.104	191.260	183.768	1.676	1.244	3.419	103.968	1734.284	1.573
E2009.451	3296.213	7.625	16.880	210.374	1095.033	4.200	2.127	2.837	39.132	397.156	6.906
E2009.452	1040.776	5.142	19.320	177.196	784.795	3.602	2.092	3.476	45.168	451.972	5.805
E2009.455	7233.174	8.022	24.752	296.185	828.950	2.008	1.162	2.745	103.920	150.294	2.397
E2009.456	4421.132	5.181	15.222	220.620	1006.851	2.468	1.622	2.977	67.092	241.866	3.234
E2009.460	13863.826	8.607	60.816	151.931	1170.972	0.997	1.402	4.865	68.991	640.790	1.045
E2009.461	15450.739	7.671	28.927	147.616	542.137	1.403	1.693	4.813	134.392	2503.398	1.558
E2009.467	24253.477	14.616	53.108	136.996	1891.760	2.093	1.665	4.902	48.005	1081.354	3.125
E2009.468	4451.551	5.876	67.312	225.655	475.027	3.387	1.770	5.277	77.496	1649.816	5.101
E2009.473	1152.939	5.805	40.505	84.135	110.993	2.492	1.049	2.384	136.634	734.882	1.848
E2009.474	8656.420	11.662	60.988	224.540	328.195	4.332	1.705	3.045	46.055	579.337	4.536
E2009.478	6628.462	12.312	37.416	150.813	893.106	7.057	2.565	3.808	59.116	493.126	11.323
E2009.479	10744.204	13.149	40.129	310.655	1251.730	4.135	2.108	5.391	40.581	706.161	5.909
E2009.483	12389.038	6.970	32.314	287.196	811.898	1.861	1.373	3.265	77.609	789.824	1.278
E2009.484	4863.371	7.595	80.337	379.577	528.108	4.806	2.542	2.975	84.243	796.323	4.667
E2009.490	22667.945	47.103	447.353	301.489	4220.539	2.108	1.272	2.244	93.417	1365.856	2.001
E2009.491	42516.361	11.066	138.000	171.960	1788.151	6.127	2.844	4.385	58.600	931.404	5.664
E2009.498	14727.380	11.061	147.098	182.601	1892.383	1.351	0.985	1.179	148.519	2223.523	1.085
E2009.499	14977.828	5.293	285.031	389.916	1257.308	3.262	1.671	3.129	169.564	391.041	3.088
E2009.504	1253.295	10.715	56.672	247.723	420.106	7.906	6.083	3.416	108.860	739.598	11.403
E2009.505	960.845	3.881	55.858	210.419	1392.223	3.284	2.530	4.195	64.869	685.906	4.505
E2009.511	9170.619	7.474	116.470	257.683	2223.307	3.005	2.890	5.449	57.154	1245.297	4.294
E2009.512	3011.774	5.513	80.443	326.160	2279.815	1.833	2.335	5.529	78.424	1309.010	2.096

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
E2009.400	0.001	0.426	2.851	0.565	0.071	0.393	0.348	0.743	0.256	0.631	780.758
E2009.406	0.343	0.612	2.089	0.492	0.078	0.172	1.935	0.891	0.172	0.496	331.038
E2009.407	1.328	0.248	1.417	0.123	0.153	0.102	0.213	1.043	0.146	1.643	155.947
E2009.412	0.001	0.101	3.075	0.814	0.040	0.081	0.611	0.173	0.169	0.322	548.791
E2009.413	0.001	0.285	2.606	1.044	0.066	0.453	1.597	0.664	0.275	0.784	614.593
E2009.419	0.001	0.105	1.684	0.670	0.042	1.779	0.069	0.270	0.097	0.650	483.047
E2009.420	0.001	0.296	1.772	0.967	0.063	1.275	0.913	0.675	0.508	0.582	190.951
E2009.426	0.195	0.258	1.123	0.418	0.054	1.594	0.171	0.564	0.108	1.453	919.323
E2009.427	0.120	0.402	4.092	0.561	0.077	1.763	0.205	1.273	0.227	1.786	159.136
E2009.432	0.285	0.109	2.148	0.344	0.173	0.684	0.454	0.894	0.171	2.289	323.247
E2009.433	0.205	0.345	1.881	0.292	0.103	0.765	0.309	0.851	0.291	1.610	236.758
E2009.437	0.001	0.480	6.658	0.403	0.055	0.863	3.729	0.597	0.387	2.253	499.644
E2009.438	0.211	0.307	2.649	0.852	0.098	0.629	3.105	0.830	0.703	1.008	790.362
E2009.440	0.001	0.079	0.514	0.471	0.048	1.050	0.064	0.221	0.148	0.781	238.424
E2009.441	0.001	0.043	0.499	0.663	0.041	0.897	0.121	0.177	0.098	0.212	357.241
E2009.444	0.001	0.131	0.689	0.474	0.047	0.743	0.127	0.363	0.131	0.979	425.589
E2009.445	0.001	0.146	0.709	0.526	0.045	0.820	0.153	0.301	0.093	0.888	497.101
E2009.447	0.126	0.143	2.611	0.494	0.052	0.598	4.031	0.687	0.137	0.622	519.224
E2009.448	0.142	0.175	1.961	0.373	0.037	0.702	0.677	0.358	0.081	1.274	293.796
E2009.451	0.199	0.629	9.273	0.498	0.148	1.031	0.125	1.052	0.230	1.044	123.676
E2009.452	0.160	0.546	5.290	0.524	0.100	1.167	0.071	0.898	0.222	0.866	135.259
E2009.455	0.189	0.498	1.730	0.244	0.062	0.588	0.340	0.514	0.186	0.726	60.075
E2009.456	0.228	0.478	6.325	0.304	0.062	0.712	0.215	0.606	0.239	1.064	84.456
E2009.460	0.001	0.232	2.869	0.820	0.055	0.140	1.415	0.157	0.065	0.434	481.338
E2009.461	0.001	0.091	1.067	0.852	0.058	0.412	0.362	0.261	0.061	1.923	718.470
E2009.467	0.211	0.001	2.535	0.652	0.076	0.312	3.745	0.149	0.036	0.698	715.101
E2009.468	0.345	0.289	1.043	0.634	0.081	0.620	0.087	0.734	0.107	1.049	939.046
E2009.473	0.166	0.091	4.054	0.305	0.033	0.421	0.254	0.287	0.114	2.760	397.693
E2009.474	0.318	0.269	1.550	0.314	0.065	0.597	0.114	0.497	0.148	1.123	593.883
E2009.478	0.230	0.513	3.162	0.423	0.157	0.874	0.516	1.150	0.365	1.509	328.842
E2009.479	0.167	0.560	8.349	0.724	0.109	1.279	0.399	0.884	0.380	0.523	241.646
E2009.483	0.593	0.278	1.076	0.825	0.083	0.428	0.544	0.471	0.310	0.383	652.059
E2009.484	0.285	0.270	1.625	0.422	0.071	0.677	0.201	1.749	1.104	1.249	575.946
E2009.490	0.146	0.254	1.769	0.720	0.068	0.506	4.631	0.427	0.288	0.476	941.142
E2009.491	0.117	0.416	2.076	0.548	0.100	1.350	0.942	1.607	1.136	0.598	169.457
E2009.498	0.148	0.192	3.461	0.843	0.072	0.265	0.939	0.384	0.268	0.392	310.308
E2009.499	0.174	0.417	2.180	0.252	0.062	1.554	0.252	1.397	0.668	0.676	244.836
E2009.504	0.407	0.049	3.934	0.442	0.128	0.691	0.326	5.860	3.126	2.135	405.099
E2009.505	0.146	0.001	2.532	0.752	0.084	0.157	0.144	1.869	0.841	0.423	528.377
E2009.511	0.161	0.098	2.462	0.836	0.119	0.216	0.677	1.841	1.349	0.515	324.189
E2009.512	0.201	0.386	3.030	0.846	0.080	0.211	0.317	1.257	1.196	0.315	440.543

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
E2009.400	5.161	9.226	1.061	3.775	0.665	0.376	0.630	0.077	0.453	0.092	0.268
E2009.406	16.574	32.244	3.266	10.949	1.721	0.349	1.625	0.183	1.046	0.196	0.549
E2009.407	69.028	136.423	13.486	46.527	7.122	1.028	6.822	0.717	3.987	0.711	1.875
E2009.412	0.829	1.487	0.164	0.586	0.112	0.220	0.114	0.001	0.083	0.001	0.044
E2009.413	5.389	8.745	0.989	3.587	0.611	0.338	0.628	0.075	0.432	0.085	0.238
E2009.419	1.643	2.992	0.349	1.254	0.224	0.202	0.228	0.001	0.167	0.034	0.093
E2009.420	3.038	5.367	0.630	2.318	0.421	0.148	0.405	0.046	0.282	0.054	0.150
E2009.426	6.028	9.857	1.276	4.727	0.899	0.513	0.961	0.120	0.689	0.133	0.370
E2009.427	11.931	17.593	2.343	8.649	1.630	0.436	1.710	0.217	1.275	0.250	0.714
E2009.432	23.884	36.528	5.492	20.878	4.089	0.967	5.413	0.690	4.205	0.865	2.456
E2009.433	17.150	29.788	3.803	14.121	2.684	0.588	3.024	0.382	2.343	0.463	1.292
E2009.437	6.131	11.698	1.271	4.525	0.819	0.342	0.887	0.111	0.666	0.131	0.383
E2009.438	14.446	28.687	3.060	10.988	1.902	0.648	1.832	0.213	1.253	0.248	0.688
E2009.440	3.717	4.453	0.677	2.444	0.416	0.170	0.489	0.061	0.358	0.068	0.178
E2009.441	5.378	7.944	0.847	2.697	0.399	0.204	0.454	0.051	0.281	0.052	0.141
E2009.444	12.933	18.586	1.935	6.199	0.933	0.337	1.103	0.122	0.727	0.145	0.403
E2009.445	13.623	17.025	1.984	6.338	0.913	0.342	1.042	0.110	0.644	0.126	0.365
E2009.447	5.294	11.823	1.140	4.133	0.763	0.310	0.759	0.093	0.548	0.105	0.294
E2009.448	3.212	7.331	0.703	2.486	0.452	0.173	0.485	0.057	0.339	0.064	0.186
E2009.451	15.543	31.212	3.310	11.587	2.036	0.354	1.972	0.230	1.383	0.270	0.749
E2009.452	13.483	27.297	2.849	9.966	1.729	0.310	1.627	0.191	1.137	0.219	0.611
E2009.455	5.414	10.553	1.121	3.907	0.692	0.130	0.633	0.076	0.480	0.093	0.262
E2009.456	7.120	13.786	1.463	5.172	0.922	0.183	0.934	0.110	0.663	0.133	0.383
E2009.460	2.236	4.137	0.446	1.596	0.286	0.229	0.290	0.032	0.192	0.037	0.102
E2009.461	4.118	6.996	0.768	2.636	0.461	0.356	0.488	0.054	0.298	0.057	0.159
E2009.467	14.401	19.888	2.536	8.365	1.309	0.445	1.224	0.124	0.643	0.113	0.297
E2009.468	24.670	41.581	4.440	14.658	2.285	0.658	2.251	0.218	1.163	0.208	0.557
E2009.473	4.278	7.773	0.798	2.777	0.496	0.247	0.535	0.065	0.378	0.076	0.209
E2009.474	11.631	19.925	2.100	7.231	1.262	0.457	1.397	0.160	0.942	0.181	0.514
E2009.478	27.752	51.139	5.599	19.867	3.441	0.745	3.584	0.406	2.359	0.455	1.305
E2009.479	14.326	25.982	2.901	10.272	1.770	0.424	1.723	0.204	1.167	0.227	0.648
E2009.483	2.145	3.859	0.424	1.574	0.295	0.333	0.306	0.039	0.232	0.046	0.136
E2009.484	8.163	15.453	1.756	6.536	1.246	0.445	1.287	0.154	0.936	0.185	0.510
E2009.490	2.839	5.096	0.574	2.099	0.400	0.477	0.427	0.052	0.307	0.059	0.174
E2009.491	7.071	12.581	1.435	5.370	1.035	0.270	1.071	0.138	0.854	0.178	0.525
E2009.498	1.565	2.522	0.305	1.110	0.225	0.170	0.230	0.031	0.178	0.034	0.105
E2009.499	4.560	7.986	0.934	3.479	0.679	0.223	0.698	0.093	0.536	0.109	0.317
E2009.504	21.838	40.105	4.545	16.538	3.078	0.718	3.308	0.396	2.355	0.456	1.302
E2009.505	8.245	14.699	1.714	6.263	1.178	0.428	1.211	0.148	0.885	0.177	0.517
E2009.511	6.643	11.571	1.346	4.909	0.915	0.311	1.073	0.134	0.809	0.165	0.474
E2009.512	3.543	6.180	0.718	2.633	0.503	0.290	0.557	0.067	0.402	0.081	0.232

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
E2009.400	0.038	0.227	0.001	0.043	0.284	0.366	10.515	1.069	0.260
E2009.406	0.072	0.446	0.062	0.001	0.101	0.359	7.558	3.587	0.327
E2009.407	0.238	1.481	0.203	0.001	0.060	0.170	16.953	12.163	1.089
E2009.412	0.007	0.001	0.001	0.001	0.055	0.398	4.475	0.272	0.099
E2009.413	0.034	0.211	0.001	0.001	0.208	1.117	11.330	1.011	0.225
E2009.419	0.014	0.081	0.001	0.001	0.102	0.283	9.728	0.572	0.196
E2009.420	0.021	0.139	0.001	0.021	0.080	0.465	14.572	0.670	0.202
E2009.426	0.050	0.316	0.048	0.001	0.095	0.081	15.672	1.659	0.389
E2009.427	0.102	0.631	0.096	0.001	0.064	0.358	12.595	2.987	0.879
E2009.432	0.342	2.185	0.323	0.037	0.391	0.411	23.150	5.689	1.698
E2009.433	0.181	1.150	0.173	0.024	0.190	0.142	8.345	5.154	1.043
E2009.437	0.052	0.352	0.053	0.035	0.209	0.852	18.362	2.730	0.394
E2009.438	0.097	0.609	0.089	0.041	0.131	0.360	30.455	2.600	0.508
E2009.440	0.023	0.130	0.001	0.001	0.090	0.001	7.432	0.327	0.125
E2009.441	0.019	0.109	0.001	0.001	0.078	0.001	5.976	0.332	0.109
E2009.444	0.057	0.342	0.052	0.001	0.067	0.200	6.250	2.240	0.220
E2009.445	0.047	0.303	0.045	0.001	0.067	0.102	7.029	1.721	0.198
E2009.447	0.039	0.250	0.001	0.001	0.069	0.063	4.263	1.977	0.632
E2009.448	0.027	0.151	0.001	0.001	0.062	0.136	9.146	1.424	0.392
E2009.451	0.106	0.670	0.098	0.091	0.595	0.468	11.614	5.037	0.662
E2009.452	0.086	0.537	0.079	0.047	0.269	0.473	12.148	5.112	0.791
E2009.455	0.035	0.212	0.001	0.046	0.149	0.677	13.654	1.752	0.233
E2009.456	0.052	0.339	0.048	0.028	0.129	0.302	13.345	2.148	0.319
E2009.460	0.014	0.092	0.001	0.001	0.099	0.498	6.593	0.534	0.171
E2009.461	0.021	0.132	0.001	0.001	0.083	0.149	7.479	0.856	0.338
E2009.467	0.036	0.235	0.001	0.001	0.074	0.189	6.899	0.831	0.181
E2009.468	0.073	0.454	0.064	0.001	0.119	0.266	13.895	7.425	0.550
E2009.473	0.029	0.180	0.001	0.001	0.053	0.001	2.592	1.418	0.868
E2009.474	0.067	0.430	0.066	0.001	0.061	0.129	9.337	2.926	0.684
E2009.478	0.181	1.187	0.181	0.057	0.455	0.348	14.116	6.599	0.934
E2009.479	0.089	0.590	0.088	0.048	0.267	0.233	12.399	3.285	2.223
E2009.483	0.019	0.123	0.001	0.029	0.124	0.342	13.564	0.476	0.154
E2009.484	0.073	0.466	0.068	0.001	0.113	0.075	25.554	2.395	0.591
E2009.490	0.023	0.142	0.001	0.020	0.078	0.211	10.466	0.510	0.153
E2009.491	0.070	0.474	0.070	0.036	0.148	0.548	24.992	1.348	0.518
E2009.498	0.014	0.092	0.001	0.001	0.070	0.329	8.075	0.236	0.103
E2009.499	0.046	0.279	0.045	0.029	0.156	0.502	20.347	0.972	0.354
E2009.504	0.180	1.149	0.168	0.001	0.129	0.102	50.232	5.732	1.624
E2009.505	0.070	0.452	0.066	0.001	0.076	0.474	27.785	1.968	0.562
E2009.511	0.066	0.413	0.060	0.038	0.289	0.520	26.468	1.507	0.450
E2009.512	0.032	0.214	0.001	0.031	0.147	0.850	17.378	0.899	0.261

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	^{87}Sr/^{86}Sr	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
E2009.518	0.711526	223.167	14530.4	68500.9	7767.220	31511.1	245914.0	552.430	18.337	23.182	8681.5
E2009.519	0.711770	466.810	45054.2	70770.7	14193.276	74171.4	123771.5	404.087	14.769	22.253	6602.8
E2009.523	0.708581	94.239	7522.6	92847.4	519.031	61930.1	241541.3	47.341	3.063	7.169	3405.3
E2009.524	0.708973	305.315	26716.9	65541.8	4331.747	68990.0	176474.4	325.091	11.077	21.492	5766.1
E2009.525	0.708529	121.909	12364.3	93237.8	1189.362	28542.0	287439.8	113.052	3.849	11.280	4627.9
E2009.526	0.707794	103.548	10204.6	63400.8	6816.851	35864.6	177314.1	497.162	19.866	24.561	11897.0
E2009.527	0.709776	112.515	9686.1	95348.9	588.332	44801.5	297709.8	54.058	3.268	8.600	4529.2
E2009.528	0.709878	119.862	10544.9	62049.7	16714.230	56969.8	229107.6	14.630	4.784	21.972	4526.9
E2009.529	0.709641	241.004	18033.9	64123.4	1395.815	78076.9	188361.0	18.746	3.520	11.904	3887.5
E2009.530	0.709435	281.931	22945.0	64273.5	13585.422	70138.8	205502.0	629.984	19.377	39.820	11050.2
E2009.531	0.707794	103.548	10204.6	63400.8	6816.851	35864.6	177314.1	497.162	19.866	24.561	11897.0
E2009.536	0.709776	112.515	9686.1	95348.9	588.332	44801.5	297709.8	54.058	3.268	8.600	4529.2
E2009.537	0.709878	119.862	10544.9	62049.7	16714.230	56969.8	229107.6	14.630	4.784	21.972	4526.9
E2009.542	0.709641	241.004	18033.9	64123.4	1395.815	78076.9	188361.0	18.746	3.520	11.904	3887.5
E2009.543	0.709435	281.931	22945.0	64273.5	13585.422	70138.8	205502.0	629.984	19.377	39.820	11050.2
NBS-987 Avg.	0.710253										
SRM612 Avg.		42.376	105192	77.440	11276	60.697	85518.580	48.134	39.6	40.268	56.603

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
E2009.518	9851.861	12.445	144.884	180.375	1555.096	3.766	2.748	5.735	92.356	1956.603	5.056
E2009.519	7565.145	6.244	170.992	330.619	1388.275	3.223	2.025	4.525	80.522	400.643	3.549
E2009.523	1341.739	1.377	9.383	146.804	2122.941	0.681	1.195	4.040	30.718	641.913	0.298
E2009.524	1170.470	2.040	11.318	380.561	1160.295	1.856	2.260	6.009	46.426	373.768	1.301
E2009.525	427.473	1.415	15.621	230.535	1717.174	0.667	0.936	2.791	45.238	641.142	0.680
E2009.526	1937.336	4.708	20.991	118.770	477.568	2.698	2.302	5.930	92.796	1253.586	3.447
E2009.527	10605.855	7.573	70.803	240.889	448.950	0.853	1.375	5.014	72.601	1125.056	0.406
E2009.528	35091.233	3.825	32.433	80.341	213.313	2.108	1.561	5.639	49.785	273.285	0.961
E2009.529	17502.067	6.919	35.385	259.644	1318.790	1.607	0.705	1.904	92.569	1005.205	0.837
E2009.530	10285.572	7.749	25.695	196.569	1040.303	3.665	1.906	5.074	99.620	750.204	2.858
E2009.531	1937.336	4.708	20.991	118.770	477.568	2.698	2.302	5.930	92.796	1253.586	3.447
E2009.536	10605.855	7.573	70.803	240.889	448.950	0.853	1.375	5.014	72.601	1125.056	0.406
E2009.537	35091.233	3.825	32.433	80.341	213.313	2.108	1.561	5.639	49.785	273.285	0.961
E2009.542	17502.067	6.919	35.385	259.644	1318.790	1.607	0.705	1.904	92.569	1005.205	0.837
E2009.543	10285.572	7.749	25.695	196.569	1040.303	3.665	1.906	5.074	99.620	750.204	2.858
SRM612 Avg.	38.745	32.417	38.724	37.156	38.372	36.364	34.874	38.288	31.963	76.543	38.6

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
E2009.518	0.226	0.375	1.444	0.878	0.093	0.289	1.261	1.092	0.658	0.318	482.712
E2009.519	0.241	0.493	2.273	0.398	0.071	0.771	0.248	1.012	0.675	0.461	100.530
E2009.523	0.001	0.116	4.430	0.807	0.066	0.072	0.091	0.105	0.069	0.258	1142.030
E2009.524	0.148	0.469	13.405	0.598	0.058	0.658	0.115	0.427	0.215	0.248	99.058
E2009.525	0.065	0.198	6.556	1.027	0.060	0.066	0.001	0.192	0.078	0.221	1852.303
E2009.526	0.223	0.300	1.533	0.746	0.073	0.263	0.112	0.420	0.090	1.998	976.585
E2009.527	0.001	0.112	2.466	1.028	0.052	0.193	1.276	0.132	0.072	0.342	1559.839
E2009.528	0.139	0.001	1.161	0.517	0.042	0.180	0.406	0.001	0.030	0.695	210.434
E2009.529	0.144	0.114	1.424	0.692	0.074	0.138	0.798	0.142	0.034	0.254	2569.346
E2009.530	0.121	0.793	2.051	0.844	0.097	0.530	0.558	1.071	0.288	1.075	296.427
E2009.531	0.223	0.300	1.533	0.746	0.073	0.263	0.112	0.420	0.090	1.998	976.585
E2009.536	0.001	0.112	2.466	1.028	0.052	0.193	1.276	0.132	0.072	0.342	1559.839
E2009.537	0.139	0.001	1.161	0.517	0.042	0.180	0.406	0.001	0.030	0.695	210.434
E2009.542	0.144	0.114	1.424	0.692	0.074	0.138	0.798	0.142	0.034	0.254	2569.346
E2009.543	0.121	0.793	2.051	0.844	0.097	0.530	0.558	1.071	0.288	1.075	296.427
SRM612 Avg.	36.662	36.216	38.137	35.898	22.057	28.715	43.095	38.257	38.519	41.997	37.872

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
E2009.518	8.622	14.612	1.774	6.558	1.225	0.453	1.347	0.166	0.973	0.187	0.536
E2009.519	5.439	9.863	1.145	4.072	0.767	0.193	0.846	0.108	0.629	0.134	0.373
E2009.523	0.488	0.916	0.104	0.395	0.085	0.542	0.088	0.001	0.057	0.001	0.001
E2009.524	2.498	4.685	0.541	1.984	0.385	0.125	0.401	0.047	0.271	0.051	0.161
E2009.525	1.045	1.891	0.215	0.797	0.174	0.930	0.187	0.001	0.131	0.026	0.072
E2009.526	7.294	13.697	1.538	5.698	1.059	0.684	1.171	0.133	0.739	0.140	0.395
E2009.527	0.816	1.306	0.139	0.504	0.100	0.789	0.115	0.001	0.062	0.001	0.001
E2009.528	1.767	3.221	0.370	1.329	0.243	0.144	0.242	0.001	0.162	0.032	0.093
E2009.529	1.657	2.804	0.325	1.186	0.253	1.326	0.226	0.001	0.145	0.028	0.076
E2009.530	6.484	12.373	1.372	5.058	0.966	0.316	0.953	0.110	0.599	0.107	0.296
E2009.531	7.294	13.697	1.538	5.698	1.059	0.684	1.171	0.133	0.739	0.140	0.395
E2009.536	0.816	1.306	0.139	0.504	0.100	0.789	0.115	0.001	0.062	0.001	0.001
E2009.537	1.767	3.221	0.370	1.329	0.243	0.144	0.242	0.001	0.162	0.032	0.093
E2009.542	1.657	2.804	0.325	1.186	0.253	1.326	0.226	0.001	0.145	0.028	0.076
E2009.543	6.484	12.373	1.372	5.058	0.966	0.316	0.953	0.110	0.599	0.107	0.296
SRM612 Avg.	35.984	38.363	37.342	35.321	37.138	34.588	37.225	36.127	36.239	38.149	37.848

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
E2009.518	0.069	0.472	0.064	0.023	0.144	0.484	17.475	1.794	0.475
E2009.519	0.052	0.331	0.050	0.041	0.131	0.579	17.273	1.393	0.328
E2009.523	0.001	0.001	0.001	0.022	0.067	0.209	10.538	0.136	0.035
E2009.524	0.021	0.131	0.001	0.044	0.108	0.212	14.151	0.585	0.237
E2009.525	0.011	0.062	0.001	0.001	0.044	0.428	14.933	0.266	0.066
E2009.526	0.050	0.316	0.044	0.001	0.069	0.568	14.830	1.893	0.543
E2009.527	0.001	0.001	0.001	0.001	0.053	0.242	11.523	0.159	0.034
E2009.528	0.013	0.074	0.001	0.001	0.070	0.203	15.018	0.102	0.098
E2009.529	0.011	0.073	0.001	0.066	0.309	0.455	13.740	0.187	0.070
E2009.530	0.038	0.260	0.001	0.077	0.363	0.523	24.402	1.478	0.285
E2009.531	0.050	0.316	0.044	0.001	0.069	0.568	14.830	1.893	0.543
E2009.536	0.001	0.001	0.001	0.001	0.053	0.242	11.523	0.159	0.034
E2009.537	0.013	0.074	0.001	0.001	0.070	0.203	15.018	0.102	0.098
E2009.542	0.011	0.073	0.001	0.066	0.309	0.455	13.740	0.187	0.070
E2009.543	0.038	0.260	0.001	0.077	0.363	0.523	24.402	1.478	0.285
SRM612 Avg.	37.806	40.218	38.004	40.095	5.206	14.081	39.718	37.555	37.786

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Faunal Samples											
Sample ID	**^{87}Sr/^{86}Sr**	**Li**	**Na**	**Mg**	**Al**	**P**	**Ca**	**Ti**	**V**	**Cr**	**Fe**
F2008.088	0.706941	2.129	4748.0	1897.2	5.994	138250.7	329175.6	2.677	1.501	0.968	2099.7
F2008.115	0.707908	2.917	4770.5	3281.5	28.770	143399.0	331529.0	4.167	1.027	0.687	2236.0
F2002.452	0.708110	0.353	3329.5	4680.1	5.497	111045.4	193056.9	1.735	3.813	0.694	1674.7
F2008.082	0.708127	2.489	4161.8	3576.9	12.190	119040.4	273315.8	3.405	1.016	2.700	1614.4
F2002.450	0.708130	0.001	2409.5	4392.1	8.676	111876.7	190062.5	1.843	0.480	1.401	1667.2
F1998.013	0.708180	0.001	2768.6	2183.0	11.173	95696.8	165062.8	1.445	1.727	1.080	1409.8
F2002.449	0.708240	0.001	3649.2	3272.2	2.297	96622.6	168478.2	1.655	2.777	0.870	1511.9
F2008.126	0.708280	2.591	3899.5	3886.1	5.803	118810.2	268983.5	2.259	1.334	0.406	1858.3
F2002.445	0.708310	0.001	2332.1	3018.4	3.171	94941.9	168834.1	1.476	1.404	1.038	1449.5
F2008.016	0.708492	1.175	8296.5	4331.2	3.426	129372.0	190886.7	1.906	0.859	0.795	1518.1
F2002.444	0.708560	0.331	4708.5	4230.5	1.724	114514.4	208756.0	1.729	1.249	0.771	1755.8
F1998.014	0.708570	0.315	2708.0	2298.9	6.499	98855.2	162806.3	1.322	1.374	0.905	1374.5
F2008.008	0.708593	0.001	3648.0	6920.3	117.030	163399.3	240318.0	6.138	2.481	2.578	2501.4
F2008.095	0.708742	0.408	6727.1	4648.8	97.477	139093.9	211464.4	3.083	0.898	0.584	1832.7
F2008.013	0.708754	0.532	1994.1	5611.5	24.691	142987.0	257647.5	2.937	0.861	0.767	2403.6
F2002.307	0.708780	0.408	2627.5	3986.8	15.495	115095.5	216263.4	1.681	0.638	0.943	1321.3
F2002.451	0.708790	0.374	2831.5	4422.9	6.044	117334.7	204747.0	1.770	0.404	1.037	1793.3
F2001.765	0.708800	0.001	5620.6	1835.8	5.114	78998.5	126736.2	1.612	0.378	0.607	1226.0
F2002.309	0.708800	0.531	2498.9	2807.2	50.341	121813.0	209205.8	2.279	0.611	0.474	1307.6
F2002.345	0.708810	0.799	1872.8	2917.8	25.305	125955.6	201362.8	1.972	0.402	0.663	1320.9
F2002.357	0.708820	0.545	2185.9	4458.3	16.169	113425.5	217867.9	2.073	1.528	5.942	1428.9
F2002.358	0.708820	0.902	2413.5	7267.4	10.638	128026.0	221509.2	1.897	0.308	1.275	1643.5
F2008.015	0.708841	4.244	9896.2	3572.6	8.108	216857.8	407102.7	4.001	1.359	0.718	3854.7
F2002.346	0.708870	0.800	3556.8	4409.4	12.050	106193.7	176757.2	1.776	0.560	1.764	1151.9
F2001.766	0.708880	0.001	7949.7	1963.6	6.340	96907.0	142164.7	1.574	0.372	0.549	822.5
F2002.354	0.708880	1.422	2990.0	4401.0	21.615	124723.8	202319.2	1.763	1.397	1.460	1332.8
F2001.671	0.708890	0.454	4382.1	8234.5	1.827	150112.1	250577.9	2.013	0.001	0.280	2165.7
F2002.347	0.708890	0.794	3016.9	4333.6	6.675	118256.2	204838.3	1.729	0.405	1.920	1364.8
F2002.342	0.708950	1.250	2274.6	2541.7	15.478	123866.4	227686.1	1.810	1.179	0.605	1457.0
F2002.343	0.708950	1.046	2416.1	2377.4	13.742	115394.7	204488.7	1.766	1.120	0.613	1315.2
F2002.308	0.709000	0.435	2614.5	2384.4	15.590	116285.2	197129.1	1.698	0.805	0.499	1160.4
F2002.417	0.709060	1.034	5012.6	4164.6	3.801	125257.0	233306.4	1.829	0.188	1.438	1897.4
F2002.400	0.709070	0.686	3643.0	5132.2	20.171	130900.2	219277.1	1.859	0.643	1.009	1695.1
F2002.419	0.709070	0.613	4183.2	4289.2	50.541	118351.2	225109.2	2.951	0.341	15.006	1871.4
F2002.427	0.709090	2.985	2795.0	3092.8	40.385	133048.8	246498.5	2.545	1.563	0.820	2070.0
F2001.774	0.709130	0.792	6035.4	3663.2	5.632	116870.6	217935.6	1.595	0.159	0.818	1248.9
F2008.094	0.709140	3.125	4560.6	3496.6	7.108	151190.9	326506.4	2.801	1.148	0.775	2066.6
F2001.669	0.709170	0.783	3335.5	2451.2	33.283	137985.9	221571.6	2.994	0.001	0.752	2129.6
F2001.773	0.709200	0.623	4524.0	2762.0	9.522	114677.7	194197.4	1.650	0.334	0.417	1121.3
F2002.362	0.709270	2.642	3259.4	2453.8	428.375	126410.9	271625.8	12.173	1.921	2.039	2581.1
F2002.410	0.709280	0.403	1173.3	3654.4	74.276	111593.9	198631.3	4.953	0.756	1.198	1700.8

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
F2008.088	15.096	0.257	2.759	0.552	59.090	0.947	1.453	5.706	0.181	382.673	0.001
F2008.115	7.501	0.350	1.616	0.379	60.185	1.019	1.215	4.661	0.160	529.004	0.037
F2002.452	54.089	0.227	0.823	2.155	113.441	0.646	0.122	0.737	0.215	683.585	0.001
F2008.082	5.220	0.152	0.001	0.267	71.237	0.789	1.098	4.322	0.088	388.997	0.001
F2002.450	53.393	0.238	1.149	4.605	117.880	0.640	0.330	0.943	0.306	501.518	0.001
F1998.013	59.221	0.247	1.809	0.559	79.831	0.693	0.222	1.193	0.072	463.854	0.001
F2002.449	90.138	0.199	0.818	2.405	136.739	0.541	0.220	0.729	0.291	560.941	0.001
F2008.126	16.470	0.264	1.543	0.336	72.058	0.878	1.346	5.216	0.137	236.522	0.001
F2002.445	22.379	0.199	0.700	2.142	98.564	0.526	0.341	0.911	0.277	571.297	0.001
F2008.016	0.499	0.281	3.963	0.190	58.746	0.781	0.708	2.549	0.249	209.258	0.001
F2002.444	25.425	0.222	0.430	1.335	95.627	0.609	0.134	0.763	0.207	617.517	0.001
F1998.014	58.774	0.225	1.474	1.734	84.626	0.683	0.142	0.941	0.065	470.743	0.001
F2008.008	11.070	0.595	8.449	0.642	136.118	1.246	1.497	4.984	0.349	225.517	0.001
F2008.095	2.468	0.168	0.163	0.441	156.539	0.593	0.580	2.052	0.127	92.502	0.001
F2008.013	113.516	0.425	5.268	1.814	171.669	1.068	0.819	3.013	0.070	604.766	0.001
F2002.307	56.114	0.069	0.001	5.076	124.948	0.492	0.235	0.948	0.052	437.670	0.001
F2002.451	26.540	0.235	0.867	2.821	122.416	0.678	0.193	0.818	0.143	525.396	0.001
F2001.765	70.061	0.271	0.643	1.423	64.914	0.531	0.145	1.050	0.425	307.756	0.001
F2002.309	52.582	0.098	0.001	14.714	134.997	0.522	0.198	0.720	0.001	446.789	0.001
F2002.345	44.629	0.085	0.001	9.547	129.734	0.520	0.232	1.181	0.001	1080.367	0.001
F2002.357	87.967	0.118	0.001	10.594	167.190	0.375	0.380	1.673	0.001	901.557	0.031
F2002.358	9.246	0.108	0.001	29.604	119.103	0.499	0.235	0.923	0.114	614.716	0.001
F2008.015	2.273	0.868	14.049	0.327	37.551	1.849	1.736	5.712	0.224	358.429	0.001
F2002.346	31.563	0.060	0.001	4.313	122.058	0.423	0.289	1.733	0.146	820.478	0.001
F2001.766	91.485	0.034	0.001	6.702	96.779	0.428	0.208	1.068	0.376	338.095	0.001
F2002.354	125.007	0.106	0.001	5.456	99.852	0.486	0.150	0.851	0.056	730.957	0.001
F2001.671	21.595	0.365	0.677	1.237	107.877	1.269	0.149	0.799	0.160	430.396	0.001
F2002.347	53.756	0.094	0.001	4.156	111.058	0.467	0.207	1.179	0.229	1103.020	0.001
F2002.342	138.470	0.135	0.001	8.020	134.099	0.537	0.150	0.795	0.001	777.810	0.001
F2002.343	239.371	0.107	0.001	6.734	116.199	0.501	0.189	0.998	0.001	670.454	0.001
F2002.308	71.921	0.090	0.001	6.196	114.959	0.481	0.181	0.680	0.001	386.741	0.001
F2002.417	0.763	0.222	0.341	2.451	234.020	0.647	0.147	0.598	0.227	441.878	0.001
F2002.400	56.322	0.162	0.001	2.466	123.982	0.594	0.188	0.793	0.097	492.127	0.001
F2002.419	8.652	0.218	0.001	1.426	106.906	0.633	0.166	0.622	0.169	152.803	0.001
F2002.427	42.339	0.285	0.314	1.786	73.931	0.716	0.338	0.604	0.001	455.254	0.001
F2001.774	19.986	0.056	0.001	1.494	73.304	0.498	0.144	0.446	0.078	204.839	0.001
F2008.094	17.815	0.269	1.279	0.390	49.435	0.945	1.130	4.377	0.113	308.027	0.001
F2001.669	30.081	0.436	3.193	2.586	330.488	0.996	0.108	0.650	0.001	410.971	0.001
F2001.773	10.738	0.001	0.001	3.332	92.348	0.479	0.252	0.928	0.001	158.805	0.001
F2002.362	61.616	0.652	0.001	1.642	75.456	0.647	0.821	0.593	0.347	631.744	0.416
F2002.410	41.982	0.253	0.072	6.341	123.942	0.607	0.264	0.947	0.127	461.204	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
F2008.088	0.001	0.001	0.104	0.101	0.014	0.001	0.001	0.001	0.001	0.001	105.402
F2008.115	0.001	0.001	0.098	0.099	0.013	0.001	0.001	0.001	0.001	0.001	189.681
F2002.452	0.001	0.001	0.026	0.067	0.013	0.001	0.001	0.001	0.001	0.001	58.516
F2008.082	0.001	0.001	0.073	0.071	0.001	0.001	0.001	0.001	0.001	0.001	325.367
F2002.450	0.001	0.001	0.027	0.039	0.017	0.014	0.001	0.062	0.001	0.001	13.326
F1998.013	0.001	0.001	0.001	0.038	0.011	0.025	0.001	0.001	0.001	0.001	44.817
F2002.449	0.200	0.001	0.117	0.055	0.032	0.024	0.001	0.163	0.001	0.001	40.861
F2008.126	0.001	0.001	0.034	0.044	0.001	0.001	0.001	0.001	0.001	0.001	249.484
F2002.445	0.001	0.001	0.029	0.052	0.001	0.001	0.001	0.001	0.001	0.001	24.132
F2008.016	0.001	0.001	0.481	0.038	0.013	0.001	0.001	0.001	0.001	0.001	153.684
F2002.444	0.001	0.001	0.055	0.050	0.011	0.001	0.001	0.001	0.001	0.001	23.221
F1998.014	0.001	0.001	0.001	0.038	0.001	0.001	0.178	0.058	0.001	0.001	39.860
F2008.008	0.001	0.058	0.147	0.055	0.026	0.013	0.001	0.077	0.013	0.001	40.250
F2008.095	0.001	0.001	0.047	0.023	0.024	0.001	0.001	0.001	0.001	0.001	11.194
F2008.013	0.001	0.001	0.257	0.110	0.022	0.001	0.001	0.001	0.033	0.001	224.047
F2002.307	0.001	0.001	0.056	0.019	0.001	0.001	0.001	0.001	0.013	0.001	32.714
F2002.451	0.001	0.001	0.001	0.034	0.001	0.001	0.001	0.001	0.001	0.001	12.614
F2001.765	0.001	0.043	0.054	0.016	0.015	0.001	0.001	0.075	0.001	0.001	23.059
F2002.309	0.001	0.001	0.045	0.017	0.001	0.001	0.001	0.001	0.001	0.001	45.496
F2002.345	0.176	0.001	0.099	0.066	0.027	0.026	0.062	0.332	0.017	0.001	37.234
F2002.357	0.170	0.001	0.001	0.001	0.058	0.031	0.001	0.115	0.012	0.001	26.552
F2002.358	0.001	0.001	0.083	0.032	0.012	0.001	0.001	0.001	0.001	0.001	38.837
F2008.015	0.001	0.001	4.399	0.208	0.019	0.001	0.001	0.001	0.001	0.001	117.102
F2002.346	0.001	0.001	0.059	0.040	0.015	0.010	0.001	0.060	0.001	0.001	42.093
F2001.766	0.143	0.001	0.050	0.001	0.026	0.020	0.001	0.079	0.024	0.001	25.726
F2002.354	0.001	0.001	0.073	0.041	0.011	0.001	0.001	0.001	0.001	0.001	26.432
F2001.671	0.001	0.001	0.080	0.087	0.001	0.001	0.001	0.001	0.001	0.001	252.888
F2002.347	0.001	0.001	0.053	0.067	0.013	0.001	0.001	0.001	0.001	0.001	29.352
F2002.342	0.001	0.001	0.106	0.036	0.013	0.001	0.001	0.073	0.014	0.001	29.953
F2002.343	0.001	0.001	0.056	0.030	0.001	0.001	0.001	0.001	0.013	0.001	32.477
F2002.308	0.001	0.001	0.043	0.001	0.001	0.001	0.001	0.001	0.017	0.001	48.397
F2002.417	0.001	0.001	0.034	0.046	0.001	0.001	0.001	0.001	0.001	0.001	49.117
F2002.400	0.001	0.001	0.075	0.023	0.001	0.001	0.067	0.001	0.001	0.001	20.736
F2002.419	0.001	0.001	0.024	0.015	0.001	0.001	0.001	0.001	0.001	0.001	12.676
F2002.427	0.001	0.001	0.883	0.045	0.001	0.001	0.001	0.001	0.144	0.001	168.438
F2001.774	0.001	0.001	0.001	0.001	0.013	0.001	0.001	0.001	0.001	0.001	231.693
F2008.094	0.001	0.001	0.167	0.090	0.014	0.001	0.001	0.001	0.001	0.001	243.631
F2001.669	0.001	0.001	0.037	0.040	0.014	0.011	0.065	0.001	0.001	0.001	128.712
F2001.773	0.001	0.001	0.001	0.001	0.016	0.001	0.001	0.001	0.001	0.001	205.632
F2002.362	0.450	0.001	0.237	0.108	0.031	0.012	0.001	0.001	0.074	0.001	252.056
F2002.410	0.001	0.001	0.055	0.029	0.012	0.001	0.001	0.001	0.001	0.001	22.418

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
F2008.088	0.001	0.044	0.005	0.001	0.001	0.032	0.001	0.001	0.001	0.001	0.001
F2008.115	0.052	0.115	0.012	0.045	0.001	0.063	0.001	0.001	0.001	0.001	0.001
F2002.452	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.082	0.001	0.001	0.001	0.001	0.001	0.095	0.001	0.001	0.001	0.001	0.001
F2002.450	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1998.013	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.449	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.126	0.001	0.001	0.001	0.001	0.001	0.084	0.001	0.001	0.001	0.001	0.001
F2002.445	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.016	0.001	0.001	0.001	0.001	0.001	0.078	0.001	0.001	0.001	0.001	0.001
F2002.444	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1998.014	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.008	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.095	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.013	0.040	0.001	0.001	0.001	0.001	0.106	0.001	0.001	0.001	0.001	0.001
F2002.307	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.451	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.765	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.309	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.345	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.357	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.358	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.015	0.001	0.001	0.001	0.001	0.001	0.069	0.001	0.001	0.001	0.001	0.001
F2002.346	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.766	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.354	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.671	0.001	0.001	0.001	0.001	0.001	0.097	0.001	0.001	0.001	0.001	0.001
F2002.347	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.342	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.343	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.308	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.417	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.400	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.419	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.427	0.001	0.001	0.001	0.001	0.001	0.056	0.001	0.001	0.001	0.001	0.001
F2001.774	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.094	0.001	0.032	0.001	0.001	0.001	0.078	0.001	0.001	0.001	0.001	0.001
F2001.669	0.001	0.001	0.001	0.001	0.001	0.050	0.001	0.001	0.001	0.001	0.001
F2001.773	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.362	0.425	0.806	0.111	0.448	0.095	0.104	0.097	0.001	0.070	0.001	0.001
F2002.410	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
F2008.088	0.001	0.001	0.001	0.001	0.045	0.001	0.184	0.001	0.001
F2008.115	0.001	0.001	0.001	0.020	0.035	0.001	0.143	0.031	0.001
F2002.452	0.001	0.001	0.001	0.033	0.001	0.001	0.559	0.001	0.037
F2008.082	0.001	0.001	0.001	0.001	0.028	0.001	0.146	0.001	0.001
F2002.450	0.001	0.001	0.001	0.092	0.001	0.001	0.092	0.001	0.001
F1998.013	0.001	0.001	0.001	0.045	0.017	0.001	0.175	0.001	0.199
F2002.449	0.001	0.001	0.001	0.189	0.001	0.001	0.158	0.001	0.040
F2008.126	0.001	0.001	0.001	0.001	0.029	0.001	0.129	0.015	0.001
F2002.445	0.001	0.001	0.001	0.023	0.001	0.001	0.069	0.001	0.001
F2008.016	0.001	0.001	0.001	0.058	0.063	0.001	3.129	0.032	0.001
F2002.444	0.001	0.001	0.001	0.022	0.001	0.001	0.230	0.001	0.001
F1998.014	0.001	0.001	0.001	0.036	0.012	0.001	0.240	0.001	0.195
F2008.008	0.001	0.001	0.001	0.205	0.122	0.001	5.112	0.086	0.001
F2008.095	0.001	0.001	0.001	0.051	0.094	0.001	0.047	0.020	0.042
F2008.013	0.001	0.001	0.001	0.032	0.044	0.001	0.342	0.046	0.283
F2002.307	0.001	0.001	0.001	0.034	0.001	0.001	0.262	0.001	0.141
F2002.451	0.001	0.001	0.001	0.053	0.001	0.001	0.077	0.001	0.001
F2001.765	0.001	0.001	0.001	0.204	0.043	0.001	0.066	0.144	0.084
F2002.309	0.001	0.001	0.001	0.001	0.001	0.001	0.912	0.001	0.212
F2002.345	0.001	0.001	0.001	0.160	0.001	0.001	0.280	0.001	0.001
F2002.357	0.001	0.001	0.001	0.138	0.001	0.001	0.633	0.001	0.050
F2002.358	0.001	0.001	0.001	0.042	0.001	0.001	0.663	0.001	0.001
F2008.015	0.001	0.001	0.001	0.001	0.051	0.001	0.124	0.012	0.001
F2002.346	0.001	0.001	0.001	0.077	0.001	0.001	0.115	0.001	0.035
F2001.766	0.001	0.001	0.001	0.141	0.001	0.001	0.092	0.001	0.001
F2002.354	0.001	0.001	0.001	0.029	0.001	0.001	0.141	0.001	0.001
F2001.671	0.001	0.001	0.001	0.063	0.010	0.001	0.464	0.019	0.001
F2002.347	0.001	0.001	0.001	0.051	0.001	0.001	0.090	0.001	0.001
F2002.342	0.001	0.001	0.001	0.040	0.001	0.001	0.767	0.001	0.001
F2002.343	0.001	0.001	0.001	0.001	0.001	0.001	0.193	0.001	0.001
F2002.308	0.001	0.001	0.001	0.001	0.001	0.001	2.166	0.001	0.309
F2002.417	0.001	0.001	0.001	0.026	0.001	0.001	0.379	0.001	0.001
F2002.400	0.001	0.001	0.001	0.001	0.001	0.001	0.094	0.001	0.001
F2002.419	0.001	0.001	0.001	0.035	0.001	0.001	0.098	0.001	0.001
F2002.427	0.001	0.001	0.001	0.001	0.001	0.001	0.245	0.001	0.001
F2001.774	0.001	0.001	0.001	0.031	0.001	0.001	0.255	0.001	0.001
F2008.094	0.001	0.001	0.001	0.021	0.044	0.001	0.093	0.034	0.001
F2001.669	0.001	0.001	0.001	0.033	0.020	0.001	0.750	0.011	0.001
F2001.773	0.001	0.001	0.001	0.035	0.001	0.001	0.363	0.001	0.001
F2002.362	0.005	0.001	0.001	0.022	0.001	0.001	0.680	0.001	0.314
F2002.410	0.001	0.001	0.001	0.046	0.001	0.001	0.196	0.001	0.085

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**$^{87}Sr/^{86}Sr$**	**Li**	**Na**	**Mg**	**Al**	**P**	**Ca**	**Ti**	**V**	**Cr**	**Fe**
F2002.423	0.709330	3.241	3023.7	2655.3	44.935	139052.5	259461.8	2.842	1.690	0.703	2159.3
F2008.092	0.709371	2.807	4678.3	3667.0	28.043	141942.9	300868.2	4.661	1.277	1.068	1943.3
F2008.118	0.709442	0.302	1777.3	3487.7	106.138	113984.4	235459.7	6.626	1.546	0.630	1710.9
F2002.364	0.709500	0.972	5609.2	4436.2	11.841	119209.8	203506.1	2.033	0.256	1.082	1500.3
F2002.403	0.709510	0.665	4794.2	5280.3	9.638	133259.5	231917.1	2.107	0.583	1.372	1817.8
F2009.139	0.709526	1.810	5392.5	3152.6	6.917	148152.8	331983.4	2.420	1.442	0.600	2408.9
F2009.140	0.709553	0.916	4895.0	5274.1	0.999	128211.9	250744.9	1.678	0.492	0.463	1804.8
F2001.760	0.709570	0.855	2919.0	2803.5	34.259	107989.5	186097.8	2.393	0.191	0.622	1783.5
F2002.390	0.709580	2.435	5002.9	5459.2	21.237	122741.7	209266.7	2.157	0.304	1.221	1670.8
F2008.014	0.709618	0.878	3411.8	6967.1	105.618	162739.5	251535.8	5.789	1.309	1.139	2378.4
F2002.429	0.709630	2.950	2833.4	4273.5	39.943	140785.3	267209.4	2.663	1.774	0.670	2263.0
F2008.128	0.709634	0.001	4162.8	2940.9	14.949	120786.6	273984.1	3.079	1.443	0.445	1955.8
F2001.767	0.709680	0.001	5575.0	2117.3	7.749	93806.2	139393.5	1.594	0.600	0.561	805.9
F1991.013	0.709690	1.398	3044.6	1077.6	72.918	107305.0	234062.0	5.753	5.911	1.852	2066.8
F2002.383	0.709730	4.464	5838.6	12494.6	2.331	160386.2	282571.8	2.004	0.114	0.934	2095.5
F2002.384	0.709730	2.154	5393.2	13933.5	3.032	156834.0	261451.1	2.088	0.160	0.899	2027.0
F2001.697	0.709740	1.870	3180.2	2593.0	157.332	105312.9	184642.8	4.267	0.328	0.569	1810.8
F2008.019	0.709769	2.076	9200.4	3283.8	11.579	207470.8	454719.9	4.788	1.187	1.950	6965.9
F2002.401	0.709830	0.460	1251.4	4512.4	54.860	122209.4	215284.0	3.880	0.608	1.025	1754.6
F2000.546	0.709850	0.001	2394.6	1958.3	32.071	124020.8	178079.2	2.714	0.109	1.059	1690.6
F2008.017	0.709866	2.321	8545.7	3000.5	13.445	199756.1	400108.3	4.171	0.864	0.954	4177.0
F2008.030	0.709877	1.880	6224.2	2730.1	11.164	192080.4	424738.6	5.429	2.400	1.138	5710.2
F2001.777	0.709910	1.867	7280.5	3971.9	25.388	117398.8	244495.9	1.987	0.217	1.094	1574.2
F2001.691	0.709940	0.001	3939.4	2883.8	17.466	109978.2	193159.4	2.254	0.369	0.373	1777.5
F2002.406	0.710040	0.001	1708.2	4709.6	19.843	113056.7	232791.2	2.088	1.247	1.724	1928.1
F2008.021	0.710097	1.560	8468.2	4219.7	3.558	191168.6	408003.7	4.300	1.554	1.612	5273.4
F2008.018	0.710199	1.754	8339.2	3605.0	6.800	192338.9	395197.3	3.807	0.938	0.940	4321.9
F2008.040	0.710209	0.937	6790.9	3430.2	2.899	188064.6	408432.1	4.488	2.090	1.140	6027.6
F2008.091	0.710228	0.435	5860.5	4449.5	15.064	130163.0	187948.5	2.178	0.711	0.404	1073.1
F2002.361	0.710270	0.001	5223.1	4254.0	8.482	134965.1	229192.4	1.862	0.181	0.961	1625.7
F2003.704	0.710350	2.742	3349.0	2970.2	2726.613	112429.6	262872.4	133.151	28.375	12.740	6202.9
F2008.130	0.710512	0.818	2011.6	2819.3	350.742	91153.1	231275.5	39.095	7.996	1.780	2437.6
F2008.131	0.710541	1.420	3154.3	3633.7	148.283	134439.5	289932.1	19.661	3.750	5.193	2409.4
F2008.112	0.710547	0.001	2662.4	3443.9	145.369	117854.2	238061.1	10.606	1.627	1.573	2523.7
F2002.370	0.710560	2.868	3073.1	4298.8	21.108	124274.9	224366.9	1.989	0.313	1.061	1701.4
F2008.035	0.710575	0.310	3870.4	3065.6	25.574	132947.8	206915.0	2.752	0.721	1.133	1684.9
F1993.081	0.710660	1.152	1523.6	1402.6	699.307	114900.4	263901.6	29.960	5.543	6.253	3079.2
F2008.117	0.710717	2.649	3962.1	3636.3	19.093	131408.3	285129.0	2.826	0.940	0.834	1987.2
F2001.757	0.710730	0.001	4320.9	1851.3	14.252	90455.2	179856.2	1.969	0.213	0.434	1711.7
F2002.397	0.710820	0.001	4620.0	5489.9	9.316	107354.6	171705.7	1.667	0.459	1.392	1439.8
F2002.366	0.710920	2.757	5957.6	5379.4	3.438	139709.9	261946.4	1.937	0.213	1.091	1932.7

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
F2002.423	21.603	0.281	0.525	1.718	82.489	0.725	0.313	0.552	0.047	389.568	0.001
F2008.092	11.622	0.298	1.529	0.389	69.796	0.874	1.154	4.393	0.107	265.933	0.100
F2008.118	21.323	0.310	1.018	0.518	230.326	0.798	1.173	4.454	0.185	135.190	0.001
F2002.364	2.081	0.139	0.001	0.001	49.529	0.494	0.177	0.544	0.071	300.138	0.001
F2002.403	60.032	0.183	0.001	6.011	119.358	0.611	0.168	0.937	0.101	469.452	0.001
F2009.139	2.113	0.365	2.296	0.227	26.861	1.058	1.500	5.673	0.084	187.494	0.001
F2009.140	0.794	0.276	1.033	0.154	48.790	0.850	0.470	1.867	0.001	216.730	0.001
F2001.760	87.665	0.351	0.720	2.063	76.024	0.759	0.123	0.612	0.068	240.441	0.001
F2002.390	8.631	0.160	0.001	1.760	142.736	0.599	0.978	0.783	0.200	168.576	0.001
F2008.014	16.434	0.450	5.264	0.339	96.132	1.016	0.894	3.132	0.200	409.518	0.001
F2002.429	23.310	0.303	0.785	0.986	93.790	0.758	0.220	0.440	0.001	359.394	0.001
F2008.128	13.177	0.312	0.938	0.663	178.480	0.882	1.442	5.285	0.303	113.455	0.001
F2001.767	122.071	0.093	0.001	6.491	104.650	0.425	0.259	1.338	0.199	350.869	0.001
F1991.013	12.905	0.370	2.694	1.637	94.926	0.702	0.755	1.562	0.048	504.016	1.463
F2002.383	7.622	0.183	0.001	1.406	144.500	0.730	0.112	0.575	0.525	402.131	0.001
F2002.384	7.745	0.180	0.001	2.716	125.313	0.715	0.127	0.528	0.530	374.024	0.001
F2001.697	16.777	0.343	0.643	2.986	61.450	0.864	0.150	0.597	0.199	273.042	0.001
F2008.019	9.480	1.374	31.874	0.762	25.355	2.471	1.470	5.092	0.209	303.878	0.001
F2002.401	76.764	0.251	0.001	6.070	112.841	0.582	0.174	0.671	0.050	417.358	0.001
F2000.546	20.939	0.340	2.509	0.382	93.646	0.859	0.096	0.717	0.001	212.843	0.001
F2008.017	4.723	0.946	14.268	0.287	36.441	1.923	0.959	3.333	0.208	323.242	0.026
F2008.030	2.490	1.426	23.087	0.344	28.757	2.644	2.808	9.465	0.116	365.832	0.029
F2001.777	14.293	0.095	0.001	1.023	109.069	0.519	0.191	0.617	0.001	268.811	0.001
F2001.691	3.024	0.310	0.367	1.615	97.049	0.830	0.149	0.780	0.267	120.500	0.001
F2002.406	55.977	0.213	0.132	16.243	202.244	0.567	0.313	1.278	0.013	439.432	0.001
F2008.021	1.923	1.283	21.187	0.351	58.616	2.500	1.701	5.917	0.213	324.062	0.001
F2008.018	2.645	1.015	16.510	0.353	31.214	2.012	1.058	3.543	0.178	281.829	0.001
F2008.040	1.553	1.552	24.267	0.300	39.756	2.729	1.701	6.068	0.122	411.428	0.001
F2008.091	1.345	0.125	0.001	0.539	47.185	0.576	0.545	2.010	0.066	229.055	0.001
F2002.361	10.232	0.099	0.001	1.462	114.281	0.528	0.125	0.605	0.001	49.615	0.001
F2003.704	778.213	6.033	34.829	17.443	112.496	1.649	0.787	2.039	2.355	376.485	11.459
F2008.130	344.554	0.603	1.525	2.433	236.377	0.824	2.002	5.021	0.713	324.717	0.359
F2008.131	128.734	0.503	1.540	2.454	118.229	0.950	2.030	5.197	0.324	443.219	0.496
F2008.112	13.270	0.656	8.082	0.658	253.566	1.178	1.104	3.633	0.285	122.522	0.001
F2002.370	10.153	0.155	0.001	0.562	63.312	0.580	0.157	0.493	0.001	96.556	0.001
F2008.035	17.626	0.329	4.548	0.298	73.324	0.862	0.621	2.233	0.051	326.607	0.001
F1993.081	32.484	1.008	15.139	8.484	52.389	1.007	0.402	1.545	0.593	470.120	2.666
F2008.117	4.387	0.306	3.816	0.320	57.644	0.885	0.854	3.628	0.079	182.535	0.001
F2001.757	16.769	0.307	0.800	4.369	178.744	0.712	0.145	0.694	0.001	91.785	0.001
F2002.397	1.289	0.120	0.001	5.402	214.463	0.503	0.287	1.080	0.984	129.483	0.001
F2002.366	2.899	0.183	0.001	0.573	97.339	0.641	0.167	0.637	0.116	123.394	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
F2002.423	0.001	0.001	0.826	0.056	0.001	0.001	0.001	0.001	0.126	0.001	214.785
F2008.092	0.001	0.001	0.211	0.089	0.021	0.012	0.001	0.001	0.001	0.001	312.705
F2008.118	0.001	0.001	0.059	0.037	0.001	0.001	0.001	0.001	0.001	0.001	73.982
F2002.364	0.001	0.001	0.059	0.001	0.010	0.001	0.001	0.001	0.010	0.001	285.872
F2002.403	0.001	0.001	0.072	0.032	0.001	0.001	0.353	0.001	0.001	0.001	24.521
F2009.139	0.001	0.001	0.530	0.083	0.015	0.001	0.001	0.001	0.001	0.001	176.938
F2009.140	0.001	0.001	0.381	0.032	0.001	0.001	0.001	0.001	0.001	0.001	242.205
F2001.760	0.185	0.119	0.085	0.013	0.025	0.032	0.001	0.130	0.118	0.001	484.259
F2002.390	0.001	0.001	0.055	0.001	0.001	0.010	0.001	0.094	0.031	0.001	232.599
F2008.014	0.001	0.074	0.089	0.083	0.027	0.018	0.001	0.001	0.001	0.001	71.401
F2002.429	0.001	0.001	0.475	0.053	0.010	0.001	0.001	0.001	0.214	0.001	277.724
F2008.128	0.001	0.001	0.284	0.044	0.011	0.001	0.001	0.001	0.018	0.001	77.202
F2001.767	0.001	0.001	0.031	0.001	0.016	0.001	0.001	0.001	0.001	0.001	33.407
F1991.013	2.416	0.062	0.051	0.060	0.108	0.001	0.001	0.001	0.110	0.001	444.565
F2002.383	0.001	0.001	0.066	0.055	0.018	0.001	0.001	0.001	0.001	0.001	141.727
F2002.384	0.001	0.001	0.001	0.052	0.011	0.001	0.001	0.001	0.001	0.001	107.775
F2001.697	0.001	0.001	0.070	0.024	0.001	0.001	0.001	0.001	0.001	0.001	110.383
F2008.019	0.001	0.001	0.832	0.189	0.017	0.001	0.001	0.082	0.001	0.001	120.568
F2002.401	0.001	0.001	0.149	0.029	0.013	0.001	0.001	0.001	0.001	0.001	31.937
F2000.546	0.001	0.001	0.027	0.011	0.001	0.011	0.001	0.082	0.014	0.001	7.490
F2008.017	0.001	0.001	1.441	0.189	0.015	0.001	0.001	0.001	0.038	0.001	121.119
F2008.030	0.001	0.001	0.648	0.219	0.020	0.001	0.001	0.001	0.001	0.001	31.340
F2001.777	0.001	0.001	0.001	0.012	0.014	0.001	0.001	1.799	0.010	0.001	376.666
F2001.691	0.001	0.001	0.020	0.021	0.001	0.001	0.001	0.001	0.001	0.001	10.940
F2002.406	0.455	0.001	0.183	0.019	0.049	0.049	0.118	0.352	0.016	0.001	41.001
F2008.021	0.001	0.001	0.817	0.165	0.015	0.001	0.001	0.001	0.001	0.001	185.892
F2008.018	0.001	0.001	1.118	0.162	0.014	0.001	0.001	0.001	0.001	0.001	120.642
F2008.040	0.001	0.001	0.128	0.289	0.024	0.001	0.001	0.001	0.001	0.001	29.006
F2008.091	0.001	0.058	0.078	0.020	0.041	0.014	0.001	0.001	0.001	0.001	323.548
F2002.361	0.001	0.001	0.001	0.001	0.012	0.001	0.001	0.176	0.001	0.001	25.277
F2003.704	3.805	0.400	0.066	0.101	0.272	0.128	0.381	0.087	0.255	0.214	202.298
F2008.130	0.254	0.070	0.422	0.056	0.023	0.001	0.001	0.001	0.028	0.042	170.123
F2008.131	0.280	0.070	0.278	0.079	0.035	0.024	0.001	0.001	0.019	0.001	73.185
F2008.112	0.001	0.001	0.057	0.055	0.001	0.001	0.001	0.001	0.001	0.001	88.940
F2002.370	0.001	0.001	0.071	0.001	0.015	0.021	0.001	0.001	0.032	0.001	222.425
F2008.035	0.001	0.001	0.074	0.053	0.012	0.001	0.001	0.001	0.012	0.001	65.747
F1993.081	3.117	0.123	0.082	0.080	0.141	0.022	0.228	0.001	0.067	0.041	253.205
F2008.117	0.001	0.001	0.072	0.060	0.001	0.001	0.001	0.001	0.001	0.001	217.651
F2001.757	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.107	0.025	0.001	92.406
F2002.397	0.001	0.001	0.174	0.001	0.013	0.023	0.001	0.001	0.001	0.001	26.492
F2002.366	0.182	0.001	0.085	0.024	0.030	0.032	0.001	0.140	0.017	0.001	192.562

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
F2002.423	0.001	0.001	0.001	0.001	0.001	0.075	0.001	0.001	0.001	0.001	0.001
F2008.092	0.136	0.274	0.032	0.122	0.001	0.105	0.001	0.001	0.001	0.001	0.001
F2008.118	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.364	0.001	0.001	0.001	0.001	0.001	0.091	0.001	0.001	0.001	0.001	0.001
F2002.403	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2009.139	0.001	0.001	0.001	0.001	0.001	0.062	0.001	0.001	0.001	0.001	0.001
F2009.140	0.001	0.001	0.001	0.001	0.001	0.085	0.001	0.001	0.001	0.001	0.001
F2001.760	0.001	0.001	0.001	0.001	0.001	0.173	0.001	0.001	0.001	0.001	0.001
F2002.390	0.001	0.001	0.001	0.001	0.001	0.075	0.001	0.001	0.001	0.001	0.001
F2008.014	0.001	0.001	0.001	0.001	0.001	0.033	0.001	0.001	0.001	0.001	0.001
F2002.429	0.001	0.001	0.001	0.001	0.001	0.106	0.001	0.001	0.001	0.001	0.001
F2008.128	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.767	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1991.013	0.674	1.227	0.179	0.860	0.205	0.224	0.282	0.038	0.233	0.052	0.146
F2002.383	0.001	0.001	0.001	0.001	0.001	0.043	0.001	0.001	0.001	0.001	0.001
F2002.384	0.001	0.001	0.001	0.001	0.001	0.034	0.001	0.001	0.001	0.001	0.001
F2001.697	0.001	0.001	0.001	0.001	0.001	0.038	0.001	0.001	0.001	0.001	0.001
F2008.019	0.001	0.035	0.001	0.001	0.001	0.082	0.001	0.001	0.001	0.001	0.001
F2002.401	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2000.546	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.017	0.036	0.050	0.007	0.028	0.001	0.075	0.001	0.001	0.001	0.001	0.001
F2008.030	0.001	0.054	0.006	0.030	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.777	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2001.691	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.406	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.021	0.001	0.001	0.001	0.001	0.001	0.140	0.001	0.001	0.001	0.001	0.001
F2008.018	0.001	0.030	0.001	0.001	0.001	0.079	0.001	0.001	0.001	0.001	0.001
F2008.040	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.091	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.361	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2003.704	23.905	16.407	3.981	15.119	2.549	0.570	2.747	0.308	1.775	0.353	0.957
F2008.130	0.460	0.855	0.112	0.447	0.086	0.076	0.089	0.001	0.066	0.001	0.001
F2008.131	0.448	0.552	0.103	0.408	0.082	0.044	0.090	0.001	0.071	0.001	0.044
F2008.112	0.001	0.001	0.001	0.001	0.001	0.050	0.001	0.001	0.001	0.001	0.001
F2002.370	0.001	0.001	0.001	0.001	0.001	0.069	0.001	0.001	0.001	0.001	0.001
F2008.035	0.001	0.001	0.001	0.001	0.001	0.032	0.001	0.001	0.001	0.001	0.001
F1993.081	4.716	2.375	0.859	3.419	0.601	0.199	0.621	0.070	0.403	0.085	0.241
F2008.117	0.001	0.001	0.001	0.001	0.001	0.076	0.001	0.001	0.001	0.001	0.001
F2001.757	0.001	0.001	0.001	0.001	0.001	0.036	0.001	0.001	0.001	0.001	0.001
F2002.397	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.366	0.001	0.001	0.001	0.001	0.001	0.057	0.001	0.001	0.001	0.001	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
F2002.423	0.001	0.001	0.001	0.001	0.001	0.001	0.194	0.001	0.001
F2008.092	0.001	0.001	0.001	0.035	0.059	0.001	0.168	0.065	0.001
F2008.118	0.001	0.001	0.001	0.001	0.027	0.001	0.507	0.012	0.001
F2002.364	0.001	0.001	0.001	0.001	0.001	0.001	0.302	0.001	0.043
F2002.403	0.001	0.001	0.001	0.001	0.001	0.001	0.349	0.001	0.001
F2009.139	0.001	0.001	0.001	0.028	0.046	0.001	0.154	0.058	0.001
F2009.140	0.001	0.001	0.001	0.035	0.030	0.001	0.125	0.046	0.001
F2001.760	0.001	0.001	0.001	0.196	0.068	0.001	1.060	0.278	0.001
F2002.390	0.001	0.001	0.001	0.028	0.001	0.001	1.260	0.001	0.039
F2008.014	0.001	0.001	0.001	0.091	0.136	0.001	0.287	0.107	0.001
F2002.429	0.001	0.001	0.001	0.001	0.001	0.001	0.965	0.001	0.001
F2008.128	0.001	0.001	0.001	0.001	0.028	0.001	0.690	0.001	0.001
F2001.767	0.001	0.001	0.001	0.080	0.001	0.001	0.114	0.001	0.001
F1991.013	0.020	0.129	0.001	0.196	0.066	0.001	0.344	0.103	1.856
F2002.383	0.001	0.001	0.001	0.046	0.001	0.001	0.192	0.001	0.001
F2002.384	0.001	0.001	0.001	0.028	0.001	0.001	0.232	0.001	0.001
F2001.697	0.001	0.001	0.001	0.044	0.011	0.001	0.239	0.001	0.001
F2008.019	0.001	0.001	0.001	0.001	0.029	0.001	0.272	0.001	0.001
F2002.401	0.001	0.001	0.001	0.001	0.001	0.001	0.186	0.001	0.132
F2000.546	0.001	0.001	0.001	0.049	0.025	0.001	0.068	0.037	0.082
F2008.017	0.001	0.001	0.001	0.001	0.033	0.001	0.135	0.010	0.001
F2008.030	0.001	0.001	0.001	0.001	0.038	0.001	0.074	0.018	0.001
F2001.777	0.001	0.001	0.001	0.059	0.001	0.001	0.999	0.001	0.001
F2001.691	0.001	0.001	0.001	0.041	0.013	0.001	0.079	0.001	0.001
F2002.406	0.001	0.001	0.001	0.465	0.001	0.001	0.751	0.001	0.082
F2008.021	0.001	0.001	0.001	0.030	0.030	0.001	0.278	0.001	0.001
F2008.018	0.001	0.001	0.001	0.001	0.030	0.001	0.185	0.010	0.001
F2008.040	0.001	0.001	0.001	0.001	0.046	0.001	0.080	0.001	0.001
F2008.091	0.001	0.001	0.001	0.077	0.161	0.001	0.133	0.051	0.001
F2002.361	0.001	0.001	0.001	0.001	0.001	0.001	0.730	0.001	0.001
F2003.704	0.123	0.779	0.116	0.001	0.001	0.055	1.604	0.820	3.079
F2008.130	0.001	0.001	0.001	0.001	0.029	0.001	0.351	0.079	1.127
F2008.131	0.001	0.001	0.001	0.039	0.094	0.001	0.125	0.166	9.717
F2008.112	0.001	0.001	0.001	0.001	0.026	0.001	0.489	0.001	0.001
F2002.370	0.001	0.001	0.001	0.057	0.001	0.001	0.230	0.001	0.001
F2008.035	0.001	0.001	0.001	0.029	0.039	0.001	0.395	0.013	0.001
F1993.081	0.034	0.230	0.038	0.058	0.015	0.001	0.367	0.191	16.881
F2008.117	0.001	0.001	0.001	0.024	0.030	0.001	0.097	0.014	0.001
F2001.757	0.001	0.001	0.001	0.038	0.001	0.001	1.211	0.001	0.001
F2002.397	0.001	0.001	0.001	0.033	0.001	0.001	0.298	0.001	0.001
F2002.366	0.001	0.001	0.001	0.162	0.001	0.001	0.129	0.001	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	$^{87}Sr/^{86}Sr$	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
F2002.360	0.710970	0.001	6419.6	4302.0	10.663	132972.2	232301.2	1.906	0.164	1.220	1626.6
F2008.122	0.711013	1.318	4116.6	2427.0	20.434	138758.3	337015.0	3.907	1.652	0.666	2351.1
F2008.039	0.711055	0.567	3513.2	2743.5	14.301	116396.6	196926.6	2.963	1.418	1.020	2068.6
F2008.086	0.711122	5.414	4488.6	3039.6	3.598	125969.1	301174.3	2.533	1.119	0.717	1812.4
F2008.020	0.711124	1.737	7401.8	3243.8	10.159	188545.4	398705.8	4.712	1.613	1.275	4920.3
F2008.069	0.711171	0.365	2280.8	3646.2	351.225	133508.1	237639.8	16.012	2.224	1.547	2472.2
F2002.396	0.711280	0.001	4158.1	5098.0	7.250	117179.4	192863.8	1.816	0.446	1.599	1554.7
F2002.409	0.711370	0.001	2234.8	5399.9	30.730	118160.3	209198.9	1.843	0.823	0.986	1660.9
F2000.547	0.711410	0.001	1632.2	1723.6	78.483	114022.8	176811.5	3.599	0.254	1.405	1783.0
F1991.109	0.711630	1.207	2412.2	1468.5	982.581	118753.2	264828.5	25.884	9.483	3.790	3028.1
F1991.104	0.711760	0.854	2642.8	1878.1	314.556	122778.4	260455.4	8.990	4.646	1.369	2288.8
F1993.079	0.711830	1.098	1459.9	1587.1	306.625	126588.4	280326.1	10.884	6.894	5.320	2870.9
F2008.105	0.712162	1.401	7117.8	5809.0	6.738	149992.0	223564.3	2.172	1.194	0.529	1314.3
F1991.108	0.712180	0.902	2400.6	1734.3	672.867	124767.6	271214.4	20.967	7.776	2.601	2800.3
F2000.230	0.712200	0.404	2413.5	2439.6	561.740	145012.1	241864.6	36.691	1.500	1.793	2857.5
F2008.057	0.712423	0.001	3816.1	3965.2	145.025	137620.9	221093.9	5.600	1.225	0.754	2098.2
F2000.229	0.712540	0.001	1740.4	2211.9	11.228	130027.5	182237.8	1.698	0.128	1.066	1660.8
F2008.074	0.713391	0.480	1625.4	2084.8	623.894	118056.2	203773.0	20.257	2.366	1.599	2444.4
F2008.085	0.714851	1.406	5145.1	4739.8	12.169	133254.9	220141.5	3.040	1.609	0.725	2349.4
F2008.061	0.714852	0.481	2067.5	3181.3	400.308	124978.5	230578.7	18.993	2.270	1.739	2399.0
F1993.151	0.715020	1.556	2231.1	1138.6	76.431	123479.8	280497.5	5.490	2.609	2.739	2495.0
F2008.129	0.715576	0.317	4245.6	5587.3	35.663	137188.0	205520.3	3.278	1.757	2.142	2573.8
F1993.094	0.716800	1.177	1406.8	1142.9	223.029	134241.9	280159.6	6.324	2.628	3.369	2670.4
F2008.070	0.718725	0.361	2150.9	2770.4	534.728	128270.3	246748.6	27.158	2.548	1.853	2822.6
F2008.080	0.719088	1.235	2202.9	3013.4	547.527	101172.9	229547.7	43.300	3.796	2.162	2169.7
F2008.068	0.719449	0.931	2420.4	2719.9	493.739	119035.5	237821.4	6.651	1.239	1.326	1422.5
F2008.076	0.720703	0.537	2102.0	2960.5	119.591	109879.7	233249.8	8.002	1.770	0.975	1508.9
F2008.075	0.720794	0.358	2217.1	3225.7	539.863	124619.0	258768.5	22.610	2.714	1.472	2996.1
F2008.065	0.721118	1.132	2260.3	2913.5	352.433	108508.4	215043.5	26.478	1.684	1.592	1532.6
F2008.072	0.722528	0.001	4023.0	2484.0	75.948	94335.0	189140.6	8.340	1.309	0.640	1183.1
F2008.071	0.722575	1.043	2188.2	3016.8	320.553	110874.8	219818.3	16.529	1.765	0.869	1471.4
F2001.707	0.728290	1.851	2200.8	1187.0	27.506	105756.6	244721.4	3.174	2.786	0.690	2314.5
F1991.054	0.731420	1.138	1940.2	1084.6	145.841	114521.0	235484.6	2.658	10.899	2.473	1972.5
F2008.056	0.734373	1.578	2855.7	4079.1	28.689	114959.8	215326.4	2.356	0.722	0.695	1002.4
F2008.089	0.739337	3.599	4927.7	2027.0	7.945	164000.0	349110.0	2.927	0.607	0.510	2145.6
F1998.238	0.743300	1.785	2378.2	1997.2	720.493	113958.6	236471.8	16.545	1.079	2.008	2916.8
F2008.051	0.746144	1.098	2554.1	4103.6	76.956	112435.0	173592.8	4.488	1.169	1.102	1908.7
F1993.098	0.708570	0.001	2093.9	2030.9	34.948	98310.5	183914.8	1.461	0.276	1.028	1616.8
F1993.100	0.708580	0.001	3126.1	2710.7	130.729	121742.3	230785.5	1.508	0.535	0.706	1943.5
F1993.101	0.708580	0.001	3565.6	2606.2	19.259	126206.6	264372.2	1.594	0.580	0.792	2236.0
F1997.068	0.713290	0.001	2336.4	2279.4	51.186	87918.0	190215.2	4.579	0.203	1.170	1762.9
F1997.059	0.713730	0.393	2303.1	2254.9	110.614	118538.6	245679.7	9.906	0.350	1.079	2219.4

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
F2002.360	2.733	0.110	0.001	0.058	110.707	0.532	0.117	0.439	0.139	43.395	0.001
F2008.122	17.303	0.366	4.724	0.379	62.519	1.042	1.763	6.772	0.078	355.878	0.042
F2008.039	4.524	0.437	6.245	0.363	65.268	1.056	0.934	3.508	0.054	392.176	0.001
F2008.086	10.420	0.195	0.254	0.267	60.321	0.896	1.444	5.832	0.242	291.289	0.001
F2008.020	2.353	1.223	19.865	0.295	48.959	2.342	1.780	6.052	0.120	240.249	0.001
F2008.069	49.587	0.698	6.231	0.886	153.375	1.112	1.306	4.283	0.597	354.856	0.001
F2002.396	1.082	0.164	0.001	4.773	247.779	0.549	0.247	1.137	0.268	147.171	0.001
F2002.409	76.768	0.204	0.001	5.218	205.024	0.613	0.210	0.886	0.056	391.515	0.001
F2000.547	25.409	0.398	3.076	0.651	89.107	0.769	0.190	0.958	0.289	199.009	0.001
F1991.109	255.930	2.130	13.321	6.840	58.948	1.095	0.287	1.255	0.472	659.098	5.045
F1991.104	29.045	1.068	4.707	1.475	73.778	0.903	0.202	1.032	0.306	426.485	2.300
F1993.079	368.308	3.626	22.497	6.824	66.276	1.024	0.710	1.746	0.125	627.503	7.717
F2008.105	3.733	0.150	0.468	0.295	71.344	0.676	1.078	3.993	0.001	277.354	0.001
F1991.108	74.736	1.212	8.458	2.716	78.745	1.008	0.189	0.818	0.529	471.107	2.366
F2000.230	61.505	0.806	4.734	0.840	219.674	1.142	0.148	0.500	0.985	214.165	0.352
F2008.057	34.207	0.460	5.418	0.551	300.564	0.983	0.841	2.847	0.177	162.647	0.001
F2000.229	4.548	0.321	2.753	0.958	270.984	0.822	0.158	0.864	0.001	191.426	0.001
F2008.074	44.803	0.750	6.529	0.943	159.437	1.172	0.862	2.684	1.061	180.827	0.001
F2008.085	7.558	0.502	6.848	0.420	90.748	1.169	1.219	4.303	0.185	255.430	0.001
F2008.061	262.822	0.905	6.549	0.830	117.111	1.033	1.292	4.300	0.880	493.693	0.031
F1993.151	251.106	0.742	3.855	2.331	117.645	0.958	0.451	0.620	0.078	399.135	0.179
F2008.129	20.151	0.584	6.976	1.605	221.412	1.087	1.063	3.837	0.211	132.762	0.001
F1993.094	10.311	0.679	9.982	5.220	96.768	1.025	0.285	1.481	0.147	319.934	0.059
F2008.070	47.580	0.879	7.499	1.038	209.313	1.237	1.173	3.787	0.931	199.848	0.001
F2008.080	26.430	0.549	0.234	1.807	214.602	0.882	1.542	5.442	1.531	285.785	0.104
F2008.068	58.704	0.855	0.001	1.023	216.198	0.738	0.879	3.339	0.347	286.237	0.001
F2008.076	47.706	0.225	0.001	0.690	317.295	0.701	1.446	5.507	0.278	274.152	0.025
F2008.075	184.089	1.073	8.596	0.880	364.558	1.276	1.352	4.449	0.670	236.778	0.054
F2008.065	51.062	0.325	0.001	0.786	233.127	0.724	0.855	2.998	1.332	194.172	0.001
F2008.072	7.612	0.119	0.001	0.755	266.219	0.531	1.016	3.937	0.272	135.292	0.023
F2008.071	161.593	0.385	0.001	1.406	296.499	0.703	1.124	4.291	0.737	193.025	0.075
F2001.707	60.895	0.867	2.179	7.407	74.023	0.876	0.663	0.669	0.093	468.495	0.001
F1991.054	151.155	1.596	12.706	9.031	54.759	0.794	1.247	1.250	0.076	408.692	0.001
F2008.056	27.346	0.064	0.001	0.648	232.932	0.610	0.881	3.374	0.183	153.546	0.001
F2008.089	3.750	0.279	0.942	0.465	43.257	0.992	0.680	2.695	0.179	340.248	0.001
F1998.238	52.415	0.886	4.626	1.384	255.519	1.032	0.267	0.651	0.795	85.078	1.090
F2008.051	10.416	0.437	5.721	0.586	74.453	0.998	0.623	2.346	0.154	161.827	0.001
F1993.098	7.328	0.287	2.103	0.437	143.610	0.667	0.172	0.914	0.050	86.687	0.001
F1993.100	5.851	0.339	2.325	0.491	168.610	0.887	0.123	0.755	0.040	182.475	0.001
F1993.101	1.519	0.413	3.122	0.645	156.862	0.922	0.096	0.608	0.100	188.457	0.001
F1997.068	11.663	0.383	2.370	1.403	242.743	0.661	0.105	0.608	0.205	205.284	0.079
F1997.059	29.909	0.446	2.630	1.454	272.010	0.902	0.121	0.719	0.230	207.537	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	**Zr**	**Nb**	**Mo**	**Ru**	**Pd**	**Ag**	**Cd**	**Sn**	**Sb**	**Cs**	**Ba**
F2002.360	0.001	0.001	0.001	0.001	0.010	0.001	0.001	0.001	0.001	0.001	26.193
F2008.122	0.001	0.001	4.129	0.109	0.013	0.001	0.001	0.001	0.001	0.001	303.335
F2008.039	0.124	0.064	0.194	0.082	0.023	0.019	0.001	0.001	0.001	0.001	74.250
F2008.086	0.001	0.001	0.115	0.070	0.010	0.001	0.001	0.001	0.043	0.001	234.625
F2008.020	0.001	0.001	1.556	0.185	0.017	0.001	0.001	0.001	0.001	0.001	133.602
F2008.069	0.001	0.065	0.107	0.079	0.012	0.023	0.001	0.001	0.012	0.020	101.317
F2002.396	0.001	0.001	0.080	0.001	0.012	0.025	0.001	0.001	0.001	0.001	34.731
F2002.409	0.001	0.001	0.073	0.021	0.012	0.001	0.076	0.001	0.001	0.001	45.136
F2000.547	0.001	0.001	0.001	0.001	0.011	0.001	0.001	0.001	0.042	0.001	6.967
F1991.109	0.737	0.049	0.264	0.092	0.067	0.061	0.586	0.001	0.026	0.030	459.954
F1991.104	0.191	0.001	0.127	0.066	0.027	0.001	0.154	0.076	0.001	0.001	321.552
F1993.079	2.095	0.087	0.127	0.085	0.133	0.023	0.330	0.001	0.095	0.001	321.565
F2008.105	0.001	0.001	0.070	0.042	0.027	0.001	0.001	0.001	0.001	0.001	259.330
F1991.108	0.380	0.046	0.254	0.074	0.039	0.014	0.323	0.069	0.015	0.023	450.633
F2000.230	0.225	0.082	0.301	0.033	0.025	0.018	0.001	0.001	0.001	0.040	227.717
F2008.057	0.001	0.001	0.161	0.042	0.013	0.001	0.001	0.001	0.001	0.001	87.359
F2000.229	0.173	0.117	0.180	0.001	0.027	0.032	0.001	0.137	0.022	0.001	101.507
F2008.074	0.001	0.093	0.057	0.033	0.010	0.012	0.001	0.001	0.018	0.045	146.252
F2008.085	0.001	0.001	0.043	0.059	0.011	0.001	0.001	0.001	0.001	0.001	382.930
F2008.061	0.001	0.095	0.435	0.109	0.015	0.001	0.072	0.001	0.020	0.034	705.023
F1993.151	0.623	0.001	0.743	0.078	0.035	0.001	0.001	0.001	0.025	0.001	487.168
F2008.129	0.141	0.108	0.194	0.031	0.039	0.031	0.001	0.157	0.082	0.001	121.388
F1993.094	0.198	0.160	0.073	0.053	0.029	0.038	0.133	0.123	0.046	0.001	274.765
F2008.070	0.001	0.095	0.059	0.069	0.013	0.001	0.001	0.001	0.022	0.040	125.765
F2008.080	0.001	0.165	0.111	0.061	0.013	0.022	0.001	0.001	0.021	0.062	217.417
F2008.068	0.001	0.054	0.057	0.042	0.013	0.010	0.102	0.001	0.034	0.022	217.136
F2008.076	0.001	0.001	0.082	0.064	0.013	0.001	0.001	0.001	0.025	0.001	162.137
F2008.075	0.001	0.068	0.074	0.094	0.015	0.020	0.068	0.001	0.020	0.024	148.498
F2008.065	0.001	0.211	0.071	0.031	0.019	0.018	0.001	0.001	0.044	0.059	196.328
F2008.072	0.001	0.044	0.063	0.034	0.014	0.001	0.001	0.001	0.001	0.001	159.530
F2008.071	0.142	0.121	0.080	0.048	0.027	0.019	0.081	0.063	0.026	0.032	209.779
F2001.707	0.001	0.001	6.325	0.072	0.001	0.001	0.001	0.001	0.028	0.001	286.463
F1991.054	0.001	0.069	0.059	0.038	0.015	0.052	0.064	0.001	0.089	0.001	165.636
F2008.056	0.001	0.103	0.070	0.017	0.028	0.019	0.001	0.001	0.060	0.001	67.787
F2008.089	0.001	0.047	0.117	0.087	0.024	0.018	0.001	0.001	0.001	0.001	295.704
F1998.238	0.890	0.042	0.175	0.022	0.047	0.001	0.001	0.001	0.029	0.090	92.771
F2008.051	0.001	0.040	0.063	0.033	0.011	0.001	0.001	0.001	0.001	0.001	373.515
F1993.098	0.001	0.001	0.053	0.001	0.013	0.010	0.001	0.068	0.001	0.001	6.552
F1993.100	0.001	0.001	0.024	0.019	0.001	0.001	0.001	0.001	0.001	0.001	13.258
F1993.101	0.001	0.001	0.289	0.037	0.012	0.001	0.001	0.001	0.001	0.001	16.741
F1997.068	0.001	0.001	0.224	0.001	0.014	0.014	0.129	0.062	0.115	0.001	139.957
F1997.059	0.001	0.001	0.443	0.022	0.001	0.011	0.177	0.001	0.024	0.001	115.276

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
F2002.360	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.122	0.047	0.074	0.011	0.044	0.001	0.104	0.001	0.001	0.001	0.001	0.001
F2008.039	0.001	0.001	0.001	0.001	0.001	0.037	0.001	0.001	0.001	0.001	0.001
F2008.086	0.001	0.001	0.001	0.001	0.001	0.072	0.001	0.001	0.001	0.001	0.001
F2008.020	0.001	0.001	0.001	0.001	0.001	0.096	0.001	0.001	0.001	0.001	0.001
F2008.069	0.036	0.001	0.001	0.001	0.001	0.055	0.001	0.001	0.001	0.001	0.001
F2002.396	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2002.409	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2000.547	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1991.109	2.241	3.074	0.486	2.256	0.542	0.345	0.789	0.112	0.764	0.172	0.510
F1991.104	0.837	0.813	0.201	0.969	0.224	0.186	0.311	0.041	0.265	0.060	0.174
F1993.079	17.348	7.521	2.887	10.899	1.814	0.439	1.903	0.207	1.171	0.239	0.682
F2008.105	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1991.108	1.324	1.563	0.265	1.215	0.282	0.253	0.394	0.053	0.334	0.077	0.225
F2000.230	1.010	1.715	0.172	0.642	0.113	0.112	0.095	0.001	0.057	0.001	0.032
F2008.057	0.001	0.001	0.001	0.001	0.001	0.045	0.001	0.001	0.001	0.001	0.001
F2000.229	0.001	0.001	0.001	0.001	0.001	0.041	0.001	0.001	0.001	0.001	0.001
F2008.074	0.057	0.001	0.001	0.001	0.001	0.082	0.001	0.001	0.001	0.001	0.001
F2008.085	0.001	0.001	0.001	0.001	0.001	0.207	0.001	0.001	0.001	0.001	0.001
F2008.061	0.166	0.084	0.005	0.001	0.001	0.365	0.001	0.001	0.001	0.001	0.001
F1993.151	0.145	0.306	0.030	0.121	0.001	0.203	0.034	0.001	0.001	0.001	0.001
F2008.129	0.001	0.001	0.001	0.001	0.001	0.068	0.001	0.001	0.001	0.001	0.001
F1993.094	0.442	0.151	0.013	0.038	0.001	0.111	0.001	0.001	0.001	0.001	0.001
F2008.070	0.096	0.051	0.001	0.001	0.001	0.070	0.001	0.001	0.001	0.001	0.001
F2008.080	0.462	0.384	0.033	0.094	0.001	0.067	0.001	0.001	0.001	0.001	0.001
F2008.068	0.170	0.083	0.001	0.001	0.001	0.059	0.001	0.001	0.001	0.001	0.001
F2008.076	0.180	0.152	0.009	0.001	0.001	0.046	0.001	0.001	0.001	0.001	0.001
F2008.075	0.620	0.494	0.030	0.072	0.001	0.087	0.001	0.001	0.001	0.001	0.001
F2008.065	0.142	0.063	0.001	0.001	0.001	0.052	0.001	0.001	0.001	0.001	0.001
F2008.072	0.059	0.067	0.008	0.031	0.001	0.048	0.001	0.001	0.001	0.001	0.001
F2008.071	0.200	0.251	0.025	0.087	0.018	0.060	0.001	0.001	0.001	0.001	0.001
F2001.707	0.033	0.001	0.001	0.001	0.001	0.110	0.001	0.001	0.001	0.001	0.001
F1991.054	0.184	0.001	0.001	0.001	0.001	0.057	0.001	0.001	0.001	0.001	0.001
F2008.056	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F2008.089	0.001	0.001	0.001	0.001	0.001	0.092	0.001	0.001	0.001	0.001	0.001
F1998.238	2.023	2.615	0.437	1.691	0.315	0.093	0.311	0.035	0.192	0.036	0.102
F2008.051	0.001	0.001	0.001	0.001	0.001	0.194	0.001	0.001	0.001	0.001	0.001
F1993.098	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1993.100	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1993.101	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F1997.068	0.088	0.156	0.017	0.064	0.001	0.057	0.001	0.001	0.001	0.001	0.001
F1997.059	0.064	0.068	0.006	0.001	0.001	0.042	0.001	0.001	0.001	0.001	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
F2002.360	0.001	0.001	0.001	0.001	0.001	0.001	0.085	0.001	0.001
F2008.122	0.001	0.001	0.001	0.001	0.032	0.001	0.267	0.001	0.001
F2008.039	0.001	0.001	0.001	0.129	0.073	0.001	0.307	0.042	0.001
F2008.086	0.001	0.001	0.001	0.001	0.028	0.001	0.727	0.001	0.001
F2008.020	0.001	0.001	0.001	0.024	0.033	0.001	0.192	0.001	0.001
F2008.069	0.001	0.001	0.001	0.001	0.039	0.001	0.606	0.001	0.047
F2002.396	0.001	0.001	0.001	0.026	0.001	0.001	0.333	0.001	0.001
F2002.409	0.001	0.001	0.001	0.055	0.001	0.001	0.193	0.001	0.032
F2000.547	0.001	0.001	0.001	0.109	0.032	0.001	0.355	0.046	0.040
F1991.109	0.073	0.463	0.074	0.001	0.022	0.001	0.317	0.066	17.276
F1991.104	0.023	0.140	0.023	0.091	0.029	0.001	0.112	0.037	1.102
F1993.079	0.091	0.592	0.090	0.028	0.017	0.001	0.689	0.325	12.098
F2008.105	0.001	0.001	0.001	0.035	0.098	0.001	0.240	0.001	0.063
F1991.108	0.031	0.192	0.031	0.061	0.022	0.001	0.209	0.052	3.356
F2000.230	0.001	0.025	0.001	0.105	0.036	0.001	0.674	0.231	0.032
F2008.057	0.001	0.001	0.001	0.029	0.043	0.001	3.560	0.011	0.033
F2000.229	0.001	0.001	0.001	0.239	0.093	0.001	0.135	0.281	0.040
F2008.074	0.001	0.001	0.001	0.021	0.029	0.001	0.928	0.001	0.001
F2008.085	0.001	0.001	0.001	0.059	0.050	0.001	0.208	0.010	0.001
F2008.061	0.001	0.001	0.001	0.037	0.046	0.001	0.358	0.010	0.001
F1993.151	0.001	0.001	0.001	0.070	0.016	0.001	0.130	0.039	6.448
F2008.129	0.001	0.001	0.001	0.218	0.179	0.058	0.296	0.205	0.001
F1993.094	0.001	0.001	0.001	0.216	0.075	0.001	0.200	0.268	11.952
F2008.070	0.001	0.001	0.001	0.025	0.034	0.001	0.843	0.001	0.001
F2008.080	0.001	0.001	0.001	0.021	0.033	0.001	0.361	0.016	0.074
F2008.068	0.001	0.001	0.001	0.026	0.043	0.001	1.077	0.021	0.001
F2008.076	0.001	0.001	0.001	0.001	0.036	0.001	0.631	0.015	0.038
F2008.075	0.001	0.001	0.001	0.001	0.030	0.001	1.126	0.001	0.068
F2008.065	0.001	0.001	0.001	0.073	0.064	0.001	0.517	0.056	0.033
F2008.072	0.001	0.001	0.001	0.050	0.045	0.001	0.697	0.045	0.001
F2008.071	0.001	0.001	0.001	0.073	0.078	0.001	0.844	0.121	0.001
F2001.707	0.001	0.001	0.001	0.046	0.001	0.001	0.075	0.001	0.418
F1991.054	0.001	0.001	0.001	0.062	0.050	0.001	0.501	0.016	0.404
F2008.056	0.001	0.001	0.001	0.058	0.090	0.001	0.373	0.078	0.001
F2008.089	0.001	0.001	0.001	0.045	0.078	0.001	0.132	0.115	0.001
F1998.238	0.013	0.079	0.001	0.055	0.001	0.001	0.982	0.240	0.881
F2008.051	0.001	0.001	0.001	0.106	0.051	0.001	0.348	0.023	0.001
F1993.098	0.001	0.001	0.001	0.183	0.048	0.001	3.106	0.101	0.001
F1993.100	0.001	0.001	0.001	0.053	0.024	0.001	0.188	0.028	0.001
F1993.101	0.001	0.001	0.001	0.092	0.021	0.001	2.955	0.033	0.001
F1997.068	0.001	0.001	0.001	0.077	0.020	0.001	0.658	0.018	0.039
F1997.059	0.001	0.001	0.001	0.079	0.121	0.001	2.741	0.020	0.042

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Water

Sample ID	$^{87}Sr/^{86}Sr$	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
W2009.023	0.708508	0.021	4.9	21.4	0.009	0.5	54.9	0.003	0.002	0.006	0.3
W2009.034	0.708692	0.038	11.6	29.4	0.005	0.4	77.8	0.005	0.003	0.006	0.4
W2009.055	0.709166	0.012	51.7	15.1	0.027	0.4	40.2	0.002	0.002	0.006	0.3
W2009.056	0.708926	0.013	22.4	14.9	0.009	0.4	39.7	0.002	0.002	0.006	0.2
W2009.057	0.708852	0.027	23.6	21.5	0.009	0.4	50.6	0.003	0.002	0.006	0.3
W2009.078	0.708360	0.008	6.0	15.9	0.027	0.5	53.1	0.002	0.003	0.006	0.6
W2009.079	0.708485	0.019	309.6	20.8	0.009	0.4	58.6	0.004	0.007	0.006	0.3
W2009.086	0.708653	0.017	14.4	20.0	0.009	0.5	48.9	0.002	0.003	0.006	0.2
W2009.099	0.708143	0.008	6.9	18.1	0.010	0.5	65.1	0.002	0.004	0.005	0.3
W2009.112	0.708409	0.005	4.7	12.5	0.010	0.6	54.5	0.001	0.003	0.006	0.3
W2009.119	0.708305	0.004	3.4	9.8	0.007	0.5	63.3	0.001	0.003	0.005	0.3
W2009.120	0.708550	0.004	3.2	10.8	0.016	0.5	50.9	0.001	0.003	0.006	0.2
W2009.141	0.708145	0.005	4.3	11.2	0.010	0.5	67.3	0.002	0.003	0.008	0.3
W2009.142	0.708222	0.005	4.2	12.2	0.009	0.5	59.0	0.002	0.003	0.005	0.3
W2009.161	0.708729	0.010	4.0	14.3	0.009	0.5	52.8	0.002	0.003	0.006	0.2
W2009.168	0.708816	0.016	11.6	17.2	0.006	0.4	48.3	0.002	0.002	0.007	1.8
W2009.207	0.710194	0.002	2.6	7.5	0.029	0.5	23.2	0.001	0.002	0.006	0.2
W2009.208	0.709803	0.001	1.3	2.0	0.034	0.4	7.7	0.001	0.001	0.008	0.1
W2009.215	0.710130	0.001	1.3	4.3	0.032	0.5	10.9	0.001	0.001	0.005	0.1
W2009.216	0.709274	0.002	2.4	5.3	0.033	0.5	24.4	0.001	0.001	0.001	0.1
W2009.229	0.709900	0.001	1.7	3.7	0.058	0.4	17.7	0.001	0.001	0.001	0.1
W2009.236	0.708856	0.003	2.6	7.1	0.020	0.5	31.3	0.001	0.002	0.001	0.1
W2009.248	0.712292	0.001	1.4	3.7	0.015	0.5	16.9	0.001	0.001	0.001	0.1
W2009.261	0.710705	<DL	3.4	7.5	0.011	0.5	19.8	0.001	0.001	0.001	0.1
W2009.265	0.713728	0.000	0.9	9.5	0.009	0.5	31.9	0.001	0.001	0.001	0.1
W2009.269	0.709777	0.001	0.8	3.7	0.027	0.5	11.0	0.001	0.001	0.001	0.1
W2009.273	0.709639	0.001	0.8	5.5	0.023	0.5	17.6	0.001	0.001	0.001	0.1
W2009.280	0.707106	0.001	1.0	5.8	0.018	0.5	20.6	0.001	0.001	0.001	0.1
W2009.284	0.708778	0.001	0.8	5.9	0.018	0.5	24.8	0.001	0.001	0.001	0.1
W2009.289	0.707332	0.005	3.3	12.5	0.012	0.5	41.0	0.001	0.001	0.001	0.1
W2009.290	0.708622	0.002	1.1	7.2	0.016	0.6	29.1	0.001	0.001	0.001	0.1
W2009.297	0.709827	0.002	1.2	7.0	0.029	0.5	35.8	0.001	0.001	0.001	0.1
W2009.304	0.709100	0.003	1.8	5.6	0.027	0.5	39.7	0.001	0.001	0.002	0.1
W2009.311	0.709145	0.007	1.6	5.5	0.017	0.5	31.4	0.001	0.001	0.003	0.1
W2009.318	0.708823	0.003	1.6	7.4	0.020	0.5	37.5	0.001	0.001	0.001	0.1
W2009.325	0.709610	0.002	1.8	5.5	0.030	0.5	28.5	0.001	0.000	0.001	0.1
W2009.329	0.709181	0.003	1.0	11.3	0.018	0.5	36.5	0.001	0.001	0.001	0.1
W2009.339	0.708783	0.002	3.6	9.5	0.018	0.6	28.6	0.001	0.001	0.001	0.2
W2009.349	0.712939	0.002	3.5	4.8	0.056	0.6	12.9	0.001	0.000	0.001	0.1
W2009.356	0.709540	0.001	1.5	2.7	0.068	0.6	20.4	0.001	0.000	0.001	0.1
W2009.357	0.708816	0.007	3.9	7.4	0.065	0.6	34.5	0.001	0.001	0.001	0.1

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
W2009.023	0.002	0.000	0.002	0.002	0.013	<DL	0.001	0.002	0.000	1.127	0.000
W2009.034	0.014	0.000	0.002	0.001	0.012	<DL	0.001	0.002	0.000	2.320	0.000
W2009.055	0.002	0.000	0.002	0.002	0.006	<DL	0.001	0.002	0.000	0.662	0.000
W2009.056	0.002	0.000	0.002	0.001	0.006	<DL	0.001	0.002	0.000	0.833	<DL
W2009.057	0.004	0.000	0.002	0.001	0.006	<DL	0.001	0.002	0.000	1.018	<DL
W2009.078	0.006	0.000	0.003	0.001	0.005	<DL	0.001	0.002	0.000	0.607	0.000
W2009.079	0.002	0.000	0.002	0.002	0.006	<DL	0.003	0.009	0.001	0.699	0.000
W2009.086	0.003	0.000	0.002	0.001	0.005	<DL	0.001	0.001	0.000	0.982	0.000
W2009.099	0.001	0.000	0.002	0.001	0.005	<DL	0.001	0.002	0.000	0.904	0.000
W2009.112	0.007	0.000	0.002	0.001	0.003	<DL	0.001	0.002	0.000	0.382	0.000
W2009.119	0.006	0.000	0.002	0.011	0.009	<DL	0.001	0.002	0.000	0.364	0.000
W2009.120	0.004	0.000	0.002	0.001	0.005	<DL	0.001	0.002	0.000	0.283	0.000
W2009.141	0.002	0.000	0.002	0.001	0.005	<DL	0.001	0.002	0.000	0.581	0.000
W2009.142	0.002	0.000	0.002	0.001	0.004	<DL	0.001	0.002	0.000	0.523	0.000
W2009.161	0.005	0.000	0.002	0.001	0.003	<DL	0.001	0.002	0.000	0.337	0.000
W2009.168	0.010	0.000	0.003	0.003	0.007	<DL	0.001	0.001	0.000	1.054	<DL
W2009.207	0.008	0.000	0.003	0.002	0.003	<DL	0.000	0.000	0.000	0.204	0.000
W2009.208	0.001	0.000	0.003	0.001	0.002	<DL	0.000	<DL	0.001	0.049	0.000
W2009.215	0.004	0.000	0.002	0.001	0.002	<DL	0.000	0.000	0.000	0.043	0.000
W2009.216	0.001	0.000	0.001	0.001	0.002	<DL	0.000	0.000	0.001	0.123	0.000
W2009.229	0.002	0.000	0.001	0.001	0.003	<DL	0.000	<DL	0.001	0.080	0.000
W2009.236	0.006	0.000	0.001	0.001	0.002	<DL	0.000	0.001	0.001	0.184	<DL
W2009.248	0.001	0.000	0.000	0.000	0.002	<DL	0.000	<DL	0.000	0.072	<DL
W2009.261	0.005	0.000	0.002	0.001	0.003	<DL	0.000	0.000	0.000	0.048	<DL
W2009.265	0.004	0.000	0.002	0.001	0.003	<DL	0.000	<DL	0.000	0.092	<DL
W2009.269	0.003	0.000	0.001	0.001	0.002	<DL	0.000	<DL	0.000	0.034	0.000
W2009.273	0.002	<DL	0.001	0.001	0.002	<DL	0.000	0.000	0.000	0.056	0.000
W2009.280	0.001	<DL	0.001	0.001	0.002	<DL	0.000	<DL	0.002	0.175	0.000
W2009.284	0.001	0.000	0.001	0.001	0.002	<DL	0.000	0.000	0.001	0.096	0.000
W2009.289	0.001	<DL	0.000	0.001	0.002	<DL	0.000	0.001	0.001	0.211	0.000
W2009.290	0.001	0.000	0.001	0.001	0.002	<DL	0.000	<DL	0.001	0.120	<DL
W2009.297	0.001	0.000	0.001	0.002	0.003	<DL	0.000	0.001	0.002	0.121	0.000
W2009.304	0.001	0.000	0.004	0.001	0.004	<DL	0.000	0.001	0.002	0.164	0.000
W2009.311	0.001	0.000	0.001	0.001	0.002	<DL	0.000	0.001	0.001	0.232	0.000
W2009.318	0.001	0.000	0.001	0.001	0.002	<DL	0.000	0.001	0.002	0.151	<DL
W2009.325	0.001	0.000	0.002	0.001	0.005	<DL	0.000	<DL	0.002	0.125	0.000
W2009.329	0.001	0.000	0.000	0.000	0.003	<DL	0.000	0.000	0.002	0.300	0.000
W2009.339	0.009	0.000	0.001	0.000	0.003	<DL	0.000	0.000	0.001	0.220	<DL
W2009.349	0.028	0.000	0.002	0.001	0.003	<DL	0.000	<DL	0.001	0.063	0.000
W2009.356	0.002	0.000	0.001	0.001	0.003	<DL	0.000	<DL	0.001	0.068	0.000
W2009.357	0.004	<DL	0.001	0.001	0.003	<DL	0.000	0.000	0.002	0.184	0.000

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
W2009.023	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.020
W2009.034	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.031
W2009.055	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.018
W2009.056	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.030
W2009.057	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.027
W2009.078	0.000	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.064
W2009.079	<DL	<DL	0.001	0.000	0.000	<DL	<DL	0.000	0.000	<DL	0.080
W2009.086	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.046
W2009.099	0.000	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.066
W2009.112	<DL	<DL	0.000	0.000	0.000	<DL	<DL	0.000	0.000	<DL	0.135
W2009.119	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.132
W2009.120	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.103
W2009.141	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.092
W2009.142	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.095
W2009.161	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.066
W2009.168	<DL	<DL	0.001	0.000	0.000	<DL	<DL	0.000	0.000	<DL	0.034
W2009.207	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.016
W2009.208	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.006
W2009.215	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.009
W2009.216	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.022
W2009.229	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.011
W2009.236	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.036
W2009.248	0.000	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.009
W2009.261	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.010
W2009.265	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.008
W2009.269	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.007
W2009.273	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.012
W2009.280	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.042
W2009.284	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.030
W2009.289	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.060
W2009.290	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.040
W2009.297	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.027
W2009.304	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.027
W2009.311	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.030
W2009.318	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.048
W2009.325	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.020
W2009.329	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.047
W2009.339	<DL	<DL	0.003	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.029
W2009.349	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.016
W2009.356	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.011
W2009.357	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.040

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
W2009.023	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.034	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.055	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.056	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.057	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.078	<DL	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.079	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.086	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.099	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.112	<DL	0.000	0.000	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL
W2009.119	<DL	0.000	0.000	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL
W2009.120	<DL	<DL	0.000	0.000	<DL	0.000	<DL	<DL	<DL	<DL	<DL
W2009.141	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.142	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.161	<DL	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.168	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.207	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.208	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.215	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.216	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.229	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.236	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.248	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.261	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.265	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.269	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.273	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.280	0.000	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.284	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.289	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.290	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.297	0.000	0.000	0.000	0.000	<DL	<DL	0.000	<DL	<DL	<DL	<DL
W2009.304	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.311	0.000	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.318	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.325	0.000	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.329	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.339	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.349	0.000	0.000	0.000	0.000	<DL	<DL	0.000	<DL	<DL	<DL	<DL
W2009.356	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.357	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
W2009.023	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.034	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.055	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.056	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.057	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.078	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.079	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.086	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.099	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.112	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.119	<DL	<DL	<DL	<DL	0.000	<DL	0.001	<DL	0.001
W2009.120	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.141	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.142	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.161	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.168	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.207	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.208	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.215	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.216	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.229	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.236	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.248	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.261	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.265	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.269	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.273	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.280	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.002
W2009.284	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.289	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.003
W2009.290	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.297	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.304	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.311	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.318	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.325	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.329	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.002
W2009.339	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.349	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.356	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.357	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	$^{87}Sr/^{86}Sr$	Li	Na	Mg	Al	P	Ca	Ti	V	Cr	Fe
W2009.370	0.709962	0.001	1.2	4.1	0.027	0.5	15.1	0.000	0.001	0.005	0.1
W2009.395	0.708772	0.003	5.0	14.0	0.045	0.6	32.9	0.001	0.001	0.001	0.2
W2009.396	0.712713	0.015	2.6	25.2	0.016	0.6	51.7	0.001	0.001	0.001	0.2
W2009.403	0.747744	0.011	6.7	8.2	0.014	0.6	32.5	0.001	0.001	0.006	0.1
W2009.416	0.773498	0.012	4.2	7.5	0.015	0.6	19.8	0.000	0.001	0.001	0.1
W2009.423	0.721274	0.002	5.4	13.2	0.024	0.6	47.4	0.001	0.001	0.001	0.2
W2009.436	0.709215	0.003	4.0	4.2	0.014	0.5	16.9	0.000	0.001	0.000	0.1
W2009.443	0.709018	0.002	3.6	3.3	0.006	0.4	15.4	0.001	0.001	0.001	0.1
W2009.450	0.725122	0.003	2.8	3.8	0.033	0.4	11.3	0.000	0.001	0.001	0.1
W2009.454	0.738304	0.003	3.7	3.8	0.013	0.4	15.9	0.001	0.001	0.001	0.1
W2009.464	0.738351	0.004	1.6	6.7	0.016	0.4	14.2	0.001	0.000	0.001	0.1
W2009.477	0.719998	0.002	2.9	7.4	0.011	0.4	33.4	0.001	0.001	0.001	0.1
W2009.175	0.707906	0.026	13.3	21.0	0.010	0.4	84.9	0.005	0.003	0.008	0.4
W2009.182	0.709821	0.003	2.2	5.5	0.030	0.5	22.4	0.001	0.001	0.005	0.1
W2009.487	0.708946	0.003	3.9	4.0	0.026	0.4	16.3	0.000	0.001	0.001	0.0
W2009.494	0.711690	0.002	4.3	4.3	0.010	0.4	8.1	0.001	0.000	0.001	0.0
W2009.495	0.709119	0.002	3.6	4.4	0.023	0.4	9.8	0.000	0.000	0.001	0.2
W2009.508	0.709761	0.003	5.6	8.5	0.017	0.4	20.6	0.001	0.000	0.001	0.1
W2009.515	0.709514	0.002	2.8	6.2	0.025	0.4	26.1	0.001	0.001	0.001	0.4

Sample ID	Mn	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y
W2009.370	0.001	0.000	0.001	0.000	0.002	<DL	0.000	<DL	0.001	0.056	<DL
W2009.395	0.037	0.000	0.001	0.001	0.003	<DL	0.000	0.000	0.000	0.165	0.000
W2009.396	0.002	0.000	0.000	0.000	0.004	<DL	0.001	0.001	0.000	0.209	0.000
W2009.403	0.001	0.000	0.001	0.001	0.003	<DL	0.000	0.000	0.000	0.110	0.000
W2009.416	0.006	<DL	0.000	0.000	0.003	<DL	0.000	<DL	0.000	0.071	0.000
W2009.423	0.003	0.000	0.000	0.000	0.004	<DL	0.000	0.000	0.000	0.187	0.000
W2009.436	0.001	<DL	0.000	0.000	0.002	<DL	0.000	<DL	0.001	0.110	<DL
W2009.443	0.001	<DL	0.000	0.000	0.001	<DL	0.000	<DL	0.001	0.104	<DL
W2009.450	0.001	0.000	0.000	0.000	0.001	<DL	0.000	<DL	0.000	0.072	<DL
W2009.454	0.001	<DL	0.000	0.000	0.001	<DL	0.000	<DL	0.001	0.105	<DL
W2009.464	0.001	<DL	0.000	0.000	0.002	<DL	0.000	<DL	0.000	0.044	<DL
W2009.477	0.003	<DL	<DL	0.000	0.004	<DL	0.000	<DL	0.000	0.147	0.000
W2009.175	0.015	0.000	0.002	0.001	0.009	<DL	0.001	0.002	0.000	1.195	0.000
W2009.182	0.003	0.000	0.003	0.002	0.003	<DL	0.000	<DL	0.001	0.126	0.000
W2009.487	0.001	<DL	0.000	0.000	0.002	<DL	0.000	<DL	0.001	0.108	<DL
W2009.494	0.012	0.000	0.001	0.001	0.003	<DL	0.000	<DL	0.000	0.057	0.000
W2009.495	0.055	0.000	0.001	0.001	0.004	<DL	0.000	<DL	0.000	0.076	0.000
W2009.508	0.026	<DL	0.001	0.001	0.003	<DL	0.000	<DL	0.000	0.118	<DL
W2009.515	0.015	0.000	0.001	0.001	0.002	<DL	0.000	<DL	0.001	0.132	<DL

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Zr	Nb	Mo	Ru	Pd	Ag	Cd	Sn	Sb	Cs	Ba
W2009.370	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.014
W2009.395	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.013
W2009.396	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.016
W2009.403	<DL	<DL	0.003	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.015
W2009.416	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.012
W2009.423	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.026
W2009.436	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.011
W2009.443	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.010
W2009.450	<DL	<DL	0.003	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.008
W2009.454	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.010
W2009.464	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.008
W2009.477	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.015
W2009.175	<DL	<DL	0.002	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.079
W2009.182	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.021
W2009.487	<DL	<DL	0.001	0.000	<DL	<DL	<DL	<DL	0.000	<DL	0.010
W2009.494	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.006
W2009.495	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.006
W2009.508	<DL	<DL	0.000	0.000	0.000	<DL	<DL	<DL	0.000	<DL	0.011
W2009.515	<DL	<DL	0.001	0.000	0.000	<DL	<DL	<DL	<DL	<DL	0.022

Sample ID	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
W2009.370	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.395	<DL	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.396	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.403	0.000	0.000	0.000	0.000	<DL	<DL	0.000	<DL	<DL	<DL	<DL
W2009.416	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.423	<DL	<DL	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.436	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.443	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.450	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.454	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.464	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.477	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.175	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.182	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.487	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.494	<DL	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.495	0.000	0.000	0.000	0.000	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.508	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W2009.515	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL

Appendix H: 87Sr/86Sr ratios and trace element concentrations (ppm) for environmental samples.

Sample ID	Tm	Yb	Lu	Ta	Au	Tl	Pb	Th	U
W2009.370	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.395	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.000
W2009.396	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.403	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.006
W2009.416	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.002
W2009.423	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.002
W2009.436	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.443	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.450	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.454	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.464	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.477	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.175	<DL	<DL	<DL	<DL	0.000	<DL	0.000	<DL	0.001
W2009.182	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.487	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.001
W2009.494	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	<DL
W2009.495	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	<DL
W2009.508	<DL	<DL	<DL	<DL	0.000	<DL	<DL	<DL	0.000
W2009.515	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.001

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Ostrov Zhiloi (OZH_000.006)

Sample ID	Tooth	$^{87}Sr/^{86}Sr$	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
1997.284a	molar	0.710004	0.420	3029.6	17.39	70896.2	316394.4	0.950	0.450	1.680	62.850
1997.284b	molar	0.710000	0.860	3078.5	305.40	84505.8	371636.3	19.470	3.500	3.680	185.910
1997.284c	molar	0.709672	1.030	2212.8	389.21	67129.7	298066.8	23.830	4.800	4.140	242.370
1997.284d	molar	0.709965	0.530	2109.0	165.93	64860.5	291554.9	7.280	2.940	1.560	128.060

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
1997.284a	171.910	1.760	0.276	0.860	541.510	0.322	0.600	0.169	117.230	0.110	0.028
1997.284b	727.180	6.010	0.540	1.270	812.700	0.680	0.500	0.870	134.220	4.390	0.620
1997.284c	892.720	10.160	0.339	1.270	604.180	0.860	0.850	1.110	128.970	8.480	0.493
1997.284d	308.760	4.650	0.281	0.630	624.020	0.520	0.390	0.430	121.140	2.640	0.264

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
1997.284a	0.020	0.230	0.010	0.140	0.410	0.028	0.010	24.640	0.238	0.335	0.047
1997.284b	0.023	0.390	0.039	0.473	0.440	0.041	0.038	41.140	10.260	9.530	1.730
1997.284c	0.052	0.270	0.035	0.483	0.280	0.037	0.043	54.520	15.730	18.470	3.090
1997.284d	0.110	0.156	0.029	0.317	0.248	0.019	0.032	43.420	5.130	6.060	0.829

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
1997.284a	0.164	0.048	0.012	0.040	0.013	0.037	0.009	0.019	0.006	0.017	0.006
1997.284b	6.110	1.240	0.201	0.886	0.123	0.767	0.150	0.356	0.051	0.307	0.052
1997.284c	10.760	1.910	0.392	1.560	0.234	1.420	0.255	0.700	0.106	0.552	0.072
1997.284d	3.120	0.494	0.097	0.453	0.060	0.396	0.067	0.205	0.021	0.201	0.023

Sample ID	Ta	Au	Tl	Pb	Th	U
1997.284a	0.019	0.077	0.013	0.233	0.009	0.014
1997.284b	0.030	0.089	0.022	3.100	0.655	0.014
1997.284c	0.012	0.062	0.029	3.700	1.280	0.036
1997.284d	0.007	0.037	0.015	1.790	0.106	0.026

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a (KHO_1978.004.02)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.171a	M1	0.724742	0.700	2543.4	83.780	63914.9	267207.3	8.310	0.780	1.790	54.130
2000.171b	M1	0.727553	1.230	2976.4	94.320	90443.1	377301.8	3.200	0.820	4.480	54.350
2000.171c	M1	0.728499	1.120	3070.9	52.430	97581.5	410911.8	4.210	1.320	2.000	72.400
2000.171d	M1	0.726334	1.100	2881.5	29.320	90359.9	375473.7	1.130	0.690	1.630	82.480
2000.172a	M2	0.727164	0.800	2830.1	25.840	61347.6	250416.2	1.990	0.520	1.290	45.030
2000.172b	M2	0.725378	0.810	2548.4	35.840	67744.9	274661.2	1.860	0.710	2.180	45.930
2000.172c	M2	0.727937	1.480	3127.1	58.670	97529.3	412024.8	7.980	1.120	2.990	56.730
2000.172d	M2	0.726489	1.120	2813.8	120.440	82388.5	350329.8	9.330	1.460	3.140	64.380
2000.173a	M3	0.728053	0.880	3559.6	21.750	62217.9	249190.8	2.360	0.620	2.120	34.220
2000.173b	M3	0.727675	1.120	3282.6	110.280	128168.2	523150.1	8.340	2.670	6.070	112.720
2000.173c	M3	0.728111	1.370	3828.4	88.200	124113.9	501383.7	8.110	1.750	6.250	47.770
2000.173d	M3	0.729911	1.140	3864.7	15.200	112087.5	449437.2	1.400	0.810	3.330	42.280

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.171a	262.970	2.410	0.251	1.770	362.860	0.375	0.260	0.370	84.250	2.020	0.226
2000.171b	230.750	1.630	0.105	1.470	637.720	0.357	0.310	0.490	107.780	4.580	0.110
2000.171c	254.680	2.830	0.119	1.510	534.810	0.440	0.680	0.123	125.470	9.190	0.371
2000.171d	94.440	0.770	0.133	1.020	475.900	0.240	0.500	0.048	100.510	2.190	0.075
2000.172a	163.230	1.900	0.306	0.860	330.920	0.260	0.320	0.125	101.680	1.030	0.097
2000.172b	234.320	2.220	0.241	0.990	396.980	0.268	0.460	0.186	93.990	1.090	0.293
2000.172c	353.490	3.040	0.830	1.090	644.570	0.453	1.040	0.380	130.980	6.230	0.475
2000.172d	483.760	5.130	0.261	1.660	423.460	0.480	0.860	0.340	121.630	11.360	0.287
2000.173a	144.050	1.460	0.125	0.850	242.040	0.232	0.204	0.071	80.530	1.610	0.142
2000.173b	952.440	9.500	0.500	2.690	642.140	0.760	1.230	0.062	209.530	6.480	1.490
2000.173c	410.560	3.920	0.401	1.460	671.670	0.540	0.880	0.340	164.060	4.210	0.880
2000.173d	102.130	1.190	0.364	1.240	588.780	0.349	0.690	0.023	129.340	1.660	0.254

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a (KHO_1978.004.02)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.171a	0.020	0.470	0.054	0.186	0.232	0.018	0.007	16.780	5.230	6.320	0.839
2000.171b	0.038	0.650	0.065	0.189	0.410	0.043	0.015	17.720	12.640	13.410	2.090
2000.171c	0.067	0.860	0.056	0.214	0.390	0.053	0.009	27.290	26.870	23.820	4.380
2000.171d	0.048	0.600	0.053	0.382	0.307	0.029	0.006	17.950	7.870	5.900	1.114
2000.172a	0.026	0.400	0.025	0.135	0.286	0.011	0.018	14.540	2.840	2.820	0.358
2000.172b	0.015	0.400	0.031	0.083	0.271	0.145	0.012	18.700	3.480	2.900	0.405
2000.172c	0.051	0.520	0.074	0.161	0.510	0.077	0.021	29.440	15.720	15.570	2.280
2000.172d	0.016	0.500	0.068	0.328	0.470	0.134	0.064	20.880	34.130	28.170	5.030
2000.173a	0.025	0.360	0.030	0.154	0.249	0.026	0.009	12.220	4.960	3.710	0.660
2000.173b	0.033	0.580	0.121	0.580	0.580	0.064	0.012	56.050	17.510	16.660	2.190
2000.173c	0.082	0.570	0.111	0.235	0.490	0.071	0.012	30.750	8.260	7.690	1.156
2000.173d	0.035	0.510	0.064	0.157	0.490	0.043	0.018	22.180	3.700	3.060	0.468

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.171a	3.210	0.521	0.076	0.507	0.061	0.343	0.064	0.161	0.028	0.156	0.029
2000.171b	7.570	1.140	0.219	1.090	0.104	0.694	0.134	0.359	0.045	0.266	0.052
2000.171c	16.100	2.630	0.408	2.070	0.233	1.320	0.266	0.800	0.100	0.545	0.102
2000.171d	3.990	0.620	0.103	0.499	0.069	0.328	0.055	0.156	0.012	0.084	0.021
2000.172a	1.320	0.154	0.028	0.138	0.021	0.113	0.022	0.062	0.010	0.070	0.011
2000.172b	1.420	0.165	0.037	0.251	0.018	0.114	0.027	0.068	0.014	0.089	0.010
2000.172c	8.110	1.280	0.223	1.130	0.153	0.819	0.155	0.414	0.072	0.421	0.071
2000.172d	17.880	2.660	0.417	2.500	0.261	1.370	0.283	0.860	0.109	0.687	0.101
2000.173a	2.150	0.241	0.055	0.293	0.027	0.211	0.027	0.076	0.014	0.093	0.016
2000.173b	8.100	1.190	0.222	0.980	0.143	0.680	0.153	0.494	0.066	0.432	0.065
2000.173c	3.730	0.489	0.077	0.695	0.053	0.388	0.098	0.264	0.040	0.258	0.033
2000.173d	1.810	0.233	0.032	0.233	0.046	0.156	0.042	0.148	0.017	0.082	0.015

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a (KHO_1978.004.02)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.171a	0.012	0.034	0.016	0.790	0.308	0.204
2000.171b	0.008	0.116	0.047	1.290	0.502	0.102
2000.171c	0.025	0.054	0.023	1.590	1.000	0.183
2000.171d	0.000	0.042	0.027	1.210	0.105	0.103
2000.172a	0.025	0.035	0.018	0.740	0.080	0.197
2000.172b	0.000	0.055	0.020	1.290	0.067	0.330
2000.172c	0.019	0.074	0.024	1.750	0.690	0.430
2000.172d	0.015	0.041	0.023	2.220	0.630	0.460
2000.173a	0.004	0.058	0.008	0.350	0.097	0.121
2000.173b	0.007	0.067	0.031	1.400	0.437	1.520
2000.173c	0.030	0.074	0.020	1.260	0.163	1.080
2000.173d	0.004	0.111	0.040	0.720	0.060	0.490

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk (KHO_Grave on the Mountain (1978))

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.175a	M1	0.709544	0.470	3152.3	14.520	72575.5	287196.7	1.470	0.810	1.880	27.720
2000.175b	M1	0.709824	0.470	2763.0	17.390	82194.7	325086.2	1.230	0.550	1.630	57.960
2000.175c	M1	0.710288	0.760	3618.7	33.390	117530.8	471479.2	2.870	2.780	3.390	23.110
2000.175d	M1	0.710202	0.800	3131.9	15.650	105755.2	424470.6	1.010	1.340	4.800	22.610
2000.176a	M2	0.709320	0.650	3160.0	6.710	56717.2	211546.9	0.470	0.185	1.060	8.790
2000.176b	M2	0.710086	0.600	2766.4	22.870	80299.3	306836.7	0.940	0.195	1.700	7.140
2000.176c	M2	0.710274	0.910	3185.1	10.110	101527.7	404080.3	2.350	0.330	1.980	4.600
2000.176d	M2	0.710292	0.770	3223.4	48.370	105446.9	416727.1	3.270	0.660	2.850	21.820
2000.177a	M3	0.712029	0.450	2830.0	14.520	70340.5	279151.9	1.270	0.940	2.420	14.020
2000.177b	M3	0.712323	0.610	3109.7	12.500	86577.9	355374.1	2.810	0.670	1.580	29.910
2000.177c	M3	0.713038	0.880	3512.7	27.980	105723.4	432174.3	1.060	1.040	2.700	22.830
2000.177d	M3	0.715202	0.730	2803.0	61.990	90608.4	369082.7	3.600	1.010	2.500	26.060

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.175a	184.350	1.380	2.270	1.620	517.900	0.412	0.256	0.320	132.330	0.106	0.025
2000.175b	108.220	1.450	1.650	1.140	602.260	0.191	0.320	0.092	105.650	0.046	0.036
2000.175c	272.270	1.440	0.238	4.010	945.690	0.470	0.440	0.040	172.870	1.790	0.102
2000.175d	237.500	1.200	0.184	1.500	872.730	0.293	0.490	0.136	141.670	1.860	0.066
2000.176a	56.450	0.209	0.070	0.240	317.370	0.223	0.228	0.035	104.210	0.077	0.014
2000.176b	190.670	0.320	0.091	0.350	636.750	0.096	0.210	0.027	103.100	0.036	0.040
2000.176c	129.760	0.360	0.078	0.640	848.760	0.161	0.340	0.054	121.870	0.041	0.061
2000.176d	255.430	0.990	0.730	1.290	975.200	0.145	0.360	0.430	137.940	0.464	0.172
2000.177a	97.880	1.000	0.275	3.570	363.290	0.172	0.330	0.038	110.020	0.453	0.049
2000.177b	98.950	0.380	0.200	1.130	471.130	0.145	0.430	0.133	112.900	0.079	0.033
2000.177c	203.200	1.010	0.391	1.700	594.960	0.160	0.300	0.050	110.400	0.640	0.048
2000.177d	193.510	2.940	0.215	0.840	661.700	0.089	0.420	0.480	94.370	0.167	0.040

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk (KHO_Grave on the Mountain (1978))

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.175a	0.024	0.129	0.038	0.099	0.323	0.017	0.037	31.580	0.614	0.950	0.097
2000.175b	0.028	0.300	0.091	0.124	0.400	0.028	0.009	18.580	0.643	1.780	0.091
2000.175c	0.031	0.179	0.064	0.171	0.470	0.014	0.018	43.000	6.840	1.470	0.653
2000.175d	0.045	0.172	0.067	0.153	0.470	0.056	0.009	27.170	7.010	1.220	0.632
2000.176a	0.020	0.120	0.006	0.061	0.274	0.006	0.004	14.330	0.272	0.164	0.038
2000.176b	0.041	0.165	0.045	0.036	0.369	0.014	0.007	11.000	0.215	0.258	0.019
2000.176c	0.064	0.300	0.094	0.116	0.560	0.019	0.015	9.080	0.187	0.230	0.070
2000.176d	0.061	0.210	0.068	0.149	3.900	0.039	0.026	15.520	1.780	1.480	0.323
2000.177a	0.043	0.149	0.019	0.093	0.363	0.046	0.005	16.570	1.830	0.780	0.240
2000.177b	0.024	0.300	0.048	0.083	0.510	0.033	0.011	10.880	0.322	0.211	0.059
2000.177c	0.042	0.310	0.042	0.193	0.600	0.038	0.015	11.870	3.480	1.200	0.305
2000.177d	0.058	0.310	0.006	0.198	0.530	0.053	0.026	11.750	0.754	0.501	0.097

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.175a	0.211	0.078	0.010	0.020	0.006	0.020	0.008	0.010	0.002	0.005	0.005
2000.175b	0.189	0.084	0.012	0.030	0.005	0.026	0.004	0.019	0.007	0.011	0.003
2000.175c	2.190	0.200	0.026	0.329	0.016	0.169	0.038	0.088	0.017	0.063	0.015
2000.175d	2.490	0.243	0.055	0.288	0.035	0.174	0.034	0.063	0.015	0.040	0.015
2000.176a	0.169	0.039	0.009	0.023	0.004	0.033	0.004	0.010	0.000	0.026	0.005
2000.176b	0.066	0.106	0.016	0.029	0.005	0.020	0.005	0.005	0.002	0.007	0.005
2000.176c	0.106	0.136	0.019	0.011	0.009	0.113	0.011	0.030	0.012	0.048	0.020
2000.176d	0.950	0.114	0.034	0.087	0.021	0.060	0.013	0.032	0.010	0.047	0.014
2000.177a	0.906	0.191	0.032	0.142	0.015	0.076	0.012	0.033	0.004	0.070	0.007
2000.177b	0.181	0.080	0.014	0.039	0.004	0.053	0.008	0.009	0.013	0.034	0.007
2000.177c	1.230	0.279	0.024	0.128	0.019	0.071	0.019	0.066	0.009	0.034	0.009
2000.177d	0.414	0.116	0.020	0.076	0.005	0.030	0.008	0.008	0.007	0.012	0.010

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk (KHO_Grave on the Mountain (1978))

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.175a	0.012	0.031	0.017	3.420	0.004	0.100
2000.175b	0.019	0.050	0.029	6.760	0.003	0.100
2000.175c	0.042	0.034	0.025	10.880	0.018	1.020
2000.175d	0.004	0.080	0.021	13.700	0.013	0.301
2000.176a	0.009	0.020	0.012	0.950	0.006	0.028
2000.176b	0.010	0.066	0.021	6.080	0.003	0.021
2000.176c	0.044	0.049	0.026	8.070	0.020	0.039
2000.176d	0.032	0.127	0.023	11.690	0.018	0.075
2000.177a	0.016	0.039	0.020	1.270	0.013	0.370
2000.177b	0.020	0.080	0.023	2.220	0.008	0.127
2000.177c	0.013	0.111	0.030	3.710	0.013	0.164
2000.177d	0.040	0.081	0.023	3.700	0.008	0.056

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a-3 (KHO_1978.004.04)

Sample ID	Tooth	$^{87}Sr/^{86}Sr$	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.179a	M1	0.721043	0.520	2533.1	40.670	59681.6	233718.1	0.890	0.610	1.270	15.880
2000.179b	M1	0.723558	0.720	2680.8	7.630	74656.7	296306.5	0.920	0.400	1.910	18.990
2000.179c	M1	0.722146	0.860	3123.4	23.850	94052.8	374928.4	1.800	1.070	2.230	18.850
2000.179d	M1	0.721673	0.720	2693.4	19.890	78131.5	319207.2	1.860	0.570	1.910	22.280
2000.180a	M2	0.724552	0.580	3020.3	41.360	51568.5	200804.3	2.200	0.850	1.460	20.780
2000.180b	M2	0.726758	0.680	2338.0	31.760	62268.3	252835.6	1.630	0.710	1.350	16.490
2000.180c	M2	0.724777	0.550	2418.6	18.790	79310.7	318679.5	1.810	0.460	1.200	10.130
2000.180d	M2	0.729078	0.920	2824.3	23.780	97133.2	400814.8	1.510	0.560	2.620	20.450
2000.181a	M3	0.722831	0.700	3726.7	48.200	65502.6	260077.0	4.210	0.890	1.990	20.340
2000.181b	M3	0.726381	0.370	2520.7	33.330	58618.0	222392.3	1.540	0.860	1.490	33.500
2000.181c	M3	0.724364	0.580	2685.9	31.720	75850.2	292528.3	4.130	1.490	1.890	12.530
2000.181d	M3	0.726782	0.870	2988.9	43.880	101651.7	406952.9	3.370	2.400	2.300	23.230

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.179a	235.720	1.960	0.152	1.200	272.330	0.215	0.214	0.520	74.000	0.290	0.080
2000.179b	154.650	0.690	0.356	0.720	423.590	0.187	0.320	0.022	82.210	1.110	0.080
2000.179c	171.470	2.040	0.110	0.770	505.570	0.124	0.240	0.330	111.030	0.800	0.058
2000.179d	170.480	1.670	0.116	0.530	376.030	0.079	0.350	0.420	83.030	0.457	0.029
2000.180a	331.010	2.640	0.171	1.520	251.320	0.231	0.309	0.097	101.930	1.220	0.171
2000.180b	218.710	2.200	0.323	0.430	283.990	0.105	0.169	0.350	70.840	0.170	0.088
2000.180c	246.550	1.290	0.120	1.100	429.850	0.129	0.280	0.086	91.050	0.160	0.067
2000.180d	239.590	2.950	0.091	0.930	481.760	0.136	0.490	0.240	109.200	0.880	0.082
2000.181a	319.600	2.390	0.158	2.150	328.000	0.265	0.360	0.146	96.660	2.270	0.401
2000.181b	240.880	2.700	2.520	1.570	267.910	0.168	0.213	0.049	63.690	0.770	0.263
2000.181c	286.250	2.550	0.093	1.960	423.720	0.136	0.177	0.039	76.770	0.477	0.168
2000.181d	320.790	2.940	0.158	1.650	640.650	0.121	0.680	0.122	85.910	0.690	0.073

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a-3 (KHO_1978.004.04)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.179a	0.013	0.210	0.039	0.101	0.280	0.027	0.068	12.100	1.024	0.920	0.137
2000.179b	0.019	0.460	0.013	0.140	0.370	0.047	0.014	12.010	3.510	2.800	0.496
2000.179c	0.030	0.540	0.043	0.276	0.610	0.031	0.014	13.480	2.430	2.130	0.297
2000.179d	0.012	0.380	0.045	0.194	0.360	0.021	0.014	10.060	1.530	1.340	0.219
2000.180a	0.007	0.203	0.027	0.182	0.242	0.009	0.009	17.690	3.210	3.740	0.487
2000.180b	0.010	0.360	0.040	0.144	0.335	0.029	0.010	7.650	0.423	0.587	0.084
2000.180c	0.021	0.250	0.031	0.142	0.420	0.037	0.015	11.250	0.462	0.509	0.084
2000.180d	0.041	0.370	0.028	0.162	0.470	0.041	0.008	13.570	2.990	2.340	0.414
2000.181a	0.020	0.207	0.040	0.335	0.334	0.028	0.009	24.450	6.880	6.330	0.924
2000.181b	0.018	0.230	0.065	0.271	0.200	0.006	0.010	13.930	1.970	2.260	0.314
2000.181c	0.007	0.410	0.049	0.452	0.390	0.019	0.011	16.560	1.270	1.430	0.194
2000.181d	0.028	0.860	0.025	0.309	0.610	0.056	0.020	12.830	1.880	2.020	0.230

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.179a	0.533	0.045	0.011	0.066	0.012	0.058	0.011	0.028	0.006	0.033	0.007
2000.179b	1.910	0.209	0.040	0.258	0.027	0.155	0.029	0.095	0.013	0.076	0.019
2000.179c	1.020	0.119	0.022	0.238	0.032	0.106	0.022	0.065	0.011	0.070	0.009
2000.179d	0.769	0.106	0.028	0.068	0.014	0.100	0.013	0.030	0.007	0.031	0.009
2000.180a	1.870	0.327	0.048	0.338	0.035	0.189	0.046	0.099	0.019	0.092	0.013
2000.180b	0.228	0.070	0.012	0.048	0.012	0.027	0.011	0.028	0.005	0.034	0.006
2000.180c	0.262	0.073	0.012	0.035	0.006	0.044	0.011	0.021	0.005	0.043	0.005
2000.180d	1.350	0.213	0.020	0.145	0.027	0.132	0.023	0.072	0.013	0.096	0.013
2000.181a	3.660	0.437	0.070	0.618	0.049	0.332	0.054	0.194	0.028	0.159	0.027
2000.181b	1.130	0.167	0.025	0.263	0.019	0.124	0.028	0.075	0.009	0.066	0.011
2000.181c	0.750	0.089	0.018	0.151	0.017	0.065	0.019	0.039	0.008	0.030	0.013
2000.181d	1.000	0.098	0.016	0.160	0.012	0.078	0.018	0.033	0.011	0.045	0.012

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a-3 (KHO_1978.004.04)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.179a	0.013	0.063	0.013	0.330	0.023	0.129
2000.179b	0.006	0.065	0.015	0.470	0.039	0.096
2000.179c	0.018	0.050	0.026	0.680	0.040	0.114
2000.179d	0.009	0.089	0.017	0.390	0.019	0.075
2000.180a	0.011	0.016	0.010	0.370	0.090	0.320
2000.180b	0.023	0.055	0.020	0.480	0.013	0.079
2000.180c	0.025	0.086	0.014	0.920	0.022	0.080
2000.180d	0.020	0.106	0.019	1.060	0.034	0.183
2000.181a	0.009	0.037	0.010	0.720	0.191	0.480
2000.181b	0.014	0.042	0.017	0.400	0.030	0.253
2000.181c	0.017	0.067	0.009	0.980	0.043	0.299
2000.181d	0.006	0.090	0.021	1.270	0.061	0.340

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 7 (KHO_1978.007)

Sample ID	Tooth	$^{87}Sr/^{86}Sr$	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.183a	M1	0.712577	0.970	3869.6	16.010	60876.7	234512.7	2.850	1.360	2.050	5.650
2000.183b	M1	0.712718	2.190	3741.9	58.120	151248.5	601134.2	11.610	5.700	5.920	16.420
2000.183c	M1	0.712424	2.490	4458.0	129.780	188494.0	736732.8	17.830	7.280	5.890	53.750
2000.183d	M1	0.712643	2.350	4284.8	143.370	173706.0	673040.1	15.140	7.850	7.150	39.820
2000.184a	M2	0.713888	1.030	3243.2	29.140	99061.9	379160.1	5.060	2.020	2.310	11.140
2000.184b	M2	0.714696	1.300	3797.2	22.010	139048.2	539053.1	10.620	3.970	4.150	21.660
2000.184c	M2	0.715165	0.760	3052.7	15.110	100704.5	390018.6	3.000	0.820	1.930	7.440
2000.184d	M2	0.715560	2.230	3998.7	54.030	154814.5	598112.9	9.830	4.360	4.000	39.100
2000.185a	M3	0.711964	1.090	3521.6	41.520	86827.8	337138.5	9.740	2.730	1.710	19.290
2000.185b	M3	0.712074	1.720	4013.1	52.800	158089.0	614321.1	13.040	5.790	3.090	23.040
2000.185c	M3	0.712130	1.640	4521.5	41.450	170184.9	647450.8	12.040	6.190	3.670	22.730
2000.185d	M3	0.712472	2.610	4884.7	56.020	196026.9	764720.3	15.300	6.320	3.920	62.230

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.183a	134.050	1.970	0.096	0.650	130.100	0.276	1.010	0.092	178.820	7.630	0.179
2000.183b	421.830	6.660	0.307	2.010	673.740	0.720	3.040	1.630	394.310	35.590	0.690
2000.183c	648.080	10.460	1.730	3.210	805.150	0.780	3.450	0.184	475.300	43.860	1.260
2000.183d	626.870	9.520	1.230	3.590	724.380	0.810	2.980	0.790	426.350	31.640	1.170
2000.184a	350.680	2.870	0.191	0.990	487.680	0.415	2.020	0.097	227.320	29.450	0.319
2000.184b	265.290	3.530	0.348	1.840	607.160	0.520	2.760	0.112	317.990	39.660	0.510
2000.184c	235.510	2.210	0.139	0.560	552.370	0.237	1.080	0.134	174.470	8.470	0.081
2000.184d	628.850	4.850	0.830	1.950	786.590	0.490	2.660	0.550	307.730	43.920	0.414
2000.185a	416.600	3.890	1.060	1.770	285.290	0.360	1.640	0.178	247.730	36.400	0.298
2000.185b	631.430	7.170	0.303	2.260	652.690	0.860	2.360	0.185	399.610	63.710	0.870
2000.185c	491.500	5.370	0.600	2.140	663.140	0.540	2.330	0.124	381.540	27.990	0.650
2000.185d	672.710	7.880	1.040	2.430	925.100	0.820	2.380	0.650	437.390	68.130	0.730

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 7 (KHO_1978.007)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.183a	0.014	0.248	0.113	0.091	0.277	0.019	0.008	30.530	12.440	14.840	2.500
2000.183b	0.030	0.640	0.392	0.392	0.690	0.088	0.012	69.850	63.100	63.340	13.170
2000.183c	0.063	0.580	0.112	0.457	0.850	0.064	0.046	80.450	74.230	69.890	15.620
2000.183d	0.064	0.500	0.169	0.326	0.630	0.129	0.144	72.320	50.150	50.450	10.430
2000.184a	0.022	0.410	0.145	0.107	0.460	0.023	0.011	35.990	41.990	44.130	9.730
2000.184b	0.029	0.560	0.225	0.309	0.560	0.072	0.013	50.950	56.650	52.660	11.510
2000.184c	0.010	0.480	0.059	0.101	0.340	0.058	0.013	22.270	13.370	10.670	2.520
2000.184d	0.038	0.630	0.196	0.268	0.820	0.057	0.071	48.980	70.590	65.530	15.270
2000.185a	0.024	0.167	0.097	0.162	0.333	0.028	0.020	37.440	50.570	37.010	9.890
2000.185b	0.028	0.590	0.171	0.318	0.650	0.087	0.064	62.740	89.340	76.750	17.820
2000.185c	0.037	0.770	0.392	0.210	0.660	0.084	0.019	49.460	36.270	28.240	7.220
2000.185d	0.060	0.750	0.298	0.320	0.860	0.087	0.113	68.570	101.400	75.580	20.530

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.183a	9.470	1.640	0.247	1.660	0.187	1.160	0.238	0.628	0.080	0.629	0.097
2000.183b	49.120	8.270	1.330	8.300	0.990	5.820	1.140	2.970	0.372	2.590	0.360
2000.183c	59.520	10.020	1.540	10.010	1.210	7.470	1.330	3.910	0.538	3.320	0.576
2000.183d	39.860	7.090	1.118	6.350	0.840	4.660	0.950	2.680	0.351	2.390	0.353
2000.184a	36.670	6.720	1.116	6.550	0.860	4.830	0.980	2.910	0.388	2.380	0.389
2000.184b	43.620	7.650	1.143	7.270	0.950	5.700	1.150	3.260	0.440	3.130	0.475
2000.184c	9.980	1.680	0.256	1.670	0.180	1.120	0.210	0.740	0.098	0.730	0.071
2000.184d	57.840	9.420	1.550	9.240	1.110	6.900	1.370	3.810	0.485	3.390	0.489
2000.185a	39.850	6.710	1.138	7.140	0.880	5.330	1.060	2.970	0.423	2.650	0.421
2000.185b	72.620	13.050	1.890	13.060	1.550	9.660	1.980	5.150	0.780	5.040	0.830
2000.185c	27.430	4.120	0.701	4.670	0.504	3.440	0.710	2.200	0.294	2.000	0.302
2000.185d	80.690	14.210	2.250	13.550	1.680	9.800	1.930	5.740	0.810	4.740	0.760

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 7 (KHO_1978.007)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.183a	0.009	0.020	0.012	0.670	0.283	0.720
2000.183b	0.030	0.096	0.035	3.020	1.170	1.680
2000.183c	0.037	0.072	0.033	3.310	2.260	2.800
2000.183d	0.023	0.085	0.025	3.020	1.130	2.180
2000.184a	0.031	0.061	0.021	1.090	1.780	1.190
2000.184b	0.029	0.092	0.021	1.750	1.130	2.030
2000.184c	0.029	0.128	0.044	0.980	0.224	0.770
2000.184d	0.040	0.088	0.020	2.800	1.510	1.710
2000.185a	0.006	0.044	0.008	0.920	0.854	1.460
2000.185b	0.049	0.124	0.032	4.700	2.320	2.550
2000.185c	0.033	0.100	0.035	1.860	0.290	2.380
2000.185d	0.041	0.089	0.046	4.780	2.320	2.760

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a-2 (KHO_1978.004.03)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.187a	M1	0.723371	0.480	2190.8	25.980	64760.3	219567.8	2.110	0.760	0.920	43.880
2000.187b	M1	0.721660	0.760	2651.6	23.440	102258.0	348025.5	2.070	1.590	1.310	71.660
2000.187c	M1	0.721904	0.590	2538.7	33.280	77719.3	270461.6	1.530	1.660	1.520	80.320
2000.187d	M1	0.726820	0.440	2611.4	6.520	66223.3	223152.9	0.550	0.410	1.450	34.950
2000.188a	M2	0.717408	0.530	2222.2	12.980	57352.9	208734.2	0.620	0.650	1.480	45.890
2000.188b	M2	0.717792	0.580	2560.3	22.390	80653.2	293560.3	2.780	1.560	2.630	65.450
2000.188c	M2	0.717142	1.060	3121.7	70.550	108443.0	390687.6	5.920	2.160	3.250	140.170
2000.188d	M2	0.717817	1.180	3771.2	139.800	142483.1	530905.3	16.510	4.220	6.180	167.470

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.187a	107.310	1.110	0.158	0.470	257.140	0.267	0.285	0.118	63.730	2.180	0.342
2000.187b	154.900	1.790	0.234	1.750	355.140	0.410	0.590	0.042	102.270	15.700	0.367
2000.187c	144.020	1.240	0.283	0.370	212.400	0.146	0.470	0.145	69.770	3.600	0.105
2000.187d	87.090	0.690	0.074	0.210	79.760	0.091	0.194	0.037	60.060	1.470	0.019
2000.188a	79.940	0.540	0.178	0.360	179.330	0.131	0.176	0.027	73.080	0.780	0.056
2000.188b	156.960	1.390	0.226	0.970	302.260	0.231	0.340	0.080	91.980	5.420	0.219
2000.188c	273.800	2.440	0.298	1.330	416.010	0.322	0.520	0.086	124.450	31.700	0.740
2000.188d	718.170	6.730	1.600	2.870	505.330	0.530	1.660	0.035	178.290	49.950	1.880

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.187a	0.012	0.228	0.012	0.123	0.263	0.024	0.005	9.400	7.460	4.650	1.038
2000.187b	0.022	0.310	0.068	0.215	0.309	0.024	0.010	25.460	50.610	17.890	6.270
2000.187c	0.005	0.300	0.086	0.348	0.420	0.011	0.010	12.940	13.670	10.300	1.730
2000.187d	0.015	0.147	0.021	0.045	0.227	0.015	0.008	9.520	5.950	3.880	0.849
2000.188a	0.007	0.231	0.027	0.105	0.223	0.022	0.008	10.530	2.820	1.950	0.522
2000.188b	0.013	0.290	0.050	0.199	0.340	0.033	0.013	19.220	18.020	9.520	2.420
2000.188c	0.020	0.380	0.056	0.383	0.490	0.074	0.007	33.360	106.190	50.920	15.220
2000.188d	0.013	0.470	0.087	0.550	0.530	0.071	0.013	51.490	181.610	84.850	22.130

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4a-2 (KHO_1978.004.03)

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.187a	3.970	0.596	0.072	0.595	0.059	0.316	0.063	0.189	0.022	0.143	0.032
2000.187b	22.660	3.140	0.503	3.130	0.373	2.160	0.390	1.050	0.145	1.040	0.191
2000.187c	6.660	0.820	0.164	0.870	0.086	0.482	0.098	0.283	0.027	0.205	0.036
2000.187d	2.930	0.504	0.044	0.323	0.046	0.201	0.046	0.125	0.015	0.096	0.018
2000.188a	1.820	0.341	0.049	0.242	0.030	0.146	0.033	0.077	0.007	0.067	0.009
2000.188b	8.160	1.120	0.165	1.110	0.110	0.604	0.120	0.374	0.048	0.270	0.041
2000.188c	54.560	9.330	1.300	8.160	0.920	4.610	1.060	2.430	0.283	2.070	0.341
2000.188d	80.850	11.060	1.590	11.070	1.080	6.320	1.290	3.760	0.496	2.860	0.546

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.187a	0.012	0.007	0.010	0.320	0.164	0.124
2000.187b	0.022	0.047	0.019	0.600	0.680	0.440
2000.187c	0.021	0.079	0.011	0.680	0.241	0.068
2000.187d	0.003	0.051	0.007	0.660	0.207	0.042
2000.188a	0.016	0.029	0.011	0.330	0.126	0.232
2000.188b	0.025	0.065	0.015	0.810	0.222	0.480
2000.188c	0.049	0.059	0.025	1.570	2.210	1.060
2000.188d	0.034	0.060	0.014	3.030	2.300	2.150

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 2a (KHO_1977.002)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.190a	M1	0.723373	1.160	2847.1	392.970	92700.0	354301.9	33.570	1.720	4.490	75.470
2000.190b	M1	0.725763	1.320	3048.4	235.400	94930.5	365098.9	11.880	1.070	4.650	112.290
2000.190c	M1	0.727223	1.260	2881.1	294.140	95265.1	355155.1	16.070	1.470	3.410	172.880
2000.190d	M1	0.725699	1.050	2790.4	238.020	90470.2	336906.3	8.440	1.510	3.630	173.790
2000.191a	M2	0.718936	1.290	3445.5	47.310	123469.5	453858.0	8.630	2.110	4.860	57.350
2000.191b	M2	0.720439	1.160	2978.7	204.210	100254.3	365769.3	17.850	1.330	4.480	66.570
2000.191c	M2	0.719150	1.270	3577.4	80.650	133844.4	470907.5	6.920	1.890	5.210	97.500
2000.191d	M2	0.720119	0.560	2927.5	260.190	110047.8	408595.7	7.120	1.600	3.320	146.250
2000.192a	M3	0.717808	0.770	2862.8	46.430	80401.2	304202.3	1.870	0.840	2.660	84.380
2000.192b	M3	0.719647	1.160	2643.3	366.840	88942.8	338307.8	16.730	1.700	4.040	85.640
2000.192c	M3	0.717841	0.800	2703.6	59.300	93958.5	353675.0	5.050	1.380	2.810	140.680
2000.192d	M3	0.719041	1.170	2789.2	46.040	99774.0	385352.5	2.640	0.990	4.230	238.120

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.190a	530.220	5.930	0.335	2.010	379.280	0.540	0.520	0.760	134.940	9.960	0.520
2000.190b	411.690	3.750	0.325	1.090	402.750	0.460	0.590	0.230	139.310	3.320	0.310
2000.190c	497.170	6.070	0.189	1.320	325.210	0.680	0.470	0.220	149.570	10.920	0.432
2000.190d	412.490	5.520	0.220	1.720	331.230	0.410	0.340	0.178	138.010	16.450	0.540
2000.191a	373.120	4.840	0.290	2.500	434.960	0.560	0.610	0.129	245.410	22.120	0.800
2000.191b	441.760	4.740	0.420	1.290	454.970	0.268	0.260	0.610	142.880	7.450	0.219
2000.191c	363.300	4.840	0.304	1.950	517.940	0.380	0.540	0.112	202.290	13.780	0.730
2000.191d	473.890	4.910	0.251	1.020	472.690	0.520	0.810	0.100	163.420	14.900	0.500
2000.192a	187.020	1.990	0.125	0.580	361.280	0.177	0.490	0.043	123.770	0.480	0.248
2000.192b	704.260	6.600	0.370	1.360	497.750	0.390	0.390	0.670	124.360	3.650	0.540
2000.192c	209.280	2.410	0.250	0.490	507.770	0.237	0.480	0.097	133.350	7.370	0.510
2000.192d	177.160	1.550	0.121	0.760	521.870	0.287	0.670	0.076	134.410	7.290	0.580

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 2a (KHO_1977.002)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.190a	0.036	0.640	0.045	0.187	0.400	0.018	0.063	33.270	27.540	30.940	3.920
2000.190b	0.014	1.150	0.084	0.210	0.420	0.036	0.013	34.730	10.470	12.130	1.670
2000.190c	0.038	0.460	0.045	0.370	0.330	0.032	0.018	47.300	40.890	44.480	5.300
2000.190d	0.031	0.540	0.036	0.383	0.440	0.051	0.012	44.940	54.840	62.690	7.580
2000.191a	0.022	0.760	0.063	0.378	0.420	0.055	0.011	59.000	60.260	72.960	9.340
2000.191b	0.040	0.410	0.060	0.318	0.274	0.040	0.043	29.800	19.300	22.630	3.050
2000.191c	0.019	0.840	0.056	0.530	0.350	0.021	0.018	50.170	35.610	42.750	5.630
2000.191d	0.007	0.840	0.100	0.520	0.330	0.030	0.015	51.760	42.150	50.510	6.710
2000.192a	0.016	0.750	0.033	0.191	0.380	0.038	0.012	17.590	1.160	1.620	0.163
2000.192b	0.034	0.760	0.050	0.175	0.360	0.022	0.045	26.230	10.280	12.680	1.520
2000.192c	0.012	0.660	0.050	0.252	0.340	0.067	0.017	29.170	16.330	12.000	2.180
2000.192d	0.036	0.810	0.052	0.550	0.470	0.053	0.012	25.210	16.540	10.710	2.190

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.190a	13.990	1.860	0.355	2.040	0.196	1.120	0.264	0.670	0.092	0.495	0.094
2000.190b	6.050	1.160	0.147	0.763	0.081	0.510	0.099	0.191	0.027	0.169	0.042
2000.190c	19.600	2.720	0.477	2.620	0.281	1.500	0.285	0.790	0.109	0.580	0.097
2000.190d	29.150	4.020	0.666	4.150	0.457	2.400	0.540	1.250	0.184	1.120	0.200
2000.191a	33.960	5.140	0.871	4.930	0.583	3.390	0.650	1.810	0.260	1.640	0.261
2000.191b	11.800	1.810	0.238	1.690	0.187	1.050	0.228	0.630	0.093	0.570	0.079
2000.191c	20.900	3.330	0.580	2.970	0.379	2.040	0.402	1.150	0.154	1.060	0.178
2000.191d	25.410	3.800	0.497	3.720	0.374	2.020	0.426	1.230	0.155	0.990	0.137
2000.192a	0.669	0.101	0.012	0.117	0.009	0.092	0.012	0.030	0.006	0.025	0.011
2000.192b	5.440	0.940	0.148	0.800	0.087	0.528	0.120	0.365	0.029	0.257	0.035
2000.192c	8.250	1.200	0.196	1.320	0.149	0.840	0.213	0.480	0.074	0.486	0.075
2000.192d	7.770	1.060	0.194	1.180	0.128	0.820	0.187	0.492	0.061	0.416	0.072

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 2a (KHO_1977.002)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.190a	0.035	0.072	0.029	1.690	1.080	0.320
2000.190b	0.030	0.062	0.014	1.380	0.589	0.272
2000.190c	0.023	0.047	0.019	1.440	0.529	0.640
2000.190d	0.018	0.046	0.018	1.240	1.450	0.720
2000.191a	0.023	0.046	0.015	1.500	3.130	1.250
2000.191b	0.036	0.059	0.019	1.590	1.170	0.410
2000.191c	0.015	0.039	0.014	1.940	2.400	0.850
2000.191d	0.007	0.071	0.023	2.130	1.340	0.930
2000.192a	0.017	0.059	0.004	0.650	0.055	0.370
2000.192b	0.048	0.077	0.018	1.900	0.483	0.620
2000.192c	0.013	0.055	0.015	1.340	0.423	0.530
2000.192d	0.046	0.052	0.021	1.510	0.356	0.650

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4 (KHO_1978.004.01)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.194a	M1	0.713782	0.730	2677.0	22.150	64596.3	247191.5	1.800	1.250	0.780	37.220
2000.194b	M1	0.713321	0.690	2986.0	29.870	92008.6	363581.7	1.640	1.460	1.430	46.640
2000.194c	M1	0.713642	0.820	2749.9	11.040	91324.2	363411.8	2.830	1.150	1.160	32.650
2000.194d	M1	0.714091	0.790	2939.0	16.520	104794.4	414540.0	1.880	1.190	2.130	29.410
2000.195a	M2	0.714575	1.220	2748.2	10.930	51230.7	199821.3	2.710	1.090	0.860	12.110
2000.195b	M2	0.713156	0.720	2275.0	25.750	56035.8	226573.2	4.120	1.130	2.070	10.510
2000.195c	M2	0.713464	0.740	2204.1	63.350	59659.8	233033.3	13.920	1.320	1.740	54.340
2000.195d	M2	0.714603	0.680	1984.0	71.150	55688.3	212125.7	5.430	1.220	2.340	10.690
2000.197a	M3	0.711040	0.240	2414.7	246.050	46749.7	165925.4	12.750	1.160	1.930	12.380
2000.197b	M3	0.712633	0.230	1998.9	85.170	59961.4	218344.5	1.120	1.560	2.320	58.070
2000.197c	M3	0.711337	0.260	2268.1	36.240	70467.3	259579.8	4.200	0.650	2.400	9.790
2000.197d	M3	0.712821	0.330	2036.6	267.950	73724.5	266445.6	39.400	1.570	1.520	19.210

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.194a	127.430	1.280	0.112	0.650	205.360	0.234	0.232	0.090	107.800	5.440	0.201
2000.194b	138.720	1.270	0.106	0.980	259.360	0.191	0.600	0.029	125.430	10.560	0.238
2000.194c	111.280	0.330	0.260	0.720	309.110	0.174	0.330	0.075	113.000	15.920	0.181
2000.194d	164.780	2.630	0.126	1.180	397.420	0.254	0.340	0.096	127.620	2.630	0.212
2000.195a	151.420	2.820	0.242	1.970	51.650	0.116	0.480	0.105	91.090	0.258	0.114
2000.195b	134.020	2.870	0.280	3.550	93.700	0.066	0.380	0.069	92.660	0.440	0.368
2000.195c	197.250	4.670	4.530	3.550	140.070	0.284	0.600	0.210	79.730	1.340	0.490
2000.195d	197.770	3.430	0.265	3.240	145.700	0.176	0.540	0.192	72.260	1.660	0.337
2000.197a	258.140	2.450	0.210	0.940	126.090	0.420	0.124	0.089	152.620	3.410	0.315
2000.197b	260.150	3.920	0.234	0.920	235.280	0.480	0.190	0.033	195.250	2.100	0.297
2000.197c	150.110	0.480	0.068	0.650	278.520	0.340	0.250	0.050	149.750	10.630	0.440
2000.197d	303.800	2.270	0.380	1.670	312.260	0.690	0.340	0.152	224.740	19.930	0.740

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4 (KHO_1978.004.01)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.194a	0.012	0.165	0.047	0.150	0.291	0.017	0.007	12.170	16.030	8.700	2.220
2000.194b	0.020	0.350	0.054	0.131	0.510	0.055	0.017	13.820	32.640	18.290	4.420
2000.194c	0.014	0.250	0.071	0.104	0.360	0.062	0.016	17.090	42.500	13.830	6.160
2000.194d	0.045	0.360	0.049	0.093	0.480	0.065	0.021	24.310	7.180	5.810	0.892
2000.195a	0.001	0.192	0.031	0.065	0.242	0.065	0.010	19.500	1.120	2.040	0.153
2000.195b	0.006	0.223	0.040	0.097	0.211	0.029	0.008	13.430	1.650	3.690	0.328
2000.195c	0.008	0.142	0.034	0.080	0.220	0.121	0.020	17.240	3.960	10.770	0.812
2000.195d	0.022	0.146	0.008	0.094	0.182	0.056	0.021	13.730	5.400	10.250	1.128
2000.197a	0.013	0.350	0.031	0.091	0.143	0.013	0.008	23.630	0.689	2.610	0.238
2000.197b	0.011	0.440	0.085	0.128	0.162	0.016	0.008	35.630	0.401	2.560	0.122
2000.197c	0.011	0.300	0.022	0.130	0.340	0.054	0.009	29.440	1.290	5.560	0.397
2000.197d	0.031	0.510	0.040	0.168	0.244	0.029	0.014	46.300	2.890	11.210	0.846

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.194a	8.060	1.290	0.199	1.310	0.132	0.758	0.154	0.470	0.057	0.299	0.062
2000.194b	17.100	2.280	0.366	2.400	0.258	1.560	0.305	0.900	0.119	0.666	0.129
2000.194c	24.120	3.600	0.583	3.710	0.444	2.570	0.475	1.310	0.166	1.260	0.177
2000.194d	3.050	0.630	0.073	0.424	0.063	0.331	0.066	0.266	0.015	0.196	0.047
2000.195a	0.623	0.109	0.011	0.096	0.011	0.081	0.011	0.032	0.005	0.017	0.004
2000.195b	1.080	0.244	0.029	0.158	0.013	0.129	0.016	0.038	0.007	0.056	0.011
2000.195c	2.720	0.560	0.053	0.410	0.059	0.218	0.062	0.162	0.016	0.126	0.019
2000.195d	3.680	0.620	0.108	0.530	0.062	0.351	0.076	0.178	0.026	0.149	0.027
2000.197a	1.160	0.283	0.110	0.415	0.046	0.393	0.102	0.286	0.044	0.286	0.057
2000.197b	0.657	0.197	0.044	0.238	0.025	0.268	0.062	0.192	0.040	0.306	0.056
2000.197c	2.160	0.550	0.221	1.010	0.148	1.260	0.312	1.090	0.143	1.080	0.176
2000.197d	4.720	1.340	0.474	1.850	0.285	2.450	0.580	1.770	0.305	2.070	0.344

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Khotoruk 4 (KHO_1978.004.01)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.194a	0.021	0.041	0.009	0.720	0.292	0.460
2000.194b	0.040	0.094	0.022	0.710	0.366	0.420
2000.194c	0.023	0.061	0.024	0.450	0.990	0.580
2000.194d	0.027	0.028	0.024	0.530	0.232	0.710
2000.195a	0.012	0.031	0.011	0.370	0.069	1.500
2000.195b	0.015	0.049	0.009	0.450	0.211	1.800
2000.195c	0.018	0.034	0.014	0.540	0.277	1.940
2000.195d	0.011	0.000	0.007	0.390	0.274	1.720
2000.197a	0.012	0.025	0.006	0.270	0.037	6.100
2000.197b	0.014	0.021	0.005	0.400	0.011	7.260
2000.197c	0.045	0.042	0.010	0.390	0.069	5.060
2000.197d	0.037	0.010	0.009	0.900	0.204	7.620

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 3 (SHM_1973.003)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.198a	M2	0.711119	0.400	2038.7	88.580	45429.8	159868.1	4.070	1.010	2.420	64.890
2000.198b	M2	0.711643	0.230	2082.0	58.960	57284.9	204495.4	6.550	0.780	1.320	62.880
2000.198c	M2	0.711696	0.380	2171.1	36.010	71613.4	257266.8	1.650	1.260	1.780	148.650
2000.198d	M2	0.711839	0.290	2045.7	190.940	75766.6	273416.6	11.540	1.800	2.250	159.210
2000.199a	M3	0.712498	0.136	2222.8	84.410	61689.8	202577.4	19.000	0.610	1.250	11.170
2000.199b	M3	0.711999	0.190	2350.0	102.570	68590.9	227266.2	3.510	0.650	1.330	14.660
2000.199c	M3	0.711851	0.240	1908.7	104.060	67768.0	227166.1	1.650	1.810	1.690	79.640
2000.199d	M3	0.711798	0.410	2257.5	108.570	82752.0	281345.8	11.010	2.180	2.130	57.270

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.198a	196.220	3.180	0.420	1.070	139.870	0.460	0.103	0.165	154.530	3.290	0.227
2000.198b	159.740	1.870	0.307	0.730	201.620	0.320	0.160	0.200	119.230	5.440	0.145
2000.198c	143.450	1.490	0.204	0.720	298.090	0.530	0.168	0.185	178.070	22.220	0.358
2000.198d	382.150	4.540	0.820	1.040	377.290	0.460	0.290	0.210	202.790	11.520	0.407
2000.199a	206.650	2.170	0.201	0.510	269.770	0.208	0.138	0.104	103.490	2.340	0.107
2000.199b	187.880	2.820	0.263	0.760	278.270	0.287	0.215	0.130	104.650	1.050	0.136
2000.199c	282.680	3.180	0.167	1.300	278.270	0.440	0.162	0.059	228.950	2.270	0.420
2000.199d	334.060	3.990	0.420	0.670	400.630	0.350	0.320	0.177	135.030	4.370	0.179

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.198a	0.014	0.640	0.112	0.125	0.233	0.008	0.012	22.110	0.749	3.700	0.248
2000.198b	0.014	0.690	0.047	0.122	0.201	0.036	0.007	22.420	1.560	6.060	0.397
2000.198c	0.012	0.750	0.053	0.249	0.300	0.030	0.008	39.870	3.240	9.680	0.954
2000.198d	0.034	0.690	0.064	0.163	0.350	0.009	0.012	36.120	1.860	5.500	0.610
2000.199a	0.014	0.220	0.038	0.063	0.200	0.012	0.022	13.640	0.553	1.970	0.164
2000.199b	0.018	0.350	0.047	0.077	0.239	0.034	0.024	12.880	0.243	1.430	0.131
2000.199c	0.012	0.560	0.085	0.204	0.222	0.025	0.005	39.750	0.565	2.420	0.164
2000.199d	0.055	1.470	0.021	0.129	0.224	0.019	0.031	23.950	1.060	5.980	0.342

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 3 (SHM_1973.003)

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.198a	1.510	0.369	0.116	0.459	0.063	0.416	0.112	0.356	0.041	0.328	0.044
2000.198b	2.400	0.650	0.187	0.850	0.120	0.970	0.220	0.630	0.097	0.652	0.098
2000.198c	5.380	1.790	0.440	2.180	0.329	2.250	0.550	1.760	0.274	1.690	0.293
2000.198d	3.310	0.850	0.260	1.350	0.197	1.340	0.334	1.080	0.145	1.030	0.179
2000.199a	0.920	0.289	0.059	0.310	0.057	0.301	0.075	0.187	0.035	0.187	0.034
2000.199b	0.476	0.167	0.057	0.123	0.014	0.163	0.028	0.116	0.021	0.096	0.021
2000.199c	0.822	0.268	0.074	0.290	0.039	0.301	0.086	0.229	0.031	0.207	0.033
2000.199d	1.790	0.720	0.160	0.590	0.092	0.600	0.125	0.448	0.057	0.347	0.064

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.198a	0.014	0.027	0.010	0.420	0.076	5.260
2000.198b	0.014	0.010	0.009	0.520	0.059	2.050
2000.198c	0.013	0.052	0.005	0.710	0.144	3.200
2000.198d	0.020	0.039	0.014	0.600	0.107	6.990
2000.199a	0.005	0.020	0.006	0.780	0.028	1.320
2000.199b	0.018	0.012	0.015	0.390	0.020	1.500
2000.199c	0.019	0.023	0.008	0.510	0.029	7.070
2000.199d	0.030	0.020	0.012	1.030	0.076	2.580

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 1 (SHM_1975.001)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.201a	M1	0.711689	0.138	1748.8	6.510	44537.4	181557.2	0.950	0.106	1.710	14.740
2000.201b	M1	0.710516	0.082	1393.7	22.830	44056.8	182432.8	1.540	0.247	0.830	25.930
2000.201c	M1	0.711827	0.108	1326.9	6.710	42215.0	165963.1	0.450	0.163	1.010	15.840
2000.201d	M1	0.713526	0.096	1818.1	23.190	58497.1	238454.7	3.170	0.479	1.340	12.380
2000.202a	M2	0.714667	0.124	1826.4	4.330	45632.3	181989.1	0.620	0.119	0.970	4.030
2000.202b	M2	0.713010	0.137	1733.9	50.700	55877.8	224581.5	0.980	0.599	1.180	13.110
2000.202c	M2	0.710841	0.204	2065.2	12.040	61100.2	257829.7	0.750	0.136	0.870	10.630
2000.202d	M2	0.717315	0.332	2621.9	13.710	80575.8	321736.3	0.700	0.153	1.490	13.510
2000.203a	M3	0.709939	0.180	826.980	18.040	19020.5	65208.6	0.696	0.337	1.030	24.120
2000.203b	M3	0.712945	0.155	1807.6	8.440	49757.5	186756.9	0.780	0.216	1.300	31.690
2000.203c	M3	0.712485	0.117	1285.4	13.990	44635.6	169894.6	1.160	0.425	1.460	12.160
2000.203d	M3	0.711714	0.175	2155.1	31.920	78038.0	298673.3	0.690	0.382	1.990	6.420

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.201a	77.430	0.700	0.033	0.264	189.860	0.197	0.087	0.067	77.460	0.006	0.012
2000.201b	113.040	1.240	0.598	0.750	212.020	0.248	0.098	0.046	141.480	0.513	0.072
2000.201c	43.740	0.296	0.079	0.195	193.040	0.177	0.088	0.023	70.800	0.061	0.024
2000.201d	88.250	0.410	0.148	0.277	334.160	0.267	0.126	0.040	115.920	0.640	0.037
2000.202a	69.230	0.208	0.061	0.157	161.730	0.112	0.095	0.031	69.150	0.020	0.017
2000.202b	160.030	1.480	0.180	0.619	202.490	0.294	0.153	0.013	179.100	0.885	0.117
2000.202c	45.260	0.280	0.057	0.340	196.810	0.188	0.215	0.055	71.200	0.014	0.031
2000.202d	80.010	0.370	0.176	0.248	333.940	0.079	0.161	0.126	102.290	0.208	0.031
2000.203a	40.300	1.040	0.148	0.633	51.950	0.590	0.053	0.072	160.580	0.064	0.074
2000.203b	59.690	0.507	0.095	0.484	219.340	0.323	0.116	0.053	112.660	0.104	0.029
2000.203c	92.090	0.850	0.076	0.545	183.080	0.239	0.980	0.028	149.000	0.596	0.098
2000.203d	93.130	0.345	0.158	0.290	382.420	0.195	0.128	0.037	157.390	0.266	0.054

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 1 (SHM_1975.001)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.201a	0.008	0.069	0.123	0.032	0.174	0.011	0.003	10.040	0.003	0.030	0.003
2000.201b	0.002	0.161	0.035	0.059	0.171	0.017	0.004	16.350	0.269	0.661	0.047
2000.201c	0.016	0.048	0.024	0.060	0.176	0.013	0.012	13.160	0.058	0.169	0.016
2000.201d	0.009	0.179	0.032	0.060	0.242	0.028	0.006	16.440	0.395	0.685	0.080
2000.202a	0.010	0.103	0.083	0.032	0.176	0.008	0.006	10.380	0.025	0.123	0.005
2000.202b	0.016	0.083	0.030	0.114	0.175	0.015	0.005	26.050	0.584	1.327	0.126
2000.202c	0.006	0.105	0.011	0.114	0.237	0.039	0.006	17.090	0.017	0.103	0.007
2000.202d	0.005	0.209	0.013	0.109	0.211	0.030	0.009	15.760	0.145	0.302	0.020
2000.203a	0.002	0.066	0.225	0.044	0.052	0.010	0.005	49.150	0.057	0.159	0.018
2000.203b	0.004	0.119	0.131	0.074	0.179	0.014	0.006	27.460	0.090	0.225	0.023
2000.203c	0.013	0.090	0.010	0.056	0.125	0.018	0.005	22.580	0.375	0.827	0.070
2000.203d	0.025	0.140	0.036	0.126	0.240	0.027	0.010	19.390	0.168	0.308	0.023

Sample ID											
2000.201a	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
2000.201b	0.023	0.028	0.003	0.002	0.004	0.016	0.006	0.009	0.005	0.003	0.003
2000.201c	0.181	0.077	0.008	0.058	0.007	0.053	0.012	0.037	0.012	0.045	0.005
2000.201d	0.031	0.046	0.006	0.026	0.004	0.006	0.006	0.022	0.003	0.018	0.008
2000.202a	0.345	0.096	0.014	0.076	0.011	0.097	0.024	0.049	0.014	0.049	0.015
2000.202b	0.032	0.065	0.010	0.018	0.006	0.015	0.004	0.006	0.000	0.002	0.005
2000.202c	0.569	0.081	0.054	0.136	0.019	0.129	0.024	0.067	0.018	0.091	0.015
2000.202d	0.039	0.071	0.001	0.022	0.004	0.040	0.005	0.022	0.006	0.032	0.007
2000.203a	0.092	0.077	0.013	0.036	0.007	0.031	0.014	0.022	0.011	0.032	0.008
2000.203b	0.065	0.014	0.003	0.014	0.003	0.013	0.003	0.006	0.001	0.004	0.001
2000.203c	0.077	0.040	0.007	0.012	0.003	0.012	0.005	0.011	0.004	0.001	0.003
2000.203d	0.309	0.039	0.022	0.075	0.012	0.078	0.014	0.044	0.004	0.074	0.012
	0.145	0.062	0.008	0.033	0.009	0.034	0.010	0.025	0.003	0.006	0.005

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 1 (SHM_1975.001)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.201a	0.013	0.020	0.008	0.237	0.001	0.179
2000.201b	0.007	0.022	0.007	0.770	0.002	0.495
2000.201c	0.001	0.014	0.011	0.204	0.003	0.211
2000.201d	0.014	0.022	0.015	0.438	0.004	0.296
2000.202a	0.008	0.027	0.008	0.167	0.000	0.129
2000.202b	0.013	0.005	0.005	0.334	0.008	0.751
2000.202c	0.000	0.081	0.020	0.123	0.011	0.088
2000.202d	0.025	0.055	0.016	0.290	0.008	0.198
2000.203a	0.003	0.003	0.002	0.146	0.009	1.950
2000.203b	0.009	0.006	0.008	1.130	0.006	0.643
2000.203c	0.008	0.004	0.004	0.393	0.005	0.721
2000.203d	0.031	0.025	0.010	0.496	0.005	0.378

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 2 (SHM_1972.002)

Sample ID	Tooth	$^{87}Sr/^{86}Sr$	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.205a	M1	0.712315	0.359	3531.8	27.990	80438.6	301196.4	0.650	0.192	2.070	58.100
2000.205b	M1	0.713115	0.530	3158.1	44.130	81465.3	302276.6	4.150	0.800	2.830	82.870
2000.205c	M1	0.713841	0.630	3889.9	2.370	93966.5	354750.6	1.190	0.600	1.810	51.170
2000.205d	M1	0.713268	0.800	3933.4	231.370	96913.5	370907.3	47.480	0.910	2.180	138.350
2000.206a	M2	0.712511	0.255	3250.0	28.520	62240.2	390760.4	1.590	0.591	1.640	59.520
2000.206b	M2	0.712215	0.286	2261.2	459.480	49716.6	314740.3	30.650	2.150	2.930	173.170
2000.206c	M2	0.713147	0.650	2849.9	52.650	93695.6	343659.7	2.050	0.398	1.820	62.310
2000.206d	M2	0.715585	0.450	2349.1	67.220	74477.8	267265.2	5.320	0.278	1.450	44.870
2000.207a	M3	0.712173	0.356	3054.8	92.470	71947.1	270371.3	4.660	0.476	1.910	74.360
2000.207b	M3	0.712752	0.280	2794.2	30.590	67696.2	255297.4	15.620	0.264	1.630	46.620
2000.207c	M3	0.712890	0.400	2883.0	11.950	90536.4	348457.4	2.970	0.232	2.450	56.240
2000.207d	M3	0.713795	0.360	2809.7	9.170	94294.9	365489.9	0.940	0.237	2.690	50.790

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.205a	166.630	0.600	0.085	0.677	331.970	0.461	0.127	0.047	83.380	0.409	0.036
2000.205b	231.330	1.480	0.109	0.626	383.990	0.590	0.155	0.267	79.830	0.424	0.033
2000.205c	88.150	0.980	0.497	0.228	469.740	0.237	0.144	0.042	77.330	0.014	0.000
2000.205d	332.070	4.640	0.138	1.200	559.940	0.632	0.204	0.226	91.450	1.920	0.148
2000.206a	161.090	0.571	0.077	0.311	298.850	0.130	0.100	0.065	127.140	0.298	0.065
2000.206b	862.980	9.410	0.587	2.790	279.520	0.780	0.110	0.546	125.680	8.620	0.287
2000.206c	144.790	1.870	0.084	0.333	444.260	0.437	0.139	0.084	87.640	0.197	0.013
2000.206d	104.310	1.010	0.186	0.163	322.000	0.294	0.127	0.075	79.340	0.599	0.019
2000.207a	178.910	1.060	0.195	0.517	284.360	0.272	0.126	0.111	103.850	1.077	0.075
2000.207b	131.450	0.510	0.094	0.650	294.310	0.268	0.104	0.089	83.910	0.626	0.033
2000.207c	85.700	0.495	0.120	0.164	426.910	0.219	0.150	0.158	110.160	0.442	0.040
2000.207d	94.580	0.450	0.249	0.230	345.550	0.254	0.147	0.028	118.110	0.318	0.048

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 2 (SHM_1972.002)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.205a	0.005	0.356	0.032	0.041	0.279	0.007	0.006	20.180	0.133	0.327	0.044
2000.205b	0.013	0.600	0.035	0.073	0.242	0.017	0.008	26.320	0.117	0.522	0.035
2000.205c	0.012	0.660	0.030	0.096	0.372	0.016	0.005	18.500	0.008	0.315	0.008
2000.205d	0.027	0.480	0.029	0.056	0.419	0.017	0.013	29.500	0.808	1.880	0.180
2000.206a	0.018	0.680	0.028	0.046	0.441	0.014	0.009	19.980	0.132	0.583	0.078
2000.206b	0.039	0.810	0.081	0.203	0.415	0.016	0.034	65.520	2.870	10.350	0.707
2000.206c	0.005	0.400	0.034	0.055	0.385	0.009	0.010	22.530	0.066	0.317	0.050
2000.206d	0.010	0.305	0.033	0.109	0.229	0.030	0.009	20.470	0.243	0.587	0.054
2000.207a	0.008	0.374	0.023	0.064	0.231	0.007	0.006	17.720	0.335	1.346	0.082
2000.207b	0.012	0.312	0.022	0.069	0.196	0.016	0.005	16.020	0.271	0.817	0.058
2000.207c	0.004	0.670	0.030	0.071	0.337	0.010	0.007	17.630	0.154	0.494	0.035
2000.207d	0.004	0.670	0.007	0.105	0.353	0.035	0.008	20.290	0.100	0.404	0.025

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.205a	0.220	0.087	0.023	0.111	0.013	0.096	0.013	0.040	0.007	0.041	0.006
2000.205b	0.154	0.086	0.010	0.047	0.004	0.039	0.014	0.032	0.007	0.041	0.005
2000.205c	0.022	0.049	0.017	0.019	0.005	0.032	0.007	0.017	0.004	0.000	0.008
2000.205d	0.992	0.322	0.053	0.216	0.027	0.254	0.059	0.134	0.015	0.190	0.013
2000.206a	0.108	0.071	0.008	0.036	0.007	0.025	0.007	0.030	0.006	0.039	0.008
2000.206b	3.250	0.856	0.176	1.040	0.126	0.930	0.186	0.502	0.065	0.492	0.073
2000.206c	0.044	0.063	0.010	0.052	0.013	0.036	0.008	0.014	0.008	0.022	0.008
2000.206d	0.340	0.057	0.024	0.058	0.013	0.087	0.016	0.044	0.004	0.043	0.005
2000.207a	0.382	0.094	0.042	0.140	0.020	0.145	0.027	0.097	0.009	0.095	0.019
2000.207b	0.316	0.071	0.014	0.122	0.017	0.132	0.025	0.064	0.006	0.073	0.009
2000.207c	0.143	0.088	0.010	0.084	0.011	0.062	0.012	0.030	0.006	0.026	0.008
2000.207d	0.114	0.077	0.008	0.059	0.009	0.039	0.007	0.035	0.012	0.047	0.009

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Shamanskii Mys 2 (SHM_1972.002)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.205a	0.006	0.016	0.011	0.416	0.013	0.053
2000.205b	0.020	0.005	0.013	0.640	0.008	0.042
2000.205c	0.022	0.035	0.014	0.317	0.004	0.026
2000.205d	0.009	0.030	0.013	0.810	0.143	0.032
2000.206a	0.023	0.041	0.015	0.850	0.008	0.063
2000.206b	0.014	0.022	0.012	2.140	0.222	0.187
2000.206c	0.015	0.023	0.014	0.506	0.005	0.018
2000.206d	0.020	0.032	0.007	0.294	0.013	0.015
2000.207a	0.022	0.020	0.007	0.489	0.040	0.094
2000.207b	0.013	0.030	0.009	0.512	0.025	0.052
2000.207c	0.002	0.003	0.012	0.527	0.019	0.077
2000.207d	0.041	0.042	0.017	0.352	0.009	0.073

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 7 (OBK_1971.007)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.209a	molar	0.711363	0.680	2850.9	43.410	98511.1	356769.3	3.550	1.030	2.140	17.490
2000.209b	molar	0.709328	0.480	2199.9	14.350	88527.3	316319.9	0.670	0.268	1.460	39.010
2000.209c	molar	0.710761	0.660	2058.4	10.180	85852.0	307860.0	0.590	0.140	2.050	10.640
2000.209d	molar	0.711537	0.460	1949.3	12.130	76808.8	274096.0	0.510	0.064	1.600	4.840
2000.210a	molar	0.709441	0.730	2821.9	40.380	95798.7	355799.6	3.380	1.740	2.510	15.440
2000.210b	molar	0.709772	0.970	2998.5	47.580	129410.5	480788.5	3.590	3.150	3.200	34.510
2000.210c	molar	0.710054	0.740	2862.7	183.920	118503.3	426910.2	1.920	2.020	3.470	48.490
2000.210d	molar	0.711698	0.480	2049.4	12.480	79317.1	288461.8	0.730	0.096	1.880	3.140

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.209a	191.220	2.030	0.150	0.290	625.190	1.370	0.267	0.103	128.220	3.910	0.263
2000.209b	68.130	0.600	0.069	0.248	519.640	0.415	0.150	0.029	54.250	0.234	0.036
2000.209c	103.530	0.870	0.050	0.084	474.070	0.224	0.126	0.170	48.200	0.044	0.033
2000.209d	74.160	0.430	0.059	0.086	432.130	0.231	0.110	0.064	42.460	0.041	0.009
2000.210a	248.770	1.590	0.156	0.527	513.990	0.830	0.395	0.245	142.750	7.090	0.433
2000.210b	251.780	1.370	0.177	0.365	627.930	1.450	0.610	0.030	250.530	19.830	1.450
2000.210c	367.050	2.450	0.304	0.588	793.320	1.470	0.690	0.131	244.570	2.780	0.496
2000.210d	85.490	0.400	0.048	0.075	474.900	0.101	0.223	0.061	43.810	0.046	0.016

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.209a	0.007	0.205	0.022	0.073	0.259	0.027	0.013	64.490	1.980	6.160	0.537
2000.209b	0.004	0.208	0.024	0.040	0.256	0.025	0.006	21.850	0.158	0.651	0.052
2000.209c	0.017	0.206	0.016	0.054	0.329	0.029	0.004	15.970	0.052	0.277	0.013
2000.209d	0.014	0.283	0.035	0.085	0.255	0.032	0.008	14.650	0.020	0.102	0.008
2000.210a	0.016	0.228	0.028	0.083	0.317	0.021	0.021	56.440	4.590	7.140	1.117
2000.210b	0.010	0.420	0.049	0.107	0.388	0.034	0.009	108.230	13.070	18.620	2.940
2000.210c	0.015	0.257	0.029	0.239	0.303	0.034	0.028	113.780	2.040	2.820	0.520
2000.210d	0.003	0.203	0.008	0.048	0.264	0.008	0.004	8.080	0.044	0.215	0.021

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 7 (OBK_1971.007)

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.209a	2.370	0.467	0.160	0.492	0.089	0.500	0.110	0.308	0.041	0.295	0.053
2000.209b	0.262	0.068	0.015	0.053	0.008	0.036	0.010	0.034	0.006	0.029	0.003
2000.209c	0.043	0.060	0.010	0.014	0.004	0.055	0.006	0.014	0.002	0.027	0.006
2000.209d	0.038	0.074	0.008	0.039	0.004	0.038	0.003	0.008	0.005	0.022	0.005
2000.210a	4.910	0.931	0.285	1.120	0.139	0.866	0.190	0.547	0.061	0.434	0.075
2000.210b	13.100	2.640	0.713	2.890	0.424	2.660	0.534	1.450	0.173	1.130	0.201
2000.210c	2.210	0.373	0.093	0.429	0.054	0.351	0.076	0.216	0.023	0.166	0.031
2000.210d	0.077	0.045	0.006	0.035	0.006	0.010	0.005	0.008	0.001	0.007	0.001

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.209a	0.014	0.029	0.007	0.990	0.063	0.049
2000.209b	0.013	0.020	0.009	0.401	0.014	0.004
2000.209c	0.025	0.022	0.011	0.276	0.010	0.003
2000.209d	0.031	0.034	0.010	0.248	0.005	0.003
2000.210a	0.017	0.039	0.009	0.840	0.066	0.075
2000.210b	0.008	0.062	0.010	1.530	0.152	0.165
2000.210c	0.009	0.026	0.006	1.520	0.015	0.209
2000.210d	0.012	0.019	0.012	0.256	0.005	0.016

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 13 (OBK_1971.013)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.212a	M1	0.712875	0.530	2146.0	13.550	83873.3	299026.2	0.910	0.157	1.260	10.420
2000.212b	M1	0.711832	0.630	2060.6	25.620	78412.0	274310.0	1.990	0.238	1.230	5.240
2000.212c	M1	0.712782	0.240	1840.9	17.100	66325.3	233829.6	0.480	0.129	2.050	8.140
2000.212d	M1	0.714384	0.520	1895.0	9.000	76805.4	275634.5	1.850	0.105	1.330	4.220
2000.213a	M2	0.709524	0.640	2041.1	10.540	82711.2	290821.4	5.340	0.172	1.060	41.250
2000.213b	M2	0.711175	0.470	1826.7	3.070	74127.0	258163.2	0.710	0.185	1.560	9.050
2000.213c	M2	0.710063	0.420	1878.8	2.890	64317.1	222303.1	0.320	0.047	1.020	5.330
2000.213d	M2	0.709678	0.490	1704.6	0.936	67490.3	237886.6	0.210	0.042	1.170	2.960
2000.214a	M3	0.709459	0.303	2127.1	5.570	47891.2	271321.4	0.330	0.421	0.990	4.510
2000.214b	M3	0.711185	0.420	2351.0	58.760	75977.6	441322.8	3.630	0.830	1.890	17.310
2000.214c	M3	0.710882	0.440	2207.5	23.540	70385.1	415524.8	4.020	0.210	1.590	8.470
2000.214d	M3	0.711380	0.410	2006.9	44.220	62686.3	364301.8	5.120	0.655	1.840	9.620

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.212a	76.870	0.840	0.074	0.121	465.170	0.314	0.121	0.248	53.870	0.021	0.013
2000.212b	121.620	0.520	0.151	0.121	394.960	0.166	0.210	0.071	44.800	0.041	0.010
2000.212c	98.390	0.340	0.015	0.050	328.730	0.191	0.205	0.093	33.550	0.106	0.023
2000.212d	88.590	0.168	0.041	0.111	378.910	0.218	0.118	0.051	36.140	0.002	0.016
2000.213a	81.390	0.224	0.042	0.161	424.820	0.356	0.116	0.044	55.390	0.474	0.019
2000.213b	45.670	0.229	0.106	0.065	366.090	0.246	0.148	0.011	50.810	2.300	0.032
2000.213c	46.710	0.131	0.020	0.064	205.540	0.154	0.149	0.021	38.540	0.122	0.009
2000.213d	47.250	0.114	0.026	0.027	280.070	0.168	0.075	0.028	35.810	0.009	0.021
2000.214a	78.470	0.158	0.045	0.192	271.360	0.216	0.080	0.018	76.320	0.014	0.048
2000.214b	199.140	0.770	0.079	0.163	489.000	0.253	0.133	0.488	101.680	4.830	0.416
2000.214c	128.360	0.405	0.053	0.086	438.530	0.139	0.159	0.075	76.700	2.880	0.124
2000.214d	216.310	0.900	0.083	0.186	352.420	0.094	0.251	0.212	61.640	0.872	0.038

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 13 (OBK_1971.013)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.212a	0.014	0.148	0.025	0.055	0.280	0.000	0.013	15.740	0.018	0.105	0.008
2000.212b	0.014	0.217	0.045	0.056	0.246	0.003	0.010	12.700	0.029	0.069	0.006
2000.212c	0.007	0.090	0.026	0.041	0.199	0.249	0.004	10.630	0.011	0.037	0.004
2000.212d	0.023	0.164	0.019	0.045	0.203	0.014	0.004	12.090	0.006	0.012	0.005
2000.213a	0.008	0.234	0.021	0.046	0.234	0.022	0.006	20.070	0.250	0.224	0.057
2000.213b	0.001	0.148	0.005	0.057	0.215	0.013	0.005	19.040	1.565	1.503	0.455
2000.213c	0.010	0.170	0.010	0.032	0.168	0.020	0.005	12.160	0.093	0.095	0.029
2000.213d	0.002	0.225	0.009	0.026	0.186	0.011	0.005	11.450	0.008	0.020	0.032
2000.214a	0.006	0.163	0.013	0.056	0.330	0.011	0.003	41.270	0.005	0.045	0.001
2000.214b	0.026	0.300	0.030	0.050	0.478	0.027	0.013	39.170	2.700	2.820	0.620
2000.214c	0.013	0.250	0.023	0.079	0.457	0.020	0.007	20.230	1.516	1.500	0.419
2000.214d	0.010	0.340	0.026	0.081	0.533	0.034	0.012	16.770	0.471	0.658	0.121

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.212a	0.026	0.014	0.004	0.023	0.005	0.023	0.005	0.014	0.006	0.022	0.000
2000.212b	0.039	0.022	0.020	0.015	0.008	0.048	0.002	0.036	0.000	0.011	0.001
2000.212c	0.016	0.040	0.007	0.030	0.000	0.010	0.003	0.010	0.004	0.015	0.004
2000.212d	0.008	0.056	0.016	0.024	0.001	0.032	0.004	0.015	0.001	0.016	0.001
2000.213a	0.328	0.087	0.018	0.091	0.011	0.067	0.007	0.026	0.005	0.029	0.004
2000.213b	1.950	0.451	0.120	0.469	0.060	0.385	0.083	0.210	0.024	0.177	0.023
2000.213c	0.124	0.026	0.009	0.024	0.004	0.030	0.004	0.012	0.004	0.013	0.005
2000.213d	0.034	0.048	0.013	0.014	0.003	0.011	0.006	0.000	0.001	0.005	0.001
2000.214a	0.011	0.028	0.004	0.007	0.003	0.025	0.003	0.004	0.003	0.002	0.002
2000.214b	3.100	0.598	0.183	0.820	0.105	0.671	0.132	0.389	0.058	0.377	0.045
2000.214c	1.780	0.384	0.082	0.621	0.068	0.398	0.084	0.232	0.026	0.145	0.028
2000.214d	0.606	0.100	0.025	0.154	0.012	0.100	0.015	0.068	0.008	0.063	0.007

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 13 (OBK_1971.013)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.212a	0.002	0.017	0.009	0.454	0.005	0.005
2000.212b	0.000	0.008	0.025	0.207	0.009	0.009
2000.212c	0.015	0.024	0.007	0.094	0.004	0.001
2000.212d	0.006	0.026	0.011	0.469	0.005	0.004
2000.213a	0.007	0.013	0.012	0.566	0.003	0.008
2000.213b	0.015	0.016	0.008	0.330	0.032	0.014
2000.213c	0.008	0.026	0.007	0.047	0.003	0.003
2000.213d	0.009	0.020	0.006	0.075	0.002	0.002
2000.214a	0.009	0.018	0.005	0.313	0.003	0.047
2000.214b	0.026	0.042	0.012	0.670	0.066	0.028
2000.214c	0.020	0.023	0.012	0.535	0.099	0.024
2000.214d	0.016	0.036	0.008	0.560	0.018	0.018

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Obkhoi 5 (OBK_1971.005)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.216a	M1	0.709504	0.830	3340.2	52.380	118505.5	397861.2	1.030	1.220	3.050	61.200
2000.216b	M1	0.709900	0.670	2674.6	30.390	108568.1	377787.7	0.990	1.610	2.370	74.120
2000.216c	M1	0.708014	0.520	2860.2	7.700	82398.0	290781.9	1.370	0.445	2.300	25.800
2000.217a	M2	0.709923	0.620	2710.7	24.490	122607.2	401557.7	0.970	0.612	2.710	17.710
2000.217b	M2	0.709852	1.160	3654.0	126.390	210009.1	680475.9	4.130	4.090	5.600	77.430
2000.217c	M2	0.710532	0.820	3021.4	68.830	154187.2	505136.0	2.090	1.800	4.070	160.200
2000.217d	M2	0.710796	1.070	3692.7	97.010	193401.6	646066.3	3.810	4.080	5.770	60.050
2000.218a	M3	0.710495	0.500	3185.6	27.190	88862.9	305582.6	1.370	0.880	2.310	63.410
2000.218b	M3	0.709360	0.440	2465.3	39.230	105306.8	360225.9	1.000	1.010	3.120	172.390
2000.218c	M3	0.711193	0.580	2452.6	9.600	114225.5	388254.2	1.350	0.221	2.630	55.550
2000.218d	M3	0.710778	0.820	3173.7	62.880	138684.9	478541.6	12.950	1.600	3.990	317.070

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.216a	168.550	0.990	0.152	0.155	672.690	0.990	0.540	0.111	138.560	5.470	0.679
2000.216b	158.910	0.820	0.100	0.262	483.070	1.070	0.395	0.061	135.420	1.980	0.714
2000.216c	95.640	0.970	0.212	0.342	230.340	0.301	0.201	0.088	61.160	1.170	0.069
2000.217a	82.950	0.590	0.105	0.252	700.260	0.568	0.328	0.027	113.590	0.900	0.236
2000.217b	355.980	4.190	0.329	0.700	1168.6	1.900	0.650	0.348	277.540	15.160	2.410
2000.217c	189.910	1.090	0.140	0.218	784.520	0.740	0.340	0.070	135.230	11.300	0.800
2000.217d	370.630	2.790	0.190	0.540	1269.8	1.660	0.780	0.190	257.260	18.560	2.730
2000.218a	106.380	0.640	0.196	0.218	383.190	0.622	0.219	0.447	115.790	1.310	0.378
2000.218b	112.940	0.960	0.129	0.131	570.270	0.740	0.154	0.029	114.530	1.770	0.651
2000.218c	82.030	0.260	0.246	0.146	624.120	0.414	0.155	0.080	83.510	1.430	0.151
2000.218d	198.500	4.710	0.354	0.860	783.770	1.260	0.240	0.760	134.180	15.180	0.800

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.216a	0.013	0.117	0.034	0.075	0.275	0.020	0.013	61.600	3.920	5.160	0.853
2000.216b	0.014	0.154	0.025	0.072	0.367	0.015	0.007	71.910	1.390	1.740	0.273
2000.216c	0.023	0.191	0.021	0.371	0.219	0.016	0.006	25.800	0.974	1.053	0.164
2000.217a	0.004	0.440	0.030	0.166	0.334	0.022	0.009	33.820	0.733	0.788	0.159
2000.217b	0.009	0.670	0.027	0.181	0.502	0.054	0.014	117.390	10.930	14.250	2.810
2000.217c	0.017	0.670	0.132	0.138	0.454	0.049	0.012	49.060	7.880	6.250	1.660
2000.217d	0.024	0.720	0.020	0.149	0.563	0.053	0.007	111.470	13.150	13.570	3.100

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Sample ID	**Nb**	**Mo**	**Ag**	**Cd**	**Sn**	**Sb**	**Cs**	**Ba**	**La**	**Ce**	**Pr**
2000.218a	0.017	0.195	0.005	0.051	0.210	0.011	0.008	37.650	0.884	1.011	0.208
2000.218b	0.023	0.168	0.009	0.131	0.293	0.011	0.007	48.520	1.033	0.840	0.261
2000.218c	0.011	0.400	0.019	0.143	0.269	0.039	0.008	28.580	0.788	0.935	0.130
2000.218d	0.037	0.210	0.013	0.266	0.412	0.047	0.010	61.800	11.270	9.470	2.570

Obkhoi 5 (OBK_1971.005)

Sample ID	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
2000.216a	4.360	0.879	0.177	0.870	0.093	0.699	0.123	0.330	0.044	0.280	0.054
2000.216b	1.223	0.148	0.055	0.248	0.030	0.169	0.043	0.104	0.016	0.094	0.025
2000.216c	0.888	0.190	0.042	0.163	0.022	0.161	0.029	0.092	0.011	0.071	0.017
2000.217a	0.567	0.150	0.038	0.167	0.023	0.067	0.025	0.059	0.006	0.072	0.006
2000.217b	11.320	2.330	0.622	2.460	0.303	2.000	0.381	1.060	0.129	0.853	0.133
2000.217c	7.770	1.460	0.324	1.610	0.189	1.300	0.265	0.732	0.100	0.591	0.055
2000.217d	14.300	2.530	0.691	2.740	0.362	2.320	0.482	1.340	0.184	1.090	0.170
2000.218a	0.953	0.123	0.050	0.153	0.030	0.144	0.035	0.075	0.015	0.068	0.015
2000.218b	1.226	0.197	0.036	0.191	0.037	0.155	0.034	0.088	0.015	0.071	0.014
2000.218c	0.567	0.152	0.033	0.181	0.012	0.203	0.023	0.092	0.012	0.070	0.018
2000.218d	10.820	1.820	0.586	2.480	0.354	1.990	0.396	1.110	0.061	1.010	0.115

Sample ID	**Ta**	**Au**	**Tl**	**Pb**	**Th**	**U**
2000.216a	0.016	0.013	0.008	1.210	0.062	0.055
2000.216b	0.015	0.024	0.009	0.670	0.013	0.058
2000.216c	0.009	0.012	0.009	0.770	0.008	0.007
2000.217a	0.018	0.051	0.016	0.600	0.001	0.038
2000.217b	0.036	0.041	0.009	3.210	0.111	0.194
2000.217c	0.008	0.037	0.018	1.110	0.084	0.076
2000.217d	0.038	0.085	0.017	2.540	0.158	0.153
2000.218a	0.013	0.021	0.005	0.348	0.017	0.044
2000.218b	0.011	0.029	0.009	0.550	0.011	0.042
2000.218c	0.035	0.019	0.008	0.620	0.011	0.015
2000.218d	0.031	0.050	0.019	7.610	0.066	0.094

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Borki 1 (BO1_1971.001)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.220a	M1	0.710598	0.283	2168.6	4.630	61993.1	206976.8	2.620	0.115	1.070	3.210
2000.220b	M1	0.711830	0.316	2155.2	21.110	76836.3	251260.2	0.640	0.107	1.180	12.930
2000.220c	M1	0.710561	0.640	1975.5	26.090	105507.9	351974.3	0.610	0.256	1.980	25.280
2000.220d	M1	0.710087	0.460	1854.5	24.610	98101.9	324719.1	1.130	0.304	2.240	9.610
2000.221a	M2	0.708861	0.440	1939.6	27.960	59741.1	200850.0	11.490	0.194	1.180	11.790
2000.221b	M2	0.709485	0.710	1675.7	76.690	82606.7	274413.3	7.270	0.382	2.320	25.980
2000.221c	M2	0.710564	0.500	1908.2	8.570	92643.0	302326.2	0.730	0.066	1.650	16.940
2000.221d	M2	0.711000	0.660	2094.3	87.530	112185.2	359749.1	1.150	0.536	2.670	251.690
2000.222a	M3	0.709804	0.450	2156.7	21.800	64023.1	208174.9	1.070	0.242	1.240	12.520
2000.222b	M3	0.709897	0.450	1796.2	17.160	76624.6	247250.8	0.800	0.340	1.030	24.520
2000.222c	M3	0.710381	0.490	2067.0	21.820	103410.3	327114.1	0.770	0.506	1.730	39.230
2000.222d	M3	0.710026	0.800	2431.4	242.240	138930.1	454872.2	3.340	2.510	3.830	149.500

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.220a	37.940	0.163	0.022	0.068	266.650	0.135	0.070	0.068	41.900	0.079	0.035
2000.220b	81.850	0.338	0.073	0.140	340.290	0.203	0.096	0.051	47.860	0.153	0.039
2000.220c	130.330	0.780	0.100	0.205	533.190	0.216	0.132	0.137	51.870	0.065	0.020
2000.220d	71.010	0.231	0.091	0.206	463.300	0.320	0.201	0.013	51.870	0.376	0.083
2000.221a	71.530	0.568	0.319	0.086	298.140	0.209	0.072	0.102	58.340	0.243	0.064
2000.221b	158.800	1.300	0.081	0.265	442.990	0.323	0.156	0.177	55.030	0.687	0.121
2000.221c	61.490	0.860	0.051	0.114	466.390	0.066	0.108	0.078	49.820	0.022	0.027
2000.221d	204.430	1.650	0.360	0.304	549.300	0.760	0.313	0.093	69.510	1.340	0.271
2000.222a	56.860	0.530	0.223	0.325	273.580	0.245	0.156	0.023	63.570	0.515	0.113
2000.222b	63.010	0.193	0.032	0.188	332.320	0.357	0.096	0.037	54.700	0.033	0.033
2000.222c	87.730	0.770	0.082	0.221	525.550	0.488	0.179	0.024	60.350	0.232	0.146
2000.222d	465.050	3.010	0.198	0.680	758.820	1.480	0.510	0.146	105.150	14.250	1.620

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Borki 1 (BO1_1971.001)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.220a	0.001	0.169	0.012	0.029	0.187	0.010	0.004	5.740	0.079	0.088	0.029
2000.220b	0.008	0.166	0.010	0.039	0.168	0.011	0.003	8.030	0.104	0.117	0.028
2000.220c	0.013	0.150	0.034	0.049	0.225	0.007	0.007	10.060	0.090	0.162	0.024
2000.220d	0.013	0.160	0.009	0.077	0.298	0.018	0.006	21.350	0.290	0.192	0.057
2000.221a	0.002	0.171	0.028	0.041	0.155	0.009	0.016	9.830	0.247	0.276	0.065
2000.221b	0.013	0.284	0.010	0.040	0.181	0.035	0.011	15.000	0.629	0.685	0.212
2000.221c	0.009	0.181	0.022	0.080	0.241	0.024	0.010	5.750	0.026	0.025	0.009
2000.221d	0.010	0.251	0.026	0.092	0.289	0.019	0.007	35.650	1.010	0.748	0.205
2000.222a	0.008	0.126	0.023	0.039	0.162	0.007	0.008	9.150	0.383	0.265	0.101
2000.222b	0.005	0.186	0.026	0.030	0.184	0.033	0.003	12.070	0.060	0.149	0.023
2000.222c	0.020	0.156	0.013	0.058	0.240	0.005	0.008	21.550	0.183	0.411	0.038
2000.222d	0.006	0.202	0.059	0.366	0.376	0.045	0.007	60.900	11.620	5.360	2.660

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.220a	0.099	0.020	0.006	0.017	0.003	0.016	0.003	0.012	0.005	0.012	0.003
2000.220b	0.102	0.039	0.009	0.025	0.003	0.019	0.007	0.018	0.003	0.010	0.004
2000.220c	0.084	0.055	0.013	0.009	0.005	0.019	0.008	0.020	0.005	0.011	0.012
2000.220d	0.285	0.065	0.010	0.047	0.007	0.033	0.009	0.024	0.010	0.020	0.005
2000.221a	0.347	0.053	0.011	0.051	0.009	0.042	0.009	0.020	0.005	0.025	0.005
2000.221b	0.796	0.119	0.045	0.150	0.022	0.121	0.023	0.063	0.010	0.057	0.006
2000.221c	0.025	0.030	0.006	0.020	0.006	0.002	0.002	0.006	0.002	0.020	0.004
2000.221d	0.891	0.162	0.046	0.214	0.025	0.136	0.030	0.076	0.009	0.055	0.012
2000.222a	0.471	0.101	0.021	0.089	0.008	0.064	0.016	0.017	0.004	0.037	0.004
2000.222b	0.088	0.024	0.014	0.019	0.002	0.011	0.010	0.021	0.001	0.016	0.005
2000.222c	0.111	0.058	0.011	0.043	0.009	0.051	0.007	0.029	0.005	0.029	0.007
2000.222d	11.850	2.200	0.542	2.600	0.301	1.870	0.412	1.070	0.110	0.805	0.117

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Borki 1 (BO1_1971.001)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.220a	0.005	0.007	0.007	0.100	0.002	0.002
2000.220b	0.001	0.025	0.006	0.228	0.007	0.003
2000.220c	0.009	0.041	0.010	0.413	0.004	0.004
2000.220d	0.011	0.032	0.007	0.340	0.011	0.004
2000.221a	0.008	0.017	0.005	0.221	0.007	0.003
2000.221b	0.025	0.023	0.005	0.540	0.022	0.007
2000.221c	0.002	0.031	0.008	0.252	0.005	0.003
2000.221d	0.016	0.036	0.012	0.590	0.013	0.024
2000.222a	0.015	0.023	0.005	0.251	0.004	0.007
2000.222b	0.000	0.002	0.007	0.231	0.003	0.005
2000.222c	0.000	0.024	0.012	0.272	0.004	0.014
2000.222d	0.030	0.058	0.007	1.820	0.048	0.072

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Manzurka 2 (MNZ_1971.002)

Sample ID	Tooth	^{87}Sr/^{86}Sr	Li	Na	Al	P	Ca	Ti	V	Cr	Mn
2000.224a	M1	0.708568	1.220	2430.7	22.680	94267.6	299136.5	2.400	1.010	1.990	24.940
2000.224b	M1	0.708408	0.850	2072.8	10.460	100297.5	317135.8	1.080	0.880	2.240	21.670
2000.224c	M1	0.708643	0.940	2260.0	34.040	121926.8	382940.2	2.850	1.470	3.030	42.920
2000.224d	M1	0.708674	1.000	2236.1	40.550	123656.6	391879.9	1.970	2.590	2.710	21.000
2000.225a	M2	0.708169	0.700	1787.4	2.680	90395.2	284858.9	0.420	0.232	1.330	3.900
2000.225b	M2	0.708771	1.150	2247.8	38.980	119743.5	377983.7	3.470	1.440	2.590	9.570
2000.225c	M2	0.708484	0.920	2273.6	19.500	132492.1	433754.3	4.850	2.810	3.490	20.570
2000.225d	M2	0.708840	1.220	2540.5	30.740	139916.2	459593.9	2.930	2.630	3.590	39.380
2000.226a	M3	0.709735	1.040	2134.4	12.160	89976.9	289955.3	1.220	0.604	2.030	10.830
2000.226b	M3	0.709468	1.120	2313.5	30.310	116964.4	381905.8	1.930	1.830	2.110	16.820
2000.226c	M3	0.709126	1.130	2446.8	26.470	133689.7	432516.4	3.070	1.960	2.940	43.050
2000.226d	M3	0.709445	0.930	1917.8	7.010	105454.6	328958.1	0.780	0.489	1.920	9.810

Sample ID	Fe	Ni	Co	Cu	Zn	Ga	As	Rb	Sr	Y	Zr
2000.224a	73.650	0.432	0.076	0.436	416.940	0.563	0.307	0.040	305.300	11.670	0.611
2000.224b	63.990	0.480	0.042	0.420	487.830	0.499	0.312	0.099	327.850	16.380	0.405
2000.224c	95.330	0.600	0.074	1.310	590.400	0.830	1.010	0.028	360.110	55.330	1.240
2000.224d	107.420	0.840	0.047	1.070	576.450	0.800	0.540	0.033	345.690	37.110	1.020
2000.225a	43.140	0.253	0.064	0.097	468.110	0.125	0.183	0.021	294.950	0.019	0.047
2000.225b	189.180	1.400	0.082	0.371	598.990	0.780	0.510	0.126	443.380	14.520	0.712
2000.225c	261.760	1.690	0.104	0.630	673.770	1.240	0.650	0.050	558.100	47.100	2.060
2000.225d	254.480	2.070	0.178	0.421	700.060	1.080	0.700	0.037	592.840	37.740	1.710
2000.226a	79.270	1.010	0.073	0.253	466.430	0.297	0.148	0.048	183.730	1.820	0.147
2000.226b	209.740	0.920	0.060	0.403	659.540	0.600	0.500	0.115	242.390	24.990	0.920
2000.226c	132.510	0.980	0.079	0.301	656.500	0.700	0.590	0.029	263.480	39.770	1.200
2000.226d	56.680	0.159	0.048	0.093	623.890	0.226	0.126	0.016	184.250	6.600	0.162

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Manzurka 2 (MNZ_1971.002)

Sample ID	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce	Pr
2000.224a	0.007	0.273	0.013	0.051	0.214	0.014	0.004	27.030	11.450	12.670	2.440
2000.224b	0.003	0.390	0.013	0.055	0.184	0.023	0.002	26.990	14.740	16.340	3.610
2000.224c	0.007	0.290	0.026	0.128	0.229	0.039	0.006	47.860	58.620	49.350	14.830
2000.224d	0.004	0.420	0.037	0.079	0.221	0.025	0.007	50.290	39.710	39.160	9.560
2000.225a	0.011	0.169	0.009	0.033	0.220	0.022	0.008	7.870	0.009	0.077	0.008
2000.225b	0.015	0.240	0.037	0.088	0.210	0.025	0.007	39.120	14.230	19.370	3.110
2000.225c	0.009	0.450	0.036	0.146	0.240	0.057	0.010	78.110	46.570	55.120	9.540
2000.225d	0.014	0.330	0.025	0.151	0.244	0.023	0.007	66.750	36.500	44.500	8.040
2000.226a	0.012	0.269	0.030	0.083	0.450	0.023	0.018	16.320	1.309	1.650	0.267
2000.226b	0.018	0.620	0.045	0.121	0.162	0.024	0.008	39.550	22.510	25.140	4.970
2000.226c	0.007	0.450	0.048	0.091	0.314	0.051	0.007	48.170	37.110	35.800	8.200
2000.226d	0.013	0.370	0.033	0.056	0.185	0.031	0.006	16.570	5.640	5.280	1.268

Sample ID	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
2000.224a	10.300	1.960	0.440	2.220	0.287	1.700	0.347	0.939	0.109	0.774	0.118
2000.224b	14.820	2.880	0.707	3.150	0.424	2.650	0.524	1.420	0.179	1.190	0.186
2000.224c	60.540	11.700	2.690	11.810	1.590	9.570	1.790	4.880	0.609	3.870	0.526
2000.224d	39.610	7.430	1.800	7.560	1.002	6.140	1.170	3.150	0.407	2.610	0.383
2000.225a	0.030	0.003	0.006	0.018	0.004	0.022	0.004	0.020	0.005	0.025	0.005
2000.225b	12.780	2.500	0.559	2.700	0.352	2.330	0.444	1.160	0.175	1.030	0.152
2000.225c	40.740	7.600	1.750	8.420	1.120	6.710	1.360	3.610	0.494	2.960	0.476
2000.225d	34.010	6.870	1.500	6.760	0.936	5.820	1.110	3.100	0.387	2.390	0.402
2000.226a	1.183	0.190	0.048	0.242	0.035	0.217	0.053	0.136	0.016	0.131	0.021
2000.226b	21.140	4.160	0.944	4.400	0.565	3.630	0.778	2.070	0.234	1.720	0.230
2000.226c	34.870	6.820	1.560	6.870	0.952	5.700	1.170	3.160	0.405	2.670	0.379
2000.226d	5.630	1.120	0.259	1.140	0.182	0.825	0.189	0.479	0.065	0.513	0.066

Appendix I: 87Sr/86Sr ratios and trace element concentrations (ppm) for human tooth samples.

Manzurka 2 (MNZ_1971.002)

Sample ID	Ta	Au	Tl	Pb	Th	U
2000.224a	0.008	0.019	0.006	1.790	0.315	0.041
2000.224b	0.006	0.027	0.007	1.330	0.456	0.035
2000.224c	0.018	0.013	0.008	3.750	2.850	0.103
2000.224d	0.013	0.045	0.008	3.700	1.650	0.086
2000.225a	0.012	0.002	0.004	0.399	0.006	0.004
2000.225b	0.023	0.013	0.006	2.070	0.454	0.068
2000.225c	0.031	0.030	0.010	4.710	1.560	0.105
2000.225d	0.016	0.035	0.003	3.840	1.360	0.119
2000.226a	0.029	0.002	0.009	0.640	0.018	0.014
2000.226b	0.028	0.014	0.015	3.090	0.750	0.056
2000.226c	0.036	0.019	0.015	3.280	1.080	0.127
2000.226d	0.015	0.025	0.009	1.050	0.138	0.043