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Elemental and isotopic analysis by (multiple collector) – inductively coupled plasma mass spectrometry in human teeth from the Early Bronze Age excavation site Franzhausen I (Lower Austria) for the investigation of population dynamics and dietary patterns

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ABSTRACT

The population recovered from the grave field Franzhausen I in the Lower Traisen Valley (Lower Austria) lived during the Early Bronze Age (~2300/2200 – 1600 B.C.), a time of extensive social changes. The north-south and the west-east trading routes met in this area, bringing business and with it wealth to the people. Archaeological and anthropological investigations conducted so far indicated an active settlement of the Traisen Valley and showed that it was probably a rather secure place as well during that time since only few bone fractures and injuries were observed on the skeletons.

The ambition of this study was to investigate whether the geographic, climatic and scenic benefits of the location had an influence on migration in the Lower Traisen Valley. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel and dentine of 103 individuals excavated at the burial ground Franzhausen I were determined via multi collector inductively coupled plasma sector field mass spectrometry (MC-ICP-SFMS). To distinguish between locals and non-locals the bioavailable Sr isotopic signal of Franzhausen was evaluated in two ways: (i) using the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios analyzed in tooth dentine and (ii) by doing soil extracts representing the bioavailable Sr fraction. Environmental samples of the surroundings of the excavation site presenting the settlement area of the Early Bronze Age were taken to identify possible origins of immigrants. Of special interest were the areas around Unterwölbling and Gemeinlebarn since previous biological investigations of the skeletons indicated the existence of marriage circles between those two and Franzhausen.

Results were compared to investigations of the population living in Franzhausen during the Late Neolithic period and the Early Bronze Age population recovered in Hainburg/Donau. A possible change of migration behavior in this area in relation to earlier times (Franzhausen II) should be examined and potential differences in mobility of a supposedly more rural population (Hainburg) living at the same time as the population excavated from the burial ground Franzhausen I were investigated.

Furthermore investigations of dietary patterns were of interest for the populations buried at the necropolis Franzhausen I. Multielemental analysis of the samples were conducted using an ICP quadrupole-MS instrument, to determine also possible diagenetic alterations of dentine as well as of enamel. Elemental fingerprints in enamel with Mg, Ca, Mn, Fe, Cu, Zn,

Rb, Sr, Ba, and Pb were evaluated and conspicuous cases were looked at in more details. The results were combined with the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios to gain further information about potential post-mortem alterations as well.

ZUSAMMENFASSUNG

Die im Gräberfeld Franzhausen I im Unteren Traisental (Niederösterreich) entdeckte Population lebte während der frühen Bronzezeit (~2300/2200 – 1600 v. Chr.), einer Zeit, in der es zu starken sozialen Umstrukturierungen kam. Damals kreuzten sich in dieser Gegend der Nord-Süd- und der West-Ost-Handelsweg, was den dort ansässigen Menschen vermehrte Handelsbeziehungen und damit auch Wohlstand brachte. Bisher durchgeführte archäologische und anthropologische Untersuchungen weisen auf eine intensive Besiedlung entlang des Traisentals hin und lassen des Weiteren die Vermutung zu, dass es sich um eine relativ sichere Gegend handelte, da die Skelette nur wenige Knochenfrakturen und -verletzungen aufwiesen.

Im Zuge dieser Arbeit soll der mögliche Zusammenhang beziehungsweise Einfluss zwischen den lokalen geographischen, klimatischen und landschaftlichen Vorteilen dieser Ansiedlung auf das Migrationsverhalten im Unteren Traisental untersucht werden. Hierfür wurden $^{87}\text{Sr}/^{86}\text{Sr}$ Verhältnisse in Zahnschmelz (Enamel) und -bein (Dentin) von 103 aus dem Gräberfeld Franzhausen I ausgehobenen Individuen mittels Multi-Kollektor induktiv gekoppeltem Plasma Sektorfeld Massenspektrometrie (MC-ICP-SFMS) bestimmt. Zur Unterscheidung von lokalen und nicht lokalen Individuen wurde die lokal bioverfügbare Sr-Isotopensignatur auf zwei Arten evaluiert: (i) mit der Sr Isotopensignatur in Dentin- und (ii) mit Bodenextrakten. Umweltproben aus der Umgebung der Ausgrabungsstätte und damit des bronzezeitlichen Siedlungsgebiets selbst wurden herangezogen, um mögliche Herkunftsgebiete der nicht-lokalen Individuen zu identifizieren. Besonders die Gebiete um Unterwölbling und Gemeinlebarn waren von Interesse, da vorangegangene biologische Untersuchungen der Skelette auf das Vorhandensein von Heiratskreisen zwischen diesen beiden und Franzhausen hinwiesen.

Die Ergebnisse wurden mit Untersuchungen der Population von Franzhausen aus dem Endneolithikum sowie der frühbronzezeitlichen Bevölkerung, die in Hainburg/Donau freigelegt wurde, verglichen. Dadurch sollten einerseits mögliche Veränderungen im Migrationsverhalten in dieser Gegend im Vergleich zu früheren Zeiten (Franzhausen II) erkannt werden und andererseits eventuell vorhandene Unterschiede der Mobilität einer vermutlich eher bäuerlichen, aber zeitgleichen Population (Hainburg) determiniert werden.

Des Weiteren wurde ein Fokus auf die Untersuchung der Ernährungsmuster der in Franzhausen I begrabenen Population gesetzt. Dafür wurden Multielementanalysen der Proben mittels eines ICP Quadrupol-MS-Geräts durchgeführt, auch um mögliche diagenetische Veränderungen von Dentin und Enamel zu detektieren. Mg, Ca, Mn, Fe, Cu, Zn, Rb, Sr, Ba, und Pb dienten der Etablierung von Element-Fingerabdrücken im Zahnschmelz, wobei Auffälligkeiten einzelner Proben im Detail evaluiert wurden. Die Ergebnisse wurden auch den $^{87}\text{Sr}/^{86}\text{Sr}$ Verhältnissen gegenübergestellt um zusätzliche Informationen zu potentiellen postmortalen Veränderungen zu erhalten.

1. INTRODUCTION

1.1. Investigations of population dynamics and dietary patterns

The investigation of population dynamics is of great interest in anthropology and archaeology as e.g. innovations have often been brought by immigrants (Price et al. 1998). Changes in technology and environment can be reflected by a change in the diet (Schoeninger and Moore 1992). It is therefore of major interest to take a look at prehistoric nutrition in order to investigate social structures. Higher social levels often had access to hardly obtainable groceries and neglected more or less other common food sources. Studies have proven that differences in concentrations of certain elements in the skeletal tissue reflect this phenomenon (Gröbmeyer 1997). Such studies are possible because the elemental and isotopic composition of the skeleton strongly depends on diet and drinks (Hedges et al. 2006).

Differentiation between locals and immigrants might give information about anthropological appearances like exogamy or slavery. If the provenance of the excavated non-local individuals can be figured out maybe even further understanding of history is possible. Additional information about topics like trading or land occupancy might be gained from investigations of faunal material (Budd et al. 2004; Sealy et al. 1995).

Determined chemical signatures from hard tissues like bones or teeth can be used to recognize the relative nutrition with foods from diverse ecosystems, climatic zones or photosynthetic categories even beyond death. Obtained data give indications for the consumption of general food groups rather than for specific groceries. Statements about trophic levels or if the food supplies originated from a discrete geochemical environment can be made as well. In order to make meaningful statements about different diets, several samples from each trophic level one wants to examine have to be taken (Blum et al. 2000). In all cases diagenetic processes need to be taken into account (Pate 1994).

1.1.1 Elemental analysis

A popular indicator for reconstruction of prehistoric diets are Sr/Ca ratios where the values decrease with each trophic level (plants > herbivores > omnivores > carnivores) (Blum et al. 2000). Even differences in herbivores between grazers and browsers were found with Sr/Ca ratios measured with an inductively coupled plasma mass spectrometry (ICP-MS) instrument by Sponheimer et al. (2005) in faunal enamel samples from Africa, suggesting that the division of food groups for mammals should be more specific.

Sillen and Smith (1984) took advantage of the large differences in Sr/Ca ratios between human milk (remarkably low) and solid foods (high) to investigate prehistoric weaning patterns. They assume that as a function of age increasing Sr/Ca ratios in juvenile bones would imply increased dietary supplementation to weaning and a maximum is expected when solid foods are eaten. The depletion at older ages is said to come from rising discrimination against Sr in the gastro-intestinal tract. Their results agree with this: newborns had always the lowest Sr/Ca ratios and after a peak between the ages of 1.5-3.5, the values decrease towards those of adults. Calculations showed that diets of 3-year-olds are already within the range of adults.

Blum et al. (2000) also found a decrease with trophic level in Ba/Ca ratios when examining about 100 samples from two sites. Differences in the available Ca concentrations were caused by the underlain bedrock material (calcium-poor crystalline silicate and calcium-rich carbonate and silicate). However, they still advise to monitor Sr/Ca values as dietary indicators as strontium has a more systematic behavior.

Sr and Ba concentrations in enamel were used by Burton et al. (2003) to identify non-locals and their origin. However, not all investigated sites allowed a distinction with both elements showing the limitation of the method when $\log(\text{Sr/Ca})$ and $\log(\text{Ba/Ca})$ values are too similar.

Determination of certain trace elements can also help with the reconstruction of diets. Baraybar and de la Rúa (1997) determined the concentrations of Zn, Fe, Mg, V, Cu, Sr, Ba, Ca and P in archaeological human and animal bone samples from Spain with ICP-AES. Prior to analysis they pictured two possible scenarios for the people's food consumption. The first assumes a diet mainly consisting of cereals, dairy products and meat coming from domesticated plants and animals, and a smaller amount of marine and/or estuarine species

in the menu. The elemental composition would be expected to display medium Sr, high Ba and V, and medium to low Zn concentration levels. Ba/Sr, usually given as log (Ba/Sr), values would fall in the range of terrestrial food sources. Ba/Sr ratios make the distinction between marine and terrestrial diets possible where lower values are an implication for the latter (Burton and Price 1990). The second scenario on the other hand claims the consumption of meat, dairy products, seafood and estuarine species, with lesser uptake of plant matter like cereals. Medium Sr, low Ba and V, high Zn levels are characteristic for such diets. The log (Ba/Sr) would fall between the signals from marine and terrestrial ecosystems (Baraybar and de la Rua 1997).

Baraybar and de la Rua (1997), aware of postmortem alteration of skeletal remains, also examined the extent of the diagenetic contamination to correctly interpret their results for dietary reconstruction. Bivariate plots between the elements showed that only Sr, Ba and V discriminate between herbivores and carnivores. With log (Ba/Sr) values it was possible to distinguish between herbivores, carnivores and marine animals. A correlation of Zn with log (Ba/Sr) could only be found after elimination of herbivorous animals and some outliers. Zinc could then be an indicator for additional marine protein. However, concerns about the use of this element for reconstruction of paleodiets have been raised since a valid model about the physiology of zinc has not been established. Furthermore its strict metabolic regulation as essential mineral could be a problem for dietary reconstructions as well (Ezzo 1994b).

Pate (1994) reviewed on the possibilities to reconstruct prehistoric diets with data retrieved from investigations of bone samples. The relationships between various elements and food consumption were summarized in a table (see table 1).

Diet	Sr	Ba	Mg	Zn
Herbivorous	high	high	High	low
Omnivorous	intermediate	intermediate	intermediate	intermediate
Carnivorous	low	low	Low	high
Marine	high	low	High	--
Terrestrial	low	high	Low	--

Table 1 Relationship between nutrition and concentrations of certain elements in bones from Pate (1994)

The use of magnesium to reconstruct prehistoric diets was not successful. Pig bones, for example did not reflect the elevated magnesium concentration in their food (Klepingera

1990). Also diagenetic processes could alter the concentration to lower levels (Byrne and Parris 1987).

Djingova, Zlateva et al. (2004) tested and validated measurements of elements that are of interest for the reconstruction of paleodiets using a quadrupole ICP-MS (Perkin Elmer Sciex ELAN 6000 with cross-flow nebulizer). They measured ^{27}Al , ^{51}V , ^{54}Fe , ^{56}Fe , ^{63}Cu , ^{65}Cu , ^{24}Mg , ^{26}Mg , ^{64}Zn , ^{66}Zn , ^{88}Sr , ^{90}Zr , ^{91}Zr , ^{92}Zr , ^{94}Zr , ^{75}As , ^{204}Pb , ^{138}Ba , ^{55}Mn in archaeological bones. Due to interferences the determination of Cu and Fe was not always possible. No serious problems from background disturbances occurred during the determination of Al, As, Ba, Pb, Sr and V. They concluded that ICP-MS is a useful instrument to reconstruct prehistoric diets through the determination of elements like Sr, Ba and Zn. Pb, As and other toxic elements were interpreted to be an indicator of probable illnesses while elements such as Zr can give information about diagenesis. Results with different dilutions were investigated as well, showing that these need to be considered too. From ashed bone material 0.2-0.3 g were taken for digestions after which the samples were filled to 25.0 ml with deionized water. For the measurements dilutions of 1:1, 1:10 and 1:100 (v/v) were conducted. The maximum dilutions gave the least accurate results. Al, Mg, Sr and Ba gave the best results at dilution 1:10 whereas As, Pb, V, Zn and Zr had a better output at dilution 1:1. This can be explained by their different concentration in bones. As compromise, if the number of analysis is restrictive, dilution 1:1 is recommended.

1.1.2. Isotopic analysis

In archaeological studies isotopic analysis of bones and teeth are a widely applied tool to answer various questions. Not only is the dating of skeletal remains and archaeological sites possible (e.g. radiocarbon dating) but also information about diet and climate can be retrieved and habitats can be reconstructed (Ambrose and Krigbaum 2003; Knudson et al. 2010).

1.1.2.1. Heavy isotopes

Probably the most powerful isotopic system for investigations of migration is strontium (Price et al. 2002; Capo et al. 1998). It was also used in this study. The idea to measure strontium isotope ratios in archaeological human tooth and bone material for the investigation of prehistoric residence pattern was brought up by Ericson (1985) in 1985. The use of the ratios instead of the absolute ^{87}Sr abundances eases out variations that are only due to different strontium contents (Price et al. 1994). In order to be able to use strontium isotope ratios for migration studies residence areas must have a significant difference in geology (Ericson 1985) (see also chapter 1.2.).

The mobility of an individual can be established according to the following consideration: If different $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are found in enamel (representing the birth place) and bone (or dentine; indicates residence of the last years before death) migration of this person can be assumed. However, there is also the possibility to use ratios of environmental samples (e.g. soil, water, plants) to differentiate between locals and non-locals (Price et al. 2000; Price et al. 1998; Kusaka et al. 2009). Sometimes also modern animal samples are taken for the evaluation of a local signal (Ezzo and Douglas Price 2002; Sealy et al. 1991). All these considerations are only applicable if diagenetic alterations can be ruled out or the biogenic Sr fraction in the bone/tooth material can be identified.

Many investigations of prehistoric human migration pattern on the basis of the strontium isotopic system have been presented since the idea was first introduced. Selected examples are listed in table 2.

If the Sr ratios in food sources, e.g. marine and terrestrial, sufficiently differ from one another, it is also possible to use the ratios in human hard tissues to investigate their diets (Kusaka et al. 2011; Price and Gestsdóttir 2006; Sealy et al. 1991). Thus Sealy et al.(1995) used $^{87}\text{Sr}/^{86}\text{Sr}$ values not only to identify those of non-local origin but also to investigate the individuals' diet. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data were evaluated as well agreeing with the distinction of marine and terrestrial diets with strontium isotope ratios.

In earlier times, unaware of its toxicity, people used lead for several possible applications, e.g. for water pipes, as sweetener, in paint or even for medical reasons. Industrial Pb pollution was very common throughout history. As lead phosphate has a low solubility, Pb

was incorporated in the bones and teeth following the metabolic cycle of Ca. Lead isotopic composition found in these tissues can then be used to identify their source. ^{204}Pb (non-radiogenic), ^{206}Pb (product of the decay of ^{238}U), ^{207}Pb (product of the decay of ^{235}U) and ^{208}Pb (product of the decay of ^{232}Th) occur naturally in rocks, soil, water and plants but can also be transported through air and travel over long distances as it is for example present in volcanic dust. Additional anthropogenic sources of Pb in the environment were mentioned before. Together with Sr and O isotope analysis nutrition differences in social classes (upper – lower) and living environment (rural – urban), migration behavior, the change of lead contamination over time can be investigated and pollution transport can be tracked as well (Åberg et al. 1998; Turner et al. 2009).

Most researches about paleodiet concentrate on stable isotopes of carbon and nitrogen. However, investigations of strontium isotope fractionations (expressed by $\delta^{88/86}\text{Sr}$ values relative to the strontium carbonate standard NBS987) are also a possibility to make a statement about this topic. Similar to the light stable isotopes Sr isotope ratios are modified in a mass-dependent way with trophic level (Knudson et al. 2010). Fractionation is due to kinetic differences during biochemical processes in photosynthesis and food metabolism allowing favorable incorporations of one isotope over others. Isotope ratios in plant or animal tissues can therefore be higher or lower than those in the environment or diet (Pate 1994). The relatively small mass differences between ^{86}Sr and ^{88}Sr lead to minor fractionation effects in comparison to C and N stable isotopes. Organisms tend to rather incorporate the lighter strontium isotope, so in different trophic levels a change in the $\delta^{88/86}\text{Sr}$ values can be observed. In both, marine and terrestrial ecosystems, values should deplete ^{88}Sr from bedrock and soils to plants, to herbivores, to omnivores, to carnivores. Marine plants and animals express seawater signatures (Knudson et al. 2010). Variations of absolute $\delta^{88/86}\text{Sr}$ values from the different trophic levels can be expected as studies (e.g. de Souza et al. 2010; Halicz et al. 2008) show regional discriminations of $\delta^{88/86}\text{Sr}$ values coming from differences in bedrock age and type of geologic formation. It is therefore of great importance to get environmental samples to identify the local signal. Weaning influences the $\delta^{88/86}\text{Sr}$ values too. Enamel and bone samples that developed before or during weaning times will give lower results representing the higher trophic level of infants. With the help of sample-standard bracketing it is possible to receive $^{87}\text{Sr}/^{86}\text{Sr}$ as well as $\delta^{88/86}\text{Sr}$ data by MC-ICP-MS measurements (Knudson et al. 2010).

1.1.2.2. Light isotopes

Isotopes of H, C, N, O and S are fractionated in nature which leads to natural variations of their isotopic compositions (Faure 1986).

The composition of stable carbon (^{12}C , ^{13}C) and nitrogen (^{14}N , ^{15}N) isotopes in human bones is directly related to the consumed food stuff and can be used to investigate paleodiets. Results are usually given relative to a standard as $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in parts per thousand (‰). The isotopic abundances in collagen can give information about the protein sources if they varied in their composition (Trimble and Macko 1997; Pate 1994; DeNiro and Epstein 1978, 1981; Tieszen and Fagre 1993). However, preservation of this part of the bone will usually be rather poor in prehistoric skeletons that is why Sullivan and Krueger (1981) tested the ability to use apatite instead, which was successful. The mineral phase will reflect the whole diet though (Ambrose and Norr 1993; Tieszen and Fagre 1993).

The main contributor to plant carbon is atmospheric CO_2 . In plants, fractionation happens during photosynthesis where different pathways lead to varying $\delta^{13}\text{C}$ values. The final composition in bones depends on the proteins in the menu. However, they do not represent the only origin of carbon. Saccharides and fat are other contributors. ^{13}C values in bone material are usually higher than in nutrition (Schoeninger and Moore 1992; Hedges et al. 2006; Bocherens and Drucker 2003; Sullivan and Krueger 1981).

Collagen nitrogen is almost solely received from protein and even more enriched compared to the diet than carbon. However, a lot of work still needs to be done to fully understand the great variability of nitrogen ratios occurring in nature. (Schoeninger and Moore 1992; Hedges et al. 2006; Bocherens and Drucker 2003). Applications of these two isotopic systems in dietary reconstruction can help to differentiate between trophic levels as well as to distinguish between nutrition with higher proportions of marine and terrestrial food supplies (Tieszen and Fagre 1993).

Differences in the isotopic composition of oxygen incorporated into the skeleton as carbonate or phosphate derive mainly from the drinking water. As the abundances of oxygen in rivers and the like are depending on geography and climate, it can be used to track migration and also to study climatic changes. $\delta^{18}\text{O}$ values are calculated relative to the so called Vienna Standard Mean Ocean Water standard (Hedges et al. 2006; Budd et al. 2004).

Hoogewerff et al. (2001) used $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values in bone samples in addition to $^{87}\text{Sr}/^{86}\text{Sr}$ ratios to determine the last residence of “Ötzi”, the Tyrolean Iceman. Another example for the use of oxygen isotopes to investigate human mobility was described by Dupras and Schwarcz (2001) in Egypt who measured oxygen and nitrogen isotopes with a SIRA mass spectrometer to identify possible immigrants.

Sulfur in plants derives from soil, consequently also from bedrock, and atmospheric sources; incorporation into hard tissues is depending on the diet. Even though $\delta^{34}\text{S}$ values in human bones have the potential to be used as paleodietary indicators and could be applied for investigations of mobility, studies utilizing this isotopic system are rare probably due to the extensive sample preparation (Krouse 1989; Richards et al. 2003).

Differentiation between trophic levels is also possible via determinations of δD values in archaeological bone samples. The final compositions in bones are depending on the composition in water. The highest proportions of ^2H isotopes were found in humans when compared to omnivores and herbivores. The idea to use it as indicator for mobility studies has also arisen (Reynard and Hedges 2008).

Examples for migration and nutrition studies on human populations are listed in table 2 and 3.

tracer	instrumentation	reference
$^{87}\text{Sr}/^{86}\text{Sr}$	MC-ICP-MS	(Knudson and Tung 2011)
	(LA-)ICP-SFMS	(Prohaska et al. 2002)
	TIMS	(Sealy et al. 1995)
	TIMS	(Ezzo et al. 1997)
	TIMS	(Ezzo and Douglas Price 2002)
	TIMS	(Schweissing and Grupe 2003a)
	TIMS	(Schweissing and Grupe 2003b)
	TIMS	(Price et al. 1994)
	TIMS	(Kusaka et al. 2009)
	TIMS	(Kusaka et al. 2011)

tracer	instrumentation	reference
$^{87}\text{Sr}/^{86}\text{Sr}$	HR-ICP-MS	(Latkoczy et al. 1998)
	ICP-SFMS	(Latkoczy et al. 2001)
	MC-ICP-MS	(Buzon et al. 2007)
	(LA-)MC-ICP-MS	(Simonetti et al. 2008)
	(LA-)Q-ICP-MS	
$^{87}\text{Sr}/^{86}\text{Sr}, ^{20n}\text{Pb}/^{20n}\text{Pb}$	TIMS	(Åberg et al. 1998)
	TIMS	(Chiaradia et al. 2003)
$^{87}\text{Sr}/^{86}\text{Sr}, ^{20n}\text{Pb}/^{204}\text{Pb}$	MC-ICP-MS	(Valentine et al. 2008)
$^{87}\text{Sr}/^{86}\text{Sr}, \delta^{18}\text{O}, ^{20n}\text{Pb}/^{204}\text{Pb}$	MC-ICP-MS, vism MS	(Turner et al. 2009)
$^{87}\text{Sr}/^{86}\text{Sr}, \delta^{18}\text{O}$	MC-ICP-MS, TIMS, IRMS	(Knudson et al. in press)
	TIMS, IRMS	(Cox et al. 2011)
	TIMS, SIRA-MS	(Wright et al. 2010)
	TIMS, IRMS	(Knudson et al. 2009)
$^{87}\text{Sr}/^{86}\text{Sr}, \delta^{18}\text{O}, \log(\text{Ba}/\text{Sr})$	MC-ICP-MS, Q-ICP-MS, CF-IRMS	(Shaw et al. 2010)
$^{87}\text{Sr}/^{86}\text{Sr}, \delta^{18}\text{O}$, trace elements	TIMS, ICP-AES, ICP-MS	(Knudson and Price 2007)
$\delta^{18}\text{O}$	IRMS	(Buzon et al. 2011)
	IRMS	(Prowse et al. 2007)
$\delta^{18}\text{O}, \delta^{15}\text{N}$	IRMS	(Dupras and Schwarcz 2001)
$\log(\text{Sr}/\text{Ca}), \log(\text{Ba}/\text{Ca})$	ICP-MS	(Burton et al. 2003)
$^{20n}\text{Pb}/^{206}\text{Pb}$	ICP-MS	(Yoshinaga et al. 1998)

Table 2 Examples for investigations on migration of human populations

paleodietary indicators	instrumentation	reference
$^{87}\text{Sr}/^{86}\text{Sr}$	TIMS	(Kusaka et al. 2011)
$^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, log(Ba/Sr)	IRMS, Q-ICP-MS, MC-ICP-MS, TIMS	(Knudson et al. in press)
$\delta^{88/86}\text{Sr}$	MC-ICP-MS	(Knudson et al. 2010)
Sr/Ca, Zn	AAS	(Sutlović et al. 2010)
Sr/Ca, Zn/Ca, Sr/Zn	ICP-OES	(Tibenská et al. 2010)
	ICP-OES	(Bodoriková et al. 2010)
Sr/Ca, Ba/Ca, Ba/Sr	AAS	(Gilbert et al. 1994)
	ICP-MS	(Szostek et al. 2009)
Sr/Ca, Ba/Ca, Zn/Ca, Ba/Sr	DRC ICP-MS, ICP-AES	(Busetto et al. 2008)
$\delta^{13}\text{C}$, $\delta^{15}\text{N}$, log(Ba/Ca), log(Sr/Ca)	SIRA-MS, TIMS	(Wright et al. 2010)
$\delta^{13}\text{C}$, $\delta^{15}\text{N}$	CF-IRMS	(Vika 2011)
	EA-IRMS	(Rick et al. 2011)
	IRMS	(Yoder 2010)
	CF-IRMS	(Petroutsas and Manolis 2010)
	CF-IRMS	(Hollund et al. 2010)
	CF-IRMS	(Choy et al. 2010a)
$\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$	EA-IRMS	(Linderholm and Kjellström 2011)
$\delta^{13}\text{C}$, $\delta^{15}\text{N}$, δD , log(Ba/Sr)	(CF-/ TC/EA-)IRMS, AAS	(Arnay-de-la-Rosa et al. 2011)
$\delta^{13}\text{C}$	LC-IRMS	(Choy et al. 2010b)
$\delta^{13}\text{C}$, $\delta^{15}\text{N}$, Ba, Sr, Ca	IRMS, AAS	(Arnay-de-la-Rosa et al. 2009)

Table 3 Examples of investigations for reconstructions of human diets

1.2. The alkaline earth element strontium

1.2.1. Isotopic system

Four isotopes of the alkaline earth element strontium occur naturally: ^{84}Sr , ^{86}Sr and ^{88}Sr are non-radiogenic, while the β^- -decay of ^{87}Rb with a half-life of approximately 4.88×10^{10} years leads to the formation of ^{87}Sr . This decay is also the reason why $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, which vary significantly in different geological areas, became a popular tool in geochronology. High ratios will be found in old, potassium rich rocks as Rb substitutes for K in many geologic processes. (Bentley 2006; Graustein 1989; Aberg 1995; Capo et al. 1998; Faure 1986). The isotopic abundances of strontium and rubidium are summarized in table 4.

Isotope	abundance [%]
^{84}Sr	0.56
^{86}Sr	9.86
^{87}Sr	7.00*
^{88}Sr	82.58
^{85}Rb	72.17
^{87}Rb	27.83

*abundance varies in nature

Table 4 Natural isotopic composition of Sr and Rb (Berglund and Wieser 2011)

Nowadays abundances of the artificial strontium isotope ^{90}Sr , which is a product of fission reactions with a half-life of approximately 30 years, are of concern too (Capo et al. 1998). Investigations on this isotope led for example Wieser, Romanyukha et al. (1996) to the supposition that tooth dentine metabolizes strontium in a very similar way as bone. However, ^{90}Sr is of no further relevance in this study.

1.2.2. Strontium in nature

Due to its similar ionic radius, Sr^{2+} can substitute for Ca^{2+} in many Ca-bearing minerals, such as apatite (Bentley 2006; Faure 1986). Weathering processes of rocks lead to the release of strontium. This is usually the dominant way that this element ends up in soils. Ground as well as surface water flows, rain and atmospheric deposition add up to the final Sr concentrations and isotopic composition found in soils (Dasch 1969; Capo et al. 1998). From

there, strontium enters the food chain: from the soil it is taken up by plants, which are then eaten by animals and humans (Capo et al. 1998; Price et al. 1998). In general, strontium enters the human body via nutrition and drinking water (Hillson 1986; McConnell 1973; Montgomery 2010). As the (human) skeleton, a frequent finding at burial grounds, is mainly build up by carbonated hydroxyapatite (dahllite; $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), most of the up taken strontium is incorporated there and can for example be used for investigations on migration patterns of archaeological populations (see chapter 1.1.). Strontium concentrations in the skeleton are correlated to the dietary available Sr/Ca ratio and will be lower the more meat is integrated in the diet (Lambert and Weydert-Homeyer 1993)

The strontium isotopic composition in rivers depends on the minerals in the sedimentary deposit, thus from the composition and age of the bedrock, and from contributions over the atmosphere (Aberg 1995; Capo et al. 1998). Seawater, the largest Sr reservoir, is continuously delivered strontium from all over the world via sediment transports by rivers. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio measured in the oceans (currently at 0.7092) reflects the average from all of these sources and is homogeneously distributed due to its long residence time relative to the oceanic mixing time (Bentley 2006; Graustein 1989).

Nowadays also contributions by fertilizers to determined Sr ratios in modern environmental samples need to be considered (Böhlke and Horan 2000).

The final concentrations found in human skeletons depend on the amount of strontium available in their nutrition and the water resources, whereby the main contributing source is plant material (Price et al. 1998; Molleson 1987; Hedges et al. 2006; Bentley 2006). A direct correlation between the amount of Sr administered orally and the incorporated Sr concentrations in skeletons is shown by several studies on animals, e.g. on rats (Price et al. 1986) or monkeys (Farlay et al. 2005). Concentrations of strontium in bones are higher than in enamel (Grupe et al. 1997; Price et al. 1994; Ezzo et al. 1997).

Reinhardt (2004) evaluated a nutrient content scale of strontium, using data on Sr concentrations in different food stuffs of her own analysis as well as those determined in several other studies (Varo et al. 1982; Nabrzyski and Gajewska 2002; Dolan and Capar 2002; Gundersen et al. 2000; Kanas 1991; Anderson et al. 1999; Rosenthal 1981). Calculated mean values for certain grocery groups are given in table 5 where it can be seen that the strontium

concentration in meat (49 µg/100g) is lower than in fruit (151 µg/100g; berries: 200 µg/100g), vegetables (84 – 201 µg/100g) and cereals (150 µg/100g). Also milk products, with exclusion of cheese, do not contribute as much to the final amount of strontium in the diet with 53 µg/100g, whereas cheese contains as much as 467 µg/100g on average. The highest concentrations of strontium are present in nuts (1270 µg/100g) and sea food (3297 µg/100g).

food category	c(Sr, average) [µg/100g]
rice	20
maize	60
cereals	150
berries	200
fruit	151
leafy vegetables and cabbage	201
onion and garlic	139
pulses	84
nuts	1270
milk products (without cheese)	53
cheese	467
fish	199
sea food	3297
meat	49
tap water	30

Table 5 Typical Sr concentrations in nutrition after Reinhardt (2004)

So far, changes of the isotopic composition of strontium due to fractionation are negligible during its way through nature. This can be explained by the rather large atomic mass of strontium resulting in smaller mass differences between the isotopes (Graustein 1989; Blum et al. 2000). Therefore varying Sr isotope ratios are caused solely by the different compositions in geologic sources and their intermixing (Graustein 1989; Dasch 1969). Biological processes do not fractionate strontium isotopes, therefore plants will, for example, represent the $^{87}\text{Sr}/^{86}\text{Sr}$ signal of the soil just like herbivores will express the ratio of the eaten plants (Capo et al. 1998).

1.2.3. Applications in science

In investigations of strontium abundances in bone and enamel samples the elemental concentration represents the trophic level, while isotope ratios express the available isotopic

composition in the geological substrate of an individual's habitat (Price et al. 1994). The applications of Sr/Ca, Ba/Sr and $\delta^{88/86}\text{Sr}$ ratios for dietary reconstruction are mentioned before. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios and total strontium concentrations were used for human migration studies and investigations of nutrition as well (see chapter 1.1.).

Beside its use in investigations of the mobility of humans, $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are also utilized to trail migrations of extinct animals, for example mammoths, which may help to improve hypotheses about topics like their evolution or the reasons for extinction (Hoppe et al. 1999). A further possibility for the use of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios is the tracing of short- as well as long-term environmental changes (Aberg 1995). Investigations of strontium inputs to nutrient reservoirs of a forest showed that it is possible to differentiate between aerosols and bedrock contributions to the final ratios in soil via the isotopic composition of strontium (Graustein and Armstrong 1983). Studies on the Hawaiian Islands with Sr isotopes were also conducted to define the amount of atmospheric and weathering inputs to different samples (Kennedy et al. 1998; Vitousek et al. 1999). The influence of sea spray to the elemental composition in soil was investigated via $^{87}\text{Sr}/^{86}\text{Sr}$ analysis as well (Whipkey et al. 2000)

Due to its similar biological and chemical behavior, strontium can also be applied as tracer for the nutrient elements calcium and magnesium, making it possible to track their way through nature (Vitousek et al. 1999; Capo et al. 1998).

Since strontium is a ubiquitous trace element, special care must be taken to avoid contamination during the sample preparation (Capo et al. 1998).

1.3. Human teeth – anatomy, composition and development

Since teeth are not as affected as the rest of the skeletal by physical and chemical alterations during their residence time in the surrounding soil (diagenesis) they are frequent findings at archaeological excavations. Among other matters they can give information about gender, age and nutrition (White and Folkens 2005).

The crown with an enamel coating and the root (or roots) which is encased from the so

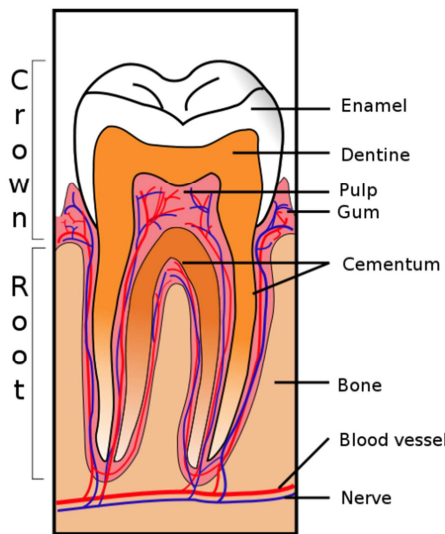


Figure 1 Tooth cross section
(wikipedia.org 2011)

called cement, a bone-like material, represent the two general parts building up a human tooth. The dentine is situated underneath the top layers and covers the pulp chamber with blood vessels and nerves running through (Hillson 1986). Figure 1 displays the general structure. Two parts of a tooth were examined in this study: The hard **enamel** and the softer **dentine**, which is build out of material similar to that of bones (White and Folkens 2005). Organic and mineral composition of enamel, dentine and cement vary a lot. The main inorganic components in all three are calcium phosphate minerals,

mostly in the form of hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) like in bones. However many substitutions are possible (Hillson 1986). Mineralization processes of the enamel structure and the dentine tissue are completely different with the first one being one-of-a-kind in the body (Goldberg et al. 1995).

Dentine composition is different depending from where it is sampled (e.g. root or crown). On average by weight it contains 70% mineral phase, 20% organic matrix and 10% water (Goldberg et al. 1995). Mainly collagen accounts to the organic phase. Dentine is a living tissue with cells interacting with the pulp which is responsible for the dentine's formation, nutrition, innervation and reparation throughout an individual's lifetime. Due to the constant exchange with blood, it represents the last years of a person's life. Also post-mortem changes happen: While fresh dentine is somewhat tougher than bones and cementum, archaeological or fossil dentine is often friable and soft. Secondary mineral deposition can occur and leaching is a possibility leading to contaminations as well (Hillson 1986; Frank and Nalbandian 1989; Chiaradia et al. 2003).

Enamel on the other side is composed of 96-98% inorganic material (Boyde 1989), the minerals form a dense crystalline mass making it hard and resistant. Decomposition of the organic matter has almost no influence on it and therefore enamel is usually a well preserved archaeological finding. Due to its non-porous structure and adsorbed fluorine from diet it is also resistant to leaching (Hillson 1986). Elemental and isotopic composition of

enamel, in contrast to bone and dentine, doesn't change anymore after mineralization (Schweissing and Grupe 2003a). At which age enamel is mineralized is shown in figure 2. It can be seen that measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios will represent the individual's childhood residence. In this study mainly first molars were investigated, representing a person's diet for approximately his first three years of life. Second molars' enamel, beginning to form just when the first molar crowns are finished, were examined during this investigations too, they will display the home at an age of approximately three to seven years (Hillson 1986).

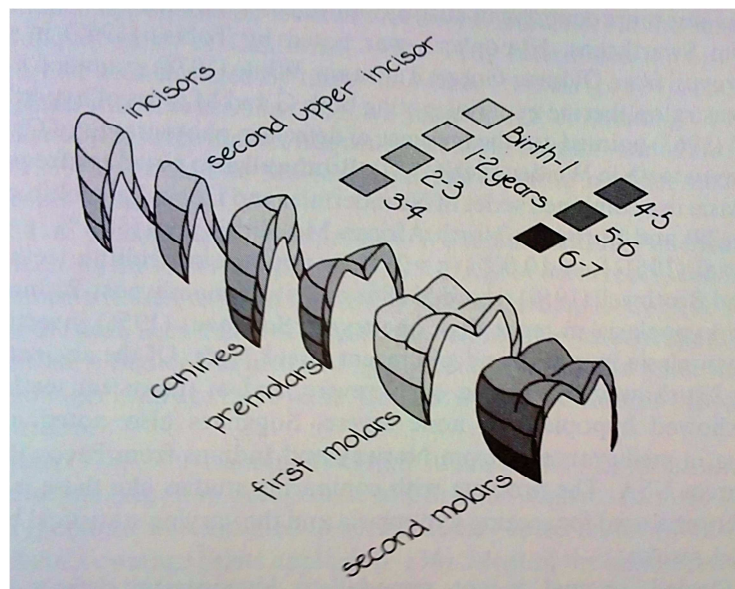


Figure 2 Enamel formation of permanent teeth (Hillson 1986)

In addition, calculus was often found on the investigated teeth from Franzhausen I. It is a dead material that is build up by mineralized plaque, which are deposits of in matrix embedded bacteria on the tooth (Hillson 1986).

1.3.1. Diagenesis

The change of the elemental composition of tooth and bone tissues is also possible after death when the bodies are buried. Organic as well as the inorganic material can be affected, with the first one being exposed to decomposition and leaching while recrystallization of the latter can happen as well. Especially ground waters cause post-mortem alterations. The degree of diagenesis of an element is on the one hand depending on its occurrence/abundance on the other hand conditioned by temperature, redox potential and

acidity in the burial ground (Molleson 1987; Hedges et al. 2006; Williams 1987). It is possible that soil grains of minimal size find their way into the porous hard tissues. Concentrations of most elements are higher in soil than in the skeleton, making the finding of elevated levels in the investigated archaeological samples more probable (Shafer et al. 2008).

Whether elemental or isotopic analyses of buried biological material are conducted, one needs to be aware of diagenetic contamination. Indicators for post-mortem changes in bones can be seen in Ca/P ratios above 2.1-2.2 (Price et al. 1994), typical values in the skeleton. The presence of elevated iron, aluminium and manganese concentrations would point to alterations after death as well (Price et al. 1994; Shafer et al. 2008; Lambert et al. 1985). Also uranium, usually not present in hard tissues of the living, is often incorporated from ground waters during burial (Molleson 1987). Strontium can also be affected by alterations after death in the burial ground, in general its concentration increases (Tuross et al. 1989). The biogenic isotopic composition of strontium and also of lead in dentine and bone is usually exposed to post-mortem changes in soil as well (Budd et al. 2000; Chiaradia et al. 2003).

Several strategies to remove contaminations have been developed and are still in use (Sillen 1986; Price et al. 1992; Schweissing and Grupe 2003a; Shafer et al. 2008; Koch et al. 1997; Schultheis 2003). However, none of these were conducted in this study since dental enamel material is investigated which is less affected by post-mortem alterations due to its structure (Hillson 1986).

1.4. Archaeological and historical aspects concerning this study

1.4.1. Bronze Age

The term Bronze Age was implemented by Christian Jürgensen Thomsen in the year 1836. It is no concept of time but rather a certain period in which bronze was generally used to manufacture weapons, tools and jewelry. Iron was of no relevance, yet (Windl et al. 1988). Gimbutas (1965) dated the Early, Middle and Late Bronze Age in Central and Eastern Europe approximately from 1800 B.C. – 1450 B.C., 1450 B.C. – 1250 B.C. and 1250 B.C. – 750 B.C.. A time table in Blesl (2005) shows the results of more recent dating attempts: the Early

Bronze Age starts 2300/2200 B.C., the Middle 1600 B.C and the Late Bronze Age covers the period between 1250 B.C. and 800/750 B.C.. Overall the Bronze Age in Central Europe was framed between the years 1800-750 B.C. at first. However, natural scientific data implemented an earlier beginning at around 2300/2200 B.C., but there were strong regional fluctuations recorded (Windl et al. 1988; Neugebauer and Neugebauer-Maresch 1989, in Teschler-Nicola 1992).

The Bronze Age brought also a change in society – age, gender and prestige weren't the only decision-makers for the social position of a person anymore (Sprenger 1999). Economic and social reorganization led to the formation of capital and the need for more security and protection in the populations. Building of political institutions and military behavior patterns were concomitant phenomena (Windl et al. 1988).

Bronze was first fabricated around 3000 B.C., it is an alloy between copper and tin with the most hardness at a proportion of ten to one. Those Cu-Sn-compositions were the first human made alloys (Riedel 1994; Windl et al. 1988).

Copper as well as tin have a lower abundance in nature than iron and experts are still astonished that the latter was not used first (Windl et al. 1988). Cu is a light red metal with the second highest (after silver) electrical and thermal conductivity. Its typical color comes from the oxide layer (Cu_2O) it builds with oxygen. For lower organisms like bacteria, algae and fungi copper is toxic (Riedel 1994).

1.4.2. The Excavation Site – Franzhausen I

In 1981, during the construction work for the freeway S33 between Krems and St. Pölten, the necropolis Franzhausen I in Lower Austria was brought up. Under the direction of Johannes-Wolfgang Neugebauer the rescue excavation was entirely finished by 1983. Together with Franzhausen II, it is the largest Early Bronze Age burial ground of Central Europe so far. 716 crouched burials from the Early Bronze Age were recovered from the Franzhausen I site. The primeval settlement in this region must have been rather intensive, looking at the partially very dense burial occupancy. With the number of graves and the time span the burial ground was used in (up to 700 years) a mean of about 110 (assuming 300

years of use), 31 (600 years) or 26.3 (700 years) people living in the neighborhood contemporaneously can be evaluated. (Sprenger 1999; Wiltshcke-Schrotta 1988; Windl et al. 1988)

The location of the Lower Traisen Valley was geographically, climatically and scenically benefited. Only few bone fractures and injuries were observed so far on the skeletons which allows the conclusion that it was a rather secure area at that time (a recent investigation by C. Knoll will shed light on this phenomenon, as the low frequency obtained so far might also be hampered by the poor preservation status of the skeletal remains). Two trade routes, north-south and the west-east, met here, making the development of a trading center possible. Many homesteads sprouted around the area of the cemeteries and the business brought wealth to parts of the population which can be retrieved by the opulent archaeological findings. The Traisen valley was densely populated from the Neolithic to the mediaeval age. Early Bronze Age burials in the Traisen valley are primarily attributed to the Unterwöbinger culture and the chronologically younger Böheimkirchner group (classical Věteřov culture). (Sprenger 1999; Wiltshcke-Schrotta 1988)

Most of the graves are oriented from north to south. Crouched burials in all variations - from one cowering extremely to one whose legs are just slightly bent - were found a lot in Franzhausen I while stretched burials were an exception. Such positions are said to be an imitation of the sidewise sleeping position. Sexual discrimination in the way a person is buried was typical for the representatives of the Unterwölbling culture. Men had their head put to north and lay on their left side. A woman's head looked south and her body was turned to the right side. Everybody was therefore looking in an eastward direction. (Wiltshcke-Schrotta 1988; Windl et al. 1988) Archaeological discrimination between men and women was also possible via the leftovers of their clothing and the pieces of grave furniture. Moreover, weapons like axes and daggers were only given to men. Jewelry, such as spiral chokers or rings, was worn by both genders, but the dual presence of bracelets or ornament needles was an indication for a woman's grave. (Windl et al. 1988) Grave robbery was a common phenomenon, over 75% of the burials in Franzhausen I were concerned. (Sprenger 1999)

The graves' depths were on average 131 cm low, the minimum was found at 37 and the maximum deepness at 429 cm. Children were generally found at higher levels, while the

major depths were reserved for adults from the upper class. Single burials were common practice in the area of the Lower Traisen Valley during the Early Bronze Age. (Windl et al. 1988)

Biological investigations by Teschler-Nicola (1992) enabled the assumption of a broader circle of marriages for women than for men in the Lower Traisen Valley. All living in the same period of time, individuals from Franzhausen I showed most similarities to the ones found in Gemeinlebarn A and also to the population in Unterwölbling. The short distance between those three necropolises, about 7-8 km from Franzhausen to the others, would explain these observations. The further away the more dissimilarities were found in the populations. A migration barrier between Melk and the Lower Traisen Valley due to the Dunkelsteiner woods seemed possible.

In prehistoric times the basis for nutrition in Lower Austria came from agriculture. Mostly wheat, barley and pulses were grown. The people's sources of meat were domestic animals, beside dogs, sheep, goats, cattle and pigs were held. They seem to have covered the demand for meat. Wild animals were only hunted to spice up the menu. The loin of a sheep was the most common food given as piece of grave furniture at the Franzhausen burial ground, seldom parts of cattle or goat were added (Windl et al. 1988).

2. INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY (ICP-MS)

2.1. General aspects of ICP-MS instruments

This part presents a brief description of solution nebulization based on an ICP-MS instrument, since only solutions were analyzed in this study. More detailed information about the technique is given elsewhere (e.g. Nelms 2005, Thomas 2001-2003). This measurement device was first introduced in 1983. Generally, an auto sampler feeds the sample with a peristaltic pump into the sample introduction system, which consists of two main parts: In the nebulizer an aerosol is generated with the help of a gas flow, in most cases argon. Self-aspiration is another possibility for a solution to enter the instrument. Then the sample goes to the spray chamber which makes sure that only droplets of about 5-10 μm in diameter enter the plasma. This is either used by gravimetric separation or centrifugal forces in cyclonic spray chambers. It also compensates for pulses produced during the aerosol formation in the nebulizer by the peristaltic pump (Thomas 2001a; Todoli and Vanhaecke 2005). Different designs are available, the ones used will be discussed below.

The next step involves desolvation, vaporization, atomization and ionization of the aerosol. All this occurs in the **plasma**, the **ion source**, where temperatures of up to 10,000K are reached. This highly ionized gas is generated as follows: The plasma gas bypasses the strong electromagnetic field from a radio frequency load coil (usually between 750 -1700W) while a high voltage spark is applied. The generated free electrons are accelerated by the magnetic field and collisions lead to the generation of the inductively coupled plasma (ICP) discharge. (Thomas 2001b; Hill et al. 2005)

Before the sample can enter the mass spectrometer which is working under vacuum, it has to pass through an interface region (~2-4 mbar). The in the plasma at atmospheric pressure (1 bar) generated ions have to travel through the sample and the skimmer cone, both are cooled to minimize damage by the high temperature. After this interface region the ion optics usher the ion beam electrostatically to the mass separation device. The ion focusing system consists of one or more lens components with certain voltages put on them. Their function is also to enhance the system's efficiency by transporting the maximum quantity of analyte while matrix and other non-analyte components, like photons or neutrons, are tried to be eliminated. (Thomas 2001c, 2001d; Hill et al. 2005)

The separation of the ions is accomplished in the mass analyzer due to their different mass-to-charge ratios (m/z) before they are finally converted to electrical pulses by a detector which gives the analyte's intensity. Electron multipliers and Faraday cups are most frequently used detectors in ICPMS instruments (Thomas 2001e, 2002b; Hunter and Stresau 2005). Several mass separation devices as well as detector types are available; the ones used will be discussed in more details in the descriptions of the used instruments (chapter 2.2.1 and 2.2.2.).

2.2. Instruments in the VIRIS laboratory used in this study

All gas flows were operated with argon gas in this study.

2.2.1. ICP-QMS: ELAN DRC-e (PerkinElmer, Ontario, Canada)

The instrument is a quadrupole based ICP-MS. It is equipped with a PerkinElmer AS93plus (PerkinElmer, Ontario, Canada) auto-sampler.

For multi-elemental analysis a concentric nebulizer (PerkinElmer, Ontario, Canada) was used. At the end of a capillary tube the high-speed parallel gas flow creates a low pressure zone leading to the generation of an aerosol. The benefits of this design are superior sensitivity and stability. (Thomas 2001a) The aerosol droplets are separated by size in a cyclonic spray chamber (CPI International, Amsterdam, Netherlands) capitalizing on the centrifugal force where the larger drops bounce on the wall and run down the drain while the smaller ones can enter the plasma with the Ar gas stream. Advantages of this design can especially be seen for clear solutions as better sensitivity and detection limits can be achieved making use of the higher sampling efficiency. (Thomas 2001a)

Rb/Sr-Screenings have to be accomplished with a perfluoroalkoxy (PFA) microflow nebulizer (PFA ST nebulizer, Amsterdam, Netherlands) due to the small sample amounts. This design is similar to the concentric nebulizer but is used with lower sample flow rate and higher gas pressure. (Thomas 2001a)

The 'ELAN DRCE' is an ICP-quadrupole-MS instrument with two quadrupoles inside. The second quadrupole in line is functioning as the mass separation device. A quadrupole is build

up by four metallic rods. On two opposites a direct current and on the other pair a radio frequency field is applied. Only ions with a certain mass-to-charge ratio are guided through by the generated electrostatic field while the others are ejected. This is done for one m/z -ratio after the other (Thomas 2001e). The first quadrupole can be used as a collision cell or dynamic reaction cell to reduce interferences. The latter was not used in this study. Figure 3 shows a schematic alignment of a quadrupole ICPMS with a reaction/collision cell.

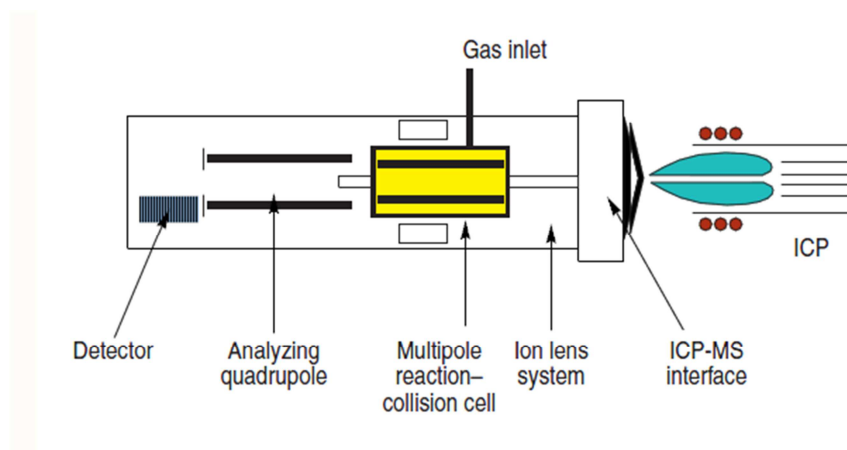


Figure 3 Schematic alignment of an ICP-MS instrument with a collision/reaction cell (Thomas 2002a)

The cell technology allows the reduction of interferences by applying gas phase reactions with a cell gas. Followed by a gas phase reaction, interfering ions can be reduced or the analyt of interest can be analyzed at a different mass/charge ratio. In a dynamic reaction cell (DRC) like in the ELAN instrument a highly reactive gas, for example CH_4 or NH_3 , or O_2 is introduced into a quadrupole set before the mass analyser, usually working in a radio frequency-only mode. Collision cells use the advantage of the effect on the kinetic energy of ions colliding with gases in the cell. The resulting energy difference is used in order to separate interferences from analytes of interest (Thomas 2002a). Cell technologies are applied for certain elements like ^{56}Fe , ^{39}K or ^{40}Ca where especially Ar-based interferences (e.g. $^{40}\text{Ar}^{16}\text{O}$, ^{38}ArH , ^{40}Ar) occur but also for interferences resulting from the matrix.

Ions detection is accomplished with a secondary electron multiplier (SEM). This detector device is build up by several dynodes with increasing voltages. When an ion reaches the first conversion dynode it generates 2-3 electrons and those lead to the release of more and more secondary electrons with every following dynode. Benefits of this detector are its great detection sensitivity, linearity over a wide range and short response time. As disadvantages one must see the limited life span due to accumulations on the conversion dynode, rather

high costs, a tolerable pressure of maximum 10^{-4} Pa and the mass and energy dependency of the electron conversion (Cammann 2001; Hunter and Stresau 2005). The SEM in the ELAN instrument can work in the dual mode: It will work in the pulse-counting mode as long as the counts are low and change to analog mode when the current increases.

2.2.2 MC-HR-ICPMS: NuPlasma (Nu Instruments Ltd., Wrexham, UK)

The NuPlasma HR is a multicollector sectorfield instrument with Nier Johnson geometry. An ESI SC 4 autosampler (Elemental Scientific, Inc., Omaha, USA) feeds the sample into the introduction system (DSN-100 - **D**esolvati**o**n **N**ebuliser; Nu Instruments Ltd, North Wales, UK) of the instrument (fig. 4 and 5). A fine aerosol generated by the PFA nebulizer enters the heated ($\sim 110^{\circ}\text{C}$) PFA spray chamber for vaporization. Then the sample has to pass through a heated ($\sim 110^{\circ}\text{C}$), semi porous PTFE membrane. This way a stable dry sample feed is produced and can enter the plasma for atomization and ionization (Nu Instruments 2007).

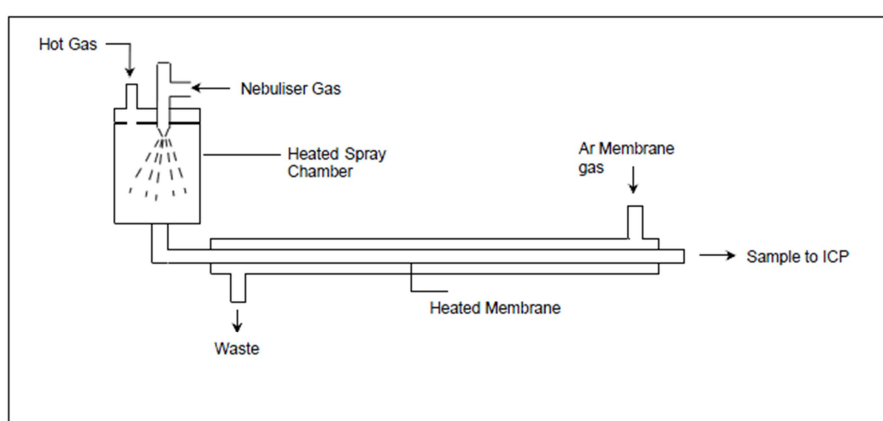


Figure 4: Schematic of the DSN-100 (Nu Instruments 2007)

The double-focusing multiple collector high resolution ICPMS sectorfield instrument has an electrostatic analyzer (ESA) before an electromagnet which acts as mass analyzer. This design is known as standard Nier-Johnson geometry. In the ESA the ions are focused with respect to their kinetic energy, while the separation is realized in the magnet as ions will have different circular trajectories depending on their m/z ratios. Benefits of this mass separation technology are high resolution, excellent sensitivity with low background levels and outstanding precision (Thomas 2001f; Batey et al. 2005). The analyzer part of the instrument is under vacuum at approximately 5×10^{-9} mbar.

The separated ion beams can be detected in up to 12 Faraday cups at the same time (→ multi collector). Measured is the impact of an ion (or electron) on one of those cups which leads to an electrical current. The emission of secondary electrons is undesired. A graphite coating on the inner surface of the detector is there to prevent their formation. It is of great importance that the ions do not exit the cup anymore as it would increase the signal. Therefore an electron suppressor/repeller is put near the entrance slit and a small magnet device can be found below and above the detectors. There is also the possibility to measure signals in up to three ion-counting multipliers. One of those additionally offers the option to use a retardation (or deceleration lens) filter which improves abundance sensitivity via reduction of low mass peak tailing, a useful tool for very large isotope ratios like $^{238}\text{U}/^{236}\text{U}$ (Nu Instruments 2007).

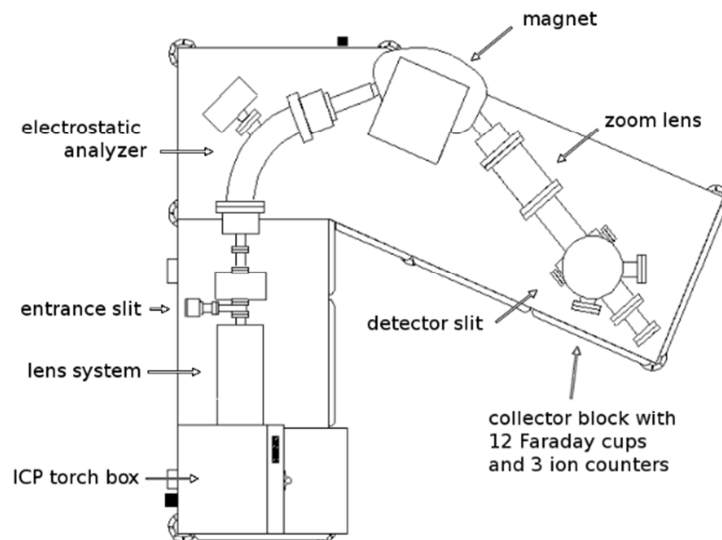


Figure 5 Schematic of the used NuPlasma MC-HR-ICP-MS instrument (Nu Instruments 2007)

3. MATERIALS AND METHODS

3.1. Laboratory materials, reagents and standards

Prior to use disposable polyethylene materials, like test tubes and pipette tips, were acid washed in 10% and 1% HNO₃ (Merck, Darmstadt, Germany) and left for at least 24 hours in each bath. They were rinsed with reagent grade I water (PURELAB® Classic, Veolia Water Systems Austria GmbH, Wien, Austria or TKA Wasseraufarbeitungssysteme GmbH “Part of Thermo Fischer Scientific”, Niederelbert, Germany) and air dried. PFA vessels for digestions were steam washed with concentrated nitric acid in a MiniVesselCleaner® (ANALAB Sàrl, Hoenheim, France) and reused.

Reagent grade I water was further subboiled (Milestone-MLS GmbH, Leutkirch, Germany or Savillex Corporation, Eden Prairie, MN, USA) and HNO₃ (p.a., 65%; Merck, Darmstadt, Germany) was double subboiled (Milestone-MLS GmbH, Leutkirch, Germany or Savillex Corporation, Eden Prairie, MN, USA) before further use. Pro analysi grade 30% H₂O₂ (MERCK KGaA, Darmstadt, Germany) was taken for digestions. Sr/matrix-separations were performed with a Sr-specific resin (Sr Resin, Eichrom Technologies, Inc., Lisle, USA), where on an inert substrate 4,4'(5')-bis(t-butyl- cyclohexano)-18-crown-6 in octanol was immobilized (Horwitz et al. 1992).

An Indium ICP Standard (1000 mg L⁻¹ In ; CertiPur, MERCK KGaA, Darmstadt, Germany) was taken as internal normalization standard for quantitative analysis. Calibration curves for multi elemental analysis and Rb/Sr-screenings were established with the ICP Multi Element Standard Solution VI (CertiPur, suprapure, MERCK KGaA, Darmstadt, Germany). This standard was also used for the fabrication of an in-house reference material, applied as quality control during measurements, spiked with 1000 µg g⁻¹ single element standards of Na, Al, Ba (all Fluka Chemie AG, Sigma-Aldrich (Switzerland) Holding AG, Buchs, Switzerland), Mg, Mn, Fe, Se, Rb, Sr, Ca, K (all MERCK KGaA, Darmstadt, Germany) and Zn (VWR International GmbH, Vienna, Austria). Final concentrations of the elements can be seen in table 27 in chapter 6.2. Certified (see chapter 6.1.) for their isotopic composition the standard reference material (SRM) NIST SRM 987 SrCO₃ (National Institute for Standards and Technology, Gaithersburg, USA) was used for strontium isotope ratio measurements.

Standard preparations were done gravimetrically on an analytical balance (Sartorius AG Germany, Goettingen, Germany).

3.2. Samples

3.2.1. Archaeological human teeth

All tooth samples were provided by the Department of Anthropology at the Museum of Natural History, Vienna. In this study the first or second molar of individuals discovered at the Early Bronze Age excavation site Franzhausen I in Lower Austria was investigated. Distinct identification and if needed extraction of samples out of the jaw bone were carried out by Hannah Dehoust and Judith Benedix under supervision of HR. Ao. Univ.-Prof. Dr. Maria Teschler-Nicola, head of the Department of Anthropology at the Museum of Natural History, Vienna. Copper and bronze pieces of furniture given to the deceased lead to green staining of skeletal parts, therefore some of the teeth had a green color. A complete sample list is attached in chapter 6.2.1.

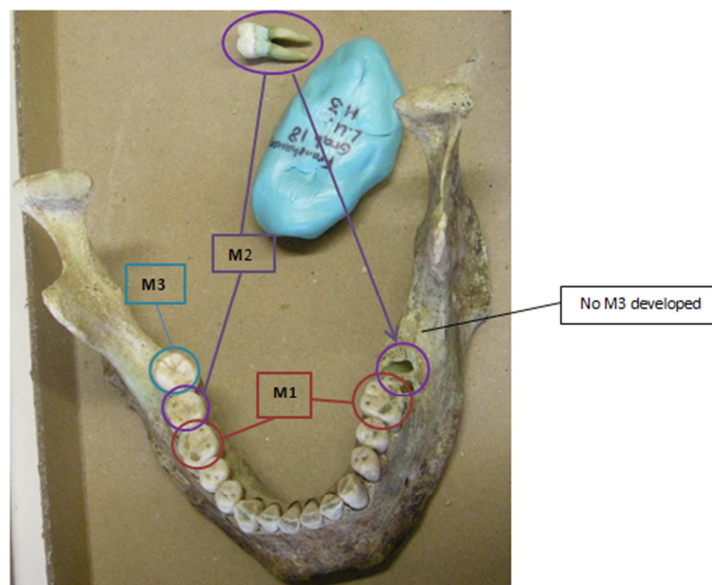


Figure 6: First, second and third molars in lower jaw bone

3.2.2. Environmental Samples

For the designation of a local and surrounding elemental and isotopic signal, which are needed to differentiate between local and non-local settlers, environmental samples are of great importance.

3.2.2.1. Samples from the excavation site

Unfortunately it was not possible to take soil samples directly from the excavation site anymore, for there is a gravel pit now. However, in two bone samples (both from the same grave) of the Neolithic excavation site Franzhausen II, which is only a few hundred meters away from Franzhausen I, there was residual earth which could be taken for analysis.

3.2.2.2. Recent background samples

As there are more samples needed of the location itself as well as of the surrounding area, a sampling campaign was accomplished. For the selection of the sampling spots other Bronze Age settlements in the area around Franzhausen were taken into account. The following places were aimed: Gemeinlebarn - Franzhausen - Reichersdorf - Getzersdorf - Inzersdorf - Unterwölbling - Statzendorf - Ratzersdorf - Unterradlberg - Pottenbrunn - Ossarn – Oberndorf.



Figure 7 Image of the geology of Franzhausen's near surrounding area (Geologische Bundesanstalt 2011)

The geology in this area is rather diverse as can be seen in Figure 7. For the determination of the environmental $^{87}\text{Sr}/^{86}\text{Sr}$ ratio and the elemental signals water samples from rivers and lakes were collected in 100 mL bottles. The water was taken about 2 m apart from land using the Köha device (University of Natural Resources, Vienna, Vienna, Austria). Soil samples were taken from 10 to 20 cm beneath the surface and stored in plastic bags. In total 25 water, 26 soil, 8 wood and 8 leaf samples, 7 other plant materials as well as some empty snail shells were collected. The investigation of fauna, wood, leaf and plant samples was not part of this diploma thesis. Figure 8 shows the actual sampling spots and the corresponding GPS data with detailed sample information are listed in table 30 in the appendix. Also a geologic map with the sample codes (figure 9) was generated by Andreas Zitek with the ArcGIS software, unfortunately not the whole sampled area was available with the needed specificity online.

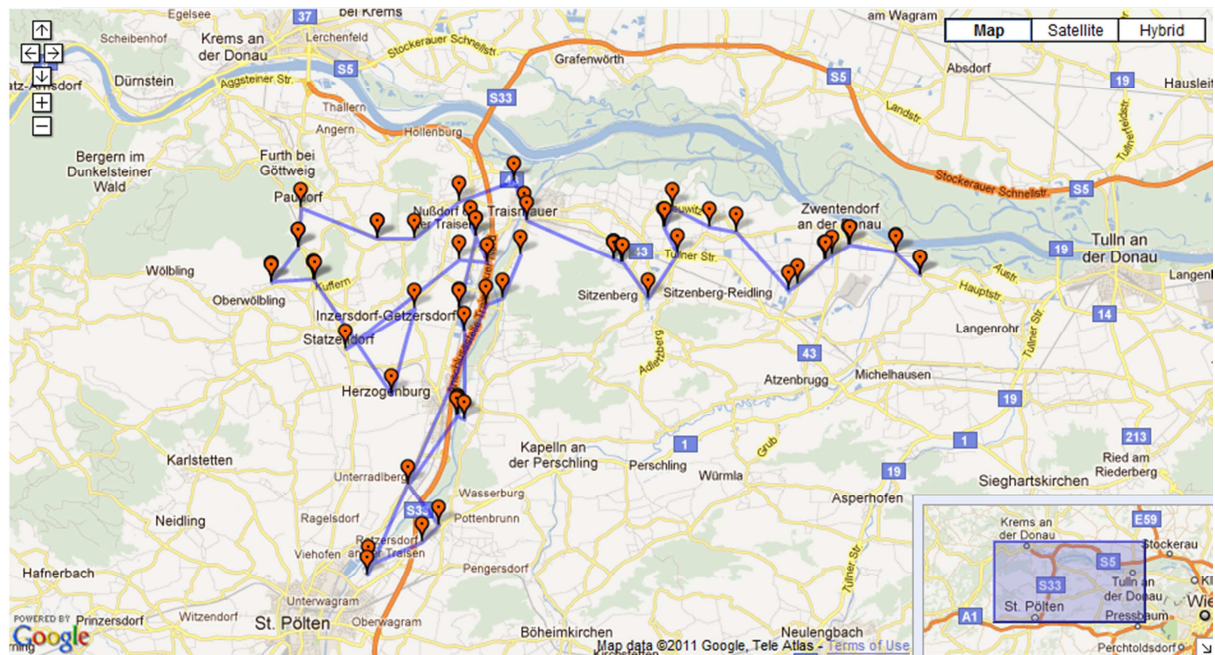


Figure 8 sampling route (generated with 'locr GPS Photo' software)

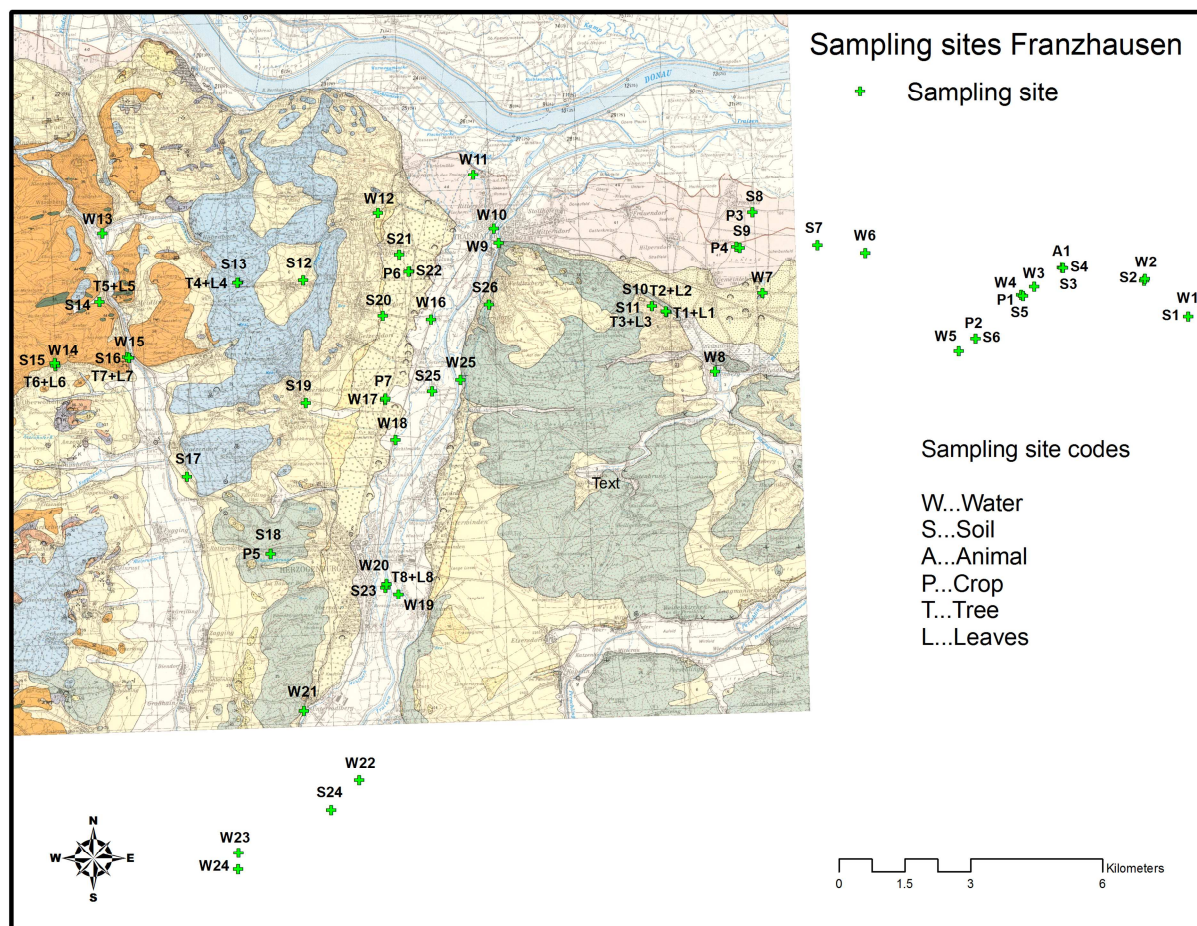


Figure 9 Sampling sites with geology (generated with ArcGIS software)

3.3. Sample preparation

3.3.1. Archaeological human teeth

3.3.1.1. Pretreatment

To clean the teeth from hydrophilic and -phobic remains they were washed in an ultrasonic bath (Eumax Technology (Shenzhen) Ltd., Hong Kong, China; model: UD80SH-2L), first with reagent grade 1 water for 10 minutes and then with 2-propanol (p.a. grade; Sigma-Aldrich (Switzerland) Holding AG, Buchs, Switzerland) for 2-3 minutes. They were dried at room temperature over night. Some teeth were still in the jaw bone- Those were wiped with a clean room cloth once with reagent grade I water and once with isopropanol.

Possibly present calculus had to be drilled off using an electrical driller (Dremel Moto-Tool, Racine, Wisconsin, USA; Mod. 396, Type 1, 10000 – 30000/min) in combination with a

diamond boring head (Edenta AG/GmbH, CH-9434 AU/SG, Switzerland) carefully before enamel samples could be taken (see fig. 10). Afterwards the teeth were cleaned ultrasonically again with reagent grade I water (10 min) to remove generated dust.

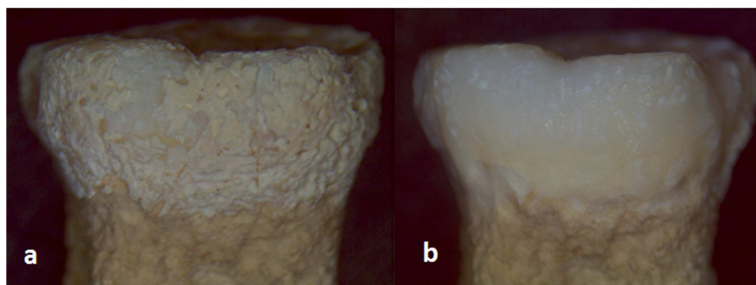


Figure 10 Tooth before (a) and after (b) calculus removal (Inv. No. 24285)

Enamel and dentine material of at least 5 mg were drilled. Correct drilling of the enamel was checked using light microscopy (Optoteam Präzisionsinstrumente Vertriebsgesellschaft m.b.H., Wien, Austria) as accidental contamination with dentine had to be avoided.

3.3.1.2. Digestion

The obtained powder was digested with 2 mL double subboiled HNO_3 (65%) and 1 mL H_2O_2 (30%) on a heating plate (ANALAB Sàrl, Hoenheim, France) at 150°C for 4 hours. 8 mol L^{-1} HNO_3 was added to the digests to obtain a total weight of approximately 10 mg. This is done to already adjust the pH-value for the subsequent Sr/matrix separation.

3.3.1.3. Sr/matrix-separation

About 0.5 mL of a Sr-specific resin (Sr Resin, Eichrom Technologies, Inc., Lisle, USA) were filled into 3 mL columns equipped with $10 \mu\text{m}$ filters (Separtis GmbH, Grenzach-Wyhlen, Germany) for Sr/matrix-separation. This step is very important to minimize the influence of isobaric (especially ^{87}Rb) and molecular (e.g. $^{48}\text{Ca}^{40}\text{Ar}^+$) interferences on the subsequently mass spectrometrically determined strontium isotope ratios. The resin was slurred in 1% HNO_3 and stored in the refrigerator for 24 hours beforehand. The first step of the separation was to wash the resin 4 times with 0.5 mL double subboiled H_2O . Then 6 times 0.5 mL 6 mol L^{-1} HNO_3 were added slowly for conditioning before 2 mL of the sample were applied carefully. Next the undesired matrix components were removed by 10 washing steps with 0.5 mL 8 mol L^{-1} HNO_3 . Finally strontium was eluted with 2 mL H_2O (2x subb.).

3.3.2. Environmental samples

3.3.2.1. Soil

3.3.2.1.1. Pretreatment

The fresh soil samples were air-dried at room temperature for five days prior to sieving. All soil samples including those from Franzhausen II were sieved with a 2 mm high quality steel sieve (ISO 595; Retsch GmbH, Haan, Germany) prior to extraction. A triple determination of the Franzhausen II samples was carried out to test the appropriateness of the method.

3.3.2.1.2. Extraction

To answer the open questions for this study only the bioavailable fractions in the collected soils are of interest and are therefore extracted following DIN V 19730.

50 mL 1 mol L⁻¹ NH₄NO₃-solution (GPA rectapur; VWR International GmbH, Vienna, Austria) were added to 20 g sieved material and then put into a GFL 3040 overhead rotator (GFL Gesellschaft für Labortechnik GmbH, Burgwedel, Germany) for 2 hours at 20 rpm. After the sample had time to settle for 5 minutes, the liquid phase was decanted and filtered with folded filters (Grade 14/N, 150 mm, 80 g/m²; Munktell Filter AB, Falun, Sweden). The first 5 mL of the filtrate were discarded to avoid possible contamination coming from the filter. 0.5 mL double subboiled HNO₃ (65%) were added to the filtrate for stabilization.

3.3.2.1.3. Sr/matrix-separation

Prior to Sr/matrix-separation double subboiled HNO₃ (65%) was added to the acidified extract (about 1% acid-solution) to obtain an approximately 8 mol L⁻¹ acid-solution. Further sample treatment is identical to the description in chapter 3.3.1.3.

3.3.2.2. Water

3.3.2.2.1. Pretreatment

To stabilize the collected aqueous solutions 1 mL HNO₃ conc. (2x subb.) was added and the bottles were stored in the fridge at 5°C. For further procedures the samples were filtered with 0.45 µm regenerated cellulose membrane filters (Sartorius Stedim Biotech GmbH, Goettingen, Germany).

3.3.2.2.2. Sr/matrix-separation

For Sr/matrix separation the filtered waters were acidified further 1:1 with HNO₃ (65 %, 2x subb.) in order to get a concentration of about 8 mol L⁻¹. In chapter 3.3.1.3. the subsequent approach is described.

3.3.2.3. Fauna and Flora

3.3.2.3.1. Pretreatment

Snail houses, wood, leaves, corn cobs and sunflowers were chopped and put in a drying oven (Memmert GmbH + Co.KG, Schwabach, Germany) at 30°C. The dried samples were stored in plastic bags for future treatments.

3.4. Measurements

3.4.1. Multi-elemental analysis by ICPQMS

All multi-elemental measurements were carried out on the ELAN DRC-e quadrupole mass spectrometer. Operational settings are summarized in table 6.

The samples were diluted with 1% HNO₃ as follows: Tooth digests and soil extracts 1:50; water samples 1:50 for the determination of Na, Mg, K and Ca concentrations which are present in high concentrations in natural waters. Other elements were measured in undiluted water samples.

The ICP Multi Element Standard Solution VI was diluted to concentrations of 0.05, 0.1, 0.5, 1, 5, 10, 25, 50 and 100 ng g⁻¹ for calibration.

10 ng g⁻¹ indium was added as internal normalization standard to the standards as well as to the samples and blanks.

Prior to measurements the x/y position of the torch and nebulizer gas flow were optimized to reach maximum indium sensitivity. The autolens was calibrated with Mg, U, In, Ce, Ba, Cu and Pb to cover the whole mass spectrum. Unwanted oxide formations were checked with CeO⁺/Ce⁺ ratios. The second undesired effect leading to interferences was the appearance of

double charged ions. As a test one looked at the $\text{Ba}^{2+}/\text{Ba}^{+}$ ratio, it should be less than ~4%. Blank and in-house quality control standard were measured after every 20 samples.

sampler cone material	nickel
skimmer cone material	nickel
nebulizer gas flow [L min^{-1}]	0.98-1.07
plasma gas flow [L min^{-1}]	15
auxiliary gas flow [L min^{-1}]	0.6
RF power [W]	1250
pump speed during analysis [rpm]	20
number of sweeps/reading	8
number of readings/replicate	1
number of replicates	4
dwell time/amu [ms]	50
scan mode peak	peak hopping
detection mode	Dual
analog stage voltage [V]	-1937
pulse stage voltage [V]	1250
analyzed isotopes	^7Li , ^9Be , ^{10}B , ^{11}B , ^{23}Na , ^{24}Mg , ^{26}Mg , ^{27}Al , ^{39}K , ^{42}Ca , ^{43}Ca , ^{44}Ca , ^{51}V , ^{52}Cr , ^{55}Mn , ^{56}Fe , ^{57}Fe , ^{58}Ni , ^{59}Co , ^{60}Ni , ^{63}Cu , ^{65}Cu , ^{66}Zn , ^{68}Zn , ^{69}Ga , ^{75}As , ^{77}Se , ^{82}Se , ^{85}Rb , ^{88}Sr , ^{98}Mo , ^{107}Ag , ^{109}Ag , ^{111}Cd , ^{114}Cd , ^{115}In , ^{128}Te , ^{130}Te , ^{137}Ba , ^{138}Ba , ^{203}Tl , ^{205}Tl , ^{207}Pb , ^{208}Pb , ^{209}Bi , ^{238}U

Table 6 ELAN DRCE settings for multielemental analysis

3.4.2. Rb/Sr-Screening by ICPQMS

These measurements were done on one hand to see if the matrix/strontium separation worked and on the other hand to determine the Sr-concentrations in the separation solutions, which need to be known to calculate dilutions for obtaining optimum concentrations for the Sr-ratio measurements. These measurements were conducted on the ELAN DRC-e instrument as well.

For measurements 100 μL 110 ng g^{-1} In-solution and 900 μL 1% HNO_3 were added to 100 μL matrix/Sr-separated sample.

The ICP Multi Element Standard Solution VI was diluted to concentrations of 0.05, 0.1, 0.5, 1, 5, 10, 25, 50 and 100 ng g^{-1} for calibration.

After tuning the x/y position and the lens, the nebulizer gas flow rate was optimized using the PFA nebulizer Instrumental parameters are listed in table 7.

sampler cone material	nickel
skimmer cone material	nickel
nebulizer gas flow [L min ⁻¹]	0.98-1.07
plasma gas flow [L min ⁻¹]	15
auxiliary gas flow [L min ⁻¹]	0.6
RF power [W]	1250
pump speed during analysis [rpm]	10
number of sweeps/reading	8
number of readings/replicate	1
number of replicates	5
dwel time/amu [ms]	50
scan mode peak	peak hopping
detection mode	Dual
analog stage voltage [V]	-1937
pulse stage voltage [V]	1250
analyzed isotopes	⁸⁵ Rb, ⁸⁸ Sr, ¹¹⁵ In

Table 7 Operational parameters for Rb/Sr Screening

3.4.3. Sr-isotope ratio measurements by MC-HR-ICPSFMS

Based on the measured Sr concentration in the Sr/matrix separated sample fractions, samples were diluted with 1% HNO₃ to a Sr-concentration of 20 ng g⁻¹. The ones with concentrations below that value were filled up to a total volume of 2.5 mL to have enough solution for the measurement.

To gain maximum Sr-sensitivity and stability for Sr isotope ratios a number of instrumental parameters like gas flows, torch position, lens voltages, peak shape and alignment were tuned on a daily routine prior to measurements with a ~20 ng g⁻¹ Sr solution (NIST SRM 987) in 1% HNO₃ solution. A summary of operation parameters is shown in table 8. During the twelve days the samples were measured, the sensitivity for strontium ranged from 213 to 500 V/ppm. A 1% HNO₃ solution was used as blank which was measured using the Measure zeros method provided by the NuPlasma software before the SRM after every 5 samples.

sampler cone material	nickel
skimmer cone material	nickel
nebulizer back pressure [psi]	~30
plasma gas flow [L min ⁻¹]	13
auxiliary gas flow [L min ⁻¹]	0.8
DSN-100 hot gas flow [L min ⁻¹]	~0.3
DSN-100 membrane gas flow [L min ⁻¹]	~3
DSN-100 membrane temperature [°C]	115
DSN-100 spray chamber temperature [°C]	115
RF power [W]	1300
axial m/z	86
mass resolution m/Δm	300
measurements / block	10
number of blocks	6
dwel time [s]	5
sample uptake rate [μL min ⁻¹]	170
mass separation	0.5

Table 8 Nu Plasma operational settings for Sr ratio measurements

cup	L5	IC2	L4	IC1	L3	IC0	L2	L1	Ax	H1	H2	H3	H4	H5	H6
mass	82		83		84		85		86		87		88		89
analyte					⁸⁴ Sr				⁸⁶ Sr		⁸⁷ Sr		⁸⁸ Sr		
interference	⁸² Kr		⁸³ Kr		⁸⁴ Kr		⁸⁵ Rb		⁸⁶ Kr		⁸⁷ Rb				

Table 9 Faraday collector setup for Sr ratio analysis

The setup of the Faraday collector together with possible isobaric interferences is specified in table 9. Krypton impurities in the argon gas can cause elevated background levels and are usually corrected via on peak baseline blank correction. Further corrections on the measured ⁸⁷Sr/⁸⁶Sr ratio performed by the instrument's software NICE are:

Rubidium and mass bias corrections are taken into account using the exponential law (Albarède et al. 2004). Under the assumption of a constant ⁸⁶Sr/⁸⁸Sr ratio a fractionation factor is calculated according to equation 1.

$$f = \frac{\log \left[\left(\frac{{}^{86}\text{Sr}}{{}^{88}\text{Sr}} \right)_{\text{true}} \cdot \left(\frac{{}^{86}\text{Sr}}{{}^{88}\text{Sr}} \right)_{\text{obs}}^{-1} \right]}{\log \left(\frac{m_{\text{Sr}86}}{m_{\text{Sr}88}} \right)}$$

Equation 1

$\left(\frac{^{86}\text{Sr}}{^{88}\text{Sr}}\right)_{true}$ natural $^{86}\text{Sr}/^{88}\text{Sr}$ ratio (0.1194 (Berglund and Wieser 2011)); corrections for NIST SRM 987 done with certificate values (see appendix)

$\left(\frac{^{86}\text{Sr}}{^{88}\text{Sr}}\right)_{obs}$ measured $^{86}\text{Sr}/^{88}\text{Sr}$ ratio

m mass of the respective isotope as given in appendix

Corrections for isobaric interferences (equ. 2) were done by recording the ^{85}Rb signal and applying the fractionation factor calculated using the $^{86}\text{Sr}/^{88}\text{Sr}$ ratio assuming a similar fractionation as for strontium.

$$U_{Rb87} = \left(\frac{^{87}\text{Rb}}{^{85}\text{Rb}}\right)_{true} \cdot U_{Rb85} \cdot \left(\frac{m_{Rb85}}{m_{Rb87}}\right)^f \quad \text{Equation 2}$$

U measured signal on respective masses

$\left(\frac{^{87}\text{Rb}}{^{85}\text{Rb}}\right)_{true}$ natural constant $^{87}\text{Rb}/^{85}\text{Rb}$ ratio (0.385706 (Berglund and Wieser 2011))

m mass of the respective isotope as given in appendix

f fractionation factor

Now the actual ^{87}Sr signal can be calculated by subtracting U_{Rb87} from the total signal on mass 87, as described in equ. 3.

$$U_{Sr87} = U_{87} - U_{Rb87} \quad \text{Equation 3}$$

Finally mass bias correction can be included to get the final $^{87}\text{Sr}/^{86}\text{Sr}$ value as:

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}} = \frac{U_{Sr87}}{U_{86}} \cdot \left(\frac{m_{Sr87}}{m_{Sr86}}\right)^f \quad \text{Equation 4}$$

4. RESULTS AND DISCUSSION

4.1. Rb/Sr Screenings

The Sr/matrix separation was successful as concentration ratios of rubidium to strontium were always below 0.004 (whereas before they were as high as 0.13). One sample (FH1_S15) contained even more Rb than Sr; with a Rb/Sr ratio was 1.6 prior to the separation and 0.0005 afterwards. Recoveries of strontium in the separated tooth digestion solutions yielded from 25% to 92% with an average of 53% with concentrations between 10 and 490 ng g⁻¹. The mean value was 100 ng g⁻¹. In the separated soil extracts only between 11% and 37% strontium were found again. However, the Sr concentrations were still rather high (approximately 45 – 1500 ng g⁻¹ with an average of 500 ng g⁻¹). Water samples, which had the lowest Sr concentrations from the beginning (on average 365 ng g⁻¹), still contained 31% to 55% of the original strontium concentration after Sr/matrix separation. Strontium concentrations in the separated water solutions yielded from 40 to 270 ng g⁻¹. The mean value was 150 ng g⁻¹.

4.2. Sr-isotope ratio measurements

4.2.1. Environment samples

In order to be able to distinguish between local and non-local individuals the establishment of the locally available ⁸⁷Sr/⁸⁶Sr signal is required. Different approaches for the evaluation are described in literature. The use of environmental samples, like soil, water or plants, as done for example by Kusaka et al. (2011) and Turner et al. (2009), is one possibility. Also bone (or dentine) samples can be used to distinguish between local and non-local individuals (e.g. Ezzo et al. 1997). Modern and archaeological animals are sometimes utilized as well to estimate biologically available ⁸⁷Sr/⁸⁶Sr values (e.g. Haverkort et al. 2008). The decision on which approach is used should be based on the finding situation. Two possibilities were checked for this study: First a local range with environmental samples was established. For this, the average value of the six soil extracts from Franzhausen II (samples soil 1A-2C), which

had been sampled at the excavation site itself, and the ratios of the two fresh soil samples FH1_S21 and FH1_S22 taken around the present-day village Franzhausen were averaged. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios therefore ranged from 0.70736 – 0.71055 in the local area.

For the second approach the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios determined in dentine samples were taken. The local range was defined by subtraction/addition of two times the standard deviation to the average value. The dentine range is narrower than the soil range, with 0.70813 – 0.70975, respectively.

Both ranges are plotted in figure 11. The geology of the area is very diverse and can lead to a larger variety of biologically available $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. Therefore the measured strontium ratios of the soil samples seem to be the more appropriate range than the dentine range for interpretations of the migration pattern in Franzhausen during the Early Bronze Age. This range is taken in the further explanations as ‘local range’. Nonetheless, both approaches show an excellent match in both cases.

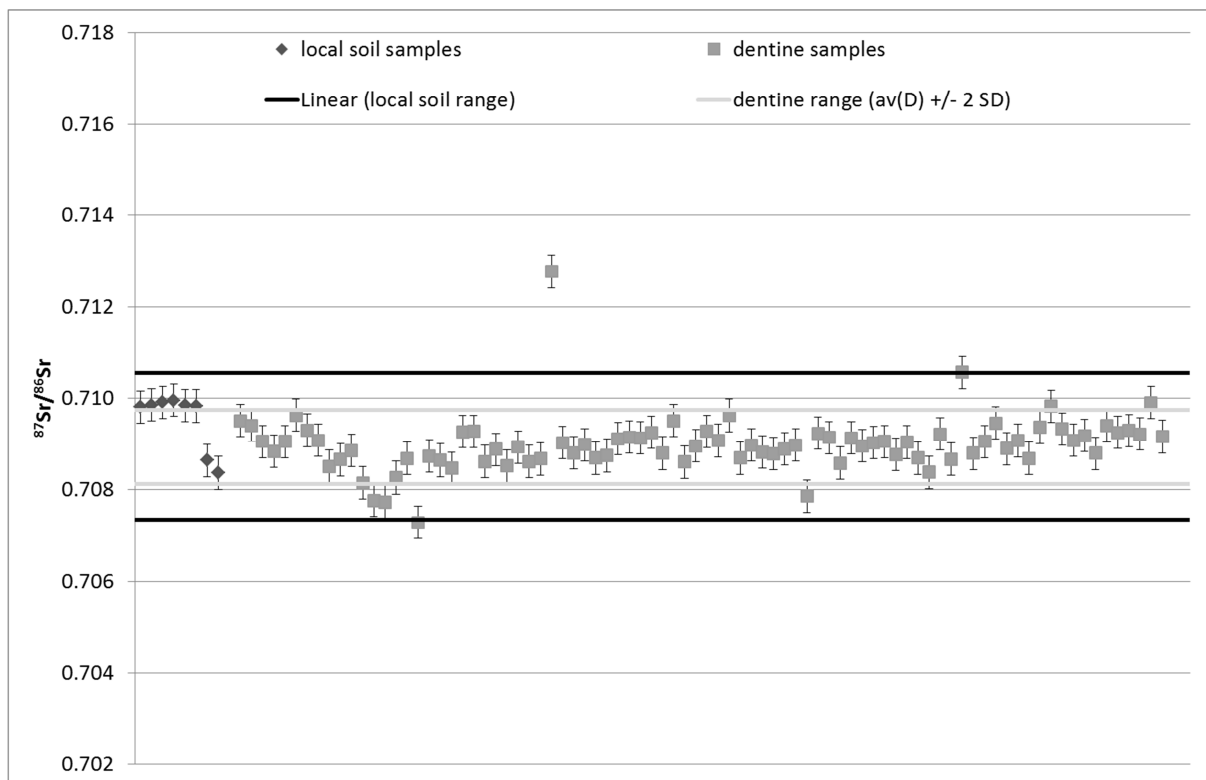


Figure 11 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of local environment and dentine samples with local soil and dentine range

Furthermore water and soil samples of Franzhausen’s surrounding were collected and analyzed. As mentioned before, the idea of marriage trading between the populations of Franzhausen, Gemeinlebarn and Unterwölbling came up during biological investigations

(Teschler-Nicola 1992). To be able to differentiate between those three and other possible emigration zones, differences in the strontium isotope ratios need to be present. The measurement results are presented in figure 12 and table 32 (appendix). Figure 13, generated by Andreas Zitek with the ArcGIS software, shows the ratios of the sampling spots on a geological map, which helps with further explanations and interpretations. Unfortunately a geological map for the whole sampled area is not available online with the specificity that would be required and therefore the underlying geology of some of the samples is not given there. Nevertheless, the existing geological maps already give indications about the relation of geology and measured Sr isotope ratios in the environmental samples reflecting the bioavailable Sr signal.

Most soil and water samples (36 out of 47) were within the local range and therefore the distinction between locals and an immigrant from these close areas on the basis of strontium isotope measurements cannot be done. However, two settlements of special interest, Unterwölbling and Gemeinlebarn, differ in their $^{87}\text{Sr}/^{86}\text{Sr}$ signature in comparison to Franzhausen and to each other. All locations with ratios outside the local range are listed in table 10. For areas, where more than one sample was taken, the average $^{87}\text{Sr}/^{86}\text{Sr}$ ratio was defined as their isotopic signal. The in the VIRIS laboratory validated relative total combined standard uncertainty of 0.05% ($k=2$) was taken for all samples analyzed in this study, since no significant changes of the method were implemented.

location	$^{87}\text{Sr}/^{86}\text{Sr}$	SU (k=2)
Gemeinlebarn	0.70462	0.00035
Unterradlberg	0.70652	0.00035
St. Georgen	0.70659	0.00035
Ossarn	0.70712	0.00035
Kleinschönbichl	0.70717	0.00035
Ahrenberg	0.71092	0.00036
Dörfl	0.71119	0.00036
Hirschberg	0.71221	0.00036
look-out Korkenzieher	0.71327	0.00036
Unterwölbling	0.71509	0.00036
local range	0.70736 - 0.71055	

Table 10 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of locations outside the local range

The rather high ratios in Unterwölbling (0.7151) and the area around it (Dörfl – 0.7112, Hirschberg – 0.7109) can be explained by the dominating geology. The bedrock material is

granite where usually $^{87}\text{Sr}/^{86}\text{Sr}$ values above 0.710 are expected (Bentley 2006). People born in Unterwölbling that were buried in Franzhausen should be distinguishable from local citizens.

In Gemeinlebarn a water sample was taken from a brash lake. Under the assumptions that it is filled with ground water, which had possibly been the people's drinking water source and that the flora adsorbed it as well, it can be taken as a good estimate of the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio that would finally be incorporated in peoples' hard tissues as 0.7046. Also here a distinction from the local people (Franzhausen) should be possible. However, samples in the near surroundings like Oberbierbaum (S7), Preuwitz (S8) or Czechkreuz (S9) had higher values ranging from 0.7084 to 0.7088 that were already in the local range. In figure 13 one can see that the geology at the sampling spot in Gemeinlebarn (W7) differs from the others in this area. Standing out in this region are also the samples from Ahrenberg (S10) and the look-out point Korkenzieher (S11) with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.7109 and 0.7133, respectively. There is a small spot displaying a different geology at the latter, which is covered by the dark purple dot and is therefore not visible in the map.

As can be seen in figure 12, water and soil samples from the same location sometimes show significantly different Sr isotope ratios. Water samples from Kleinschönbichl and Ossarn tend to show lower $^{87}\text{Sr}/^{86}\text{Sr}$ values, 0.7062 and 0.7065, respectively, than the corresponding soil extracts which displayed ratios of 0.7081 and 0.7083. Hence a difference in the isotopic signature between water and soil samples of approximately 0.002 could be observed at both sampling sites. This difference might also be taken into account when looking at the situation in Gemeinlebarn, where a water sample was taken, whereas from its surroundings soil samples were collected. They differ, however, even more ($\Delta = 0.004$). Further samples should be taken to clarify this situation and to reliably identify the strontium isotopic composition available for the Bronze Age population of Gemeinlebarn. Interpretations in this study concerning the relationship between Franzhausen and Gemeinlebarn should therefore be taken with reservation.

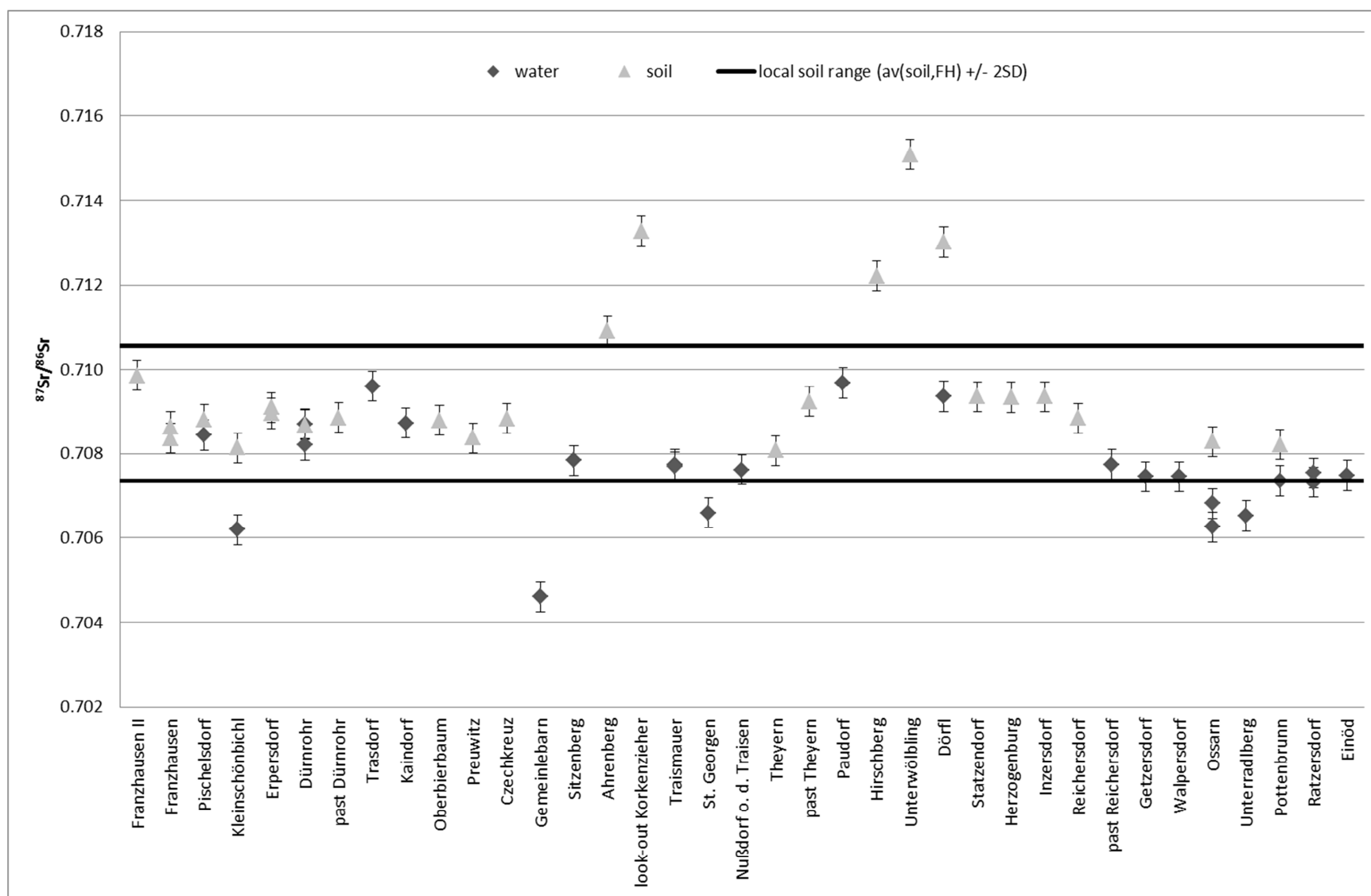


Figure 12 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of soil extracts and water samples

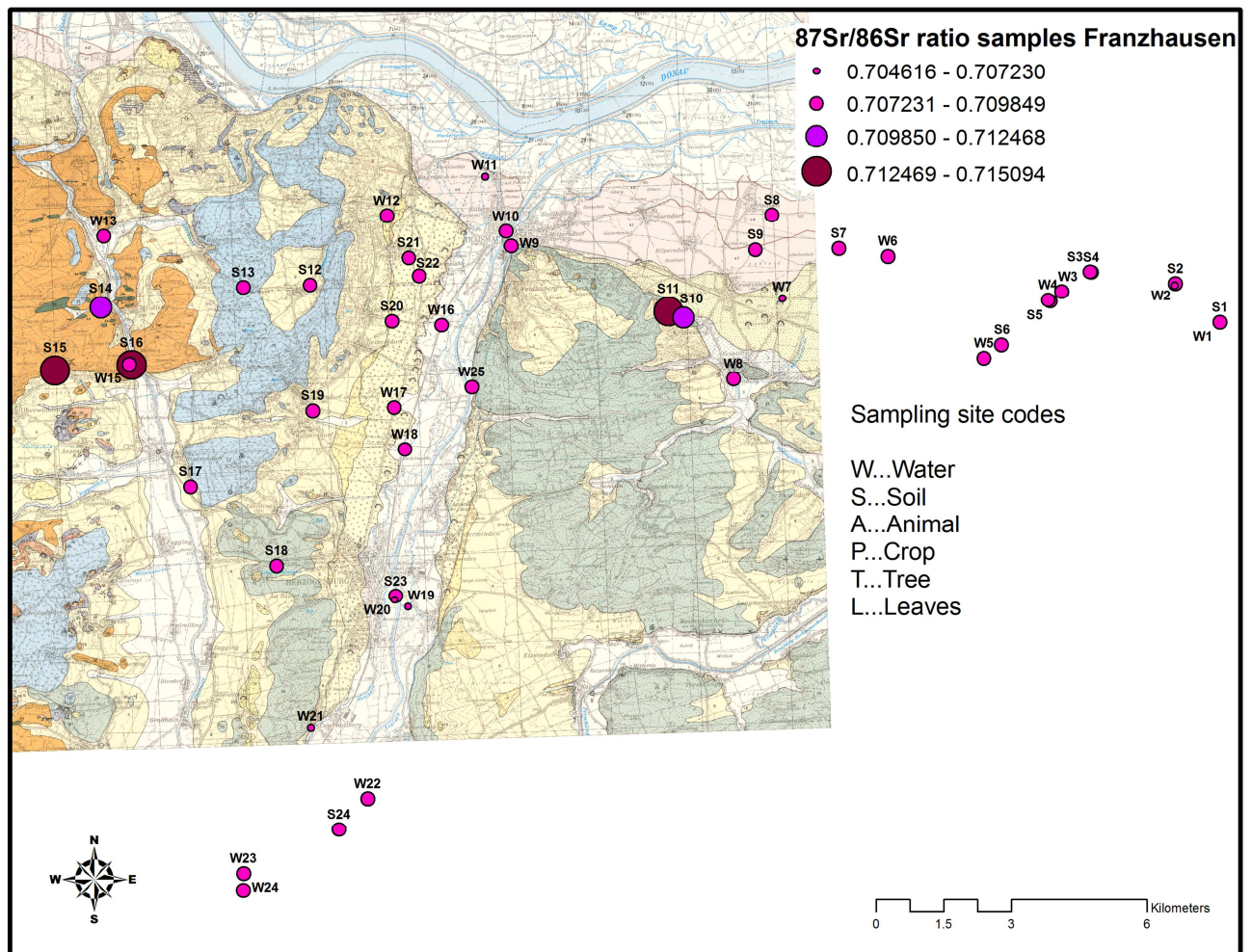


Figure 13 Geological map with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of environmental samples

Appropriateness of soil extractions

To test the appropriateness of the method to extract the biologically available strontium fraction a triple determination of the Franzhausen II soil samples was carried out. As those two soil samples were from the same grave, all should display the same values if the soil sample preparation is reproducible.

The measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the six samples ranged between 0.70981 and 0.70996. With respect to a relative standard uncertainty of 0.05% ($k=2$) these values do not differ significantly, as presented in figure 14.

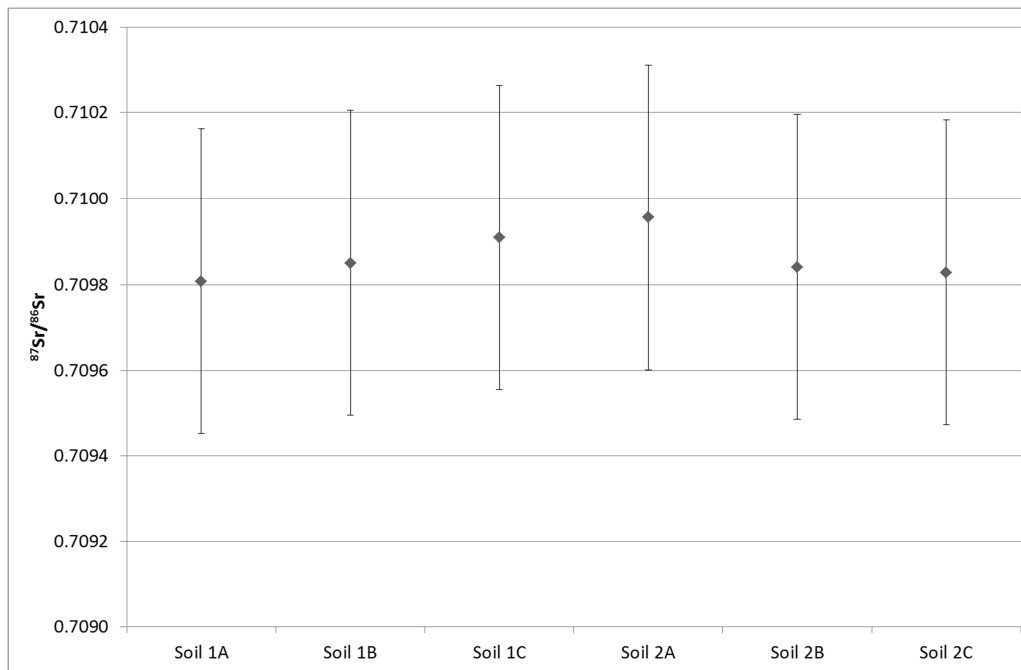


Figure 14 Replicate analysis of soil extracts of Franzhausen II with SU (k=2)

4.2.2. Archaeological human tooth samples

$^{87}\text{Sr}/^{86}\text{Sr}$ values in enamel and dentine of 103 individuals excavated at the Bronze Age burial ground Franzhausen I were determined. Figure 15 presents the results in ascending order of enamel values with the corresponding dentine ratios. Numerical values are given in table 31 in the appendix.

With the enamel data, representing the person's living environment during his childhood, discriminations between locals and non-locals are possible when they are combined with the designated local signal which was evaluated in two approaches: Once $^{87}\text{Sr}/^{86}\text{Sr}$ of the dentine samples and the once ratios in the soil extracts of the samples from the grave field Franzhausen II (soil 1A - 2C) and the present-day village Franzhausen (S21, S22) were taken to establish a local range (see chapter 4.2.1). Mean values plus/minus two times the standard deviation were taken as limits. If the dentine range of the in Franzhausen I buried people (0.7081 – 0.7098) was used, a lot more individuals would be identified as not local (31%) which seems inappropriate since $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel between 0.7075 - 0.7100 are very close to each other. Taking the local soil range (0.7074 - 0.7106) includes these values showing a better fit for this finding situation and leading to the definition of the local signal with the analysis of environmental samples. 18 individuals were identified as non-

locals to this as locally defined Sr signal, which corresponded to 18% of the investigated population.

For further interpretation, the results will be evaluated with discrimination by gender and age at death. Mostly first molars were investigated representing the individual's habitat during his first three years of life, consequently his origin. The enamel of second molars mineralizes at an age of 3 to 7 years (Hillson 1986), so they are still representing the childhood. Investigations in this study showed that residence change before an age of at least 11 years is not very probable in the area of the Lower Traisen Valley during the Early Bronze Age. In this case, it can therefore be assumed that second molars represent a person's birth place as well.

Gender, age and tooth type information were provided by the Department of Anthropology of the Museum of Natural History in Vienna.

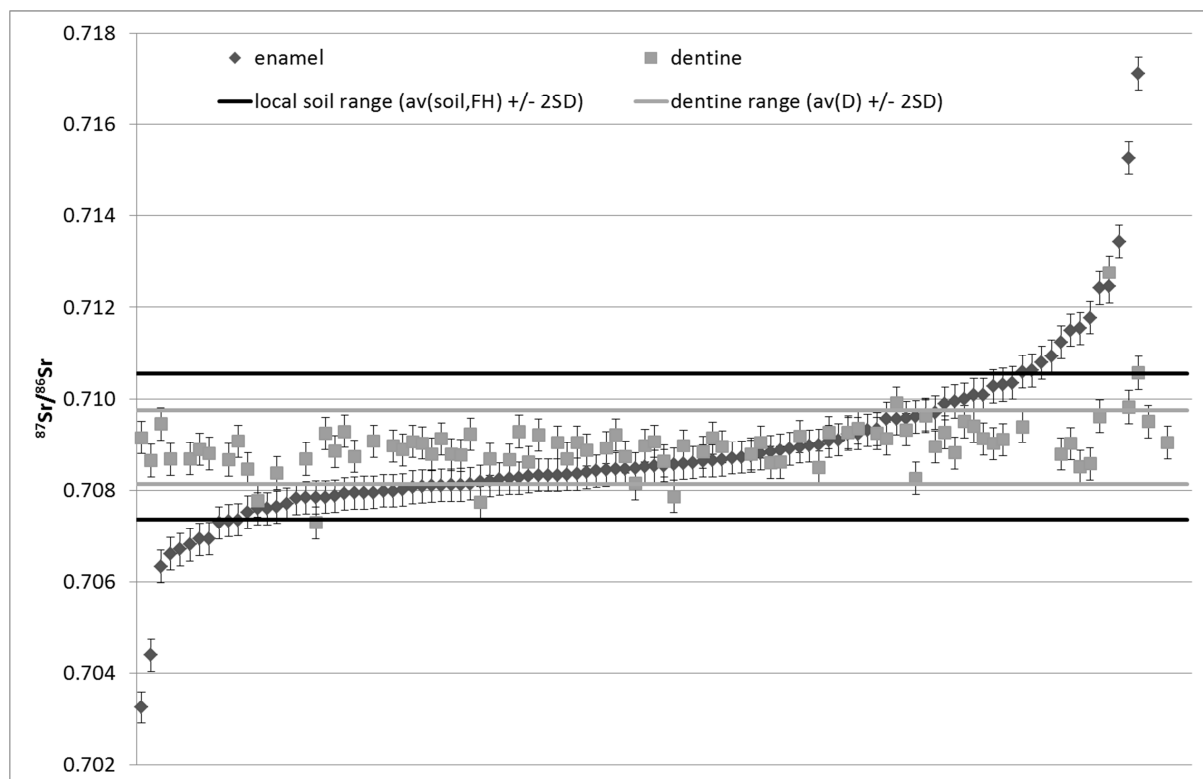


Figure 15 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in teeth

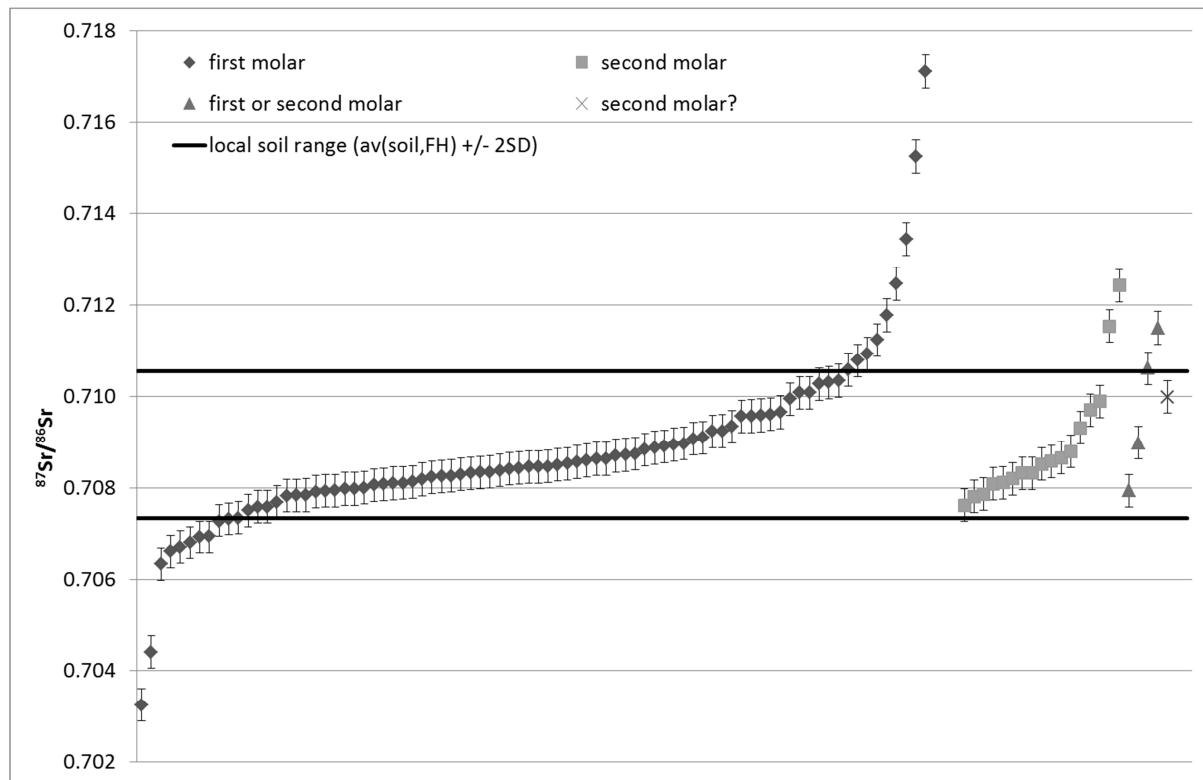


Figure 16 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel discriminated by tooth type

4.2.2.1 Gender discrimination

In the set of analyzed archaeological human tooth enamel samples 29 individuals were identified as females and 27 as males (anthropological sexes). For 30 findings identification of sex was not possible while 12 were possibly female and the remaining 5 were most likely male individuals according to anthropological analysis. The measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios differentiated by the gender groups can be seen in figure 17.

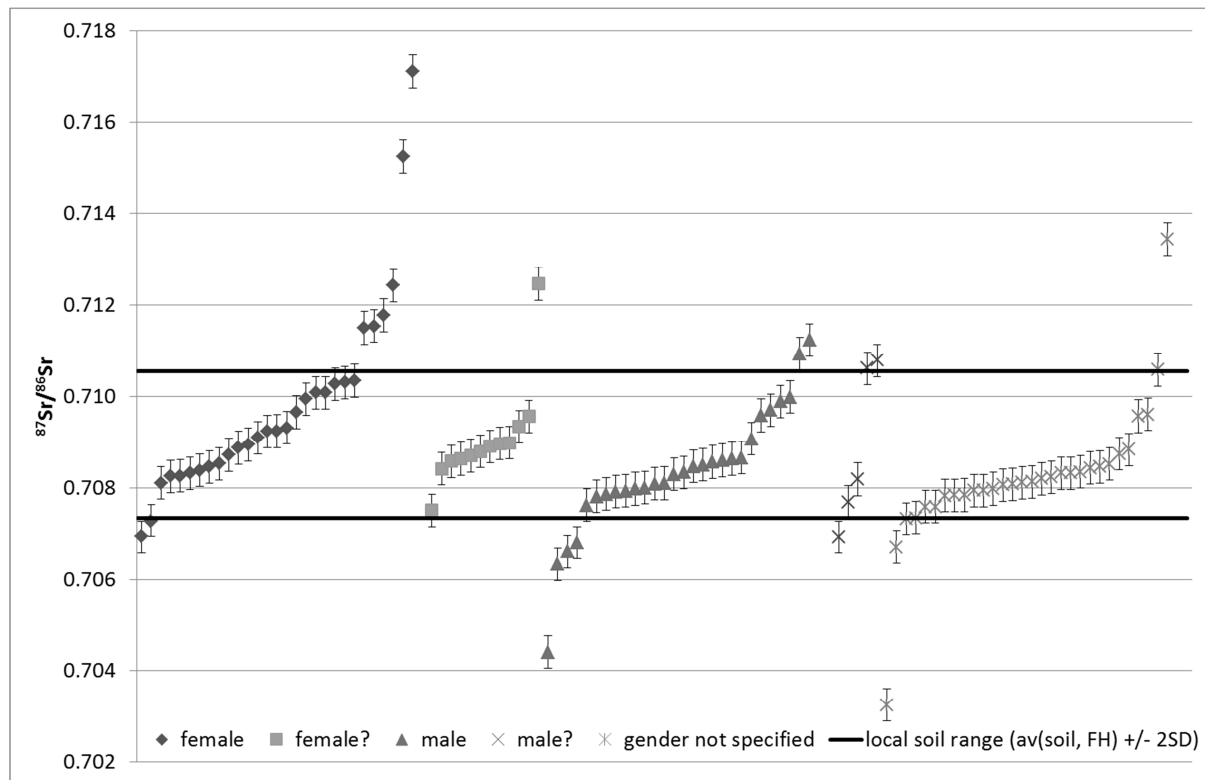


Figure 17 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel discriminated by gender

Progression of the curves of female and questionable females show similar pattern and average strontium isotope ratios in those two groups are in good agreement as well with values of $0.70987 \pm 0.00219(\text{SD})$ and $0.70908 \pm 0.00118(\text{SD})$, respectively. For this reasons they will be taken as one group for interpretations and be corresponded to as females. The same goes for males and possibly males, where the ratios averaged $0.70836 \pm 0.00138(\text{SD})$ and $0.70885 \pm 0.00175(\text{SD})$. They will all be referred to as males in the following.

$^{87}\text{Sr}/^{86}\text{Sr}$	female	female?	Male	male?	gender not specified
average	0.70987	0.70908	0.70836	0.70885	0.70825
SD	0.00219	0.00118	0.00138	0.00175	0.00153

Table 11 Average $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel discriminated by gender

Female individuals

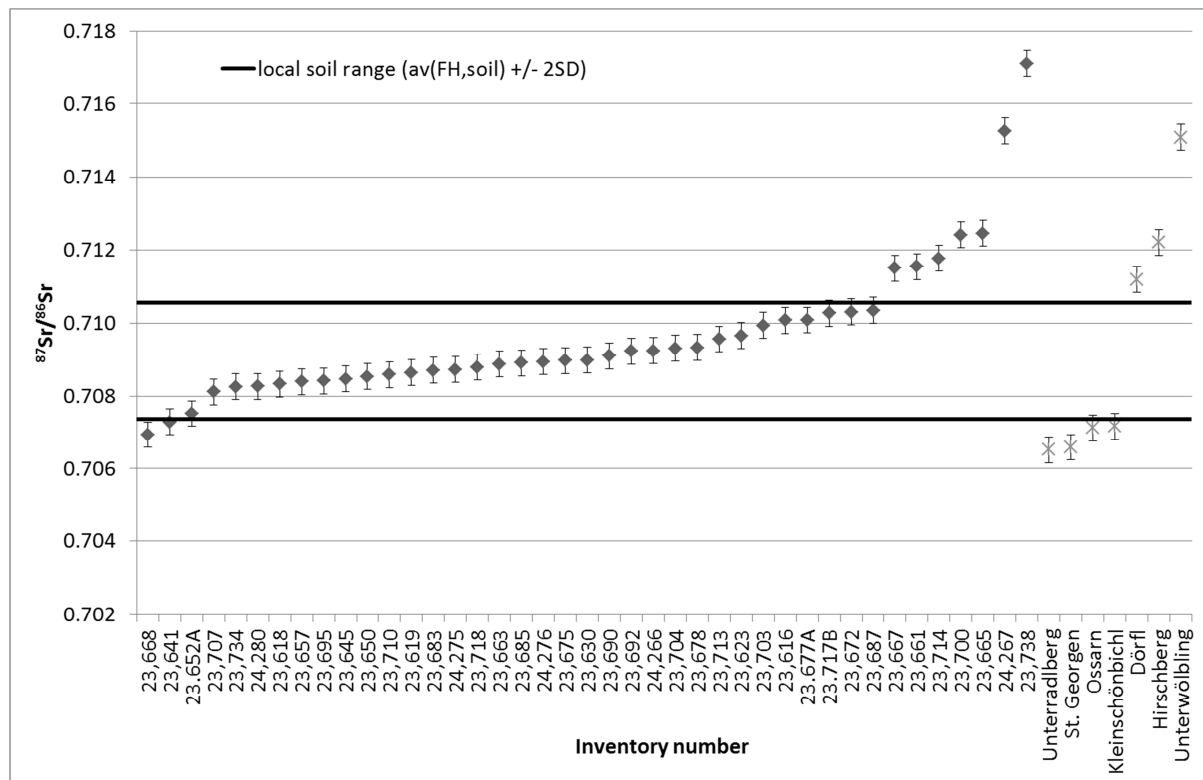


Figure 18 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios determined in enamel of female individuals (including possibly females) and Sr isotopic signals of possible origins of non-local individuals

Out of the 41 female individuals 8 were identified as non-locals (see table 12). They tend to display higher values, as seven out of the eight have an $^{87}\text{Sr}/^{86}\text{Sr}$ ratio above the local range (maximum: 0.71055) and would fit better to the ones in Unterwölbling and the samples taken in its surroundings, Hirschberg and Dörfel. One individual (23738) is even above those values ($^{87}\text{Sr}/^{86}\text{Sr} = 0.71712$). The geologic map shows that Unterwölbling lies at the edge of a granite bedrock. Such rock materials can have ratios between 0.710 and 0.740 (Bentley 2006). This person might therefore possibly originate from an area with underlying granite close to Unterwölbling.

One female individual (23668) was found with a lower ratio (0.70693) than the local range (minimum: 0.70736). Samples from Unterradlberg (0.70652), St. Georgen (0.70659), Ossarn (0.70712) or Kleinschönbichl (0.70717) could be considered as that person's probable childhood residence. It is known that there were Bronze Age settlements in Ossarn and Unterradlberg, making those two the most possible locations of origin. St. Georgen is the closest in distance of them all to Franzhausen and should be taken into account too, there might have been a small population living there (pers. comm. with Maria Teschler-Nicola).

Additionally, individual 23665 stands out due to the corresponding dentine value, which is the only dentine sample revealing an $^{87}\text{Sr}/^{86}\text{Sr}$ ratio outside the local range. Enamel (0.71246) and dentine (0.71277) values are in good agreement with each other. It is possible, that this (most likely) woman moved to Franzhausen just before death or she was brought there after she died to be buried in the grave field. Nonetheless, considerations of diagenetic changes of dentine have to be taken into account.

Inv. No.	$^{87}\text{Sr}/^{86}\text{Sr}$	SU (k=2)	possible origins
23,668	0.70693	0.00035	Unterradlberg (0.70652) St. Georgen (0.70659) Ossarn (0.70712) Kleinschönbichl (0.70717)
23,667	0.71150	0.00036	Dörfl (0.71119) Hirschberg(0.71221)
23,661	0.71154	0.00036	Dörfl (0.71119) Hirschberg(0.71221)
23,714	0.71177	0.00036	Dörfl (0.71119) Hirschberg(0.71221)
23,700	0.71242	0.00036	Dörfl (0.71119) Hirschberg(0.71221)
23,665	0.71246	0.00036	Dörfl (0.71119) Hirschberg(0.71221)
24,267	0.71527	0.00036	Unterwölbling (0.71509)
23,738	0.71712	0.00036	none of the sampled areas
local range	0.70736 - 0.71055		

Table 12 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of non-local women

Male individuals

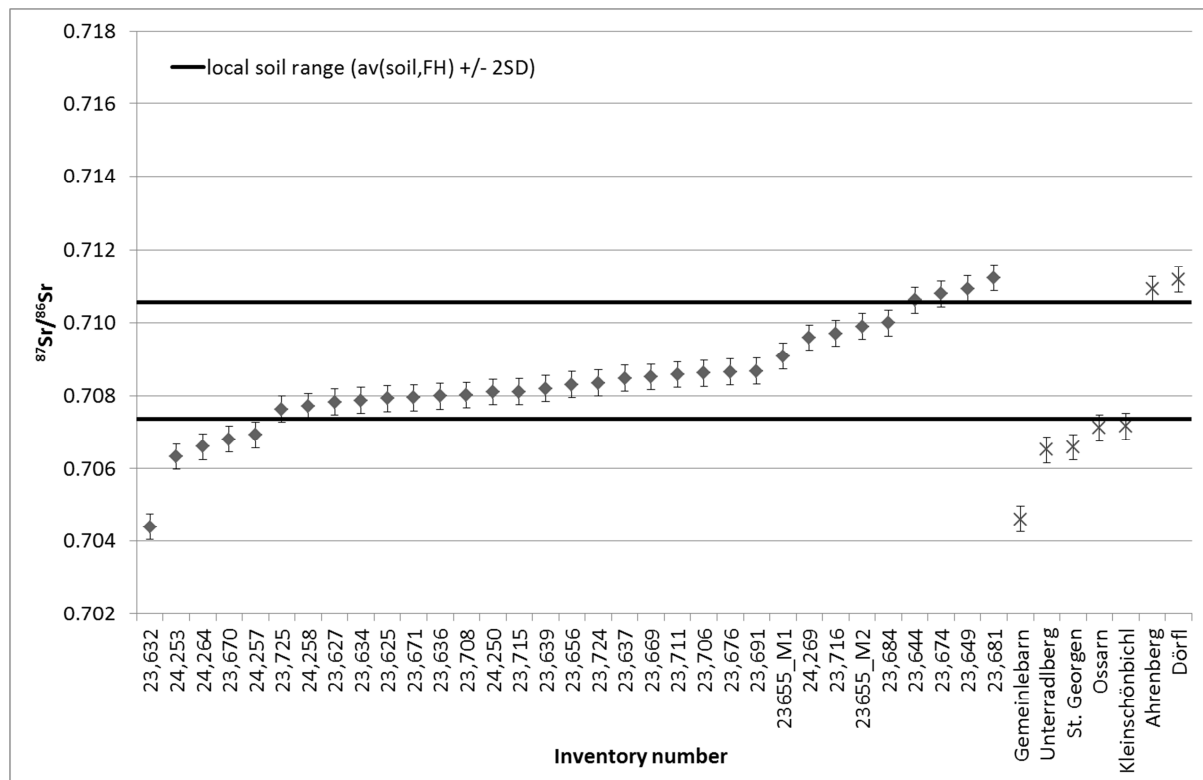


Figure 19 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios determined in enamel of male individuals (including possibly males) and Sr isotopic signals of possible origins of non-local individuals

Overall 7 of the 32 men could be identified as non-locals (22%); they are listed in table 13. 5 foreigners showed Sr isotope ratios below Franzhausen's isotopic signal incorporated in their enamel. The lowest value (0.70440), determined for individual 23632, would be in good agreement with the ratio measured in Gemeinlebarn (0.70462). Possible native places for the four individuals (24253, 24264, 23670, 24257) with ratios between 0.7063 and 0.7069 would be Kleinschönbichl (0.70717), St. Georgen (0.70659), Ossarn (0.70712) or Unterradlberg (0.70652). As mentioned before it is known that Bronze Age settlements were situated in Ossarn and Unterradlberg, and again these two are therefore the most plausible origins. St. Georgen (sample W11) is the closest in distance of them all to Franzhausen as can be seen in figure 13, it should therefore also not be excluded as possible origin. Individuals 23649 and 23681 were also non-locals, as their ratios were found to be above the local range with 0.71093 and 0.71123, respectively. Possible provenances could have been the areas around the Ahrenberg (0.71092) or Dörfli (0.71119). The first one is a hill close to Gemeinlebarn, while the latter is situated near Unterwölbling. At both locations, Bronze Age populations were buried and considerations of marriage circles between the two and

Franzhausen were discussed (Teschler-Nicola 1992). Due to their closeness to those grave fields, the area around the Ahrenberg as well as the region of Dörfl can be considered as a possible place of birth.

Inv. No.	$^{87}\text{Sr}/^{86}\text{Sr}$	SU (k=2)	possible origins
23,632	0.70440	0.00035	Gemeinlebarn (0.70462)
24,253	0.70633	0.00035	Unterradlberg (0.70652) St. Georgen (0.70659) Ossarn (0.70712) Kleinschönbichl (0.70717)
24,264	0.70661	0.00035	Unterradlberg (0.70652) St. Georgen (0.70659) Ossarn (0.70712) Kleinschönbichl (0.70717)
23,670	0.70681	0.00035	Unterradlberg (0.70652) St. Georgen (0.70659) Ossarn (0.70712) Kleinschönbichl (0.70717)
24,257	0.70693	0.00035	Unterradlberg (0.70652) St. Georgen (0.70659) Ossarn (0.70712) Kleinschönbichl (0.70717)
23,649	0.71093	0.00036	Ahrenberg (0.71092) Dörfl (0.71119)
23,681	0.71123	0.00036	Ahrenberg (0.71092) Dörfl (0.71119)
local range		0.70736 - 0.71055	

Table 13 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of non-local men

Due to the bad preservation status of the first molar of individual 23655 (see figure 20) it could not be guaranteed that the enamel sample was not contaminated with dentine and/or calculus during drilling. To make sure not to draw wrong conclusions from this data, the second molar was sampled as well. Both samples are within the local range, leading to the conclusion that the person was of local origin.

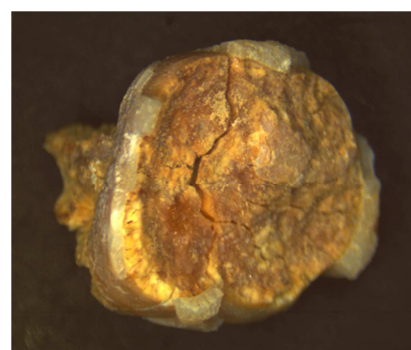


Figure 20 First molar of individual 23655

Figure 21, however, shows that they do not represent the same ratio as the two teeth's ratios do not overlap within their uncertainties. Contamination

with dentine during sample preparation did most likely happen as the ratio determined in the first molar is in good agreement with its dentine value. Whether this is a normal variation between first and second molar or really due to contamination with dentine cannot be answered in this study. However, the fact that this question arises definitely stresses the importance of a careful sample collection and cautious interpretation.

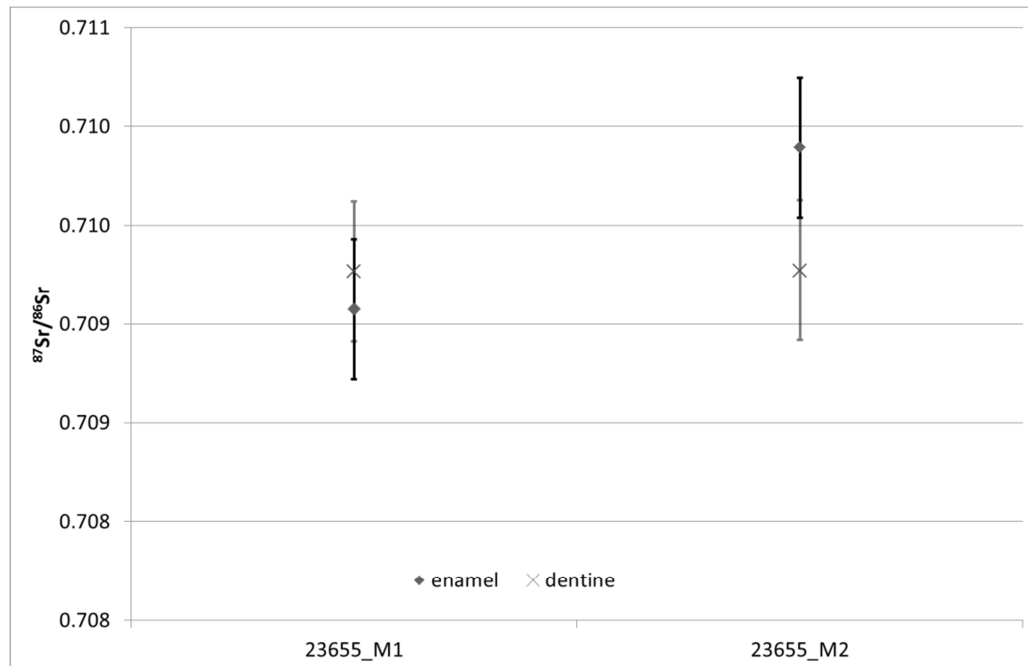


Figure 21 $^{87}\text{Sr}/^{86}\text{Sr}$ from individual 23655 with SU (k=2)

Individuals with unspecified sex

With the 30 individuals of unspecified sex (most of them were children, where gender identification is challenging) it is not possible to draw further gender specific conclusions, but we can still see (figure 22) that 3 possibly were not raised in Franzhausen. Individual 24285 has the lowest $^{87}\text{Sr}/^{86}\text{Sr}$ ratio (0.70325) out of all analyzed samples. It is even below the isotopic signal determined in the brash lake near Gemeinlebarn (0.70462), which was the lowest data of the taken soil and water samples. Their uncertainties do not overlap leading to the assumption that this person did not grow up in Gemeinlebarn and must have come from an area that was most likely not sampled. Data points from St.Georgen (0.70659) and Unterradlberg (0.70652) would fit well with sample 23653 (0.70671). Last but not least individual 23682 (0.71344) was also a foreigner and might have come from an area with granite geology such as the area where today the look-out Korkenzieher is situated.

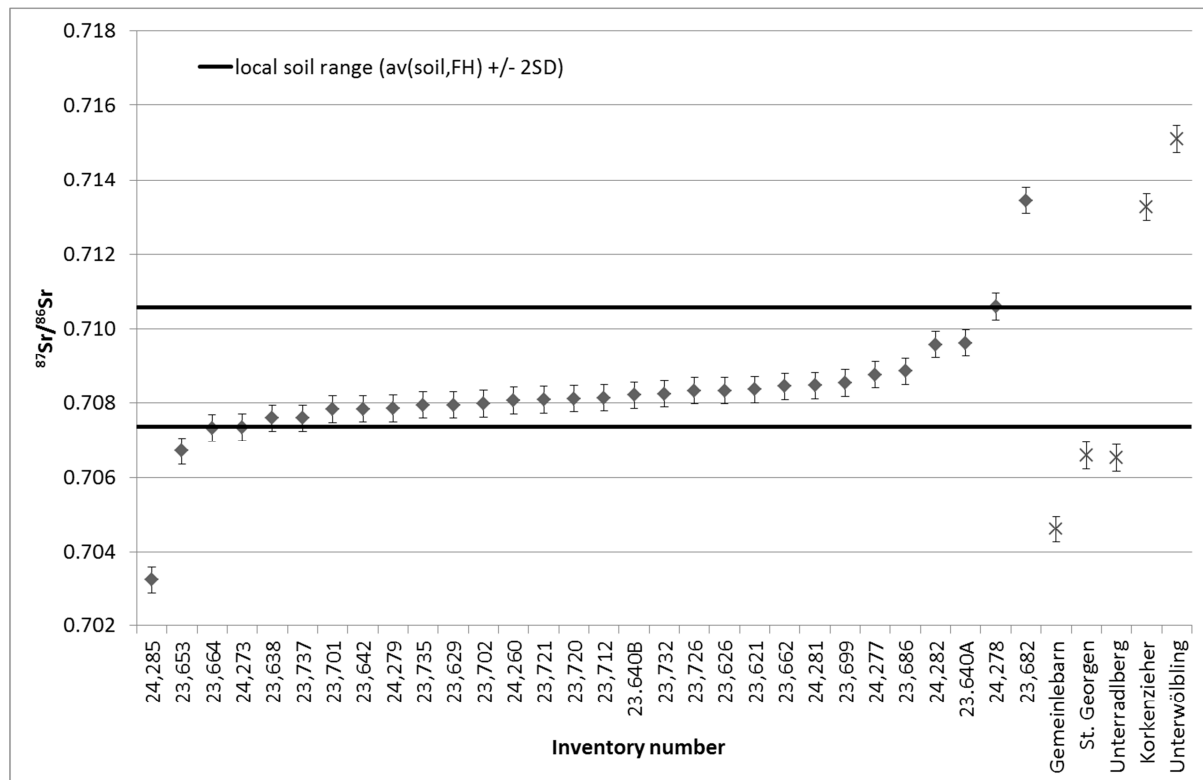


Figure 22 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios determined in enamel of individuals with unspecified gender and Sr isotopic signals of possible origins of non-local individuals

Inv. No.	$^{87}\text{Sr}/^{86}\text{Sr}$	SU (k=2)	possible origins
24,285	0.70325	0.00035	none of the sampled areas
23,653	0.70671	0.00035	St. Georgen (0.70659) Unterradlberg (0.70652)
23,682	0.71344	0.00036	Korkenzieher (0.71327)
local range		0.70736 - 0.71055	

Table 14 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of non-locals with unspecified gender

The results of the gender discrimination are summarized in table 15.

gender	n (total)	n (non-locals)	% (non-locals)
female	29	8	20
female?	12		
male	27	7	22
male?	5		
not specified	30	3	10

Table 15 Gender groups

4.2.2.2. Age Discrimination

The individuals were classified into 13 age groups as can be seen in figure 23. The age range each group represents is listed in table 16.

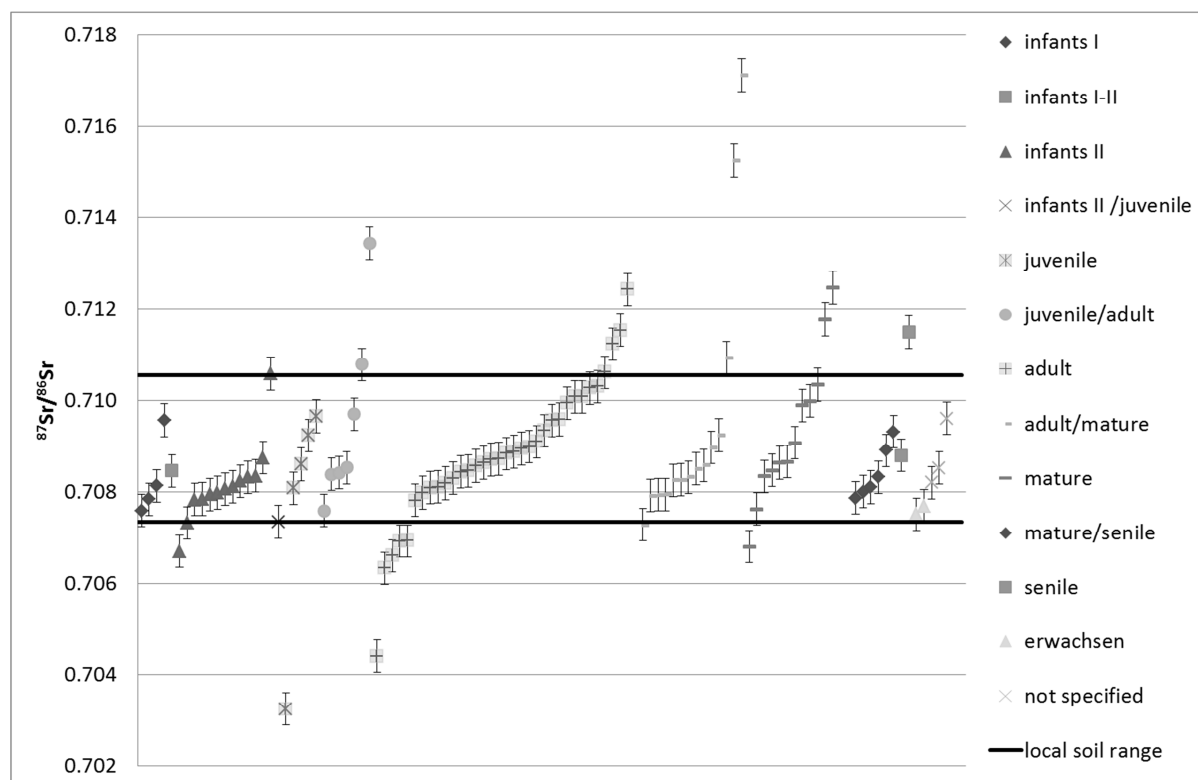


Figure 23 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in enamel discriminated by age

age group	age range [years]	n (total)	n (non-locals)	% (non-locals)
infants I	0 - 7	4	0	0
infants I-II	0 - 14	1	0	0
infants II	7 - 14	13	1	7
infants II /juvenile	12 - 16	1	1	7
juvenile	14 - 20	5	2	17
juvenile/adult	18 - 22	7	2	17
adult	20 - 40	34	8	24
adult/mature	30 - 50	14	3	21
mature	40 - 60	11	3	27
mature/senile	50 - 70	6	0	0
senile	> 60	2	1	50
erwachsen	--*	2	0	0
not specified	--	3	0	0

*grown up, but not further determinable

Table 16 Anthropological age groups

For interpretations the following groups will be pooled due to the overlap in ages and in order to increase the sample number per age group: Infants I and infants I-II will be referred to as infants I, infants II and infants II/juvenile will be seen as infants II group. Juvenile and juvenile/adult will be put in one plot as well as they show similar curve shapes and their age ranges overlap. They will all be referred to as juvenile. For the individuals specified as 'erwachsen' it is known that they were already grown-ups, however, probably due to a bad preservation status of the skeleton, no definite age determination was possible. They will therefore be added to the not specified group for further interpretations.

age group	pool
infants I infants I-II	infants I
infants II infants II/juvenile	infants II
juvenile juvenile/adult	juvenile
erwachsen not specified	not specified

Table 17 Pooled anthropological age groups

Infants I and infants II individuals

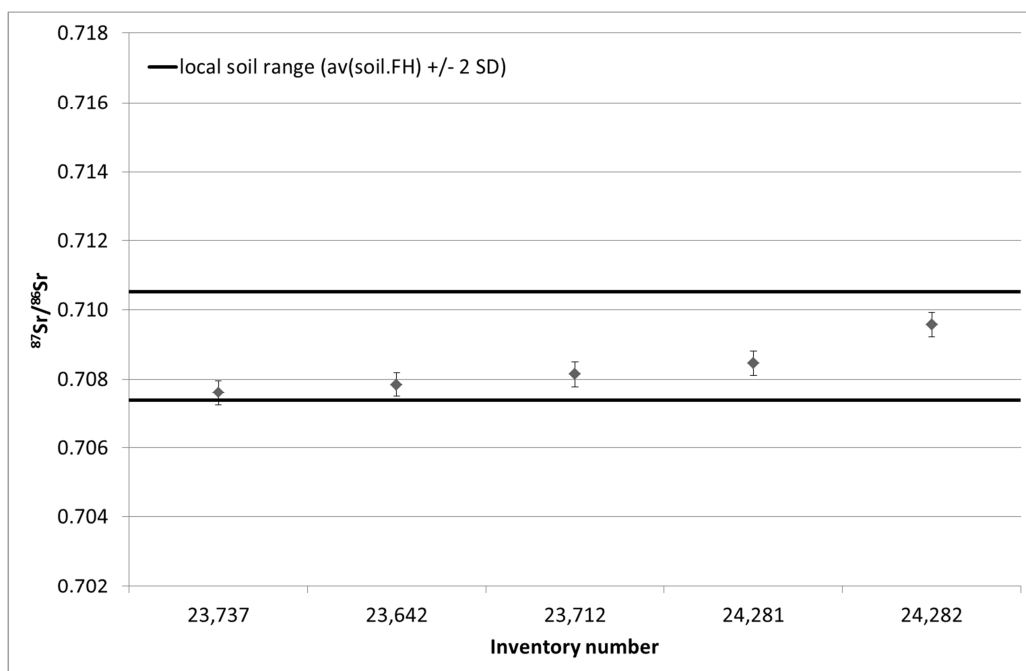


Figure 24 $^{87}\text{Sr}/^{86}\text{Sr}$ in the Infants I age group (including infants I-II)

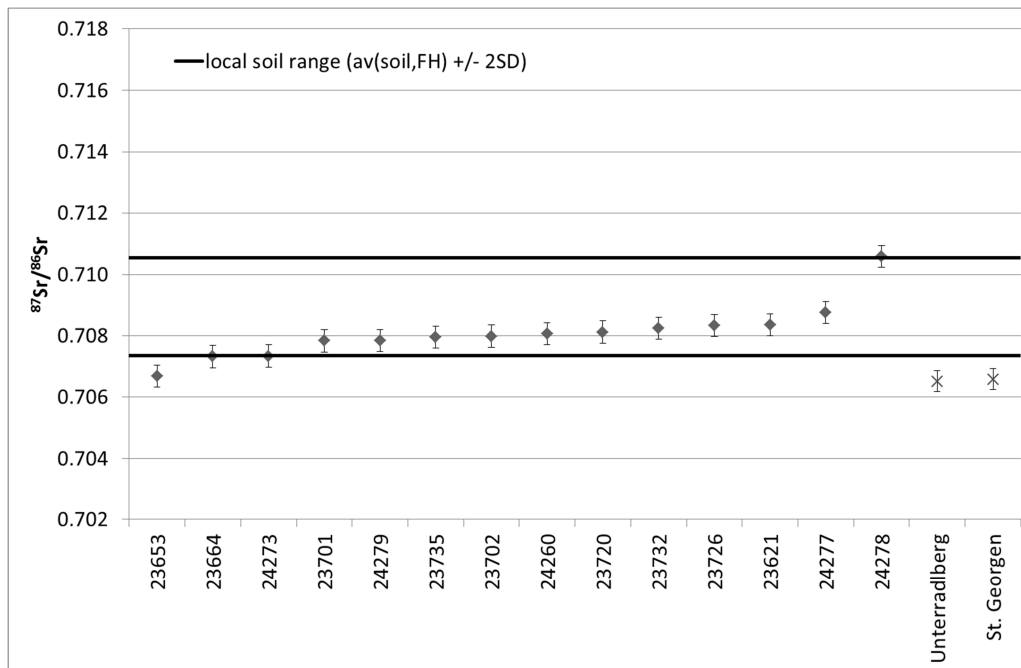


Figure 25 $^{87}\text{Sr}/^{86}\text{Sr}$ in the Infants II age group (including infants II/juvenile) and Sr isotopic signals of possible origins of non-local individuals

All individuals in the infants I group were of local origin according to the Sr data. In the Infants II group one individual (23653, gender not specified) has an $^{87}\text{Sr}/^{86}\text{Sr}$ signal (0.70671) below the local soil range (0.70736 – 0.71055). Since this person shows an age at death of supposedly 11 to 12 years (upper age limit in this age group), this individual probably just moved to Franzhausen before he/she died. The $^{87}\text{Sr}/^{86}\text{Sr}$ value would fit to the strontium isotopic signal of St. Georgen (0.70659) which is at close distance to Franzhausen. Another possible origin would be Unterradlberg (0.70652) from where he/she must have travelled approximately the same distance (~7-8 km) as one from Gemeinlebarn or Unterwölbling, which was a plausible distance for that time.

Juvenile Individuals

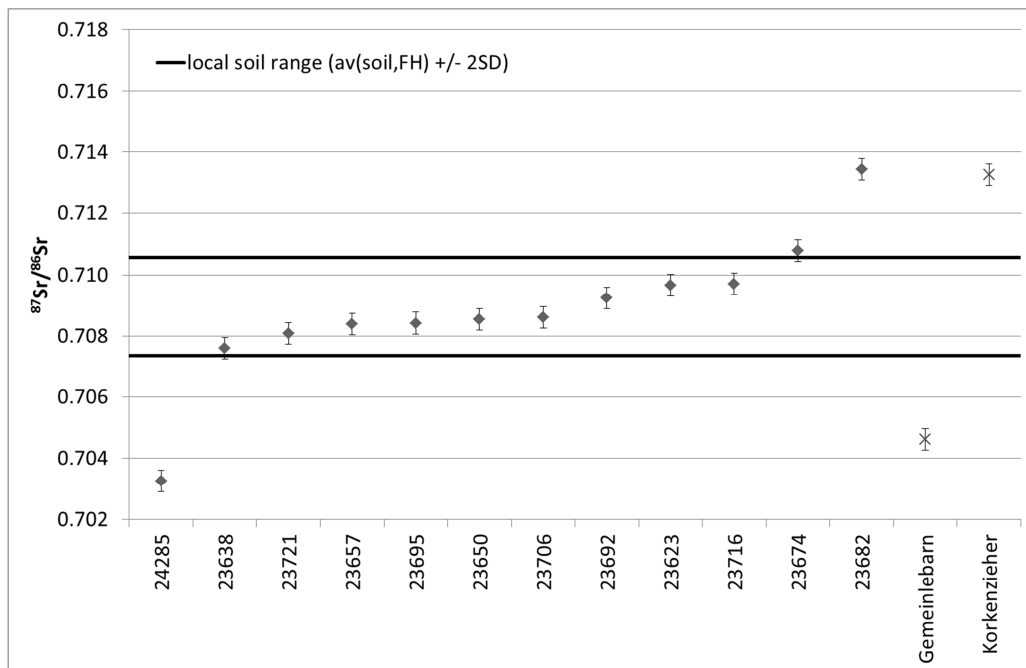


Figure 26 $^{87}\text{Sr}/^{86}\text{Sr}$ in the juvenile age group (including juvenile/adult) and Sr isotopic signals of possible origins of non-local individuals

Two juveniles can be identified as non-locals: individual 24285 (0.70325) and 23682 (0.71344). For both, no sex determinations were possible. Their age at death was possibly between 14 and 22 years, resulting in the assumption that residence changes in the Lower Traisen Valley usually might have taken place around this age period in the Early Bronze Age. (Including the one foreign individual in the infants II group (inventory number – $^{87}\text{Sr}/^{86}\text{Sr}$: 23653 - 0.70671) which was at an age of 11-12).

Adult individuals

Most of the investigated individuals died between 20 and 40 years of age. 24% of those were of non-local origin, 3 females (23668, 23661, 23700) and 5 males (23632, 24253, 24264, 24257, 23681). Their possible locations of origin were discussed in more detail above (see chapter 4.2.2.1.) and are also shown in figure 27.

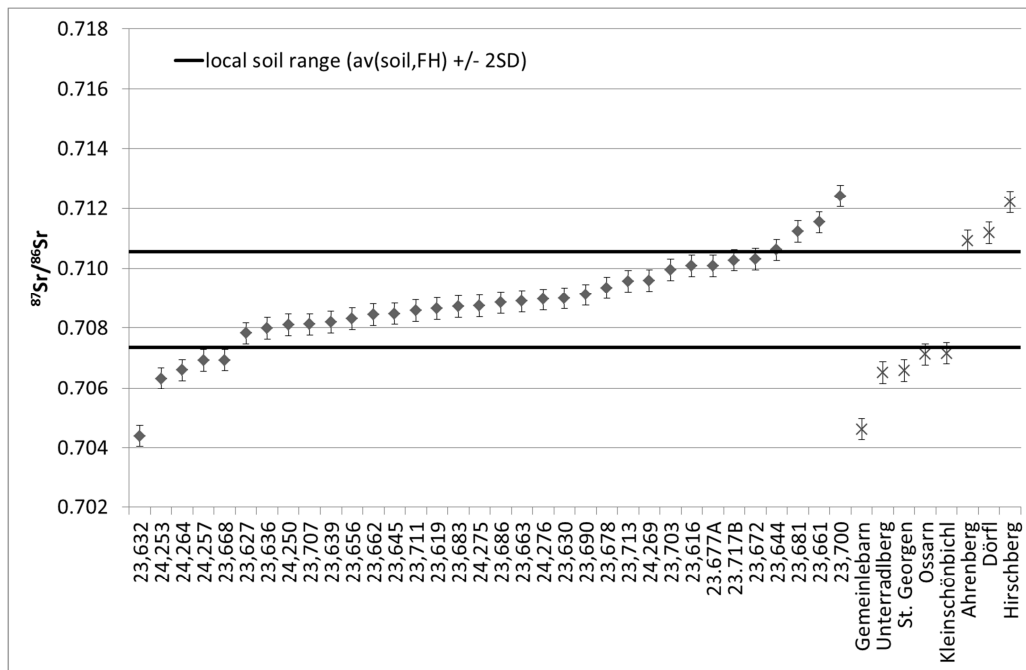


Figure 27 $^{87}\text{Sr}/^{86}\text{Sr}$ in the adult age group and Sr isotopic signals of possible origins of non-local individuals

Adult/mature individuals

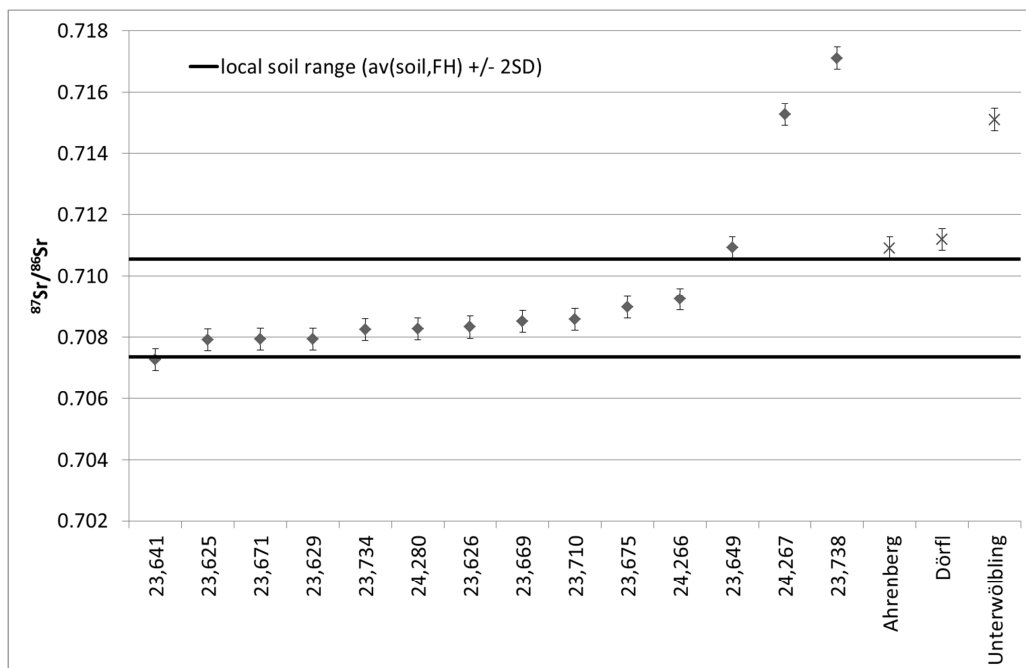


Figure 28 $^{87}\text{Sr}/^{86}\text{Sr}$ in the adult/mature age group and Sr isotopic signals of possible origins of non-local individuals

80% of individuals in the adult/mature age group were locals, three of the investigated non-locals died at an age between 30 and 50 years, two of which were women (24267 - 0.71527, 23738 - 0.71712) coming from a location with high $^{87}\text{Sr}/^{86}\text{Sr}$ ratios like in Unterwölbling

(0.71509) and the other one was a man (23649 - 0.71093) who might have also come from the Unterwölbling region (Dörfl - 0.71119) or from the hill called Ahrenberg (0.71092) which is close to Gemeinlebarn.

Mature individuals

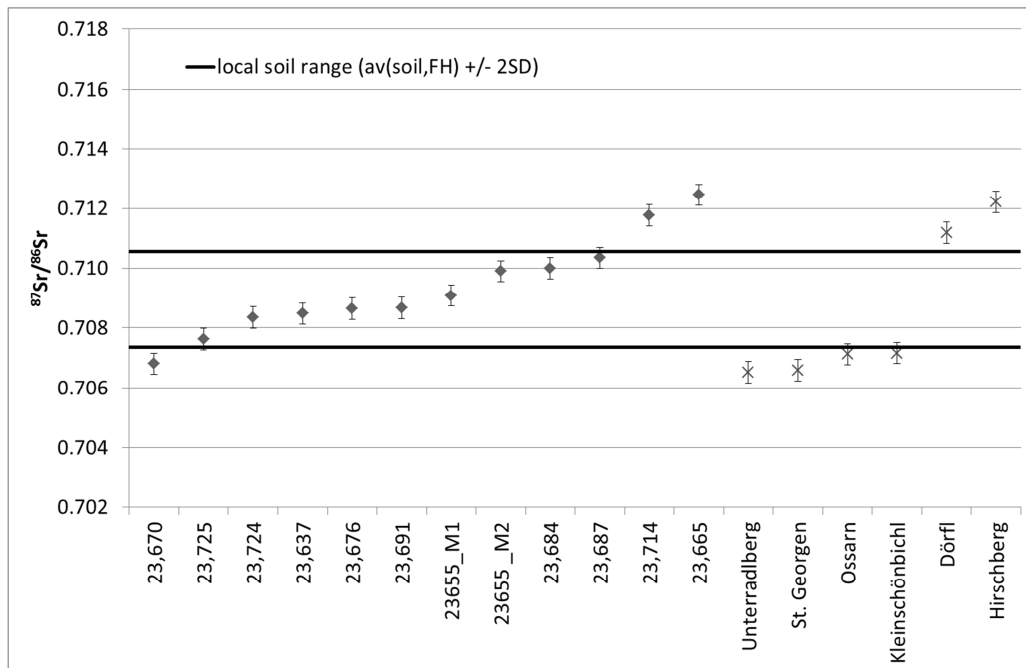


Figure 29 $^{87}\text{Sr}/^{86}\text{Sr}$ in the mature age group and Sr isotopic signals of possible origins of non-local individuals

Two mature women (23714 - 0.71177; 23665 - 0.71246) and one mature man (23670 - 0.70681) grew up in a place different to Franzhausen.

Mature/senile, senile and 'age unspecified' individuals

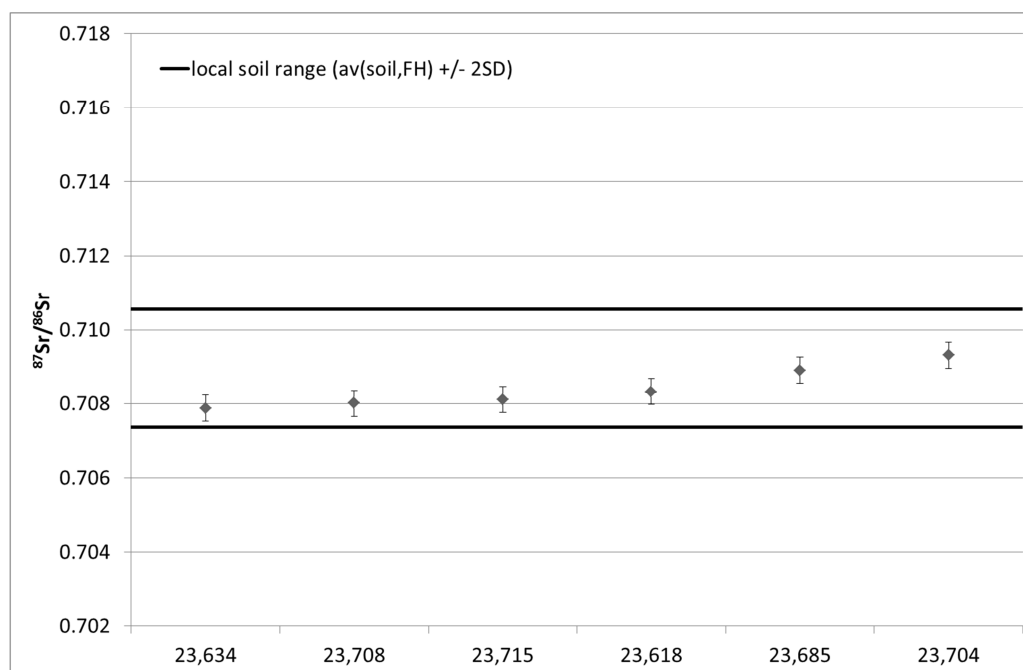


Figure 30 $^{87}\text{Sr}/^{86}\text{Sr}$ in the mature/senile age group

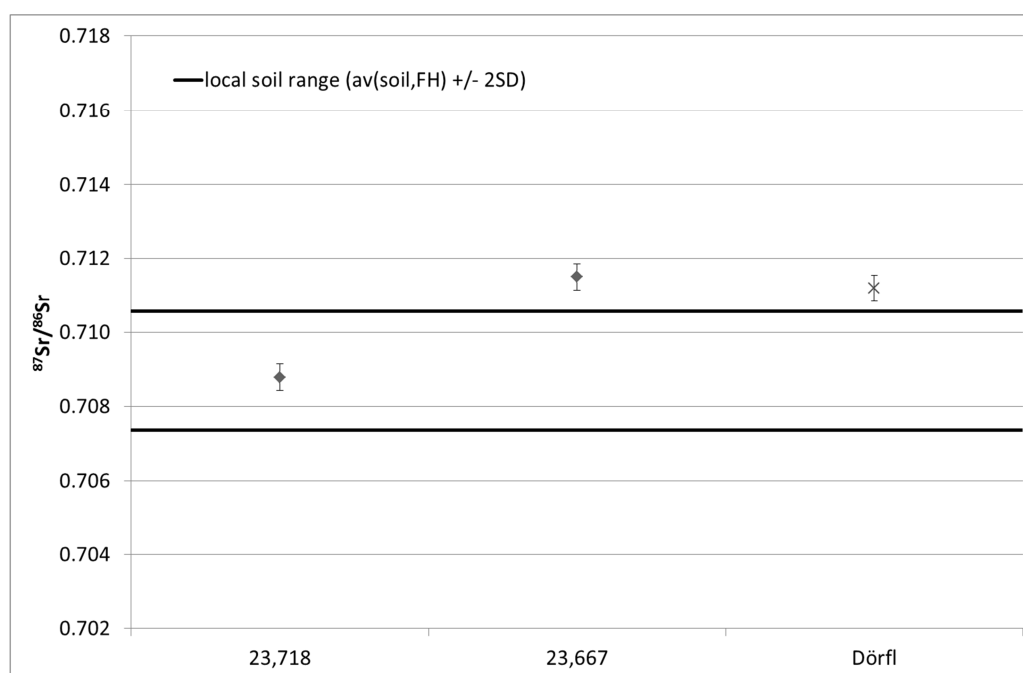


Figure 31 $^{87}\text{Sr}/^{86}\text{Sr}$ in the senile age group and Sr isotopic signals of possible origins of non-local individuals

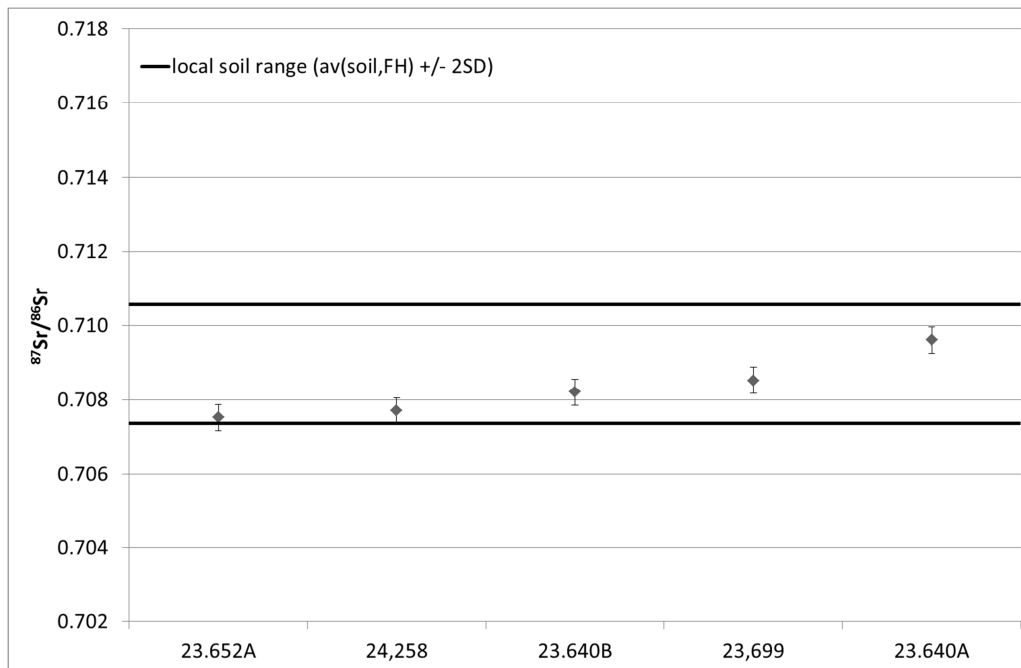


Figure 32 $^{87}\text{Sr}/^{86}\text{Sr}$ in the individuals with unspecified age

While all of the 50 – 70 aged ones were domiciled in Franzhausen, one of the two examined females who were specified as over 60 years old (23667) exhibited an enamel $^{87}\text{Sr}/^{86}\text{Sr}$ ratio (0.71150) that could not have been local and who must have been raised somewhere else, probably near Unterwölbling, in the area around Dörfel (0.71119). The ones where the evaluation of age was not possible were either also not specified in their sex or the classification was not distinct (female?: 23652A; male?: 24258). All of them possibly came from Franzhausen.

4.2.3. Biogenic and diagenetic strontium

In order to see whether diagenetic alterations might have occurred, strontium concentrations in enamel and dentine were plotted against the corresponding $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (figures 33 and 34). The local range for the isotopic composition is included as well. For the estimation of a biogenic Sr concentration in enamel of local individuals, the average in local adult people's enamel was taken, two times the standard deviation was added and accordingly subtracted (local $c(\text{Sr}) = 71 - 179 \mu\text{g g}^{-1}$).

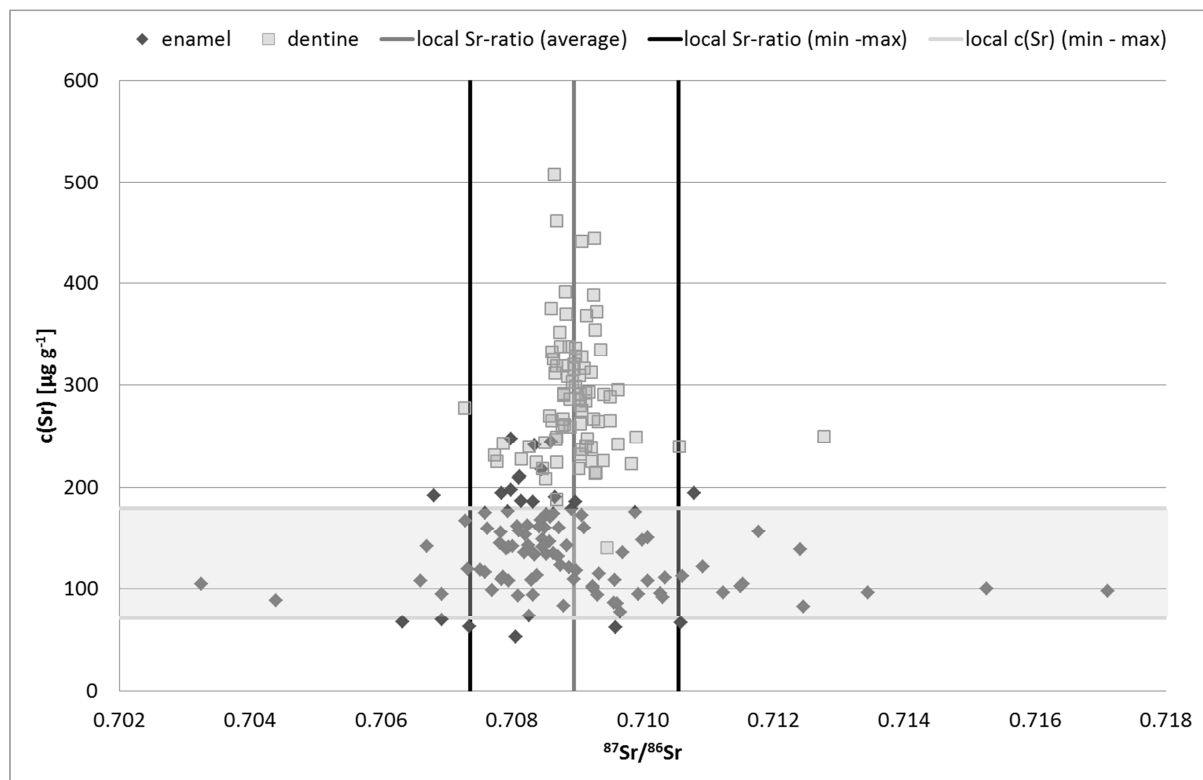


Figure 33 Strontium concentration versus $^{87}\text{Sr}/^{86}\text{Sr}$ ratio in tooth dentine and enamel

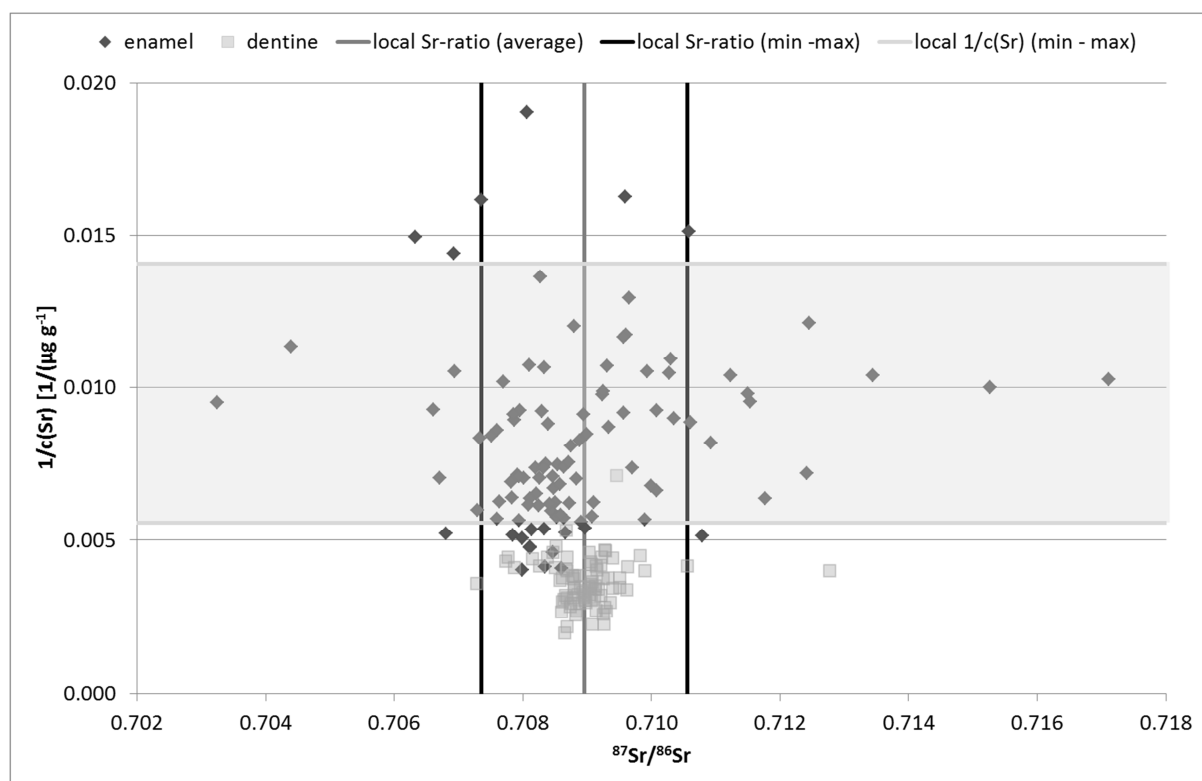


Figure 34 $1/c(\text{Sr})$ versus $^{87}\text{Sr}/^{86}\text{Sr}$ in tooth dentine and enamel

4.2.3.1 Dentine

It can be seen that all but one dentine sample (23655 – 0.71277) had strontium isotope ratios within the local range (0.70736 - 0.71055). Strontium concentrations on the other hand ranged from 140 to 508 $\mu\text{g g}^{-1}$. A correlation between the strontium concentration and the measured ratio in dentine can be seen in figures 33 and 34. $^{87}\text{Sr}/^{86}\text{Sr}$ values are approaching the average ratio detected in local soil samples (0.70896) with increasing concentration. This is indicating the occurrence of diagenetic alterations during burial time.

4.2.3.1. Enamel

The ratios in enamel spread depending on the people's childhood residence. Sr concentrations ranged from 53 to 248 $\mu\text{g g}^{-1}$. Values outside the local enamel range (71 – 179 $\mu\text{g g}^{-1}$) in samples of non-locals can be explained by different Sr availability in their diet. Some of the concentrations of Sr in enamel are close to the ones detected in dentine. If this can be attributed to diagenetic alteration is part of an additional study.

As is known, the excavation site Franzhausen I lied in brash soil, today a gravel pit can be found there. The investigated skeletons were buried in very harsh conditions, resulting in bad preservation as water is running through continuously.

Inv. No.	Age	Gender	$^{87}\text{Sr}/^{86}\text{Sr}$		c (Sr) [$\mu\text{g g}^{-1}$]	
			Enamel	Dentine	Enamel	Dentine
24,281	infants I-II	n.s.	0.70846	0.70922	217	239
23,642	infants I	n.s.	0.70784	0.70729	194	278
23,712	infants I	n.s.	0.70814	0.70923	187	225
23,702	infants II	n.s.	0.70799	0.70897	248	299
23,720	infants II	n.s.	0.70812	0.70877	211	260
23,706	juvenile	m	0.70861	--	245	345
23,675	adult/mature	f?	0.70898	--	186	323
23,724	mature	m	0.70835	0.70869	241	249
23,691	mature	m	0.70867	0.70896	190	316
23,715	mature/senile	m	0.70811	0.70913	209	285
23,618	mature/senile	f	0.70833	0.70905	186	280

Table 18 Local individuals with high Sr-concentrations in enamel

Most of these conspicuous individuals were infants, therefore the mineralization process of enamel might not have been completed at the age of death. However, also some older

individuals (above the adult age group) had rather high Sr concentrations in enamel (see table 18). Demineralization might have already started making the tooth's crowns vulnerable to postmortem alterations. Diagenetic and biogenetic strontium concentrations and isotopic composition in those enamel samples were calculated as follows:

As described above the range for the biogenic Sr concentration in locals was established with the enamel concentrations of individuals in the adult age group, under the assumption that no diagenetic Sr can be found in those. The maximum value was taken as biogenic Sr fraction (c_{bio}) in the enamel samples suspected to have undergone post-mortem changes, everything above will be declared as diagenetic strontium (c_{dia}). The local abundance of ^{87}Sr can then be calculated with the average local $^{87}\text{Sr}/^{86}\text{Sr}$ ratio and the natural abundance of ^{86}Sr :

$$A(^{87}\text{Sr}) = (^{87}\text{Sr}/^{86}\text{Sr})_{\text{local soil}} * A(^{86}\text{Sr}) \quad \text{Equation 5}$$

The natural abundances of the other isotopes then need to be corrected for this value to get the diagenetic abundances:

$$A_{\text{dia}}(^{**}\text{Sr}) = A(^{**}\text{Sr}) / (A(^{84}\text{Sr}) + A(^{86}\text{Sr}) + A(^{87}\text{Sr}) + A(^{88}\text{Sr})) \quad \text{Equation 6}$$

Multiplication of diagenetic concentrations with diagenetic abundances gives the diagenetic amount of each isotope:

$$n_{\text{dia}}(^{**}\text{Sr}) = c_{\text{dia}} * A_{\text{dia}}(^{**}\text{Sr}) \quad \text{Equation 7}$$

Analogue the amounts of each isotope in the whole sample are calculated to estimate the biogenic amount as:

$$n_{\text{bio}}(^{**}\text{Sr}) = n_{\text{sample}}(^{**}\text{Sr}) - n_{\text{dia}}(^{**}\text{Sr}) \quad \text{Equation 8}$$

Finally the biogenic $^{87}\text{Sr}/^{86}\text{Sr}$ ratio is determined:

$$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{biogenic}} = n_{\text{bio}}(^{87}\text{Sr}) / n_{\text{bio}}(^{86}\text{Sr}) \quad \text{Equation 9}$$

The results are presented in table 19. All biogenic ratios were still in the local range. Therefore, no wrong conclusions were drawn from probably diagenetically altered enamel data. The situation might, however, look different at other findings.

Inv. No.	c (Sr) [$\mu\text{g g}^{-1}$]			$^{87}\text{Sr}/^{86}\text{Sr}$		
	sample	biogenic	diagenetic	sample	biogenic	diagenetic
24,281	217	179	38	0.70846	0.70836	0.70896
23,642	194	179	15	0.70784	0.70775	0.70896
23,712	187	179	8	0.70814	0.70811	0.70896
23,702	248	179	68	0.70799	0.70762	0.70896
23,720	211	179	31	0.70812	0.70797	0.70896
23,706	245	179	65	0.70861	0.70848	0.70896
23,675	186	179	6	0.70898	0.70898	0.70896
23,724	241	179	62	0.70835	0.70814	0.70896
23,691	190	179	11	0.70867	0.70865	0.70896
23,715	209	179	29	0.70811	0.70797	0.70896
23,618	186	179	6	0.70833	0.70831	0.70896
local range	71 - 179			0.70736 - 0.71055		

Table 19 Biogenic and diagenetic Sr fractions in enamel

4.3. Multielemental analysis

4.3.1. Limit of Detection, Limit of Quantification and standard uncertainty

The lowest concentration of an analyte that can be distinguished from the background noise with a certain probability is given by the **limit of detection (LoD)**. It can be estimated according to equation 10 with a significance of approximately 99.7%.

$$LoD = 3 * \sigma_{blank} \quad \text{Equation 10}$$

σ_{blank} ... standard deviation of the blank

Quantifications with reliable uncertainties can only be calculated with values above the **limit of quantification (LoQ)**.

$$LoQ = 10 * \sigma_{blank} \quad \text{Equation 11}$$

Measurement and method blanks can be taken for calculations of LoD and LoQ. Instrumental values are presented in table 20.

Table 20 Instrumental LoD and LoQ

Analyte	Li-7	Be-9	B-10	B-11	Na-23	Mg-24	Mg-26	Al-27
LoD [ng/g]	0.007	0.02	0.2	0.4	2	0.9	2	0.7
LoQ [ng/g]	0.02	0.06	0.6	1	6	3	6	2
Analyte	K-39	Ca-42	Ca-43	Ca-44	V-51	Cr-52	Mn-55	Fe-56
LoD [ng/g]	40	690	40	170	0.2	0.4	0.03	70
LoQ [ng/g]	130	2300	140	580	0.6	1	0.09	220
Analyte	Fe-57	Ni-58	Co-59	Ni-60	Cu-63	Cu-65	Zn-66	Zn-68
LoD [ng/g]	10	0.2	0.002	0.05	0.03	0.1	0.5	7
LoQ [ng/g]	40	0.7	0.008	0.2	0.1	0.4	2	20
Analyte	Ga-69	As-75	Se-77	Se-82	Rb-85	Sr-88	Mo-98	Ag-107
LoD [ng/g]	0.01	0.05	1	0.2	0.002	0.02	0.01	0.004
LoQ [ng/g]	0.04	0.2	4	0.5	0.007	0.06	0.04	0.01
Analyte	Ag-109	Cd-111	Cd-114	In-115	Te-128	Te-130	Ba-137	Ba-138
LoD [ng/g]	0.003	0.005	0.01	n.d.	0.01	0.01	0.2	0.2
LoQ [ng/g]	0.01	0.02	0.03	n.d.	0.04	0.04	0.7	0.7
Analyte	Tl-203	Tl-205	Pb-207	Pb-208	Bi-209	U-238		
LoD [ng/g]	0.002	0.002	0.02	0.01	0.03	0.002		
LoQ [ng/g]	0.006	0.006	0.05	0.05	0.09	0.005		

To state the reliability of the results above the LoQ a relative **standard uncertainty** was evaluated for each matrix in a spread sheet using the Kragten approach. Average contributions to the uncertainties are shown in figure 35 -39.

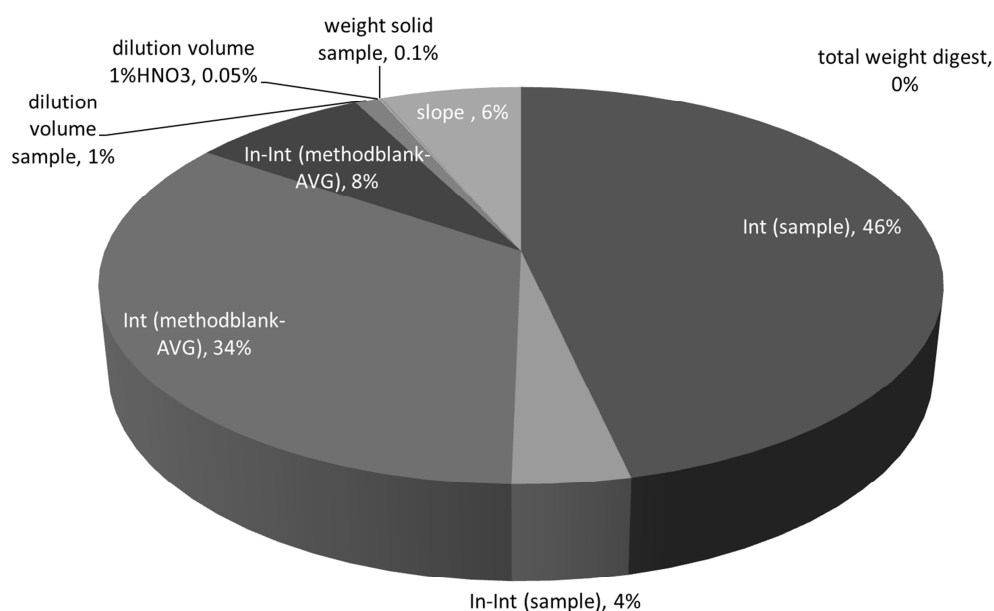


Figure 35 Average contributions to the SU for multielement analysis in enamel

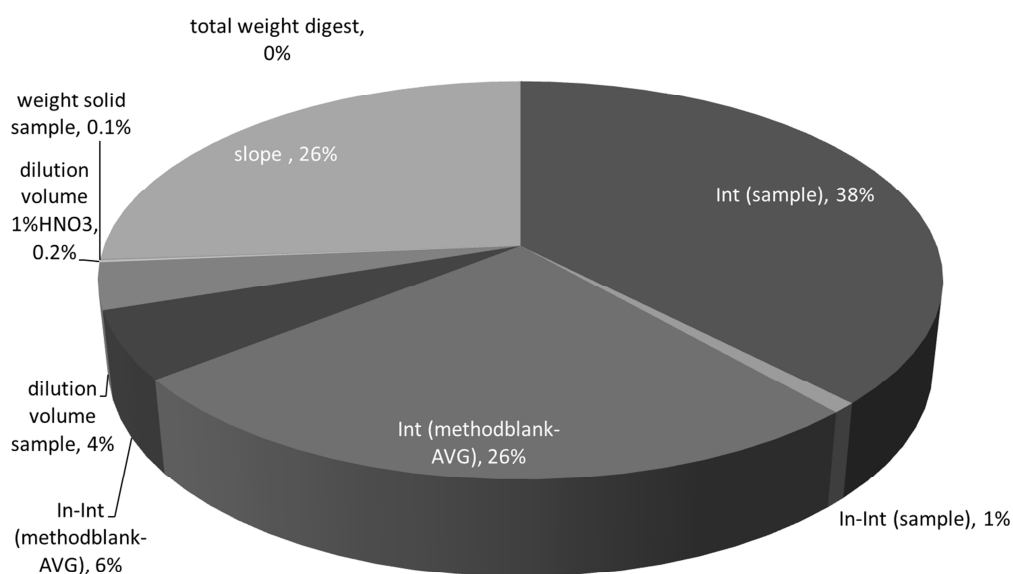


Figure 36 Average contributions to the SU for multielement analysis in dentine

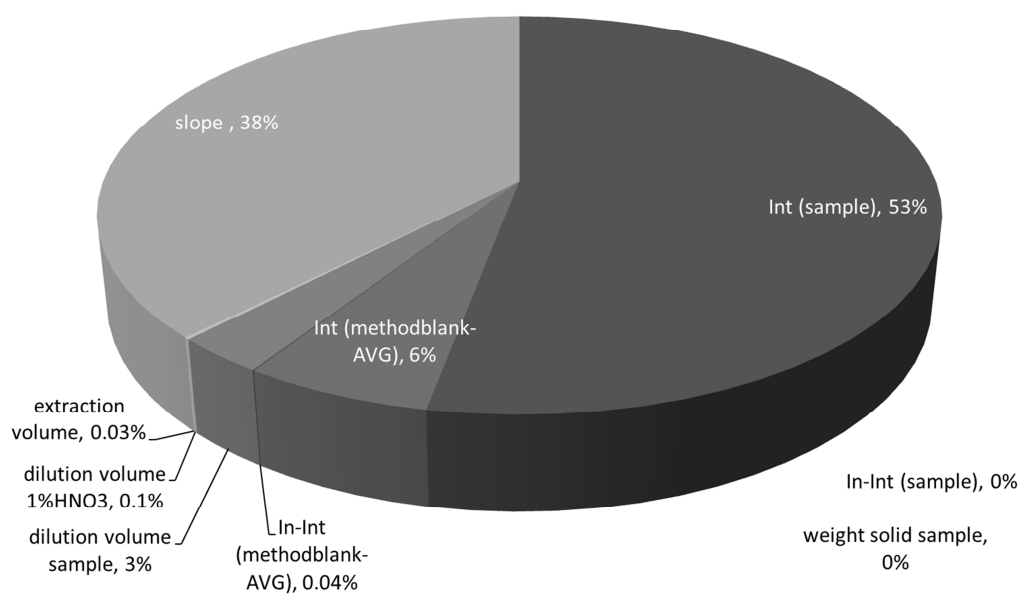


Figure 37 Average contributions to the SU for multielement analysis in soil extracts

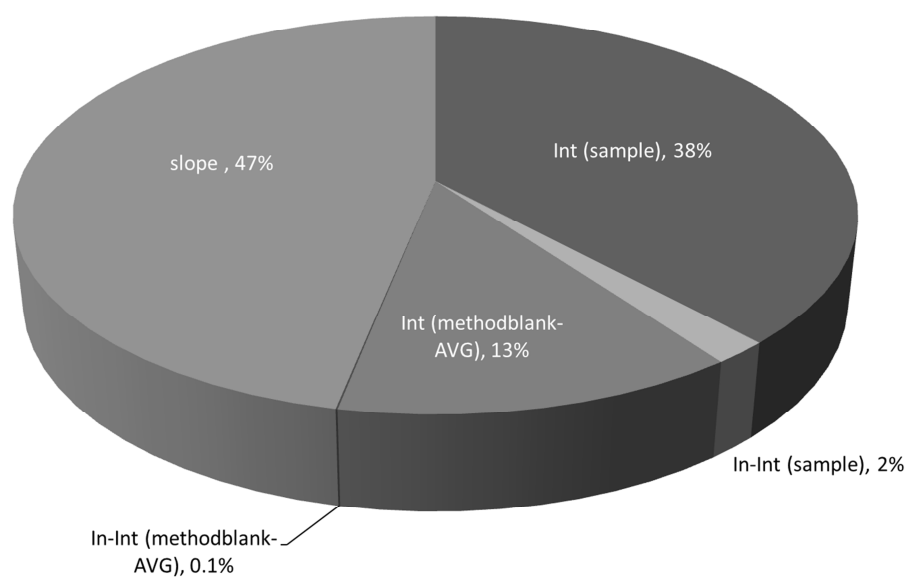


Figure 38 Average contributions to the SU for multielement analysis in water (undiluted)

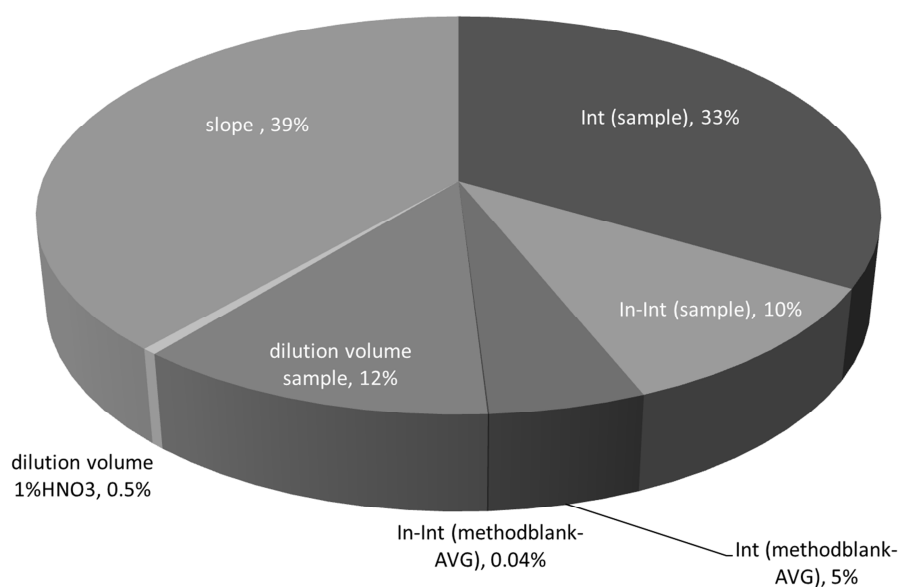


Figure 39 Average contributions to the SU for multielement analysis in water (diluted)

4.3.2. General results of multielemental analysis

A complete list of the multielement results is attached in the appendix (chapter 6.4., tables 33-41). A few noticeable results and differences between enamel and dentine will be discussed shortly.

The average calcium concentration is higher in enamel which can be explained by the composition of the two tooth parts: 96-98% and 70% inorganic material in enamel and dentine, respectively (Boyde 1989; Goldberg et al. 1995).

The average Sr concentration in dentine was more than two times higher than in enamel with 290 mg g⁻¹ compared to 135 µg g⁻¹. Rubidium was detected in a lot more dentine samples, namely in 35, while only 11 individuals had Rb concentrations in enamel above the LoD, these samples will be discussed below.

Arsenic was below the detection limit in all enamel samples and could only be detected in three dentine samples (23655_M1, 23677A, 23683). Incorporation of this element could

have been an indication for ore smelting or mining in this area (Choudhury and Mudipalli 2008).

A huge difference can be seen between the uranium concentrations in the analyzed tooth samples. Its presence can indicate diagenetic alterations (Molleson 1987). Uranium was found in one enamel sample only with a concentration of $0.5 \mu\text{g g}^{-1}$; all the others were below the limit of detection ($0.1 \mu\text{g g}^{-1}$). This conspicuous sample was taken from the first molar of individual 23655 which was already discussed previously. Most possibly contamination of the enamel sample during drilling with dentine happened, the advanced uranium concentration supports this assumption. The strontium concentration in this sample ($173 \mu\text{g g}^{-1}$) was close to the upper limit of the Sr concentration range ($71 - 179 \mu\text{g g}^{-1}$) that would be expected in enamel of local individuals. The concentration in the dentine sample of this tooth was $445 \mu\text{g g}^{-1}$, possible contamination with dentine could have raised the concentration in the enamel sample. Contrary to enamel, dentine uranium concentrations were elevated with an average concentration of $12 \mu\text{g g}^{-1}$, only four samples were below the LoD.

Some more eye-catching cases in enamel will be discussed in the next chapter.

4.3.3. Elemental fingerprints in enamel

Fingerprints of the enamel samples were done with the following elements: Mg, Ca, Mn, Fe, Cu, Zn, Rb, Sr, Ba, and Pb.

Elemental concentrations (always relative to the maximum) were plotted for all samples (figure 40). The according numeric values are attached in the appendix (table 37). The red circles in figure 40 mark obvious deviations from the common pattern.

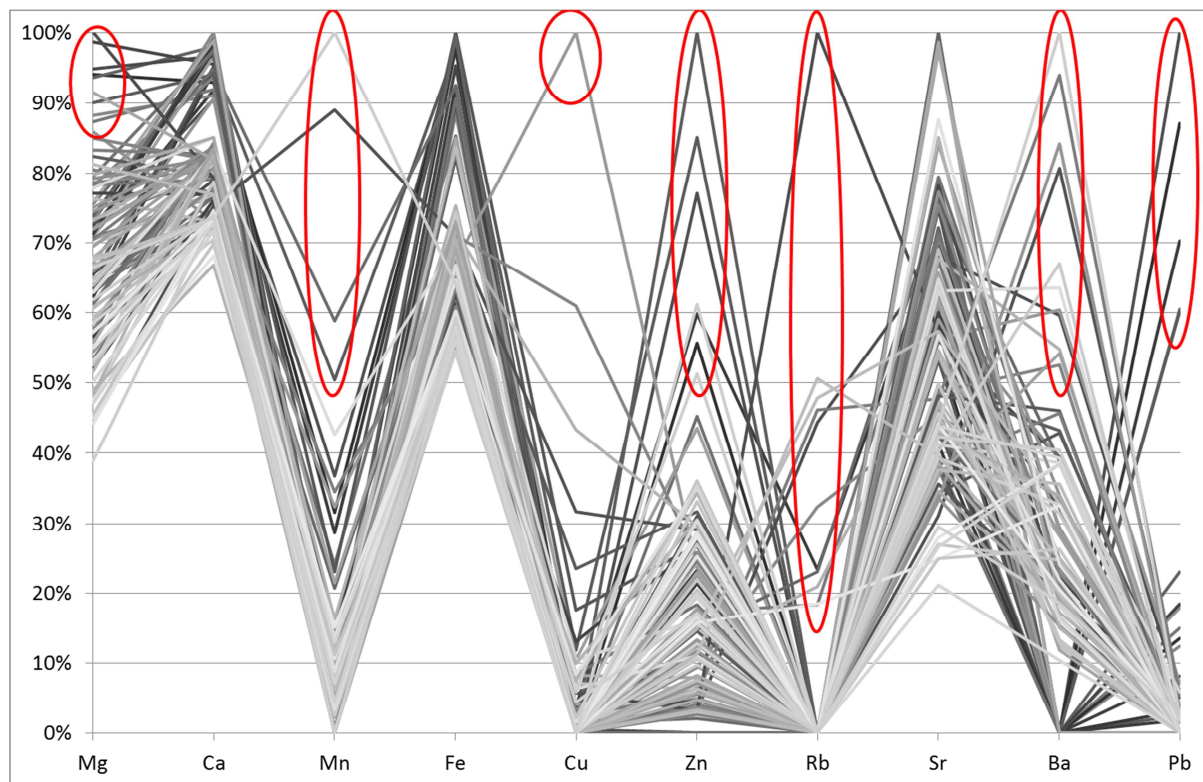


Figure 40 Elemental fingerprints in enamel

Magnesium

Values above 85% were looked at more closely; these individuals are summarized in table 21.

Inv. No.	Tooth	Age	Gender	Mg [$\mu\text{g g}^{-1}$]		
				Enamel	Dentine	
23,616	M1	adult	f	5188	3002	local
23,653	M1	infants II	n.s.	6037	2669	non-local
23,663	M1	adult	f	5134	2463	local
23,676	M1	mature	m	5681	3591	local
23,678	M1	adult	f?	5326	3528	local
23,682	M1	juv./adult	n.s.	5274	3305	non-local
23,685	M1	mature/senile	f?	5649	4171	local
23,687	M1	mature	f	5959	3648	local
23,691	M2	mature	m	5435	2778	local
23,700	M2	adult	f	5730	3683	non-local
23,724	M1	mature	m	5527	1942	local

Table 21 Individuals with high Mg concentrations in enamel

Most of these persons were already grown-ups, some of local some of non-local origin. Females as well as males were represented. No trend can be seen. Like in the other teeth, values in enamel were higher than in dentine, mean values were 4050 and 2900 ng g⁻¹, respectively. In general higher Mg concentrations are found in herbivores (Pate 1994). These 11 individuals with especially high Mg concentrations might have had even a higher proportion of vegetables in their meals than the others. However, doubts about the use of this element for dietary reconstruction have been announced (Klepingera 1990).

The non-local individual 23653 had the highest magnesium concentration in enamel (6037 µg g⁻¹). Aged 11-12 years at death he or she probably just moved to the Franzhausen. Magnesium concentrations of the collected water samples ranged from 18 to 61 µg g⁻¹ with a mean of 33 µg g⁻¹. The water samples collected at the possible origins Unterradlberg and St. Georgen had Mg concentrations below the average with 22 and 21 µg g⁻¹, respectively. Soil samples were not taken there, they might have given an explanation for the high Mg concentration in this person's enamel.

Manganese

Inv. No.	Tooth	Age	Gender	Mn [µg g ⁻¹]		Sr [µg g ⁻¹]		
				Enamel	Dentine	Enamel	Dentine	
23,623	M1	juvenile	f	71	35	77	242	local
23.677A	M1	adult	f	40	158	108	292	local
23,695	M1	juv./adult	f?	47	29	161	421	local
24,276	M1	adult	f	80	11	109	293	local

Table 22 Individuals with high Mn concentrations in enamel

Only local female individuals had elevated concentrations of manganese. All were between 14 and 40 years of age when they died, so the mineralization of the first molars' enamel was already completed. These enamel-Mn values were mostly above the correlating dentine values and also by far higher than the average dentine concentration (22 µg g⁻¹).

Elevated levels of manganese can be an indicator for diagenesis (Price et al. 1994; Shafer et al. 2008), therefore higher values in enamel are also interesting in comparison to the investigations in chapter 4.2.3.1. However, none of these individuals expressed Sr concentrations above the local maximum (179 µg g⁻¹). Also the uranium concentration, a

further indicator for diagenetic alterations, was below the limit of detection (110 ng g^{-1}). Mn concentrations in the soil samples of Franzhausen were all below the limit of detection ($0.2 \text{ } \mu\text{g g}^{-1}$) as well. There have also been investigations about the correlation between elevated concentrations of manganese and neurological diseases in modern populations (Aschner and Aschner 2005). Whether this was the case with these individuals we cannot say.

Copper

Individual 23625 had a rather high Cu concentration ($1628 \text{ } \mu\text{g g}^{-1}$). This can be explained if one looks at figure 41. Obviously the bronze pieces of grave goods led to a green staining of the tooth. That enamel was affected as well might be due to the bad preservation status of the tooth which might have made it more susceptible to post mortem changes. The concentration in dentine was even higher by a factor of 10 with $12512 \text{ } \mu\text{g g}^{-1}$.

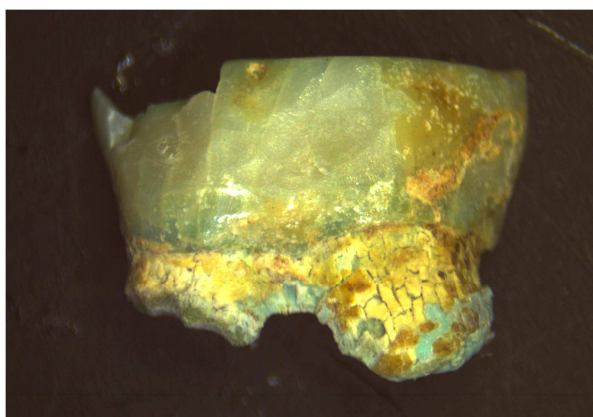


Figure 41 Tooth of individual 23625, drilled

Zinc

Individuals with values above 50% relative to the maximum (table 23) were examined to see if some peculiarities about zinc in the Early Bronze Age population of Franzhausen are visible.

Inv. No.	Tooth	Age	Gender	Zn [$\mu\text{g g}^{-1}$]		
				Enamel	Dentine	
23655_M2	M2	mature	m	1096	1007	local
23,675	M1	adult/mature	f?	1414	1236	local
23,676	M1	mature	m	1020	892	local
23.677A	M1	adult	f	1560	489	local
23,691	M2	mature	m	1832	1804	local
24,276	M1	adult	f	940	367	local
24,285	M1	juvenile	n.s.	1120	465	non-local

Table 23 Individuals with high Zn concentrations in enamel

Zinc was used to determine additional marine proteins (e.g. Baraybar and de la Rua 1997) which does not make sense for this population. In carnivores usually higher concentrations are found than in herbivores (Pate 1994), assuming that these individuals would have eaten relatively more meat than the others. However, two of these individuals (23676, 23691) also displayed higher Mg concentrations indicating the opposite. Furthermore concerns about the application of zinc for dietary studies on ancient populations were expressed (Ezzo 1994a). It can be seen that reconstruction of paleodiets is not an easy task.

Rubidium

While most Rb-values in enamel were below the LoD, some displayed a higher concentration; they are listed in table 24

Inv. No.	Tooth	Age	Gender	Rb [ng g^{-1}]		
				Enamel	Dentine	
23,613	M1	mature	m	415	314	not specified
23,618	M2	mature/senile	f	216	1388	local
23,620	M1	mature	m	171	< 170	not specified
23,621	M1	infants II	?	195	< 170	local
23,644	M1 or M2	adult	m?	303	< 170	local
23.652A	M1	erwachsen	f?	432	1086	local
23,653	M1	infants II	n.s.	936	< 170	non-local
23655_M2	M2	mature	m	219	232	local
23,734	M1	adult/mature	f	448	480	local
24,258	M1	erwachsen	m?	474	2342	local
24,269	M1	adult	m	173	844	local

Table 24 Individuals with high Rb concentrations in enamel

All but one enamel value are below the LoQ (500 ng g⁻¹). For the soil in Franzhausen a mean rubidium concentration of 404 ng g⁻¹ was evaluated. The mean concentration of samples from Franzhausen II was 766 ng g⁻¹, while the fresh samples displayed only a mean concentration of 223 ng g⁻¹. Locals are close to or in-between those values. Maybe diagenetic alterations were the reason for the elevated Rb values, other indications (Sr, Mn, U) were also determined in individual 23618. This woman had an enamel Sr concentration (186 µg g⁻¹) a little above the as biogenic defined maximum (179 µg g⁻¹).

The highest Rb concentration in enamel (936 ng g⁻¹) - which was also the only one above the LoQ - was found in the non-local individual 23653, who possibly originated from St. Georgen or Unterradlberg where only water samples were taken. These had very low rubidium concentrations, both around 1 ng g⁻¹. Examinations of soil extracts from that area might help with further interpretations.

Barium

Log(Ba/Sr) can be used as an indicator for additional marine food sources (Burton and Price 1990). This seems, as already mentioned, very unlikely. The eleven individuals above 50% relative value will be looked at to see whether another reason for the higher concentrations can be found.

Inv. No.	Tooth	Age	Gender	Ba [µg g ⁻¹]		
				Enamel	Dentine	
23,613	M1	mature	m	15	75	not specified
23,623	M1	juvenile	f	20	65	local
23,625	M1	adult/mature	m	15	112	local
23.652A	M1	erwachsen	f?	24	67	local
23,662	M1	adult	n.s.	14	76	local
23,663	M1	adult	f	13	68	local
23,665	M1	mature	f?	21	75	non-local
23,672	M1	adult	f	14	88	local
23,714	M1	mature	f	16	48	non-local
24,267	M1	adult/mature	f	17	58	non-local
24,276	M1	adult	f	25	87	local

Table 25 Individuals with high Ba concentrations in enamel

Most of these individuals were women between an age of 20 and 60. A tendency from the locality cannot be establish because locals and immigrants were found with higher Ba concentrations. There have been investigations about Ba/Ca ratios and the changes with trophic level, but it is advised to better use Sr/Ca ratios (Blum et al. 2000), which will be done below.

As zinc can also be used to investigate additional marine food stuff in the diet, it was compared whether some of these individuals had conspicuously high concentrations of both elements, Ba and Zn. No correlations were found, confirming the assumption that marine proteins were not part of this population's diet.

Lead

Lead can be used as indicator for anthropogenic contamination and high concentrations could show intoxication (Åberg et al. 1998; Shafer et al. 2008). These intoxications must have happened during the childhood already since enamel is investigated. All of the concerned individuals (table 26) reached an age above 18, mostly even above 30 so at least it would not have been a deadly dosage.

Most of the other enamel samples had lead concentrations below LoD (450 ng g^{-1}) or LoQ (1500 ng g^{-1}), values ranged from 458 to 31143 ng g^{-1} . Male as well as female individuals were found with exceptionally high lead concentrations in comparison to the rest of the population, all of them were of local origin.

Inv. No.	Tooth	Age	Gender	Pb [ng g^{-1}]		
				Enamel	Dentine	
23655_M2	M2	mature	m	21881	11585	local
23,674	M1	juv./adult	m?	18840	26354	local
23,675	M1	adult/mature	f?	31143	24581	local
23,676	M1	mature	m	27149	14499	local
23,677A	M1	adult	f	18754	2668	local

Table 26 Individuals with high Pb concentrations in enamel

4.3.4. Sr/Ca ratios

Investigations of 277 human bones from places all over the world by Turekian and Kulp (1956) showed that variations in Sr/Ca ratios are independent of skeletal part, age or sex, whereas regional fluctuations (e.g. geology, diet) seemed to be the main contributors to occurring differences. An average ($\%Sr/\%Ca \times 1000$) value of 0.60 was found, the individual samples varied between 0.11 and 1.98 ($\%Sr/\%Ca \times 1000$).

Figures 42 and 43 display the Sr/Ca concentration ratios evaluated in this study once sorted by enamel, once by dentine values. The average ($Sr/Ca \times 1000$) ratios were 0.25 and 0.65, respectively for enamel and dentine, with ($Sr/Ca \times 1000$) values varying from 0.11 to 0.44 and from 0.38 to 1.15. These values are in good agreement with the results from Turekian and Kulp. If teeth are also included as part of the skeleton we cannot completely agree with the assumption that Sr/Ca ratios are not depending on the part of the skeleton analyzed as ratios in enamel are generally lower than in dentine. What must be considered though is the fact that the compositions of enamel and bone are completely different, making comparisons like this doubtful. However, the ratios in dentine, which behaves similar to bone material, coincided very well with an average of 0.65 compared to 0.60 as found by Turekian and Kulp. Therefore these values were looked at closer for comparison with other general assumptions made by them to see whether these were true for the Bronze Age population in Franzhausen as well.

There did not seem to be a connection between sex and these ratios. The curves in figure 44 do all have a similar shape, only single individuals stand out. Men as well as women displayed advanced Sr/Ca ratios - indicating a diet with a higher proportion of vegetables - and minor values - usually higher the more meat is included in nutrition (Blum et al. 2000).

When discriminated by age (figure 45) the lower values seemed to be more concentrated in the juvenile, adult and also mature/senile age group, the average values ($Sr/Ca \times 1000$: 0.63, 0.65, 0.61) were close to the whole population's average (0.65) though. The two senile samples, two women, were lower than the average (0.51, 0.54), but due to the small number of samples a general assumption was not possible. Adult/mature people had the highest average with 0.74, but standard uncertainty was high as well (0.11) and would then overlap with the overall average level again.

No significant differences between the sex and age groups could be establish, agreeing with the results of Turekian and Kulp.

13 of the 18 individuals identified as non-locals had Sr/Ca ratios below the average. A regional discrimination, however, was still not possible, since the according $^{87}\text{Sr}/^{86}\text{Sr}$ ratios correlated them to different origins.

Throughout all these interpretations, diagenetic alterations have to be taken into account accordingly.

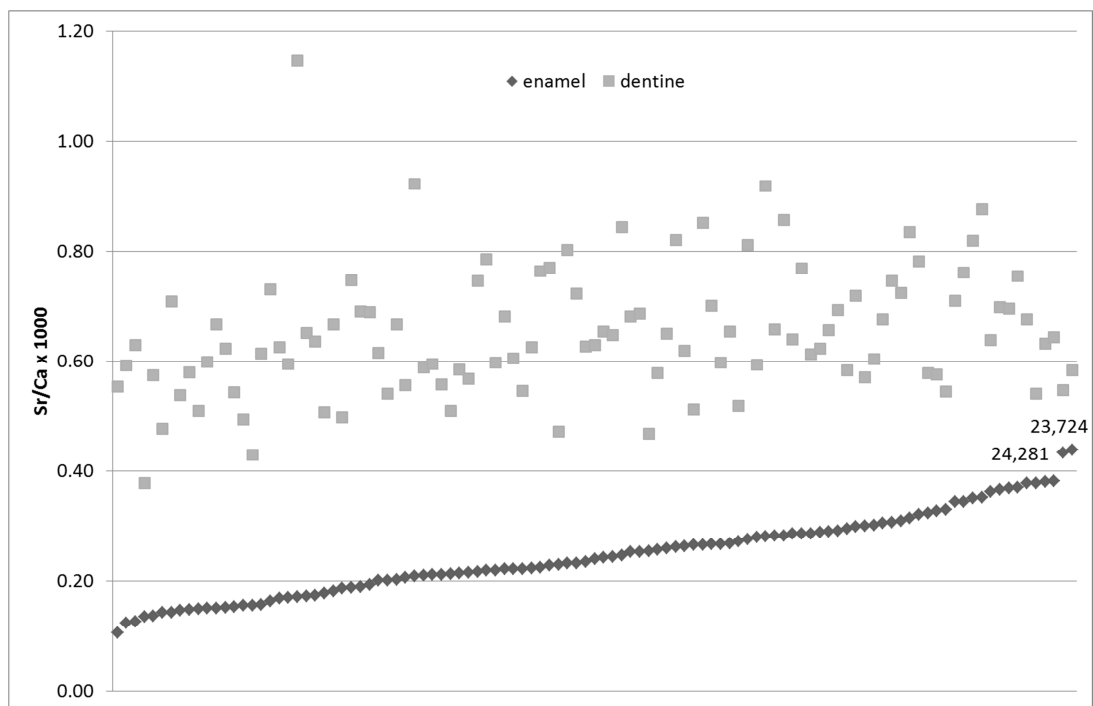


Figure 42 Sr/Ca ratios in ascending order of enamel values

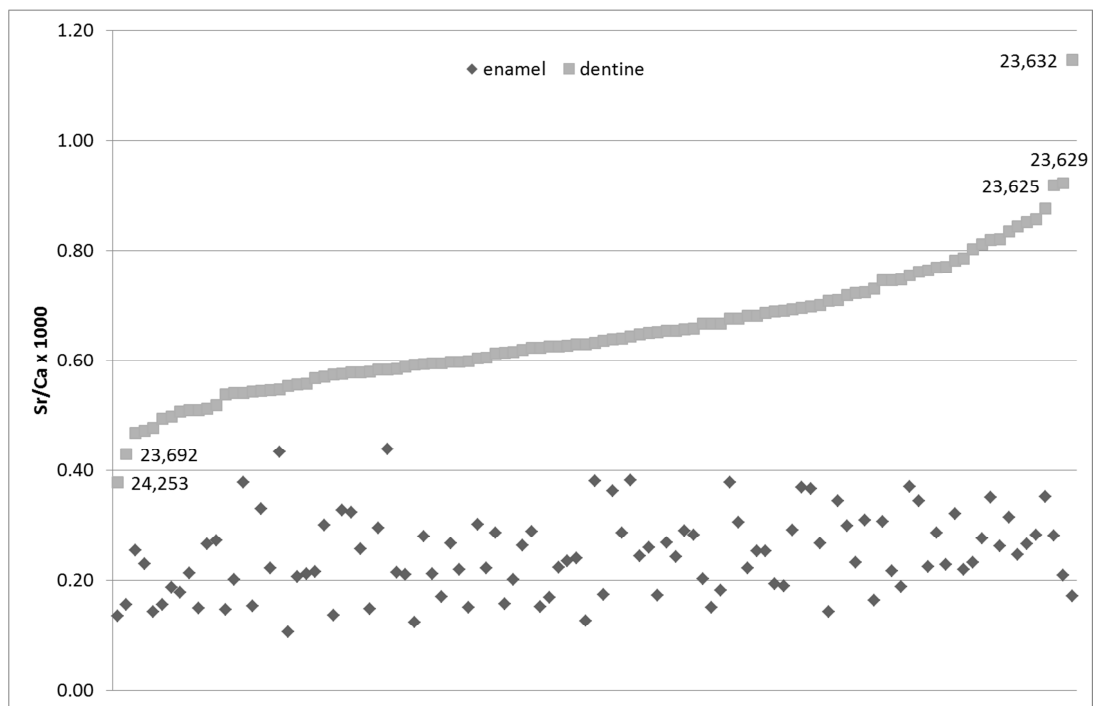


Figure 43 Sr/Ca ratios in ascending order of dentine values

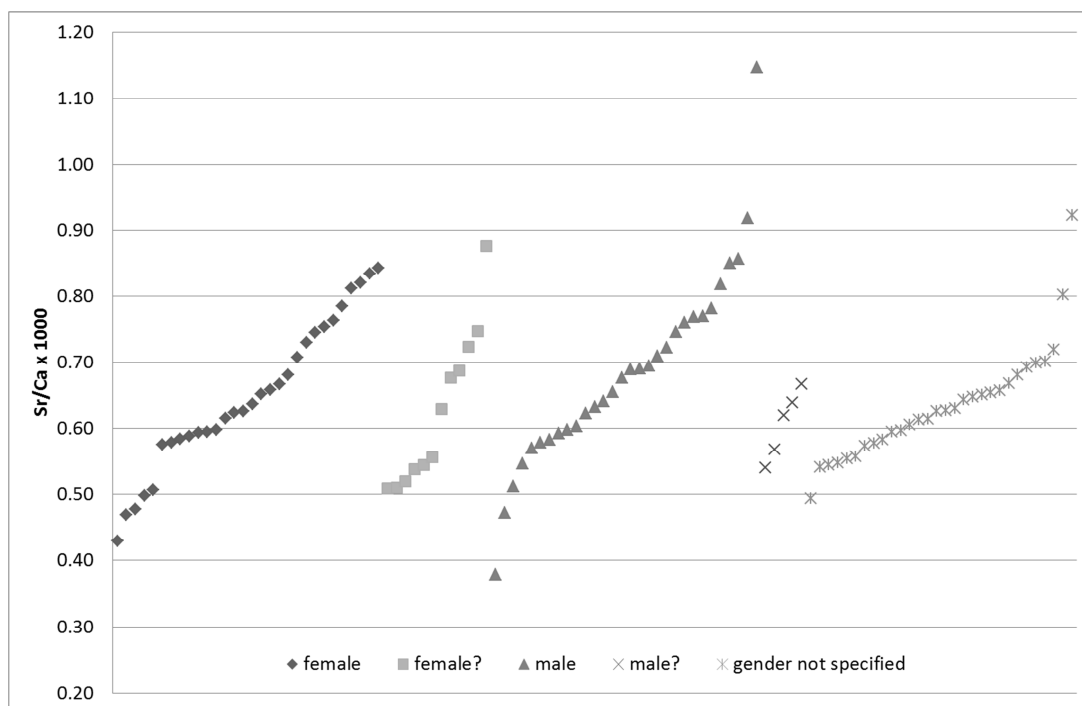


Figure 44 Sr/Ca ratios in dentine discriminated by gender

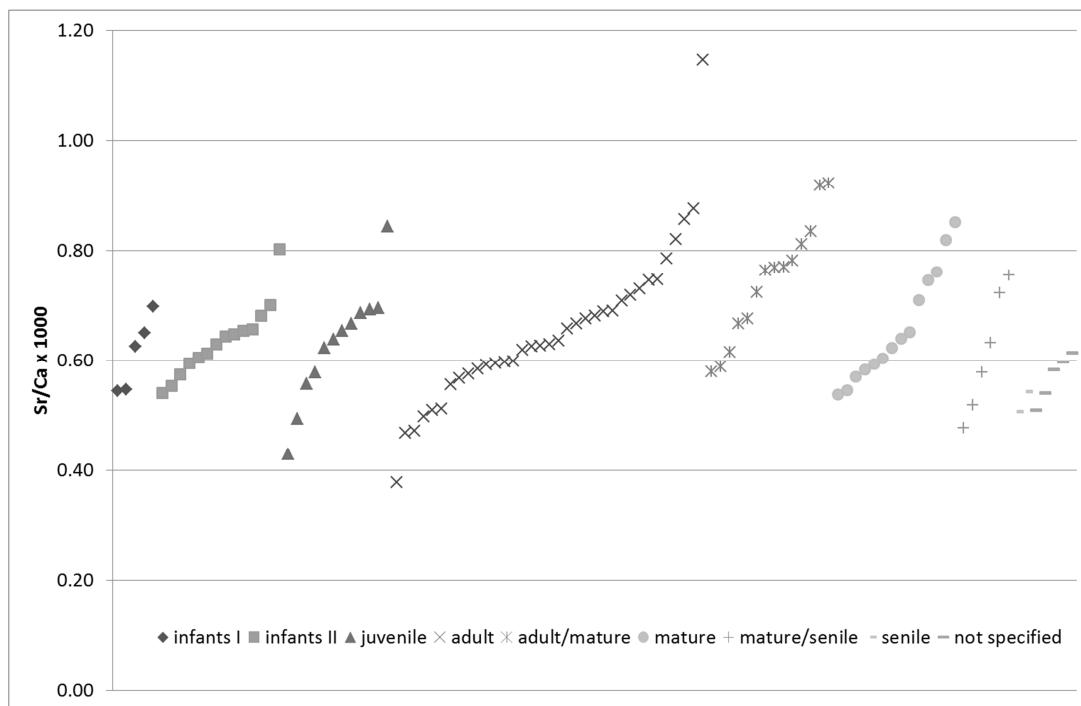


Figure 45 Sr/Ca ratios in dentine discriminated by age

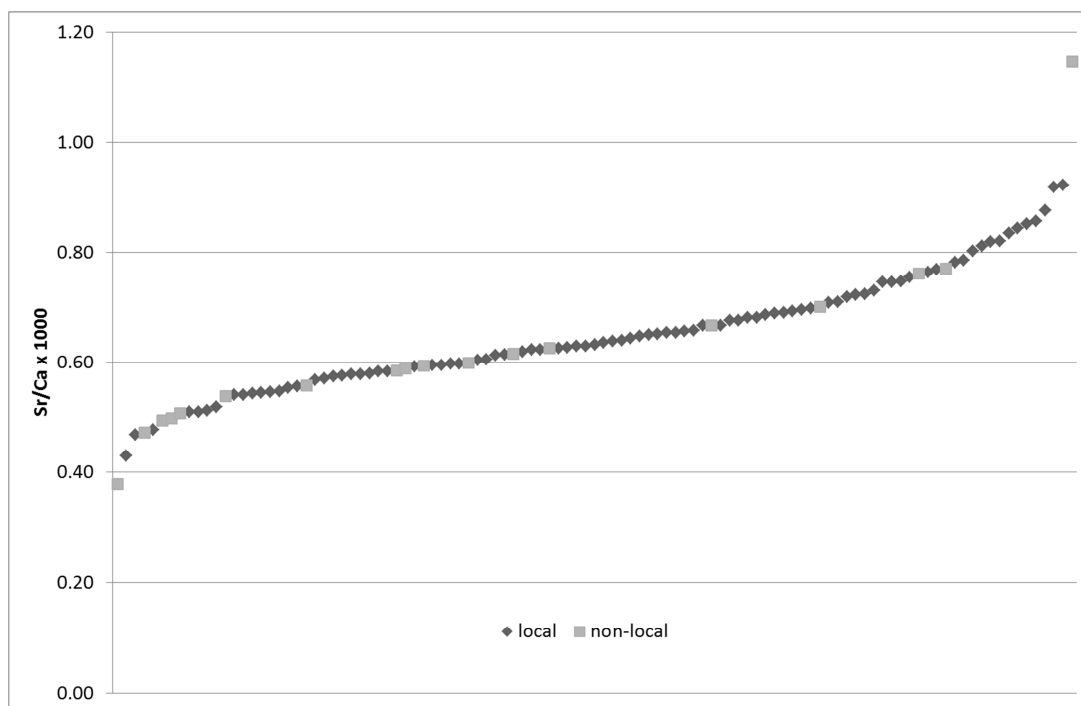


Figure 46 Sr/Ca ratios in dentine discriminated by origin

4.4. Comparison with the Late Neolithic excavation site at Franzhausen II and the Bronze Age site Hainburg/Donau

Data concerning the Neolithic population of Franzhausen derived from Irrgeher et al. (in press). Results from Hainburg were taken from Irrgeher et al. (2011), additionally unpublished data established in the VIRIS lab were used as well. Immense input was also given by HR a.o. Univ.-Prof. Dr. Maria Teschler-Nicola during personal communications.

Franzhausen - at the time of the Early Bronze Age - was a wealthy region. Different social structures were developed and a center of trade was established. New technologies were introduced as well. This, however, was different during the Neolithic time where 12% of the population living there was identified as non-local. Comparing this with the results in this study, where 18% of the individuals were non-locals, confirm the assumption that there must have been a trading center in the Early Bronze Age. This led people to move to Franzhausen, 22% of the male individuals were of non-local origin. They probably moved to be able to carry on trade. Women moved in about the same degree to Franzhausen during the Early Bronze Age as 20% were identified as individuals with non-local origin. They most likely came for marital reasons. During Neolithic times on the other hand more men immigrated to Franzhausen, approximately 20 to 30% depending on the sex specification, whereas only around 10% (for both, anthropological and archaeological sex) of the women were identified as non-locals. The number of individuals investigated though was rather small with 49 individuals. Further investigations will be conducted.

The skeletons found in Hainburg/Donau also belonged to a Bronze Age population, like the ones investigated in this study. The situation of the finding site is assumed to be different from Franzhausen, since it used to be more of a rural population which is authenticated by the higher percentage of local individuals (92%) identified using $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. 7% of the women and 14% of the men were of non-local origin, the proportion between male and female immigrants is similar to the Neolithic but not to the Bronze Age population of Franzhausen where women were more mobile, as well. Maybe the region's wealth was a reason for that. Men might have had the means to afford a woman from a different population, and the families of those women might have been in need for some financial support or the like. Such assumption, however, are far beyond our knowledge about these populations and cannot be taken as proven scenarios.

4.5. Summary and conclusion

The analyzed quantity of 103 individuals is an adequate sampling entity to be representative for the Early Bronze Age population in Franzhausen. Overall 18% of the analyzed enamel samples represented $^{87}\text{Sr}/^{86}\text{Sr}$ ratios outside the values defined as local range. Hence these individuals were non-locals who moved to Franzhausen and were buried there. We found 20% non-local females and 22% non-local males. (From the skeletons that could not be specified for their gender, 10% were identified as non-locals). The first migrators were identified in individuals of an age between 14 and 22 years, with the exception of an individual who was 11-12 years old at death. This is bringing up the assumption that for Bronze Age people in the Lower Traisen Valley it was usual that children started to leave their home when they were around 14 years old. In some age groups (infants I (including infants I-II), mature/senile, not specified) all investigated individuals were local. A little above the general percentage of non-locals was the adult group with 24% individuals having a different origin. These 20 to 40 aged ones accounted to one third of the whole individuals analyzed in this study. Three of the as 40 to 60 year old and one of the senile aged ones were non-locals.

Indicating post-mortem changes in dentine were $^{87}\text{Sr}/^{86}\text{Sr}$ ratios that draw nearer to the soil average with ascending strontium concentrations. Also elevated levels of uranium could indicate diagenetic alterations in dentin. However, enamel was found to be possibly affected by diagenesis as well, mostly in infant individuals where the mineralization process might not have been finished at the time of death. Calculations showed that the classification of the individuals with high Sr concentrations was not affected though as the corrected ratios identified them as locals, as well.

Multi element data displayed some differences between enamel and dentine which could be due to the unequal composition and structure or caused by diagenetic changes. Multi element fingerprints of enamel samples brought up some conspicuous cases which could give further indications for changes of enamel during burial conditions. It was also tried to figure out a little about the diet of those individuals, but some of the results led to contrary interpretations. Further data processing is necessary to gain more information. Sr/Ca ratios did not display any dependencies on age, gender or location. They must be a result of diet

where usually higher values are correlated to a greater proportion of vegetables in the daily menu.

Franzhausen I with 18% non-locals has a higher proportion of individuals classified as non-locals than the population in the same area, but at an earlier time. Social structures were not as developed and there has not been a trading center yet. Only 12% non-locals were found in the Neolithic population of Franzhausen. When compared to another Early Bronze Age excavation site in a different area in Austria, Franzhausen I exhibits also a larger percentage of non-locals. In Hainburg only 8% of the individuals were non-locals, which is in good agreement with the assumption that it was more of a rural population. These comparisons reinforce the existence of a trading center in Franzhausen during the Early Bronze Age.

The question arising now also is: What could have been the reason for those individuals to move to Franzhausen?

The most plausible explanation would be that women came out of marital reasons, as mentioned before, indications for marriage trading were already found in biological investigations. The results of this study support this thesis. In comparison to the Neolithic population in Franzhausen and the Early Bronze Age population in Hainburg, a higher percentage of women were of non-local origin. Was the wealth of the men in Franzhausen during the Early Bronze Age a reason for this difference, could they 'afford' to get a wife from a different location? This could be an explanation for the higher mobility of women in the Early Bronze Age population of the grave field Franzhausen I. However, there is no evidence for it.

Franzhausen used to be a trading center during the Early Bronze Age. This could have drawn tradespeople to the location and could explain the migration of male individuals to this place. Young men might have left their hometown to find work in this area.

However, we can only make assumptions about what caused people to change their place of residence and we will never know the truth for sure.

5. OUTLOOK

An interesting task for further investigations of this and other populations excavated in the necropolises of Franzhausen would be to find out what served as their water source and where did they cultivate their crops. Then samples could be taken directly from there and an even better distinction of the population might be possible also concerning information about their diet and the possible Sr sources. The same should be done with its surroundings, especially more investigations on the local signal of Gemeinlebarn need to be done to check that no wrong conclusion were drawn from only one water sample of that area. Collaborations with geologists are currently set up and will help with the selection and the needed quantity of the sampling spots in the different geologic regions.

Further investigations about diagenesis in enamels of excavated children and older individuals need to be done. The samples of local individuals with the highest strontium concentrations could be leached for example with the method which is used at the VIRIS laboratory based on the sequential extraction scheme proposed by Sillen (1986) to see whether possible diagenetic contributions can be removed and/or distinguished from biogenic ones. The same should be done with dentine samples to see if they behave similar. Recent teeth of all age groups could be incubated to simulate burial under extreme conditions to get maximum possible alterations. Measurements of concentration and ratio before and after this experiment could answer questions concerning the occurrence of diagenesis in enamel. Further information might be gained with chemical imaging or spectroscopic techniques.

The examination of the multi element data with a statistics program will be necessary to see whether any groupings can be found and dependencies of elements can be revealed. Additional information about the population's diet could be found and it might also be helpful for investigations of post-mortem changes in enamel. In order to get a better insight into people's nutrition, investigations of animal species of different trophic level in the area around Franzhausen could support the data. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values which are often used for dietary reconstruction could be investigated as well. With those it might be possible to define the proportions of meat and plant material in nutrition. Possibly present sex and/or age discriminations might be discovered.

Many of the sampled locations were not distinguishable from Franzhausen with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. $\delta^{18}\text{O}$ values might be able to discriminate between them. Maybe for foreigners with more than one possible origin a further differentiation would be possible with oxygen isotope analysis as well. Considerations that the modern $\delta^{18}\text{O}$ values differ from the ancient ratios have to be taken into account (this is not the case for Sr). Additionally multi element data could be implemented to investigate people origins further.

Combining the archaeological findings with the anthropological results and chemical evidence might give some additional information that could be of use when reconstructing an individual's diet. Maybe graves rich in grave goods display different multi element pattern indicating different nutrition, as they were wealthy and could afford different food stuff.

The collected samples of wood, leaves, grains and the like that were not analyzed yet, but might lead to further assumptions about the diet of the Early Bronze Age populations in the Lower Traisen Valley. The evaluation of an average diet and the determination of its elemental and isotopic composition could also help. There is still a lot of information receivable in the already measured data and even more questions might be answered with further investigations.

6. APPENDIX

6.1. Certificate of Analysis



National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material[®] 987

Strontium Carbonate
(Isotopic Standard)

This Standard Reference Material (SRM) is certified for use as an isotopic reference material for the calibration of mass spectrometers. The material consists of highly purified strontium carbonate of high homogeneity. A unit of SRM 987 consists of 1 g of powder.

Certified Values: The certified values for the absolute strontium isotopic abundance ratios and the atom fractions of ⁸⁸Sr, ⁸⁷Sr, ⁸⁶Sr and ⁸⁴Sr are listed in Table 1. A NIST-certified value is a value for which NIST has the highest confidence in its accuracy, in that all known or suspected sources of bias have been investigated or accounted for by NIST. A certified value is the present best estimate of the true value based on the results of analyses performed at NIST and cooperating laboratories. Value assignment categories are based on the definition of terms and modes used at NIST for chemical reference materials [1]. The uncertainties listed with the values are expanded uncertainties (95 % confidence interval) and are calculated according to the methods in the ISO and NIST Guides [2].

Table 1. Certified Values for SRM 987 Strontium Carbonate

Absolute Abundance Ratios	$^{88}\text{Sr}/^{86}\text{Sr} = 8.378\,61 \pm 0.003\,25$
	$^{87}\text{Sr}/^{86}\text{Sr} = 0.710\,34 \pm 0.000\,26$
	$^{84}\text{Sr}/^{86}\text{Sr} = 0.056\,55 \pm 0.000\,14$
that yield atom percents of:	$^{88}\text{Sr} = 82.584\,5 \pm 0.006\,6$
	$^{87}\text{Sr} = 7.001\,5 \pm 0.002\,6$
	$^{86}\text{Sr} = 9.856\,6 \pm 0.003\,4$
	$^{84}\text{Sr} = 0.557\,4 \pm 0.001\,5$

This material was used as the reference sample in a determination of the absolute abundance ratios and atomic weight of strontium [3]. The atomic weight of strontium calculated from the absolute abundance ratios is $87.616\,81 \pm 0.000\,12$.

Expiration of Certification: The certification of this SRM is deemed to be indefinite within the stated uncertainties. However, certification is nullified if the SRM is contaminated or otherwise altered.

Maintenance of Certified Values: NIST will monitor this SRM and, if substantive changes occur in the certified values, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

Stephen A. Wise, Chief
Analytical Chemistry Division

Gaithersburg, MD 20899
Certificate Issue Date: 19 June 2007
See Certificate Revision History on Last Page

Robert L. Watters, Jr., Chief
Measurement Services Division

The overall direction and coordination of the technical measurements leading to the certification of this SRM were performed under the chairmanship of I.L. Barnes and W.R. Shields of the NIST Analytical Chemistry Division.

The characterization of this SRM was performed by G. Marinenko, E.E. Etz, D.G. Friend, I.L. Barnes, L.J. Moore, T.C. Rains, T.A. Rush, L.A. Machlan, T.J. Murphy, and P.J. Paulsen, all of the NIST Analytical Chemistry Division.

The support aspects involved in the preparation of this SRM were coordinated through the NIST Measurement Services Division. The current revised certificate was coordinated by Robert D. Voeke, Jr. of the Analytical Chemistry Division.

Storage and Handling: There are no special storage or handling instructions. While strontium carbonate is slightly hygroscopic (absorbing approximately 0.02 % moisture at 90 % humidity), this has no effect on the isotopic abundances.

The strontium carbonate used for this SRM was obtained from Spex Industries, Inc.¹ of Metuchen, NJ. The material, when received, was of high purity in relation to cationic impurities but assayed only 99.0 % due to moisture and other volatile impurities. The impurities reported in the strontium carbonate material are lithium, 4 mg/kg; sodium, 6 mg/kg; potassium, < 1 mg/kg; magnesium, < 2 mg/kg; calcium, 5 mg/kg; barium, < 15 mg/kg; copper, < 3 mg/kg; iron, < 3 mg/kg; aluminum, < 1 mg/kg; and silicon, < 1 mg/kg.

REFERENCES

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- [2] ISO; *Guide to the Expression of Uncertainty in Measurement*; ISBN 92-67-10188-9, 1st ed., International Organization for Standardization: Geneva, Switzerland (1993); see also Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at <http://physics.nist.gov/Pubs/>.
- [3] Moore, L.J.; Murphy, T.J.; Barnes, I.L.; Paulsen, P.J.; *Absolute Isotopic Abundance Ratios and Atomic Weight of a Reference Sample of Strontium*, J. of Res. (NBS) Vol. 87, No. 1, pp. 1-8 (1982).

Certificate Revision History: 19 June 2007 (Editorial change); 14 June 2007 (Editorial changes and revised as isotopic standard only); 01 May 2000 (Editorial changes); 01 October 1982 (Revision of certified values); 06 March 1972 (Editorial changes); 08 November 1971 (Original certificate date).

Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: telephone (301) 975-6776; fax (301) 926-4751; e-mail srminfo@nist.gov; or via the Internet at <http://www.nist.gov/srm>.

¹Certain commercial equipment, instrumentation, or materials are identified in this certificate to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the NIST, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

6.2. Additional data

Element	Multi IV Standard [ng g ⁻¹]	spiked [ng g ⁻¹]	final concentration in VIRIS-RM [ng g ⁻¹]
Li	3.1		3.1
B	31.0		31.0
Be	29.5		29.5
Na	3.0	40.4	43.4
Mg	3.0	101.6	104.6
Al	3.0	37.7	40.7
V	3.0		3.0
Cr	3.1		3.1
Mn	3.1	67.9	71.0
Fe	30.4	122.5	152.9
Co	3.0		3.0
Ni	3.1		3.1
Cu	3.0		3.0
Zn	31.0	30.5	61.5
Ga	3.0		3.0
As	30.1		30.1
Se	31.0	50.6	81.6
Rb	3.0	17.4	20.4
Sr	3.1	17	20.1
Mo	3.1		3.1
Ag	3.1		3.1
Cd	3.0		3.0
Te	3.1		3.1
Ba	3.1	47	50.1
Tl	3.1		3.1
Pb	3.0		3.0
Bi	3.0		3.0
U	3.0		3.0
Ca	307.1	607.9	915.0
K	3.1	88.7	91.8

Table 27 Element concentrations of in-house reference material

Isotope	Atomic mass	Uncertainty
⁸⁴ Sr	83.913425	0.000003
⁸⁶ Sr	85.9092602	0.0000012
⁸⁷ Sr	86.9088771	0.0000012
⁸⁸ Sr	87.9056121	0.0000012
⁸⁵ Rb	84.91178974	0.000000012
⁸⁷ Rb	86.90918053	0.000000013

Table 28 Atomic masses of Sr and Rb isotopes (Audi et al. 2003)

6.2.1. Archaeological human tooth samples

Inv. No.	Grave	Tooth	Age	Gender
23,613	3	M1	mature	m
23,616	6	M1	adult	f
23,618	8	M2	mature/senile	f
23,619	9	M1	adult	f?
23,620	10	M1	mature	m
23,621	11	M1	infants II	?
23,623	14	M1	juvenile	f
23,625	16	M1	adult/mature	m
23,626	17	M2	adult/mature	n.s.
23,627	18	M2	adult	m
23,629	20	M1 or M2	adult/mature	n.s.
23,630	21	M1 or M2	adult	f?
23,632	26	M1	adult	m
23,634	28	M2	mature/senile	m
23,636	30	M1	adult	m
23,637	31	M1	mature	m
23,638	32	M1	juvenile/adult	n.s.
23,639	35	M1	adult	m?
23.640A	34	M1	n.s.	n.s.
23.640B	36	M2	n.s.	n.s.
23,641	37	M1	adult/mature	f
23,642	38	M1	infants I	n.s.
23,644	40	M1 or M2	adult	m?
23,645	41	M1	adult	f
23,649	46	M1	adult/mature	m
23,650	47	M1	juv./adult	f
23.652A	50	M1	erwachsen	f?
23,653	51	M1	infants II	n.s.
23655_M1	57	M1	mature	m
23655_M2	57	M2	mature	m
23,656	58	M1	adult	m
23,657	59	M1	juv./adult	f
23,661	64	M2	adult	f
23,662	65	M1	adult	n.s.
23,663	66	M1	adult	f
23,664	67	M1	infants II	n.s.
23,665	68	M1	mature	f?
23,667	74	M1? (M2)	senile	f
23,668	75	M1	adult	f
23,669	79	M1	adult/mature	m
23,670	81	M1	mature	m
23,671	82	M1	adult/mature	m
23,672	84	M1	adult	f
23,674	85	M1	juv./adult	m?

Inv. No.	Grave	Tooth	Age	Gender
23,675	85	M1	adult/mature	f?
23,676	86	M1	mature	m
23.677A	87	M1	adult	f
23,678	88	M1	adult	f?
23,681	93	M1	adult	m
23,682	94	M1	juv./adult	n.s.
23,683	97	M1	adult	f?
23,684	96	M2?	mature	m
23,685	98	M1	mature/senile	f?
23,686	99	M1	adult	n.s.
23,687	100	M1	mature	f
23,690	101	M1	adult	f
23,691	102	M2	mature	m
23,692	103	M1	juvenile	f
23,695	107	M1	juv./adult	f?
23,699	112	M2	n.s.	n.s.
23,700	113	M2	adult	f
23,701	114	M1	infants II	n.s.
23,702	115	M1	infants II	n.s.
23,703	116	M1	adult	f
23,704	118	M2	mature/senile	f
23,706	120	M1	juvenile	m
23,707	121	M1	adult	f
23,708	122	M1	mature/senile	m
23,710	125	M2	adult/mature	f?
23,711	126	M1	adult	m
23,712	127	M1	infants I	n.s.
23,713	129	M1	adult	f?
23,714	128	M1	mature	f
23,715	130	M1	mature/senile	m
23,716	131	M2	juv./adult	m
23.717B	132	M1	adult	f
23,718	133	M2	senile	f?
23,720	137	M2	infants II	n.s.
23,721	138	M1	juvenile	n.s.
23,724	140	M1	mature	m
23,725	141	M2	mature	m
23,726	143	M1	infants II	n.s.
23,732	151	M1	infants II	n.s.
23,734	153	M1	adult/mature	f
23,735	154	M1	infants II	n.s.
23,737	157	M1	infants I	n.s.
23,738	158	M1	adult/mature	f
24,250	940	M2	adult	m
24,251	941	M1	adult	f
24,253	942	M1	adult	m

Inv. No.	Grave	Tooth	Age	Gender
24,257	950	M1	adult	m?
24,258	960	M1	erwachsen	m?
24,260	952	M1	infants II	n.s.
24,264	956	M1	adult	m
24,266	958	M1	adult/mature	f
24,267	959	M1	adult/mature	f
24,269	961	M1	adult	m
24,273	964	M1	infants II/juv.	n.s.
24,275	965	M1	adult	f
24,276	966	M1	adult	f
24,277	968	M1	infants II	n.s.
24,278	969	M1	infants II	n.s.
24,279	970	M1	infants II	n.s.
24,280	971	M1	adult/mature	f
24,281	972	M1	infants I-II	n.s.
24,282	1003	M1	infants I	n.s.
24,285	1013	M1	juvenile	n.s.

Table 29 Specification of the investigated individuals

6.2.2. Environmental samples

sample code	location name	sample type	Y coord.	X coord.
soil				
FH1_S1	Pischelsdorf	soil	48.328386	15.95344
FH1_S2	Kleinschönbichl	soil	48.336411	15.940518
FH1_S3	Erpersdorf	soil	48.339292	15.915048
FH1_S4	Erpersdorf	soil	48.339206	15.915434
FH1_S5	Dürnrohr	soil	48.333743	15.902817
FH1_S6	past Dürnrohr	soil	48.325355	15.887861
FH1_S7	Oberbierbaum	soil	48.345582	15.840182
FH1_S8	Preuwitz	soil	48.352684	15.820505
FH1_S9	Czechkreuz	soil	48.345881	15.815291
FH1_S10	Ahrenberg	soil	48.332816	15.793211
FH1_S11	look-out Korkenzieher	soil	48.334121	15.788728
FH1_S12	Theyern	soil	48.341667	15.681867
FH1_S13	past Theyern	soil	48.341548	15.661808
FH1_S14	Hirschberg	soil	48.33847	15.618991
FH1_S15	Unterwölbling	soil	48.326068	15.604833
FH1_S16	Dörfel	soil	48.326668	15.627761
FH1_S17	Statzendorf	soil	48.302094	15.644316
FH1_S18	Herzogenburg	soil	48.285751	15.669273
FH1_S19	Inzersdorf	soil	48.316509	15.681481
FH1_S20	Reichersdorf	soil	48.333872	15.705964
FH1_S21	Franzhausen	soil	48.346409	15.711629
FH1_S22	Franzhausen	soil	48.342786	15.714526

sample code	location name	sample type	Y coord.	X coord.
soil				
FH1_S23	Ossarn	soil	48.278908	15.704634
FH1_S24	Pottenbrunn	soil	48.232841	15.685464
FH1_S25	Einöd	soil	48.318064	15.720362
FH1_S26	Traismauer	soil	48.335513	15.738734
water				
FH1_W1	Pischelsdorf	water	48.32839	15.953443
FH1_W2	Kleinschönbichl	water	48.336079	15.940201
FH1_W3	Dürnrohr	water	48.335555	15.906443
FH1_W4	Dürnrohr	water	48.334015	15.902345
FH1_W5	Trasdorf	water	48.322815	15.882582
FH1_W6	Kaindorf	water	48.343714	15.85488
FH1_W7	Gemeinlebarn	water	48.336097	15.822908
FH1_W8	Sitzenberg	water	48.320276	15.807545
FH1_W9	Traismauer	water	48.34812	15.742249
FH1_W10	Traismauer	water	48.351101	15.74094
FH1_W11	St. Georgen	water	48.36218	15.735146
FH1_W12	Nußdorf o. d. Traisen	water	48.35493	15.705428
FH1_W13	Paudorf	water	48.352548	15.620584
FH1_W14	Unterwölbling	water	48.325505	15.60492
FH1_W15	Dörfl	water	48.326832	15.627064
FH1_W16	past Reichersdorf	water	48.332813	15.720781
FH1_W17	Getzersdorf	water	48.316608	15.705814
FH1_W18	Walpersdorf	water	48.308321	15.708711
FH1_W19	Ossarn	water	48.276738	15.708174
FH1_W20	Ossarn	water	48.278195	15.704205
FH1_W21	Unterradlberg	water	48.253287	15.678085
FH1_W22	Pottenbrunn	water	48.238738	15.694425
FH1_W23	Ratzersdorf	water	48.224565	15.65674
FH1_W24	Ratzersdorf	water	48.221241	15.656397
FH1_W25	Einöd	water	48.320219	15.729288
fauna and flora				
FH1_A1	Erpersdorf	snail houses	48.339206	15.915434
FH1_P1	Dürnrohr	grain	48.333743	15.902817
FH1_P2	past Dürnrohr	corn	48.325355	15.887861
FH1_P3	Preuwitz	corn	48.352684	15.820505
FH1_P4	Czechkreuz	grain	48.345625	15.816342
FH1_P5	Herzogenburg	corn	48.285751	15.669273
FH1_P6	Franzhausen	sunflower	48.342758	15.714354
FH1_P7	Getzersdorf	grain	48.316908	15.705943
FH1_T1+L1	Ahrenberg	wood and leaves	48.332987	15.79291
FH1_T2+L2	look-out Korkenzieher	wood and leaves	48.334139	15.78875
FH1_T3+L3	look-out Korkenzieher	wood and leaves	48.334109	15.788768
FH1_T4+L4	past Theyern	wood and leaves	48.341499	15.661609

sample code	location name	sample type	Y coord.	X coord.
fauna and flora				
FH1_T5+L5	Hirschberg	wood and leaves	48.338458	15.618989
FH1_T6+L6	Unterwölbling	wood and leaves	48.326047	15.604759
FH1_T7+L7	Dörfel	wood and leaves	48.326675	15.627601
FH1_T8+L8	Ossarn	wood and leaves	48.278843	15.704648

Table 30 Environmental samples with GPS coordinates

6.3. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios

6.3.1. Archaeological human tooth samples

Inv. No.	Enamel	SU (k=2)	Dentine	SU (k=2)
23,613	--		0.70950	0.00035
23,616	0.71008	0.00036	0.70940	0.00035
23,618	0.70833	0.00035	0.70905	0.00035
23,619	0.70864	0.00035	0.70883	0.00035
23,621	0.70835	0.00035	0.70905	0.00035
23,623	0.70966	0.00035	0.70963	0.00035
23,625	0.70792	0.00035	0.70930	0.00035
23,626	0.70833	0.00035	--	
23,627	0.70782	0.00035	--	
23,629	0.70795	0.00035	0.70907	0.00035
23,630	0.70899	0.00035	0.70851	0.00035
23,632	0.70440	0.00035	0.70865	0.00035
23,634	0.70787	0.00035	0.70885	0.00035
23,636	0.70799	0.00035	--	
23,637	0.70848	0.00035	0.70815	0.00035
23,638	0.70759	0.00035	0.70777	0.00035
23,639	0.70819	0.00035	0.70773	0.00035
23,640A	0.70961	0.00035	0.70826	0.00035
23,640B	0.70821	0.00035	0.70868	0.00035
23,641	0.70729	0.00035	--	
23,642	0.70784	0.00035	0.70729	0.00035
23,644	0.71061	0.00036	--	
23,645	0.70847	0.00035	0.70873	0.00035
23,649	0.71093	0.00036	--	
23,650	0.70854	0.00035	0.70864	0.00035
23,652A	0.70752	0.00035	0.70847	0.00035
23,653	0.70671	0.00035	--	
23655_M1	0.70908	0.00035	0.70927	0.00035
23655_M2	0.70989	0.00035	0.70927	0.00035
23,656	0.70830	0.00035	0.70861	0.00035
23,657	0.70839	0.00035	0.70888	0.00035
23,661	0.71154	0.00036	0.70851	0.00035
23,662	0.70844	0.00035	0.70893	0.00035

Inv. No.	Enamel	SU (k=2)	Dentine	SU (k=2)
23,663	0.70888	0.00035	0.70861	0.00035
23,664	0.70733	0.00035	0.70867	0.00035
23,665	0.71246	0.00036	0.71277	0.00036
23,667	0.71150	0.00036	0.70903	0.00035
23,668	0.70693	0.00035	0.70881	0.00035
23,669	0.70851	0.00035	0.70898	0.00035
23,670	0.70681	0.00035	0.70869	0.00035
23,671	0.70794	0.00035	0.70874	0.00035
23,672	0.71031	0.00036	0.70911	0.00035
23,674	0.71079	0.00036	--	
23,675	0.70898	0.00035	--	
23,676	0.70864	0.00035	0.70914	0.00035
23.677A	0.71008	0.00036	0.70913	0.00035
23,678	0.70934	0.00035	0.70925	0.00035
23,681	0.71123	0.00036	0.70880	0.00035
23,682	0.71344	0.00036	--	
23,683	0.70871	0.00035	--	
23,684	0.70999	0.00035	0.70951	0.00035
23,685	0.70891	0.00035	--	
23,686	0.70884	0.00035	0.70861	0.00035
23,687	0.71035	0.00036	--	
23,690	0.70910	0.00035	--	
23,691	0.70867	0.00035	0.70896	0.00035
23,692	0.70924	0.00035	0.70927	0.00035
23,695	0.70842	0.00035	--	
23,699	0.70853	0.00035	0.70907	0.00035
23,700	0.71242	0.00036	0.70962	0.00035
23,701	0.70784	0.00035	0.70869	0.00035
23,702	0.70799	0.00035	0.70897	0.00035
23,703	0.70994	0.00035	0.70882	0.00035
23,704	0.70932	0.00035	--	
23,706	0.70861	0.00035	--	
23,707	0.70811	0.00035	0.70878	0.00035
23,708	0.70801	0.00035	0.70889	0.00035
23,710	0.70859	0.00035	0.70897	0.00035
23,711	0.70857	0.00035	0.70787	0.00035
23,712	0.70814	0.00035	0.70923	0.00035
23,713	0.70956	0.00035	0.70913	0.00035
23,714	0.71177	0.00036	0.70858	0.00035
23,715	0.70811	0.00035	0.70913	0.00035
23,716	0.70970	0.00035	0.70896	0.00035
23.717B	0.71027	0.00036	0.70903	0.00035
23,718	0.70880	0.00035	0.70905	0.00035
23,720	0.70812	0.00035	0.70877	0.00035
23,721	0.70809	0.00035	0.70904	0.00035
23,724	0.70835	0.00035	0.70869	0.00035

Inv. No.	Enamel	SU (k=2)	Dentine	SU (k=2)
23,725	0.70763	0.00035	0.70838	0.00035
23,726	0.70833	0.00035	0.70921	0.00035
23,732	0.70824	0.00035	--	
23,734	0.70826	0.00035	0.70866	0.00035
23,735	0.70795	0.00035	--	
23,737	0.70760	0.00035	--	
23,738	0.71712	0.00036	0.71056	0.00036
24,250	0.70810	0.00035	0.70879	0.00035
24,251	--		0.70905	0.00035
24,253	0.70633	0.00035	0.70945	0.00035
24,257	0.70693	0.00035	0.70890	0.00035
24,258	0.70770	0.00035	--	
24,260	0.70807	0.00035	0.70907	0.00035
24,264	0.70661	0.00035	0.70868	0.00035
24,266	0.70925	0.00035	0.70936	0.00035
24,267	0.71527	0.00036	0.70982	0.00035
24,269	0.70959	0.00035	0.70933	0.00035
24,273	0.70735	0.00035	0.70908	0.00035
24,275	0.70873	0.00035	--	
24,276	0.70895	0.00035	0.70918	0.00035
24,277	0.70875	0.00035	0.70879	0.00035
24,278	0.71058	0.00036	0.70940	0.00035
24,279	0.70785	0.00035	0.70925	0.00035
24,280	0.70827	0.00035	0.70929	0.00035
24,281	0.70846	0.00035	0.70922	0.00035
24,282	0.70957	0.00035	0.70990	0.00035
24,285	0.70325	0.00035	0.70916	0.00035

Table 31 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in tooth samples

6.3.2. Environmental samples

location (sample)	$^{87}\text{Sr}/^{86}\text{Sr}$			average	SU (k=2)
Franzhausen II (1A, 1B,1C)	0.70981	0.70985	0.70991	0.70987	0.00035
(2A,2B,2C)	0.70996	0.70984	0.70983		
Franzhausen (S21,S22)	0.70864	0.70837		0.70850	0.00035
Pischelsdorf (W1,S1)	0.70845	0.70881		0.70863	0.00035
Kleinschönbichl (W2,S2)	0.70619	0.70814		0.70717	0.00035
Erpersdorf (S3,S4)	0.70896	0.70910		0.70903	0.00035
Dürnrohr (W3,W4,S5)	0.70871	0.70821	0.70868	0.70853	0.00035
past Dürnrohr (S6)	0.70886			0.70886	0.00035
Trasdorf (W5)	0.70961			0.70961	0.00035
Kaindorf (W6)	0.70873			0.70873	0.00035
Oberbierbaum (S7)	0.70879			0.70879	0.00035
Preuwitz (S8)	0.70838			0.70838	0.00035
Czechkreuz (S9)	0.70884			0.70884	0.00035
Gemeinlebarn (W7)	0.70462			0.70462	0.00035
Sitzenberg (W8)	0.70784			0.70784	0.00035
Ahrenberg (S10)	0.71092			0.71092	0.00036
look-out Korkenzieher (S11)	0.71327			0.71327	0.00036
Traismauer (W9,W10)	0.70774	0.70769		0.70772	0.00035
St. Georgen (W11)	0.70659			0.70659	0.00035
Nußdorf o. d. Traisen (W12)	0.70761			0.70761	0.00035
Theyern (S12)	0.70807			0.70807	0.00035
past Theyern (S13)	0.70924			0.70924	0.00035
Paudorf (W13)	0.70968			0.70968	0.00035
Hirschberg (S14)	0.71221			0.71221	0.00036
Unterwölbling (S15)	0.71509			0.71509	0.00036
Dörfel (W15,S16)	0.70936	0.71302		0.71119	0.00036
Statzendorf (S17)	0.70935			0.70935	0.00035
Herzogenburg (S18)	0.70934			0.70934	0.00035
Inzersdorf (S19)	0.70936			0.70936	0.00035
Reichersdorf (S20)	0.70885			0.70885	0.00035
past Reichersdorf (W16)	0.70774			0.70774	0.00035
Getzersdorf (W17)	0.70745			0.70745	0.00035
Walpersdorf (W18)	0.70746			0.70746	0.00035
Ossarn (W19,W20,S23)	0.70626	0.70682	0.70829	0.70712	0.00035
Unterradlberg (W21)	0.70652			0.70652	0.00035
Pottenbrunn (W22,S24)	0.70736	0.70822		0.70779	0.00035
Ratzersdorf (W23,W24)	0.70732	0.70755		0.70743	0.00035
Einöd (W25)	0.70748			0.70748	0.00035

Table 32 $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of water and soil samples

6.4. Multielemental data

6.4.1. Archaeological human tooth samples

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]
23655 E_M1	2114	< 1700	15.5	6966	4725	124	< 2200	647594	< 5.6	< 23	17.5	2587	590	18.5	< 3.4	136	< 170	< 2.3	< 11
23655 E_M2	3595	< 1700	29.5	8944	4288	236	< 2200	615481	< 5.6	< 23	22.9	2742	< 110	39.3	61.4	1096	< 170	< 2.3	< 11
23674 E	5756	< 1700	< 5.6	8167	4411	468	< 2200	536653	< 5.6	< 23	19.2	2395	< 110	46.0	< 3.4	830	< 170	< 2.3	< 11
23675 E	2394	< 1700	< 5.6	8763	4378	289	< 2200	606444	< 5.6	< 23	29.3	2749	< 110	48.1	< 3.4	1414	< 170	< 2.3	< 11
23676 E	2316	< 1700	< 5.6	8711	5681	161	< 2200	623325	< 5.6	< 23	25.2	2767	< 110	74.2	< 3.4	1020	< 170	< 2.3	< 11
23677A E	2385	< 1700	< 5.6	7886	3952	235	< 2200	632044	< 5.6	< 23	40.2	2738	< 110	63.3	192.4	1560	< 170	< 2.3	< 11
23678 E	1134	< 1700	< 5.6	9111	5326	130	< 2200	610156	< 5.6	< 23	4.8	2562	< 110	59.8	3.9	< 28	< 170	< 2.3	< 11
23681 E	1263	< 1700	< 5.6	8193	3762	< 56	< 2200	633942	< 5.6	< 23	3.4	2595	169	63.0	< 3.4	450	< 170	< 2.3	< 11
23682 E	1564	< 1700	< 5.6	9620	5274	74	< 2200	616401	< 5.6	< 23	4.5	2577	< 110	30.3	< 3.4	< 28	< 170	< 2.3	< 11
23683 E	1184	< 1700	< 5.6	8026	3847	145	< 2200	638185	< 5.6	29	18.4	2806	113	57.1	285.2	492	< 170	< 2.3	< 11
23684 E	3224	< 1700	< 5.6	8293	4306	196	< 2200	664589	< 5.6	< 23	8.9	2746	< 110	76.2	< 3.4	568	< 170	< 2.3	< 11
23685 E	2155	< 1700	< 5.6	9171	5649	244	< 2200	657426	< 5.6	< 23	9.1	2789	< 110	31.5	7.2	564	< 170	< 2.3	< 11
23686 E	1117	< 1700	7.0	7941	4053	131	< 2200	607652	< 5.6	< 23	6.8	2524	< 110	23.8	< 3.4	119	< 170	< 2.3	< 11
23687 E	1724	< 1700	< 5.6	9941	5959	196	< 2200	640373	< 5.6	< 23	4.8	2674	< 110	35.7	7.9	< 28	< 170	< 2.3	< 11
23690 E	1563	< 1700	< 5.6	10140	4723	98	< 2200	628177	< 5.6	< 23	< 1.7	2485	< 110	26.9	< 3.4	< 28	< 170	< 2.3	< 11
23691 E	1823	< 1700	< 5.6	9498	5435	183	< 2200	630923	< 5.6	< 23	2.9	2579	235	29.3	15.6	1832	< 170	< 2.3	< 11
23692 E	1306	< 1700	< 5.6	8514	4416	246	< 2200	651504	< 5.6	< 23	< 1.7	2587	< 110	71.7	< 3.4	< 28	< 170	< 2.3	< 11
23695 E	1715	< 1700	< 5.6	8271	4565	147	< 2200	635884	< 5.6	< 23	47.0	2594	< 110	46.6	23.3	38	< 170	< 2.3	< 11
23699 E	1443	< 1700	< 5.6	7592	4275	80	< 2200	647915	< 5.6	< 23	7.5	2509	< 110	45.6	170.2	799	< 170	< 2.3	< 11
23700 E	1524	< 1700	< 5.6	7408	5730	77	< 2200	648066	< 5.6	< 23	4.1	2357	565	18.1	< 3.4	206	< 170	< 2.3	< 11
23701 E	1198	< 1700	< 5.6	7106	4421	141	< 2200	670444	< 5.6	< 23	3.7	2533	< 110	88.3	< 3.4	473	< 170	< 2.3	< 11
23702 E	923	< 1700	< 5.6	8672	4458	< 56	< 2200	654499	< 5.6	< 23	< 1.7	2518	< 110	50.8	< 3.4	< 28	< 170	< 2.3	< 11
23703 E	1151	< 1700	< 5.6	8761	4305	< 56	< 2200	660377	< 5.6	< 23	4.8	2533	< 110	23.1	21.9	427	< 170	< 2.3	< 11
23704 E	2203	< 1700	< 5.6	8912	4808	120	< 2200	653594	< 5.6	< 23	< 1.7	2542	< 110	20.3	< 3.4	< 28	< 170	< 2.3	< 11
23706 E	2131	< 1700	< 5.6	6789	4581	< 56	< 2200	663257	< 5.6	< 23	< 1.7	2385	467	18.9	8.0	281	< 170	< 2.3	< 11
23613 E	3962	2059	97.0	8485	3888	< 56	< 2200	489982	< 5.6	< 23	5.0	1847	690	31.0	< 3.4	57	811	< 2.3	< 11
23616 E	3867	< 1700	45.1	8564	5188	< 56	< 2200	489767	< 5.6	< 23	7.0	1793	715	20.1	< 3.4	139	549	< 2.3	< 11
23618 E	3851	2335	49.0	7618	3824	262	< 2200	500672	< 5.6	< 23	16.5	2028	828	< 1.7	19.2	270	617	< 2.3	< 11

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]
23619 E	2168	< 1700	21.4	6514	3418	119	< 2200	494509	< 5.6	< 23	13.0	1799	780	28.0	7.0	391	408	< 2.3	< 11
23620 E	1998	< 1700	19.4	6951	3919	216	< 2200	502243	< 5.6	< 23	6.9	1854	752	15.0	< 3.4	317	427	< 2.3	< 11
23621 E	1626	< 1700	7.1	7038	4032	142	< 2200	496482	< 5.6	< 23	4.5	1754	601	56.9	15.6	224	231	< 2.3	< 11
23623 E	1550	< 1700	10.0	6320	2726	284	< 2200	505393	< 5.6	< 23	71.1	1990	728	4.4	516.5	533	927	< 2.3	< 11
23625 E	1494	< 1700	11.4	7931	3290	196	< 2200	495952	< 5.6	< 23	25.8	1887	642	< 1.7	1627.6	432	868	< 2.3	< 11
23626 E	1852	< 1700	11.1	7445	3794	136	< 2200	513158	< 5.6	< 23	5.2	1809	692	33.3	< 3.4	239	355	< 2.3	< 11
23627 E	1251	< 1700	< 5.6	7228	3143	69	< 2200	510457	< 5.6	< 23	8.0	1725	623	11.9	213.1	490	341	< 2.3	< 11
23629 E	1842	2929	12.7	8978	4863	< 56	< 2200	518162	< 5.6	< 23	27.6	1800	709	14.2	< 3.4	74	325	< 2.3	< 11
23630 E	1157	< 1700	8.4	7888	4611	125	< 2200	488978	< 5.6	< 23	10.9	1753	686	9.5	< 3.4	458	287	< 2.3	< 11
23632 E	854	< 1700	< 5.6	8191	4272	169	< 2200	513883	< 5.6	< 23	1.9	1757	634	52.2	< 3.4	86	252	< 2.3	< 11
23634 E	1501	< 1700	< 5.6	9495	3921	70	< 2200	479313	< 5.6	< 23	< 1.7	1547	566	15.3	65.9	91	296	< 2.3	< 11
23636 E	1251	< 1700	< 5.6	6792	3226	58	< 2200	521121	< 5.6	< 23	10.4	1788	758	123.6	< 3.4	506	295	< 2.3	< 11
23637 E	1495	< 1700	< 5.6	6564	4656	< 56	< 2200	515539	< 5.6	< 23	3.2	1644	559	9.3	< 3.4	176	222	< 2.3	< 11
23638 E	1599	< 1700	< 5.6	7136	4749	123	< 2200	539805	< 5.6	< 23	< 1.7	1709	619	10.3	< 3.4	49	309	< 2.3	< 11
23639 E	2510	< 1700	< 5.6	6563	4218	< 56	< 2200	515905	< 5.6	< 23	< 1.7	1617	577	9.8	115.5	115	< 170	< 2.3	< 11
23.640A E	4078	1751	< 5.6	7749	3823	255	< 2200	541021	< 5.6	< 23	4.2	1875	743	69.5	30.9	231	405	< 2.3	< 11
23.640B E	2212	< 1700	< 5.6	9464	4254	45	< 2200	517173	< 5.6	< 23	2.7	1692	608	14.2	134.0	144	< 170	< 2.3	< 11
23641 E	793	< 1700	< 5.6	7521	4731	380	< 2200	530542	< 5.6	< 23	5.1	1822	720	55.7	< 3.4	195	< 170	< 2.3	< 11
23642 E	1236	< 1700	< 5.6	7793	3957	< 56	< 2200	529770	< 5.6	< 23	< 1.7	1809	600	31.4	35.4	87	< 170	< 2.3	< 11
23644 E	1031	< 1700	< 5.6	7805	3911	342	< 2200	522570	< 5.6	< 23	4.2	1791	750	59.1	< 3.4	171	482	< 2.3	< 11
23645 E	1242	< 1700	< 5.6	8799	4424	84	< 2200	538344	< 5.6	< 23	2.8	1863	659	52.1	< 3.4	177	220	< 2.3	< 11
23649 E	1332	< 1700	< 5.6	8105	4976	319	< 2200	532579	< 5.6	< 23	5.3	2107	765	28.7	8.7	265	677	< 2.3	< 11
23650 E	1390	< 1700	< 5.6	7008	3542	112	< 2200	543052	< 5.6	< 23	7.6	1896	711	37.7	< 3.4	558	356	< 2.3	< 11
23652A E	1469	3064	10.7	9933	5028	359	< 2200	555057	< 5.6	< 23	9.2	2021	1129	30.3	41.5	102	1516	< 2.3	< 11
23653 E	1483	2390	9.0	9248	6037	687	< 2200	531836	< 5.6	< 23	7.8	2308	919	34.8	93.4	58	596	< 2.3	< 11
23656 E	1604	< 1700	< 5.6	8626	3874	178	< 2200	560493	< 5.6	< 23	3.5	1933	791	38.9	< 3.4	215	348	< 2.3	< 11
23657 E	818	2568	< 5.6	7873	3804	269	< 2200	557975	< 5.6	< 23	3.3	2026	645	64.4	25.5	355	170	< 2.3	< 11
23661 E	1805	2273	8.3	8985	3699	210	< 2200	561050	< 5.6	< 23	2.3	1949	699	43.6	22.3	61	458	< 2.3	< 11
23662 E	2008	< 1700	< 5.6	7797	4419	338	< 2200	559312	< 5.6	< 23	12.9	2114	863	52.8	< 3.4	447	908	< 2.3	< 11
23663 E1	1425	< 1700	< 5.6	10325	5134	154	< 2200	548377	< 5.6	< 23	1.9	1789	669	4.7	< 3.4	59	602	< 2.3	< 11
23664 E	1353	2632	10.8	7653	3460	315	< 2200	564007	< 5.6	< 23	8.8	1978	818	6.1	382.5	580	910	< 2.3	15

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]
23665 E	702	< 1700	< 5.6	8553	4538	156	< 2200	559847	< 5.6	< 23	4.6	1926	782	39.0	< 3.4	243	1056	< 2.3	11
23667 E	1690	< 1700	< 5.6	10542	4707	128	< 2200	570815	< 5.6	< 23	9.8	1918	736	8.2	< 3.4	58	506	< 2.3	< 11
23668 E	662	2235	< 5.6	8279	4258	160	< 2200	562223	< 5.6	24	7.8	2327	911	< 1.7	48.1	452	666	< 2.3	20
23669 E	1749	< 1700	< 5.6	7955	3860	64	< 2200	559381	< 5.6	< 23	4.2	1884	704	17.2	< 3.4	315	271	< 2.3	< 11
23670 E	1553	< 1700	< 5.6	8681	4351	74	< 2200	557257	< 5.6	< 23	8.7	1896	619	25.6	< 3.4	130	444	< 2.3	< 11
23671 E	1085	1890	< 5.6	6773	3699	58	< 2200	548863	< 5.6	< 23	11.1	1933	695	31.6	136.5	337	432	< 2.3	< 11
23672 E	1128	1739	< 5.6	8314	4345	< 56	< 2200	555024	< 5.6	< 23	2.8	1948	690	15.8	< 3.4	236	738	< 2.3	< 11
23707 E	1341	< 1700	< 5.6	8373	3891	89	< 2200	554396	< 5.6	< 23	10.8	2049	910	13.3	168.0	296	365	< 2.3	< 11
23708 E	1654	1809	12.4	9492	4785	149	< 2200	551301	< 5.6	< 23	< 1.7	2047	691	11.5	< 3.4	66	408	< 2.3	< 11
23710 E	2395	< 1700	< 5.6	8917	3901	< 56	< 2200	553012	< 5.6	< 23	3.1	1858	718	15.9	< 3.4	139	321	< 2.3	< 11
23711 E	1598	2018	< 5.6	8270	4195	161	< 2200	550698	< 5.6	< 23	9.2	1977	1140	2200.9	< 3.4	325	463	< 2.3	< 11
23712 E	1077	< 1700	< 5.6	6264	3481	< 56	< 2200	565398	< 5.6	< 23	4.2	1994	1063	7.9	992.0	460	301	< 2.3	< 11
23713 E	1395	2045	< 5.6	7951	4821	94	< 2200	570864	< 5.6	< 23	2.1	2072	711	28.2	15.8	290	364	< 2.3	< 11
23714 E	2270	< 1700	< 5.6	6375	3357	165	< 2200	559057	< 5.6	< 23	34.0	1960	680	12.1	103.2	202	816	< 2.3	< 11
23715 E	1318	2918	< 5.6	8425	4500	356	< 2200	547978	< 5.6	< 23	7.7	2056	987	53.2	< 3.4	234	540	< 2.3	< 11
23.716 E	2153	< 1700	< 5.6	7007	3170	< 56	< 2200	556262	< 5.6	< 23	3.3	1927	658	43.8	< 3.4	374	223	< 2.3	< 11
23.717B E	1298	< 1700	< 5.6	7585	4103	65	< 2200	546886	< 5.6	< 23	1.8	1941	640	77.9	< 3.4	151	275	< 2.3	< 11
23718 E	1048	< 1700	< 5.6	7666	3981	< 56	< 2200	542195	< 5.6	< 23	9.5	1959	753	35.0	11.5	414	< 170	< 2.3	< 11
23720 E	2122	1885	< 5.6	6959	3121	109	< 2200	551884	< 5.6	< 23	4.7	2014	1565	60.9	705.6	543	291	< 2.3	< 11
23721 E	1442	< 1700	8.4	7262	3797	< 56	< 2200	555574	< 5.6	< 23	3.8	1875	767	57.2	25.6	305	360	< 2.3	< 11
23724 E	2097	< 1700	< 5.6	10745	5527	67	< 2200	549551	< 5.6	< 23	3.9	1961	735	16.3	< 3.4	106	399	< 2.3	< 11
23725 E	1035	2077	< 5.6	6670	2882	< 56	< 2200	528627	< 5.6	< 23	5.5	2089	755	18.8	< 3.4	494	337	< 2.3	< 11
23726 E	783	< 1700	5.8	6138	2915	< 56	< 2200	555880	< 5.6	< 23	7.2	1981	681	102.1	121.3	630	239	< 2.3	< 11
23732 E	671	< 1700	< 5.6	7680	3369	128	< 2200	559408	< 5.6	< 23	17.1	2045	776	22.0	5.1	420	346	< 2.3	< 11
23734 E	1580	3098	< 5.6	7346	4909	498	< 2200	515575	< 5.6	< 23	9.3	2350	679	< 1.7	< 3.4	272	579	< 2.3	< 11
23735 E	1464	1792	23.9	6155	3321	159	< 2200	490885	< 5.6	< 23	6.7	1815	884	118.0	25.5	528	199	< 2.3	< 11
23737 E	1295	1994	12.5	5021	2954	< 56	< 2200	447571	< 5.6	< 23	7.3	1587	923	23.2	162.0	559	179	< 2.3	< 11
23738 E	1833	< 1700	< 5.6	7758	3541	< 56	< 2200	482611	< 5.6	< 23	2.4	1673	831	7.9	< 3.4	233	310	< 2.3	< 11
24250 E	1591	< 1700	< 5.6	7526	3584	< 56	< 2200	489413	< 5.6	< 23	< 1.7	1663	774	39.8	< 3.4	115	267	< 2.3	< 11
24251 E	1477	< 1700	< 5.6	8253	3672	< 56	< 2200	484966	< 5.6	< 23	< 1.7	1673	738	4.5	< 3.4	88	395	< 2.3	< 11
24253 E1	1403	1981	< 5.6	8697	4073	< 56	< 2200	492737	< 5.6	< 23	< 1.7	1660	994	< 1.7	< 3.4	57	< 170	< 2.3	< 11

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]
24257 E	734	2643	< 5.6	5698	2874	< 56	< 2200	456925	< 5.6	< 23	8.4	1574	1047	14.7	< 3.4	463	235	< 2.3	< 11
24258 E	1689	2339	< 5.6	7695	4101	< 56	< 2200	486396	< 5.6	< 23	5.0	1686	989	< 1.7	< 3.4	206	265	< 2.3	< 11
24260 E	1627	2778	< 5.6	5557	3030	< 56	< 2200	492481	< 5.6	< 23	3.0	1579	1098	16.5	< 3.4	287	< 170	< 2.3	< 11
24264 E	962	2225	< 5.6	5106	2742	< 56	< 2200	468019	< 5.6	< 23	8.9	1526	1053	< 1.7	< 3.4	607	264	< 2.3	< 11
24266 E1	1278	< 1700	< 5.6	8577	3659	< 56	< 2200	496801	< 5.6	< 23	< 1.7	1640	732	5.3	< 3.4	60	263	< 2.3	< 11
24267 E	1981	< 1700	< 5.6	6923	3467	< 56	< 2200	473092	< 5.6	< 23	2.0	1532	850	19.3	6.1	194	635	< 2.3	< 11
24269 E	1017	1868	< 5.6	6189	3455	< 56	< 2200	494435	< 5.6	< 23	12.1	1681	907	43.9	< 3.4	288	216	< 2.3	< 11
24273 E	1063	< 1700	< 5.6	6170	3192	< 56	< 2200	489466	< 5.6	< 23	6.1	1638	809	24.8	< 3.4	401	176	< 2.3	< 11
24275 E	2255	1764	< 5.6	6249	2717	< 56	< 2200	489201	< 5.6	< 23	2.6	1627	988	54.5	< 3.4	558	< 170	< 2.3	< 11
24276 E	981	< 1700	< 5.6	5312	2353	< 56	< 2200	493724	< 5.6	< 23	79.8	1801	862	2.4	95.8	940	1011	< 2.3	< 11
24277 E	1435	2011	< 5.6	4931	2755	< 56	< 2200	489583	< 5.6	< 23	6.1	1602	849	6.8	35.5	660	< 170	< 2.3	< 11
24278 E	760	< 1700	< 5.6	5788	2851	< 56	< 2200	481062	< 5.6	< 23	5.7	1572	758	12.1	< 3.4	365	427	< 2.3	< 11
24279 E	1067	< 1700	< 5.6	5372	2675	< 56	< 2200	493282	< 5.6	< 23	10.6	1688	831	16.8	4.6	515	191	< 2.3	< 11
24280 E	409	< 1700	< 5.6	6642	4015	< 56	< 2200	493195	< 5.6	< 23	3.5	1611	876	24.4	72.5	313	< 170	< 2.3	< 11
24281 E	950	< 1700	< 5.6	6140	2670	< 56	< 2200	500759	< 5.6	< 23	7.0	1689	818	8.0	135.8	643	202	< 2.3	< 11
24282 E	1967	< 1700	< 5.6	5869	3214	< 56	< 2200	488298	< 5.6	< 23	10.4	1623	924	6.6	< 3.4	649	272	< 2.3	< 11
24285 E	918	2532	< 5.6	7421	3737	< 56	< 2200	495038	< 5.6	< 23	< 1.7	1665	1635	18.0	< 3.4	1120	376	< 2.3	< 11
average	1645	2255	--	7748	4049	185	--	548199	--	27	10	2016	768	56	149	380	442	--	15
method LoD	280	1700	5.6	39	39	56	2200	450	5.6	23	1.7	560	110	1.7	3.4	28	170	2.3	11
method LoQ	930	6100	20.0	140	120	230	7600	1500	18.0	75	5.7	1900	460	5.0	10.0	97	510	8.2	33
RSU (k=2)	15%	--*	--	4%	3%	3%	--	3%	--	--*	23%	33%	24%	13%	8%	11%	27%	--	--*

* all values below LoQ

Table 33 Multielemental data of enamel samples

Analyte	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23655 E_M1	230	173	934	< 110	< 390	< 560	5.9	< 110	1203	< 170	513
23655 E_M2	219	176	1145	< 110	< 390	< 560	< 2.3	< 110	21881	< 170	< 110
23674 E	< 170	195	444	< 110	< 390	< 560	< 2.3	< 110	18840	< 170	< 110
23675 E	< 170	186	235	< 110	< 390	< 560	< 2.3	< 110	31143	2987	< 110
23676 E	< 170	135	< 230	< 110	< 390	< 560	< 2.3	< 110	27149	< 170	< 110
23677A E	< 170	108	< 230	< 110	< 390	< 560	< 2.3	< 110	18754	< 170	< 110
23678 E	< 170	115	< 230	< 110	774	< 560	< 2.3	< 110	3868	< 170	< 110
23681 E	< 170	96	< 230	< 110	< 390	< 560	< 2.3	< 110	2531	< 170	< 110
23682 E	< 170	96	< 230	< 110	< 390	< 560	< 2.3	< 110	4656	< 170	< 110
23683 E	< 170	132	< 230	2244	< 390	< 560	< 2.3	< 110	5700	< 170	< 110
23684 E	< 170	148	342	< 110	< 390	< 560	< 2.3	< 110	4203	< 170	< 110
23685 E	< 170	179	< 230	< 110	< 390	< 560	< 2.3	< 110	7188	< 170	< 110
23686 E	< 170	143	< 230	< 110	< 390	< 560	< 2.3	< 110	5569	< 170	< 110
23687 E	< 170	111	< 230	< 110	< 390	< 560	< 2.3	< 110	5761	< 170	< 110
23690 E	< 170	160	< 230	< 110	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23691 E	< 170	190	< 230	< 110	< 390	< 560	< 2.3	< 110	797	< 170	< 110
23692 E	< 170	102	< 230	< 110	< 390	< 560	< 2.3	< 110	982	< 170	< 110
23695 E	< 170	161	< 230	1189	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23699 E	< 170	173	< 230	< 110	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23700 E	< 170	139	< 230	< 110	< 390	< 560	9.9	< 110	< 450	< 170	< 110
23701 E	< 170	156	< 230	< 110	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23702 E	< 170	248	< 230	< 110	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23703 E	< 170	95	< 230	359	< 390	< 560	< 2.3	< 110	559	< 170	< 110
23704 E	< 170	94	< 230	< 110	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23706 E	< 170	245	< 230	933	< 390	< 560	< 2.3	< 110	< 450	< 170	< 110
23613 E	415	169	2305	564	< 390	774	15.0	143	1712	< 170	< 110
23616 E	< 170	151	568	260	< 390	< 560	9.8	< 110	1197	< 170	< 110
23618 E	216	186	1334	304	< 390	< 560	9.8	< 110	< 450	< 170	< 110
23619 E	< 170	175	< 230	177	< 390	< 560	4.8	< 110	853	< 170	< 110
23620 E	171	176	< 230	162	< 390	< 560	5.1	< 110	684	2245	< 110
23621 E	195	133	< 230	143	< 390	< 560	3.7	< 110	945	< 170	< 110
23623 E	< 170	77	< 230	184	< 390	< 560	20.3	< 110	1587	< 170	< 110
23625 E	< 170	140	< 230	336	< 390	583	15.2	< 110	2206	1485	< 110
23626 E	< 170	94	< 230	< 110	< 390	< 560	5.4	< 110	< 450	< 170	< 110
23627 E	< 170	145	< 230	518	< 390	< 560	5.6	< 110	1011	< 170	< 110
23629 E	< 170	108	< 230	149	< 390	< 560	6.3	< 110	888	< 170	< 110
23630 E	< 170	118	< 230	< 110	< 390	681	6.0	< 110	993	< 170	< 110
23632 E	< 170	88	< 230	< 110	< 390	764	4.9	< 110	< 450	< 170	< 110
23634 E	< 170	112	< 230	611	< 390	< 560	5.9	< 110	< 450	< 170	< 110
23636 E	< 170	197	672	< 110	< 390	< 560	7.4	< 110	584	< 170	< 110
23637 E	< 170	149	< 230	< 110	< 390	< 560	5.0	< 110	< 450	< 170	< 110
23638 E	< 170	175	< 230	< 110	< 390	< 560	6.3	< 110	< 450	< 170	< 110
23639 E	< 170	136	< 230	152	< 390	< 560	3.1	< 110	499	< 170	< 110
23.640A E	< 170	85	< 230	605	< 390	< 560	10.8	< 110	1262	< 170	< 110
23.640B E	< 170	153	< 230	578	< 390	< 560	3.0	< 110	< 450	< 170	< 110
23641 E	< 170	167	< 230	< 110	< 390	< 560	4.1	< 110	564	229	< 110

Analyte	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23642 E	< 170	194	< 230	246	< 390	< 560	4.9	< 110	1921	< 170	< 110
23644 E	303	113	< 230	< 110	< 390	1038	8.4	< 110	1236	< 170	< 110
23645 E	< 170	141	< 230	< 110	< 390	752	4.8	< 110	513	< 170	< 110
23649 E	< 170	122	< 230	353	< 390	< 560	10.8	< 110	824	< 170	< 110
23650 E	< 170	134	< 230	< 110	< 390	768	7.1	< 110	530	< 170	< 110
23652A E	432	118	238	144	< 390	588	23.6	< 110	1680	< 170	< 110
23653 E	936	142	< 230	< 110	< 390	672	8.1	< 110	527	< 170	< 110
23656 E	< 170	108	< 230	113	< 390	639	4.9	< 110	< 450	< 170	< 110
23657 E	< 170	113	< 230	2085	< 390	1167	7.3	< 110	1281	< 170	< 110
23661 E	< 170	105	< 230	< 110	< 390	954	6.0	< 110	< 450	< 170	< 110
23662 E	< 170	168	< 230	< 110	< 390	< 560	13.8	< 110	< 450	< 170	< 110
23663 E1	< 170	121	< 230	< 110	< 390	< 560	13.2	< 110	< 450	< 170	< 110
23664 E	< 170	120	< 230	1752	< 390	< 560	11.6	< 110	< 450	< 170	< 110
23665 E	< 170	82	< 230	< 110	< 390	< 560	21.1	< 110	984	< 170	< 110
23667 E	< 170	102	< 230	< 110	< 390	< 560	9.7	< 110	1836	< 170	< 110
23668 E	< 170	95	< 230	1065	< 390	1189	11.5	< 110	< 450	< 170	< 110
23669 E	< 170	160	< 230	< 110	< 390	< 560	5.2	< 110	656	< 170	< 110
23670 E	< 170	192	< 230	< 110	< 390	< 560	8.5	< 110	< 450	< 170	< 110
23671 E	< 170	177	< 230	3140	< 390	988	6.2	< 110	< 450	< 170	< 110
23672 E	< 170	91	< 230	< 110	< 390	< 560	13.6	< 110	748	< 170	< 110
23707 E	< 170	157	8698	2527	< 390	931	4.6	< 110	< 450	< 170	< 110
23708 E	< 170	142	< 230	< 110	< 390	< 560	5.3	< 110	< 450	< 170	< 110
23710 E	< 170	171	< 230	1131	< 390	< 560	4.7	< 110	< 450	< 170	< 110
23711 E	< 170	146	< 230	< 110	< 390	< 560	7.1	< 110	< 450	< 170	< 110
23712 E	< 170	187	< 230	5405	< 390	< 560	5.7	< 110	1190	< 170	< 110
23713 E	< 170	86	< 230	1013	< 390	588	4.9	< 110	< 450	< 170	< 110
23714 E	< 170	157	< 230	612	< 390	< 560	16.0	< 110	648	< 170	< 110
23715 E	< 170	209	< 230	< 110	< 390	< 560	7.3	< 110	691	< 170	< 110
23.716 E	< 170	135	< 230	< 110	< 390	< 560	3.3	< 110	< 450	< 170	< 110
23.717B E	< 170	96	< 230	< 110	< 390	< 560	4.6	< 110	< 450	< 170	< 110
23718 E	< 170	83	< 230	627	< 390	< 560	3.9	< 110	< 450	< 170	< 110
23720 E	< 170	211	< 230	4297	< 390	< 560	3.8	< 110	< 450	< 170	< 110
23721 E	< 170	162	< 230	4161	< 390	< 560	4.6	< 110	< 450	< 170	< 110
23724 E	< 170	241	< 230	< 110	< 390	< 560	4.8	< 110	< 450	< 170	< 110
23725 E	< 170	159	< 230	< 110	< 390	< 560	4.1	< 110	< 450	< 170	< 110
23726 E	< 170	136	< 230	613	< 390	< 560	4.9	< 110	< 450	< 170	< 110
23732 E	< 170	163	< 230	< 110	< 390	787	4.7	< 110	458	< 170	< 110
23734 E	448	142	< 230	< 110	< 390	807	8.2	< 110	701	< 170	< 110
23735 E	< 170	141	2970	< 110	< 390	< 560	5.5	< 110	< 450	< 170	< 110
23737 E	< 170	116	523	113	< 390	< 560	4.3	< 110	860	< 170	< 110
23738 E	< 170	97	326	< 110	< 390	< 560	8.2	< 110	< 450	< 170	< 110
24250 E	< 170	93	< 230	< 110	< 390	791	8.9	< 110	< 450	< 170	< 110
24251 E	< 170	106	< 230	< 110	< 390	< 560	8.5	< 110	< 450	< 170	< 110
24253 E1	< 170	67	< 230	< 110	< 390	< 560	6.2	< 110	996	< 170	< 110
24257 E	< 170	69	< 230	< 110	< 390	< 560	9.7	< 110	< 450	< 170	< 110
24258 E	474	98	385	< 110	< 390	< 560	5.0	< 110	892	< 170	< 110

Analyte	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
24260 E	< 170	53	< 230	< 110	< 390	< 560	2.6	< 110	< 450	< 170	< 110
24264 E	< 170	108	< 230	< 110	< 390	1089	7.9	< 110	< 450	< 170	< 110
24266 E1	< 170	111	< 230	< 110	< 390	< 560	6.3	< 110	< 450	< 170	< 110
24267 E	< 170	100	< 230	< 110	< 390	601	16.8	< 110	< 450	< 170	< 110
24269 E	173	61	< 230	< 110	< 390	< 560	8.2	< 110	< 450	< 170	< 110
24273 E	< 170	62	< 230	< 110	< 390	< 560	6.6	< 110	< 450	< 170	< 110
24275 E	< 170	161	< 230	< 110	< 390	590	4.0	< 110	< 450	< 170	< 110
24276 E	< 170	109	< 230	500	509	< 560	25.1	< 110	700	< 170	< 110
24277 E	< 170	124	354	664	< 390	627	3.2	< 110	< 450	< 170	< 110
24278 E	< 170	66	< 230	< 110	< 390	< 560	9.6	< 110	< 450	< 170	< 110
24279 E	< 170	109	< 230	< 110	< 390	< 560	5.1	< 110	584	< 170	< 110
24280 E	< 170	73	< 230	1201	< 390	< 560	4.7	< 110	669	< 170	< 110
24281 E	< 170	217	< 230	566	< 390	< 560	6.0	< 110	619	< 170	< 110
24282 E	< 170	109	< 230	< 110	< 390	782	9.9	< 110	< 450	< 170	< 110
24285 E	< 170	105	< 230	< 110	7653	< 560	10.2	< 110	554	< 170	< 110
average	351	135	1342	1045	2979	798	8	143	3537	1736	513
method LoD	170	0.28	230	110	390	560	2.3	110	450	170	110
method LoQ	500	1.0	710	430	1300	1900	7.6	320	1500	570	300
RSU (k=2)	10%	9%	17%	30%	18%	--*	11%	--*	17%	15%	14%

* all values below LoQ

Table 34 Multielemental data of enamel samples (continued)

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]
23655 D_M1	4642	< 1700	27.8	3630	4272	652	< 2200	522491	7.5	< 23	227.6
23655 D_M2	2985	< 1700	20.9	3434	3152	291	< 2200	552947	5.9	< 23	48.6
23674 D	4107	< 1700	10.5	3894	3194	618	< 2200	500937	9.2	27	45.0
23675 D	2066	< 1700	< 5.6	3821	2682	227	< 2200	477266	6.9	26	22.9
23676 D	1831	< 1700	< 5.6	4496	3591	633	< 2200	493796	7.6	25	23.3
23677A D	2188	< 1700	< 5.6	3853	2453	87	< 2200	491706	< 5.6	< 23	157.8
23678 D	1192	< 1700	< 5.6	4079	3528	260	< 2200	518824	6.4	< 23	10.4
23681 D	3323	< 1700	< 5.6	3099	6124	713	< 2200	485413	5.8	< 23	32.2
23682 D	2140	< 1700	< 5.6	3634	3305	425	< 2200	508046	7.8	25	13.6
23683 D	1168	< 1700	< 5.6	3071	2833	117	< 2200	503771	< 5.6	< 23	4.9
23684 D	2100	< 1700	< 5.6	4092	3801	779	< 2200	528612	8.2	< 23	17.2
23685 D	1679	< 1700	< 5.6	4652	4171	473	< 2200	502119	6.3	< 23	8.0
23686 D	1413	< 1700	< 5.6	3148	3864	265	< 2200	599298	< 5.6	< 23	8.5
23687 D	1575	< 1700	< 5.6	3452	3648	286	< 2200	552240	8.6	< 23	8.6
23690 D	1667	< 1700	< 5.6	4444	2939	271	< 2200	474860	6.8	< 23	7.6
23691 D	1524	< 1700	< 5.6	4203	2778	195	< 2200	523040	7.1	< 23	1.9
23692 D	2478	< 1700	< 5.6	3125	2265	131	< 2200	497311	7.2	< 23	16.8
23695 D	2430	< 1700	< 5.6	2591	2753	213	< 2200	612930	9.4	< 23	29.3
23699 D	1775	< 1700	< 5.6	3608	2926	56	< 2200	549005	< 5.6	< 23	4.5
23700 D	1850	< 1700	< 5.6	4999	3683	160	< 2200	506569	< 5.6	< 23	3.5
23701 D	2431	< 1700	< 5.6	3109	2595	658	< 2200	575904	10.2	26	36.6

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]
23702 D	1894	< 1700	< 5.6	1833	2618	228	< 2200	552182	6.8	< 23	7.4
23703 D	1794	< 1700	< 5.6	3355	2546	132	< 2200	553221	< 5.6	< 23	4.2
23704 D	2087	< 1700	< 5.6	3458	3063	78	< 2200	577566	6.0	< 23	< 1.7
23706 D	2710	< 1700	< 5.6	2698	2082	104	< 2200	497090	11.0	< 23	37.2
23613 D	2227	< 1700	34.1	3878	2646	191	< 2200	373898	< 5.6	< 23	4.5
23616 D	2673	< 1700	28.6	3557	3002	512	< 2200	390448	< 5.6	< 23	23.3
23618 D	4963	< 1700	24.6	3668	3775	896	< 2200	371283	< 5.6	< 23	43.6
23619 D	2625	< 1700	12.9	2115	6060	1074	< 2200	422297	< 5.6	< 23	22.4
23620 D	1471	< 1700	15.4	3416	2581	234	< 2200	400558	< 5.6	< 23	3.3
23621 D	1827	< 1700	7.0	3034	2394	199	< 2200	401283	< 5.6	< 23	2.9
23623 D	3363	< 1700	10.0	3406	2065	165	< 2200	388108	< 5.6	< 23	35.3
23625 D	2133	< 1700	12.5	3965	1759	206	< 2200	404965	< 5.6	< 23	236.1
23626 D	2596	< 1700	12.8	3221	4052	1004	< 2200	433251	5.8	< 23	28.1
23627 D	734	< 1700	< 5.6	5691	3539	< 56	< 2200	367622	< 5.6	< 23	3.9
23629 D	2922	< 1700	13.4	2026	6079	1961	< 2200	478481	7.1	24	17.3
23630 D	1556	< 1700	10.4	4184	3851	326	< 2200	388093	< 5.6	< 23	4.1
23632 D	2078	< 1700	14.4	2998	3822	1068	< 2200	442876	7.0	< 23	32.7
23634 D	1904	< 1700	8.0	3476	3086	381	< 2200	426911	< 5.6	< 23	11.7
23636 D	1827	< 1700	< 5.6	3583	2555	93	< 2200	384152	< 5.6	< 23	6.7
23637 D	1314	< 1700	< 5.6	4732	5842	323	< 2200	365188	< 5.6	< 23	4.1
23638 D	2606	< 1700	< 5.6	3165	1873	229	< 2200	389758	5.6	< 23	2.2
23639 D	1668	< 1700	69.3	4193	2710	384	< 2200	373063	< 5.6	< 23	3.3
23.640A D	3450	< 1700	41.8	3564	5042	1170	< 2200	390969	< 5.6	< 23	25.9
23.640B D	1822	< 1700	< 5.6	3862	2307	230	< 2200	385270	< 5.6	< 23	6.9
23641 D	1163	< 1700	6.9	3477	2873	504	< 2200	438176	< 5.6	< 23	9.4
23642 D	5427	1792	< 5.6	3958	2739	549	< 2200	397821	< 5.6	< 23	13.1
23644 D	1795	< 1700	6.5	3611	2715	354	< 2200	457543	< 5.6	< 23	10.6
23645 D	1428	< 1700	< 5.6	4106	2534	180	< 2200	428537	< 5.6	23	7.7
23649 D	1112	< 1700	< 5.6	3539	2811	319	< 2200	451866	< 5.6	< 23	4.6
23650 D	1616	< 1700	< 5.6	3722	3511	705	< 2200	386553	5.9	< 23	9.2
23652A D	1901	1941	18.5	4596	2856	957	< 2200	427968	8.8	25	14.5
23653 D	1213	< 1700	6.7	4107	2669	368	< 2200	433904	6.0	< 23	9.1
23656 D	2101	< 1700	< 5.6	3000	3038	444	< 2200	482269	6.3	< 23	29.1
23657 D	2168	< 1700	31.4	2742	4651	587	< 2200	507104	< 5.6	< 23	10.5
23661 D	2903	1881	< 5.6	3553	1872	412	< 2200	418038	6.9	< 23	31.6
23662 D	1395	< 1700	< 5.6	4419	2278	148	< 2200	421437	8.1	< 23	5.4
23663 D	962	2550	< 5.6	4005	2463	284	< 2200	444445	8.7	< 23	2.1
23664 D	1200	2160	< 5.6	4131	2305	129	< 2200	415868	5.6	< 23	19.0
23665 D	1286	< 1700	< 5.6	3483	2442	311	< 2200	465089	8.4	< 23	6.5
23667 D	1470	1910	< 5.6	4452	4608	436	< 2200	430187	6.8	25	21.7
23668 D	814	2345	< 5.6	4402	3086	272	< 2200	418417	< 5.6	< 23	< 1.7
23669 D	1292	< 1700	< 5.6	4799	3302	305	< 2200	437500	< 5.6	< 23	3.9
23670 D	2292	< 1700	< 5.6	3882	2264	66	< 2200	418630	< 5.6	35	< 1.7
23671 D	1092	1751	< 5.6	4242	3834	202	< 2200	432329	< 5.6	< 23	2.3
23672 D	898	< 1700	< 5.6	3948	3086	118	< 2200	433800	< 5.6	< 23	< 1.7
23707 D	1348	< 1700	5.9	3175	2412	488	< 2200	483981	< 5.6	< 23	25.3

Analyte	Li [ng/g]	Be [ng/g]	B [µg/g]	Na [µg/g]	Mg [µg/g]	Al [µg/g]	K [µg/g]	Ca [µg/g]	V [µg/g]	Cr [µg/g]	Mn [µg/g]
23708 D	1836	< 1700	< 5.6	3889	2573	204	< 2200	448765	7.6	< 23	5.5
23710 D	2393	< 1700	8.7	3353	2823	141	< 2200	453954	6.0	< 23	2.7
23711 D	1945	< 1700	5.6	2851	2523	170	< 2200	475125	6.0	< 23	4.0
23712 D	2565	< 1700	< 5.6	3628	1808	57	< 2200	413046	< 5.6	< 23	11.2
23713 D	1895	2129	6.9	3640	2630	365	< 2200	472520	< 5.6	< 23	14.8
23714 D	2519	< 1700	< 5.6	2349	2738	178	< 2200	454766	7.2	< 23	297.0
23715 D	1588	< 1700	< 5.6	3395	2396	162	< 2200	451079	7.1	< 23	5.3
23.716 D	1668	< 1700	6.7	2556	2771	67	< 2200	489425	< 5.6	< 23	2.1
23.717B D	1496	< 1700	6.9	3113	2418	198	< 2200	448849	6.0	< 23	2.7
23718 D	1557	< 1700	< 5.6	4152	2366	115	< 2200	427586	< 5.6	< 23	2.2
23720 D	1652	1714	< 5.6	4067	2481	89	< 2200	404256	< 5.6	< 23	1.8
23721 D	1475	< 1700	7.1	2346	1996	220	< 2200	446543	< 5.6	< 23	19.9
23724 D	2381	< 1700	< 5.6	3341	1942	198	< 2200	427909	6.9	31	117.2
23725 D	2317	3233	< 5.6	3087	1646	< 56	< 2200	394218	5.7	32	14.7
23726 D	2652	< 1700	< 5.6	2000	2081	68	< 2200	482473	< 5.6	< 23	17.0
23732 D	1144	< 1700	< 5.6	2776	2289	82	< 2200	437257	< 5.6	< 23	3.2
23734 D	2318	1738	52.0	3320	2483	276	< 2200	384437	< 5.6	< 23	6.7
23735 D	2550	< 1700	13.6	2039	1980	117	< 2200	425067	< 5.6	< 23	6.1
23737 D	2514	< 1700	8.2	1888	1680	139	< 2200	430444	< 5.6	< 23	8.5
23738 D	978	< 1700	< 5.6	3343	1999	< 56	< 2200	390098	< 5.6	< 23	3.6
24250 D	1693	2433	< 5.6	2343	1674	300	< 2200	387235	< 5.6	< 23	9.3
24251 D	1547	< 1700	< 5.6	3062	3606	158	< 2200	370845	< 5.6	< 23	5.7
24253 D	1346	< 1700	< 5.6	4022	3502	< 56	< 2200	371235	< 5.6	< 23	7.8
24257 D	2214	< 1700	< 5.6	2461	2106	186	< 2200	428794	< 5.6	< 23	5.8
24258 D	2276	1734	< 5.6	3436	3390	1079	< 2200	395354	5.7	< 23	17.7
24260 D	2338	< 1700	< 5.6	2259	4463	807	< 2200	427570	< 5.6	< 23	35.1
24264 D	2004	< 1700	< 5.6	2031	1996	206	< 2200	398588	< 5.6	< 23	6.0
24266 D	1426	< 1700	< 5.6	2834	2413	207	< 2200	438743	< 5.6	< 23	7.0
24267 D	1532	< 1700	< 5.6	3465	2566	< 56	< 2200	379215	< 5.6	< 23	2.4
24269 D	3108	< 1700	< 5.6	1790	2254	542	< 2200	447300	< 5.6	< 23	8.5
24273 D	1723	< 1700	< 5.6	2184	1968	92	< 2200	436923	< 5.6	< 23	5.8
24275 D	1753	< 1700	< 5.6	2615	1942	177	< 2200	429483	< 5.6	< 23	7.3
24276 D	2250	< 1700	< 5.6	1941	1801	< 56	< 2200	430581	< 5.6	< 23	11.4
24277 D	1634	< 1700	< 5.6	2665	2053	211	< 2200	427855	6.9	< 23	9.9
24278 D	2079	< 1700	< 5.6	2619	2727	161	< 2200	393876	< 5.6	< 23	5.7
24279 D	1034	< 1700	< 5.6	1978	2156	113	< 2200	440962	< 5.6	< 23	6.5
24280 D	1210	< 1700	< 5.6	3587	2347	< 56	< 2200	370926	< 5.6	< 23	1.9
24281 D	1819	< 1700	< 5.6	2960	3973	625	< 2200	437692	< 5.6	< 23	17.1
24282 D	1205	< 1700	< 5.6	3467	3788	125	< 2200	397328	< 5.6	< 23	2.4
24285 D	1650	< 1700	< 5.6	2136	2221	110	< 2200	445030	< 5.6	< 23	2.5
Average	1990	2094	17	3382	2924	348	--	446546	7	27	22
method LoD	280	1700	5.6	39	39	56	2200	450	5.6	23	1.7
method LoQ	930	6100	20.0	140	120	230	7600	1500	18.0	75	5.7
RSU (k=2)	22%	--*	36%	3%	5%	14%	--	3%	--*	--*	17%

* all values below LoQ

Table 35 Multielemental data of dentine samples

Analyte	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23655 D_M1	2756	890	31.3	18.9	1321	< 170	75.1	< 11	570	445	1586	< 110	641	< 560	65.0	< 110	16158	< 170	13784
23655 D_M2	2417	528	27.7	11.1	1007	< 170	< 2.3	< 11	232	354	433	< 110	< 390	< 560	43.4	< 110	11585	< 170	14779
23674 D	2596	< 110	37.9	8.0	1266	< 170	< 2.3	< 11	571	320	< 230	< 110	< 390	< 560	49.9	< 110	26354	< 170	11323
23675 D	2261	< 110	36.3	4.2	1236	< 170	< 2.3	< 11	< 170	323	< 230	< 110	< 390	< 560	49.4	< 110	24581	< 170	21861
23676 D	2420	621	29.3	32.3	892	< 170	< 2.3	< 11	510	369	< 230	< 110	< 390	< 560	74.6	< 110	14499	< 170	17650
23677A D	2026	321	20.6	541.8	489	< 170	18.2	< 11	< 170	292	< 230	< 110	< 390	< 560	45.0	< 110	2668	< 170	14442
23678 D	2274	174	19.9	86.5	291	< 170	< 2.3	< 11	< 170	388	< 230	< 110	< 390	< 560	82.3	< 110	4739	< 170	20493
23681 D	2344	< 110	22.6	32.9	205	< 170	< 2.3	< 11	< 170	290	< 230	< 110	< 390	< 560	28.1	< 110	5435	< 170	16338
23682 D	2291	168	22.8	7.6	250	< 170	< 2.3	< 11	< 170	251	< 230	< 110	< 390	< 560	40.0	< 110	6263	< 170	24778
23683 D	2162	2881	100.9	775.8	441	< 170	13.6	< 11	< 170	280	< 230	3689	< 390	< 560	59.4	< 110	3345	< 170	279
23684 D	2506	809	22.1	7.6	324	< 170	< 2.3	< 11	706	289	< 230	< 110	< 390	< 560	72.0	< 110	3818	< 170	18232
23685 D	2184	293	18.1	116.3	550	< 170	< 2.3	< 11	< 170	261	< 230	528	< 390	< 560	34.6	< 110	4074	< 170	3439
23686 D	2455	224	51.3	252.4	524	< 170	< 2.3	< 11	< 170	376	< 230	305	< 390	< 560	28.6	< 110	3698	< 170	< 110
23687 D	2262	709	26.2	278.7	633	< 170	< 2.3	< 11	< 170	360	< 230	184	< 390	< 560	92.5	< 110	3775	< 170	19103
23690 D	1986	223	14.0	272.3	315	< 170	< 2.3	< 11	< 170	223	< 230	< 110	< 390	< 560	46.5	< 110	701	< 170	4251
23691 D	2224	395	20.8	342.1	1804	< 170	< 2.3	< 11	< 170	316	< 230	< 110	1110	< 560	56.7	< 110	742	< 170	14099
23692 D	1972	167	18.8	47.6	253	< 170	< 2.3	< 11	< 170	214	< 230	< 110	< 390	< 560	27.9	< 110	558	< 170	8712
23695 D	2559	276	17.4	809.0	310	< 170	< 2.3	< 11	< 170	421	< 230	466	< 390	< 560	112.1	< 110	< 450	< 170	25443
23699 D	2087	209	18.0	731.7	152	< 170	< 2.3	< 11	< 170	328	< 230	< 110	< 390	< 560	59.7	< 110	< 450	< 170	6726
23700 D	1936	181	19.2	3.5	322	< 170	< 2.3	< 11	< 170	296	< 230	< 110	< 390	< 560	33.5	< 110	< 450	< 170	875
23701 D	2423	634	23.7	23.6	110	< 170	< 2.3	< 11	269	462	< 230	< 110	< 390	< 560	80.7	< 110	1753	< 170	25457
23702 D	2232	309	16.0	373.7	70	< 170	< 2.3	< 11	< 170	299	< 230	< 110	< 390	< 560	79.1	< 110	< 450	< 170	11095
23703 D	2158	159	17.0	172.0	454	< 170	< 2.3	< 11	< 170	392	< 230	311	< 390	< 560	53.8	< 110	< 450	< 170	24503
23704 D	2231	528	20.4	23.6	213	< 170	< 2.3	< 11	< 170	276	< 230	< 110	< 390	< 560	49.2	< 110	< 450	< 170	3319
23706 D	2052	577	23.8	262.5	222	< 170	< 2.3	< 11	< 170	345	< 230	387	< 390	< 560	70.3	< 110	< 450	< 170	8648
23613 D	1422	665	4.6	3.5	321	3355	< 2.3	< 11	314	265	356	177	< 390	< 560	75.1	< 110	916	< 170	4865
23616 D	1628	809	6.8	12.0	289	4186	< 2.3	< 11	591	291	< 230	209	< 390	< 560	93.1	< 110	2714	< 170	24397
23618 D	1937	741	< 1.7	52.9	193	2590	< 2.3	< 11	1388	280	< 230	121	< 390	< 560	56.4	< 110	1779	< 170	1335

Analyte	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23619 D	2226	982	6.7	9.4	162	2468	< 2.3	< 11	2695	370	< 230	< 110	< 390	< 560	47.5	< 110	1154	< 170	5727
23620 D	1522	615	2.8	7.0	326	3257	< 2.3	< 11	< 170	328	< 230	116	< 390	< 560	71.1	< 110	1115	1731	12908
23621 D	1498	643	< 1.7	112.8	190	2381	< 2.3	< 11	< 170	262	< 230	546	< 390	< 560	49.4	< 110	828	< 170	20310
23623 D	1514	583	< 1.7	511.6	202	2967	< 2.3	< 11	< 170	242	< 230	599	< 390	< 560	64.6	< 110	< 450	< 170	6160
23625 D	1688	872	< 1.7	12511.6	668	4821	< 2.3	< 11	< 170	372	< 230	437	487	< 560	111.6	< 110	1366	< 170	23535
23626 D	2057	1086	6.7	22.5	187	4189	< 2.3	< 11	1227	289	< 230	< 110	< 390	< 560	90.4	< 110	2498	< 170	20364
23627 D	1301	511	< 1.7	923.6	380	6911	< 2.3	< 11	< 170	315	< 230	184	< 390	< 560	157.1	< 110	< 450	< 170	1789
23629 D	2700	1267	7.7	9.4	157	4647	< 2.3	< 11	2619	441	< 230	< 110	< 390	< 560	94.6	< 110	2652	< 170	26411
23630 D	1533	585	< 1.7	< 3.4	249	1618	< 2.3	< 11	< 170	244	< 230	< 110	< 390	< 560	37.3	< 110	469	< 170	1328
23632 D	2172	1178	5.8	42.2	271	5524	< 2.3	< 11	1360	508	< 230	139	< 390	707	120.8	< 110	2368	< 170	25946
23634 D	1663	982	3.8	904.6	245	3482	< 2.3	< 11	461	309	< 230	3489	< 390	< 560	75.6	< 110	1689	< 170	12110
23636 D	1347	564	5.5	< 3.4	240	2515	< 2.3	< 11	< 170	260	< 230	< 110	< 390	< 560	56.0	< 110	460	< 170	4016
23637 D	1535	656	< 1.7	< 3.4	313	1911	< 2.3	< 11	< 170	227	< 230	< 110	< 390	< 560	42.6	< 110	3003	< 170	2645
23638 D	1469	686	< 1.7	84.7	255	2777	< 2.3	< 11	< 170	225	< 230	1060	< 390	< 560	60.2	< 110	1221	< 170	11217
23639 D	1392	579	2.3	2312.1	348	3107	< 2.3	< 11	< 170	231	< 230	313	< 390	< 560	68.4	< 110	2759	< 170	< 110
23.640A D	1959	925	< 1.7	933.0	108	4231	< 2.3	< 11	1005	240	< 230	810	< 390	< 560	87.5	< 110	2203	< 170	36601
23.640B D	1413	870	5.6	332.7	292	2347	< 2.3	< 11	< 170	224	< 230	1307	< 390	< 560	50.3	< 110	1067	< 170	7790
23641 D	1702	897	3.4	38.5	307	3967	< 2.3	< 11	426	366	< 230	201	< 390	< 560	89.7	< 110	2199	< 170	29280
23642 D	1863	864	1.9	1365.0	136	2461	< 2.3	< 11	355	278	< 230	266	< 390	< 560	53.3	< 110	8692	< 170	21048
23644 D	1677	947	6.8	8.5	301	3354	< 2.3	< 11	< 170	260	< 230	< 110	< 390	< 560	72.3	< 110	1661	< 170	19549
23645 D	1495	638	4.5	< 3.4	295	4070	< 2.3	< 11	< 170	352	< 230	113	< 390	825	88.0	< 110	701	< 170	11293
23649 D	1675	749	4.3	296.2	339	3701	< 2.3	< 11	< 170	348	< 230	937	< 390	< 560	80.9	< 110	761	< 170	19228
23650 D	1765	672	< 1.7	54.9	264	4494	< 2.3	< 11	525	326	< 230	389	< 390	< 560	92.9	< 110	562	< 170	4237
23652A D	1905	941	< 1.7	37.8	299	3125	< 2.3	< 11	1086	218	< 230	< 110	< 390	< 560	66.7	< 110	1461	< 170	16864
23653 D	1680	768	< 1.7	250.8	170	2828	< 2.3	< 11	< 170	304	< 230	110	< 390	655	59.3	< 110	489	427	17001
23656 D	1700	1030	7.5	68.9	284	3569	< 2.3	< 11	291	333	< 230	289	< 390	< 560	76.6	< 110	1501	< 170	10948
23657 D	1965	985	7.5	459.7	261	3650	< 2.3	< 11	385	338	< 230	1563	< 390	< 560	74.4	< 110	1551	< 170	19222
23661 D	1750	914	< 1.7	4302.4	289	2649	< 2.3	14	< 170	208	< 230	248	< 390	800	56.1	< 110	1169	< 170	10231

Analyte	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23662 D	1523	786	2.1	10.2	365	3556	< 2.3	< 11	< 170	303	< 230	< 110	< 390	< 560	76.2	< 110	< 450	< 170	10038
23663 D	1754	1292	< 1.7	54.6	263	3336	< 2.3	< 11	< 170	266	< 230	342	< 390	1104	67.9	< 110	1055	< 170	10014
23664 D	1595	916	< 1.7	6812.6	167	3224	< 2.3	< 11	< 170	247	< 230	623	< 390	955	65.8	< 110	14088	< 170	1718
23665 D	1717	940	6.3	< 3.4	389	3457	< 2.3	< 11	< 170	250	< 230	< 110	< 390	< 560	75.2	< 110	612	< 170	13160
23667 D	1903	814	< 1.7	< 3.4	186	2504	< 2.3	< 11	229	218	< 230	138	< 390	< 560	50.7	< 110	1862	< 170	13728
23668 D	1784	744	< 1.7	288.6	316	2848	< 2.3	< 11	< 170	262	< 230	1003	< 390	768	55.8	< 110	454	< 170	1689
23669 D	1545	743	16.2	4.5	260	4247	< 2.3	< 11	< 170	336	< 230	< 110	< 390	< 560	90.0	< 110	1280	< 170	10223
23670 D	1462	503	4.5	< 3.4	309	3927	< 2.3	< 11	< 170	318	< 230	148	< 390	< 560	85.6	< 110	842	< 170	11169
23671 D	1687	624	8.2	1035.4	294	3302	< 2.3	< 11	< 170	338	< 230	4762	< 390	657	68.7	< 110	752	< 170	3960
23672 D	1445	637	8.3	< 3.4	348	4014	< 2.3	< 11	< 170	317	< 230	< 110	< 390	< 560	88.4	< 110	486	< 170	1277
23707 D	1957	3870	37.9	3246.9	398	3846	< 2.3	< 11	359	318	< 230	6570	< 390	< 560	81.0	< 110	1567	< 170	7358
23708 D	1510	738	9.2	< 3.4	242	2875	< 2.3	< 11	< 170	260	< 230	< 110	< 390	< 560	59.3	< 110	823	< 170	13370
23710 D	1629	915	10.9	195.4	312	3768	< 2.3	< 11	< 170	329	< 230	1060	< 390	< 560	78.4	< 110	584	< 170	2856
23711 D	1800	915	6.5	10.3	339	2440	< 2.3	< 11	< 170	243	< 230	< 110	< 390	< 560	51.1	< 110	< 450	< 170	9937
23712 D	1382	5462	48.2	4561.8	149	3506	< 2.3	< 11	< 170	225	< 230	3760	< 390	< 560	77.8	< 110	< 450	< 170	6812
23713 D	1817	873	7.1	1653.3	349	3195	< 2.3	< 11	< 170	241	< 230	5837	< 390	< 560	67.8	< 110	825	< 170	20673
23714 D	1828	908	6.5	731.3	383	2274	< 2.3	< 11	< 170	270	< 230	446	< 390	< 560	48.2	< 110	832	< 170	7475
23715 D	1620	748	7.0	75.0	348	3416	< 2.3	< 11	< 170	285	< 230	696	< 390	< 560	74.9	< 110	< 450	< 170	19589
23.716 D	1636	876	8.2	22.1	323	4283	< 2.3	< 11	< 170	320	< 230	280	< 390	< 560	93.1	< 110	< 450	< 170	9872
23.717B D	1666	753	4.3	54.6	337	4409	< 2.3	< 11	< 170	286	< 230	253	< 390	< 560	97.0	< 110	< 450	< 170	15570
23718 D	1633	826	25.4	260.5	433	2823	< 2.3	< 11	< 170	232	< 230	954	< 390	< 560	59.8	< 110	< 450	< 170	4604
23720 D	1604	4185	78.6	879.0	159	2660	< 2.3	< 11	< 170	260	< 230	1937	< 390	576	59.6	< 110	< 450	< 170	< 110
23721 D	1670	737	5.3	4657.7	318	4736	< 2.3	< 11	< 170	309	< 230	7672	496	< 560	101.7	< 110	1198	< 170	12344
23724 D	1634	1142	4.9	27.5	407	2781	< 2.3	< 11	< 170	249	< 230	697	476	< 560	61.0	< 110	2979	< 170	14193
23725 D	1688	741	< 1.7	5.0	297	2111	< 2.3	< 11	< 170	225	< 230	< 110	< 390	< 560	50.3	< 110	583	< 170	16122
23726 D	1670	892	8.4	776.5	257	3155	< 2.3	< 11	< 170	312	< 230	220	< 390	< 560	68.4	< 110	756	< 170	17415
23732 D	1690	657	< 1.7	612.1	290	3009	< 2.3	< 11	< 170	287	< 230	< 110	< 390	< 560	60.0	< 110	< 450	< 170	4243
23734 D	1692	1075	< 1.7	8.9	374	4624	< 2.3	< 11	480	312	2134	< 110	< 390	< 560	107.5	< 110	1213	< 170	8979

Analyte	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	Ga [ng/g]	As [µg/g]	Se [µg/g]	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
23735 D	1629	906	3.5	26.5	252	2697	< 2.3	< 11	< 170	261	475	< 110	< 390	< 560	67.6	< 110	600	< 170	19175
23737 D	1705	934	3.0	966.1	193	2223	< 2.3	< 11	< 170	280	348	< 110	< 390	< 560	52.1	< 110	457	< 170	14714
23738 D	1658	792	2.4	63.4	444	3080	< 2.3	< 11	< 170	240	< 230	< 110	< 390	< 560	70.2	< 110	459	< 170	16207
24250 D	1415	940	< 1.7	28.9	221	3319	< 2.3	< 11	217	267	< 230	< 110	412	< 560	83.9	< 110	3918	< 170	23758
24251 D	1367	1078	3.9	9.3	294	3689	< 2.3	< 11	305	291	< 230	< 110	< 390	< 560	91.4	< 110	263562	< 170	11878
24253 D	1344	713	< 1.7	< 3.4	187	806	< 2.3	< 11	< 170	140	< 230	< 110	< 390	< 560	21.5	< 110	1073	< 170	623
24257 D	1569	914	9.6	13.0	284	3272	< 2.3	< 11	208	286	< 230	< 110	< 390	< 560	80.3	< 110	667	< 170	12315
24258 D	2079	1187	< 1.7	6.9	334	3437	< 2.3	< 11	2342	214	< 230	< 110	< 390	< 560	74.2	< 110	1471	< 170	6376
24260 D	2067	1372	7.8	7.8	184	2343	< 2.3	< 11	1347	237	< 230	< 110	< 390	< 560	52.2	< 110	3206	< 170	15427
24264 D	1454	895	6.6	28.7	301	1962	< 2.3	< 11	315	188	< 230	< 110	< 390	< 560	47.3	< 110	651	< 170	5506
24266 D	1518	1048	< 1.7	458.4	280	3485	< 2.3	< 11	< 170	335	< 230	< 110	< 390	< 560	85.1	< 110	955	< 170	23815
24267 D	1285	832	< 1.7	140.8	375	2357	< 2.3	< 11	< 170	223	< 230	< 110	< 390	< 560	57.9	< 110	671	< 170	< 110
24269 D	1862	1160	10.7	7.0	294	3886	< 2.3	< 11	844	265	< 230	< 110	< 390	< 560	89.2	< 110	1231	< 170	10571
24273 D	1554	1001	6.9	69.2	214	2327	< 2.3	< 11	< 170	275	< 230	< 110	< 390	< 560	56.9	< 110	523	< 170	13387
24275 D	1546	1059	5.3	10.3	309	2709	< 2.3	< 11	< 170	247	< 230	< 110	< 390	< 560	66.1	< 110	798	< 170	15350
24276 D	1468	900	7.3	185.7	367	3700	< 2.3	< 11	< 170	293	< 230	1718	< 390	< 560	87.5	< 110	< 450	< 170	19922
24277 D	1500	785	11.3	768.5	166	3313	< 2.3	< 11	197	291	< 230	591	< 390	< 560	76.7	< 110	1571	< 170	10304
24278 D	1433	890	13.0	49.3	221	1820	< 2.3	< 11	235	226	< 230	< 110	< 390	< 560	42.3	< 110	586	< 170	3134
24279 D	1595	951	14.2	66.2	182	2762	< 2.3	< 11	177	267	< 230	135	< 390	< 560	60.5	< 110	< 450	< 170	5357
24280 D	1309	643	5.5	47.1	309	2599	< 2.3	< 11	< 170	215	< 230	359	< 390	< 560	62.2	< 110	< 450	< 170	112
24281 D	1870	1290	12.3	332.3	107	2037	< 2.3	< 11	1172	239	< 230	1335	< 390	< 560	46.2	< 110	845	< 170	9999
24282 D	1391	874	5.0	< 3.4	178	2073	< 2.3	< 11	< 170	249	< 230	< 110	< 390	< 560	50.1	< 110	< 450	< 170	1865
24285 D	1579	1025	11.4	6.1	465	2284	< 2.3	< 11	< 170	248	< 230	< 110	564	< 560	55.8	< 110	545	< 170	16580
Average	1801	894	15	627	344	3215	36	14	743	290	889	1130	598	783	68	--	5910	1079	12454
method LoD	560	110	1.7	3.4	28	170	2.3	11	170	0.28	230	110	390	560	2.3	110	450	170	110
method LoQ	1900	460	5.0	10.0	97	510	8.2	33	500	1.0	710	430	1300	1900	7.6	320	1500	570	300
RSU (k=2)	9%	17%	9%	24%	11%	10%	30%	--*	19%	11%	20%	32%	--*	--*	9%	--	20%	14%	13%

* all values below LoQ

Table 36 Multielemental data of dentine samples (continued)

Analyte	Mg	Ca	Mn	Fe	Cu	Zn	Rb	Sr	Ba	Pb
23655 E_M2	71%	92%	29%	98%	4%	60%	23%	71%	< LoD	70%
23674 E	73%	80%	24%	85%	< LoD	45%	< LoD	79%	< LoD	60%
23675 E	73%	90%	37%	98%	< LoD	77%	< LoD	75%	< LoD	100%
23676 E	94%	93%	32%	99%	< LoD	56%	< LoD	54%	< LoD	87%
23677A E	65%	94%	50%	98%	12%	85%	< LoD	44%	< LoD	60%
23678 E	88%	91%	6%	91%	0%	< LoD	< LoD	46%	< LoD	12%
23681 E	62%	95%	4%	92%	< LoD	25%	< LoD	39%	< LoD	8%
23682 E	87%	92%	6%	92%	< LoD	< LoD	< LoD	39%	< LoD	15%
23683 E	64%	95%	23%	100%	18%	27%	< LoD	53%	< LoD	18%
23684 E	71%	99%	11%	98%	< LoD	31%	< LoD	60%	< LoD	13%
23685 E	94%	98%	11%	99%	0%	31%	< LoD	72%	< LoD	23%
23686 E	67%	91%	8%	90%	< LoD	7%	< LoD	58%	< LoD	18%
23687 E	99%	96%	6%	95%	0%	< LoD	< LoD	45%	< LoD	18%
23690 E	78%	94%	< LoD	89%	< LoD	< LoD	< LoD	65%	< LoD	< LoD
23691 E	90%	94%	4%	92%	1%	100%	< LoD	77%	< LoD	3%
23692 E	73%	97%	< LoD	92%	< LoD	< LoD	< LoD	41%	< LoD	3%
23695 E	76%	95%	59%	92%	1%	2%	< LoD	65%	< LoD	< LoD
23699 E	71%	97%	9%	89%	10%	44%	< LoD	70%	< LoD	< LoD
23700 E	95%	97%	5%	84%	< LoD	11%	< LoD	56%	39%	< LoD
23701 E	73%	100%	5%	90%	< LoD	26%	< LoD	63%	< LoD	< LoD
23702 E	74%	98%	< LoD	90%	< LoD	< LoD	< LoD	100%	< LoD	< LoD
23703 E	71%	98%	6%	90%	1%	23%	< LoD	38%	< LoD	2%
23704 E	80%	97%	< LoD	91%	< LoD	< LoD	< LoD	38%	< LoD	< LoD
23706 E	76%	99%	< LoD	85%	0%	15%	< LoD	99%	< LoD	< LoD
23613 E	64%	73%	6%	66%	< LoD	3%	44%	68%	60%	5%
23616 E	86%	73%	9%	64%	< LoD	8%	< LoD	61%	39%	4%
23618 E	63%	75%	21%	72%	1%	15%	23%	75%	39%	< LoD
23619 E	57%	74%	16%	64%	0%	21%	< LoD	70%	19%	3%
23620 E	65%	75%	9%	66%	< LoD	17%	18%	71%	20%	2%
23621 E	67%	74%	6%	62%	1%	12%	21%	54%	15%	3%
23623 E	45%	75%	89%	71%	32%	29%	< LoD	31%	81%	5%
23625 E	54%	74%	32%	67%	100%	24%	< LoD	56%	60%	7%
23626 E	63%	77%	6%	64%	< LoD	13%	< LoD	38%	21%	< LoD
23627 E	52%	76%	10%	61%	13%	27%	< LoD	58%	22%	3%
23629 E	81%	77%	35%	64%	< LoD	4%	< LoD	44%	25%	3%
23630 E	76%	73%	14%	62%	< LoD	25%	< LoD	48%	24%	3%
23632 E	71%	77%	2%	63%	< LoD	5%	< LoD	36%	20%	< LoD
23634 E	65%	71%	< LoD	55%	4%	5%	< LoD	45%	23%	< LoD
23636 E	53%	78%	13%	64%	< LoD	28%	< LoD	80%	29%	2%
23637 E	77%	77%	4%	59%	< LoD	10%	< LoD	60%	20%	< LoD
23638 E	79%	81%	< LoD	61%	< LoD	3%	< LoD	71%	25%	< LoD
23639 E	70%	77%	< LoD	58%	7%	6%	< LoD	55%	12%	2%
23.640A E	63%	81%	5%	67%	2%	13%	< LoD	34%	43%	4%
23.640B E	70%	77%	3%	60%	8%	8%	< LoD	62%	12%	< LoD
23641 E	78%	79%	6%	65%	< LoD	11%	< LoD	67%	16%	2%
23642 E	66%	79%	< LoD	64%	2%	5%	< LoD	78%	19%	6%

Analyte	Mg	Ca	Mn	Fe	Cu	Zn	Rb	Sr	Ba	Pb
23644 E	65%	78%	5%	64%	< LoD	9%	32%	45%	33%	4%
23645 E	73%	80%	3%	66%	< LoD	10%	< LoD	57%	19%	2%
23649 E	82%	79%	7%	75%	1%	14%	< LoD	49%	43%	3%
23650 E	59%	81%	10%	68%	< LoD	30%	< LoD	54%	28%	2%
23.652A E	83%	83%	11%	72%	3%	6%	46%	48%	94%	5%
23653 E	100%	79%	10%	82%	6%	3%	100%	57%	32%	2%
23656 E	64%	84%	4%	69%	< LoD	12%	< LoD	44%	19%	< LoD
23657 E	63%	83%	4%	72%	2%	19%	< LoD	46%	29%	4%
23661 E	61%	84%	3%	69%	1%	3%	< LoD	42%	24%	< LoD
23662 E	73%	83%	16%	75%	< LoD	24%	< LoD	68%	55%	< LoD
23663 E1	85%	82%	2%	64%	< LoD	3%	< LoD	49%	53%	< LoD
23664 E	57%	84%	11%	71%	24%	32%	< LoD	48%	46%	< LoD
23665 E	75%	84%	6%	69%	< LoD	13%	< LoD	33%	84%	3%
23667 E	78%	85%	12%	68%	< LoD	3%	< LoD	41%	39%	6%
23668 E	71%	84%	10%	83%	3%	25%	< LoD	38%	46%	< LoD
23669 E	64%	83%	5%	67%	< LoD	17%	< LoD	65%	21%	2%
23670 E	72%	83%	11%	68%	< LoD	7%	< LoD	77%	34%	< LoD
23671 E	61%	82%	14%	69%	8%	18%	< LoD	71%	25%	< LoD
23672 E	72%	83%	3%	69%	< LoD	13%	< LoD	37%	54%	2%
23707 E	64%	83%	14%	73%	10%	16%	< LoD	63%	18%	< LoD
23708 E	79%	82%	< LoD	73%	< LoD	4%	< LoD	57%	21%	< LoD
23710 E	65%	82%	4%	66%	< LoD	8%	< LoD	69%	19%	< LoD
23711 E	69%	82%	12%	70%	< LoD	18%	< LoD	59%	28%	< LoD
23712 E	58%	84%	5%	71%	61%	25%	< LoD	75%	23%	4%
23713 E	80%	85%	3%	74%	1%	16%	< LoD	35%	19%	< LoD
23714 E	56%	83%	43%	70%	6%	11%	< LoD	63%	64%	2%
23715 E	75%	82%	10%	73%	< LoD	13%	< LoD	84%	29%	2%
23.717A E	53%	83%	4%	69%	< LoD	20%	< LoD	55%	13%	< LoD
23.717B E	68%	82%	2%	69%	< LoD	8%	< LoD	39%	18%	< LoD
23718 E	66%	81%	12%	70%	1%	23%	< LoD	34%	15%	< LoD
23720 E	52%	82%	6%	72%	43%	30%	< LoD	85%	15%	< LoD
23721 E	63%	83%	5%	67%	2%	17%	< LoD	65%	18%	< LoD
23724 E	92%	82%	5%	70%	< LoD	6%	< LoD	97%	19%	< LoD
23725 E	48%	79%	7%	74%	< LoD	27%	< LoD	64%	17%	< LoD
23726 E	48%	83%	9%	71%	7%	34%	< LoD	55%	20%	< LoD
23732 E	56%	83%	21%	73%	0%	23%	< LoD	66%	19%	1%
23734 E	81%	77%	12%	84%	< LoD	15%	48%	57%	33%	2%
23735 E	55%	73%	8%	65%	2%	29%	< LoD	57%	22%	< LoD
23737 E	49%	67%	9%	57%	10%	31%	< LoD	47%	17%	3%
23738 E	59%	72%	3%	60%	< LoD	13%	< LoD	39%	33%	< LoD
24250 E	59%	73%	< LoD	59%	< LoD	6%	< LoD	38%	36%	< LoD
24251 E	61%	72%	< LoD	60%	< LoD	5%	< LoD	43%	34%	< LoD
24253 E1	67%	73%	< LoD	59%	< LoD	3%	< LoD	27%	25%	3%
24257 E	48%	68%	11%	56%	< LoD	25%	< LoD	28%	38%	< LoD
24258 E	68%	73%	6%	60%	< LoD	11%	51%	40%	20%	3%
24260 E	50%	73%	4%	56%	< LoD	16%	< LoD	21%	10%	< LoD

Analyte	Mg	Ca	Mn	Fe	Cu	Zn	Rb	Sr	Ba	Pb
24264 E	45%	70%	11%	54%	< LoD	33%	< LoD	43%	32%	< LoD
24266 E1	61%	74%	< LoD	58%	< LoD	3%	< LoD	45%	25%	< LoD
24267 E	57%	71%	3%	55%	0%	11%	< LoD	40%	67%	< LoD
24269 E	57%	74%	15%	60%	< LoD	16%	18%	25%	33%	< LoD
24273 E	53%	73%	8%	58%	< LoD	22%	< LoD	25%	26%	< LoD
24275 E	45%	73%	3%	58%	< LoD	30%	< LoD	65%	16%	< LoD
24276 E	39%	74%	100%	64%	6%	51%	< LoD	44%	100%	2%
24277 E	46%	73%	8%	57%	2%	36%	< LoD	50%	13%	< LoD
24278 E	47%	72%	7%	56%	< LoD	20%	< LoD	27%	38%	< LoD
24279 E	44%	74%	13%	60%	0%	28%	< LoD	44%	20%	2%
24280 E	67%	74%	4%	57%	4%	17%	< LoD	30%	19%	2%
24281 E	44%	75%	9%	60%	8%	35%	< LoD	88%	24%	2%
24282 E	53%	73%	13%	58%	< LoD	35%	< LoD	44%	39%	< LoD
24285 E	62%	74%	< LoD	59%	< LoD	61%	< LoD	42%	40%	2%

Table 37 Data for elemental fingerprinting in enamel

6.4.2. Environmental samples

Analyte	Li [ng/g]	Be [ng/g]	B [ng/g]	Na [µg/g]	Mg [µg/g]	Al [ng/g]	K [µg/g]	Ca [µg/g]	V [ng/g]	Cr [ng/g]	Mn [ng/g]	Fe [µg/g]	Co [ng/g]	Ni [ng/g]	Cu [ng/g]
FH1_W1	12	< 0.02	83	11	18	674	16	79	2.0	0.6	78	0.8	0.7	5	23
FH1_W2	9	< 0.02	83	18	40	233	24	83	1.3	0.4	64	0.5	0.4	5	18
FH1_W3	10	< 0.02	61	11	40	30	19	68	0.6	< 0.4	7	0.3	0.2	3	19
FH1_W4	7	< 0.02	53	10	30	68	17	72	0.5	< 0.4	42	0.3	0.2	3	17
FH1_W5	12	< 0.02	56	10	47	39	21	59	0.7	0.3	5	0.3	0.2	3	16
FH1_W6	6	< 0.02	29	11	38	559	16	97	1.7	0.4	114	0.6	0.5	5	17
FH1_W7	4	< 0.02	44	13	30	113	15	26	0.7	< 0.4	23	0.2	0.2	3	19
FH1_W8	7	< 0.02	21	10	47	207	16	60	2.3	0.4	63	0.4	0.3	3	19
FH1_W9	2	< 0.02	15	4	23	149	11	79	0.8	0.7	7	0.4	0.2	3	23
FH1_W10	2	< 0.02	17	6	23	47	16	101	0.7	0.5	3	0.4	0.2	3	20
FH1_W11	2	< 0.02	16	5	21	147	10	73	0.7	0.4	7	0.4	0.2	3	18
FH1_W12	6	< 0.02	36	11	46	41	15	115	1.1	1.6	3	0.5	0.3	4	18
FH1_W13	13	< 0.02	49	9	52	226	24	128	2.3	1.9	24	0.6	0.4	6	19
FH1_W14	11	< 0.02	31	8	61	489	25	83	2.8	7.3	71	0.5	0.5	6	29
FH1_W15	9	< 0.02	35	11	46	68	18	139	2.0	0.9	17	0.6	0.3	7	19
FH1_W16	2	< 0.02	14	4	22	109	12	75	0.6	0.4	7	0.3	0.2	3	15
FH1_W17	3	< 0.02	43	15	31	63	15	61	0.9	< 0.4	3	0.3	0.2	2	16
FH1_W18	2	< 0.02	14	4	22	83	12	78	0.7	0.5	5	0.4	0.2	3	20
FH1_W19	2	< 0.02	14	4	23	89	12	82	0.7	0.5	5	0.4	0.2	3	17
FH1_W20	2	< 0.02	24	10	24	34	13	81	0.7	0.4	4	0.4	0.2	3	19
FH1_W21	1	< 0.02	13	3	22	58	11	75	0.6	0.4	4	0.3	0.2	3	17
FH1_W22	4	< 0.02	26	10	39	31	11	138	1.0	1.1	3	0.5	0.2	4	15
FH1_W23	2	< 0.02	25	9	24	144	14	83	0.7	0.9	10	0.4	0.2	3	17
FH1_W24	1	< 0.02	12	3	22	158	12	76	0.7	0.4	10	0.4	0.2	3	19
FH1_W25	2	< 0.02	14	5	23	135	9	82	0.7	0.4	7	0.4	0.2	3	17
instr. LoD	0.007	0.02	0.2	0.002	0.002	0.7	0.04	0.04	0.2	0.4	0.03	0.01	0.002	0.05	0.1
instr. LoQ	0.02	0.06	0.6	0.006	0.006	2	0.1	0.1	0.6	1	0.09	0.04	0.008	0.2	0.4
RSU (k=2)	7%	--	9%	2%	4%	3%	11%	1%	8%	11%	10%	3%	6%	7%	19%

* all values below LoQ

Table 38 Multielement data of water samples

Analyte	Zn [ng/g]	Ga [ng/g]	As [ng/g]	Se [ng/g]	Rb [ng/g]	Sr [ng/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
FH1_W1	14	3	2.2	0.3	2	411	0.3	< 0.004	0.02	< 0.01	46	0.006	1.2	< 0.03	1.0
FH1_W2	10	3	2.6	1.3	1	402	0.8	< 0.004	0.02	< 0.01	55	0.005	0.5	< 0.03	15.6
FH1_W3	8	2	1.0	0.5	2	225	0.7	< 0.004	0.01	< 0.01	43	0.003	0.2	< 0.03	2.1
FH1_W4	10	1	1.1	< 0.2	3	201	0.3	< 0.004	0.01	< 0.01	27	0.001	0.2	< 0.03	0.6
FH1_W5	5	3	1.7	0.5	1	255	0.6	< 0.004	0.01	< 0.01	52	0.003	0.2	< 0.03	2.7
FH1_W6	12	2	5.7	0.4	2	224	0.5	< 0.004	0.03	< 0.01	40	0.005	0.8	< 0.03	2.4
FH1_W7	27	1	4.6	< 0.2	1	198	0.9	< 0.004	0.01	< 0.01	20	0.003	0.8	0.03	0.8
FH1_W8	11	1	4.6	0.3	2	165	0.3	< 0.004	0.01	< 0.01	26	0.002	0.5	< 0.03	2.6
FH1_W9	13	1	0.6	< 0.2	1	509	0.8	< 0.004	0.01	< 0.01	20	0.011	0.4	< 0.03	0.7
FH1_W10	33	1	0.6	< 0.2	1	458	0.8	< 0.004	0.01	< 0.01	23	0.007	0.2	< 0.03	0.6
FH1_W11	31	1	0.6	< 0.2	1	502	0.8	< 0.004	0.02	< 0.01	22	0.010	0.4	< 0.03	0.7
FH1_W12	10	2	0.7	0.7	2	233	0.3	< 0.004	0.01	< 0.01	38	0.003	0.2	< 0.03	1.9
FH1_W13	17	3	1.4	2.0	2	278	1.3	< 0.004	0.02	< 0.01	62	0.007	0.6	< 0.03	4.8
FH1_W14	16	2	1.5	0.5	2	120	0.7	< 0.004	0.02	< 0.01	35	0.004	0.7	< 0.03	2.5
FH1_W15	9	2	1.7	1.9	2	229	0.9	< 0.004	0.01	< 0.01	42	0.004	0.2	< 0.03	4.0
FH1_W16	12	1	0.5	< 0.2	1	512	0.9	< 0.004	0.01	< 0.01	19	0.011	0.4	< 0.03	0.7
FH1_W17	11	1	1.3	< 0.2	1	378	0.8	< 0.004	0.01	< 0.01	25	0.004	0.4	< 0.03	1.5
FH1_W18	16	1	0.6	< 0.2	1	515	0.9	< 0.004	0.01	< 0.01	19	0.010	0.5	< 0.03	0.7
FH1_W19	9	1	0.5	< 0.2	1	521	0.9	< 0.004	0.01	< 0.01	20	0.010	0.3	< 0.03	0.7
FH1_W20	71	1	0.6	< 0.2	1	406	0.7	< 0.004	0.01	< 0.01	27	0.009	0.2	< 0.03	0.7
FH1_W21	7	1	0.5	< 0.2	1	520	0.9	< 0.004	0.01	< 0.01	18	0.011	0.3	< 0.03	0.7
FH1_W22	4	2	0.6	0.3	1	434	0.4	< 0.004	0.01	< 0.01	41	0.003	0.4	< 0.03	1.0
FH1_W23	8	1	0.6	< 0.2	1	386	1.1	< 0.004	0.01	< 0.01	25	0.004	0.3	< 0.03	0.9
FH1_W24	15	1	0.5	< 0.2	1	531	0.9	< 0.004	0.01	< 0.01	19	0.012	0.6	< 0.03	0.7
FH1_W25	9	1	0.5	< 0.2	1	523	0.8	< 0.004	0.01	< 0.01	21	0.011	0.4	< 0.03	0.8
instr. LoD	0.5	0.01	0.05	0.2	0.002	0.02	0.01	0.004	0.005	0.01	0.2	0.002	0.02	0.03	0.002
instr. LoQ	2	0.04	0.2	0.5	0.007	0.06	0.04	0.012	0.02	0.04	0.7	0.006	0.05	0.09	0.005
RSU (k=2)	4%	4%	11%	35%	9%	11%	3%	--	(71%)	--	14%	31%	9%	--	7%

* all values below LoQ

Table 39 Multielement data of water samples (continued)

Analyte	Li [ng/g]	Be [ng/g]	B [ng/g]	Na [µg/g]	Mg [µg/g]	Al [ng/g]	K [µg/g]	Ca [µg/g]	V [ng/g]	Cr [ng/g]	Mn [µg/g]	Fe [µg/g]	Co [ng/g]	Ni [µg/g]	Cu [ng/g]
Soil 1A	66	< 1	62	16	< 530	< 70	< 3	3807	< 5	< 60	< 0.2	15	4	0.1	41
Soil 1B	66	< 1	46	16	< 530	< 70	< 3	3776	< 5	< 60	< 0.2	15	4	0.1	39
Soil 1C	69	< 1	53	16	< 530	< 70	< 3	3734	< 5	< 60	< 0.2	15	4	0.1	34
Soil 2A	88	< 1	81	16	< 530	< 70	< 3	3683	< 5	< 60	< 0.2	15	3	0.1	20
Soil 2B	86	< 1	68	16	< 530	< 70	< 3	3676	< 5	< 60	< 0.2	15	3	0.1	19
Soil 2C	83	< 1	77	17	< 530	< 70	< 3	3781	< 5	< 60	< 0.2	15	3	0.1	23
FH1_S1	123	< 1	120	33	< 530	< 70	127	3305	< 5	< 60	0.7	11	6	< 0.1	281
FH1_S2	18	< 1	42	1	< 530	< 70	58	1631	< 5	< 60	< 0.2	5	3	< 0.1	50
FH1_S3	61	< 1	33	3	< 530	< 70	234	2441	< 5	< 60	< 0.2	8	3	< 0.1	48
FH1_S4	60	< 1	64	3	< 530	< 70	251	2958	< 5	< 60	0.2	10	8	< 0.1	101
FH1_S5	67	< 1	70	5	< 530	< 70	328	2870	< 5	< 60	< 0.2	10	4	< 0.1	62
FH1_S6	75	< 1	29	7	< 530	107	356	3083	< 5	< 60	< 0.2	11	4	< 0.1	63
FH1_S7	38	< 1	71	3	< 530	< 70	79	2319	< 5	< 60	< 0.2	8	6	< 0.1	119
FH1_S8	36	< 1	125	3	< 530	< 70	139	1998	< 5	< 60	< 0.2	7	3	< 0.1	91
FH1_S9	52	< 1	111	29	< 530	< 70	130	2751	< 5	< 60	< 0.2	10	4	< 0.1	575
FH1_S10	29	< 1	< 10	2	< 530	< 70	13	1219	< 5	< 60	< 0.2	4	2	< 0.1	12
FH1_S11	39	60.2	22	6	< 530	213357	33	761	< 5	< 60	6.7	4	549	0.8	105
FH1_S12	32	< 1	30	4	< 530	160	152	2380	< 5	< 60	< 0.2	8	3	< 0.1	60
FH1_S13	30	< 1	35	4	< 530	98	164	6084	< 5	< 60	0.5	22	8	0.1	53
FH1_S14	52	1.3	142	5	534	1006	175	2347	< 5	< 60	12.2	8	74	2.2	24
FH1_S15	30	8.8	< 10	6	< 530	214198	107	80	< 5	< 60	4.6	8	117	0.3	31
FH1_S16	32	1.3	145	10	< 530	5218	154	2465	< 5	< 60	11.6	9	511	0.4	63
FH1_S17	60	< 1	52	26	< 530	< 70	252	3597	< 5	< 60	< 0.2	13	9	0.1	122
FH1_S18	65	< 1	39	11	< 530	< 70	164	3893	< 5	< 60	< 0.2	14	5	0.1	70
FH1_S19	46	< 1	35	2	< 530	< 70	385	2421	< 5	< 60	< 0.2	9	4	< 0.1	158
FH1_S20	54	< 1	91	3	< 530	< 70	452	2500	7	< 60	< 0.2	9	3	< 0.1	180
FH1_S21	66	< 1	41	3	< 530	< 70	201	2916	< 5	< 60	< 0.2	11	4	< 0.1	100
FH1_S22	65	< 1	42	2	< 530	< 70	312	2701	< 5	< 60	< 0.2	10	4	< 0.1	59
FH1_S23	23	< 1	100	3	< 530	< 70	115	2456	< 5	< 60	< 0.2	9	4	< 0.1	167
FH1_S24	74	< 1	34	20	< 530	< 70	340	3193	< 5	< 60	< 0.2	12	4	< 0.1	54
method LoD	4	1	10	1	530	70	3	55	5	60	0.2	1	2	0.1	10
method LoQ	10	4	30	4	1700	240	9	180	20	210	0.6	15	7	0.4	40
RSU (k=2)	11%	14%	26%	6%	--*	4%	4%	1%	--*	--	9%	9%	3%	4%	5%

* all values below LoQ

Table 40 Multielement data of soil samples

Analyte	Zn [µg/g]	Ga [µg/g]	As [ng/g]	Se [ng/g]	Rb [ng/g]	Sr [µg/g]	Mo [ng/g]	Ag [ng/g]	Cd [ng/g]	Te [ng/g]	Ba [µg/g]	Tl [ng/g]	Pb [ng/g]	Bi [ng/g]	U [ng/g]
Soil 1A	< 0.2	1.7	< 6	< 10	757	6.3	< 1	< 0.4	< 0.6	< 1	13	5.4	< 1	< 0.4	3.3
Soil 1B	< 0.2	1.7	< 6	< 10	757	6.3	< 1	< 0.4	< 0.6	< 1	14	5.3	< 1	< 0.4	3.0
Soil 1C	< 0.2	1.7	< 6	< 10	760	6.4	< 1	< 0.4	< 0.6	< 1	14	5.4	< 1	< 0.4	3.1
Soil 2A	< 0.2	1.8	< 6	< 10	762	6.0	< 1	< 0.4	< 0.6	< 1	14	5.1	< 1	< 0.4	4.9
Soil 2B	< 0.2	1.8	< 6	< 10	790	5.9	< 1	< 0.4	< 0.6	< 1	15	5.5	< 1	< 0.4	4.7
Soil 2C	< 0.2	1.8	< 6	< 10	772	5.9	1	< 0.4	< 0.6	< 1	14	5.4	< 1	< 0.4	4.9
FH1_S1	< 0.2	0.9	< 6	19	319	17.7	4	< 0.4	1.3	< 1	23	2.3	1.5	< 0.4	2.1
FH1_S2	< 0.2	0.2	< 6	< 10	81	3.7	2	0.5	1.4	< 1	5	1.6	< 1	< 0.4	0.5
FH1_S3	< 0.2	0.7	< 6	< 10	161	4.3	< 1	< 0.4	0.7	< 1	17	0.7	< 1	< 0.4	< 0.2
FH1_S4	< 0.2	0.7	< 6	< 10	221	5.1	< 1	< 0.4	0.9	< 1	18	1.2	< 1	< 0.4	< 0.2
FH1_S5	< 0.2	0.8	< 6	< 10	244	6.2	2	< 0.4	0.6	< 1	21	1.5	< 1	< 0.4	< 0.2
FH1_S6	< 0.2	1.1	< 6	11	183	5.8	1	< 0.4	0.7	< 1	28	1.2	1.3	< 0.4	0.6
FH1_S7	0.4	0.6	< 6	12	113	6.1	2	< 0.4	2.1	< 1	15	1.2	< 1	< 0.4	1.4
FH1_S8	< 0.2	0.5	< 6	14	119	6.1	3	< 0.4	0.7	< 1	12	1.0	< 1	< 0.4	2.1
FH1_S9	0.8	0.8	< 6	< 10	84	7.9	2	< 0.4	0.6	< 1	21	0.9	2.7	< 0.4	2.0
FH1_S10	< 0.2	0.1	< 6	< 10	208	4.8	< 1	< 0.4	< 0.6	< 1	2	0.8	< 1	0.4	0.8
FH1_S11	1.6	0.9	< 6	12	218	1.8	< 1	< 0.4	54.9	< 1	23	2.5	533.7	< 0.4	< 0.2
FH1_S12	< 0.2	0.7	< 6	< 10	75	4.9	< 1	< 0.4	0.7	< 1	17	1.3	< 1	< 0.4	3.5
FH1_S13	< 0.2	0.4	< 6	< 10	257	6.4	1	< 0.4	3.3	< 1	11	1.4	< 1	< 0.4	< 0.2
FH1_S14	1.1	1.2	< 6	< 10	348	5.2	< 1	< 0.4	22.7	< 1	32	3.0	26.4	< 0.4	< 0.2
FH1_S15	3.0	0.1	< 6	< 10	653	0.4	< 1	< 0.4	42.8	1	3	1.7	364.1	< 0.4	0.2
FH1_S16	2.3	0.5	< 6	< 10	366	4.3	< 1	< 0.4	26.5	< 1	12	3.7	62.9	< 0.4	0.3
FH1_S17	< 0.2	0.9	< 6	< 10	192	6.0	< 1	< 0.4	0.9	< 1	23	1.0	< 1	< 0.4	< 0.2
FH1_S18	< 0.2	0.8	< 6	< 10	275	6.8	2	< 0.4	0.7	< 1	21	1.4	< 1	< 0.4	0.9
FH1_S19	< 0.2	0.6	< 6	< 10	229	4.2	4	< 0.4	0.8	< 1	16	2.1	< 1	< 0.4	1.2
FH1_S20	< 0.2	0.5	< 6	10	404	5.7	4	< 0.4	0.6	< 1	13	2.1	< 1	< 0.4	< 0.2
FH1_S21	< 0.2	0.8	< 6	< 10	201	6.5	1	< 0.4	1.0	< 1	20	1.4	< 1	< 0.4	0.4
FH1_S22	< 0.2	0.6	< 6	< 10	246	5.2	2	< 0.4	0.9	< 1	16	2.9	< 1	< 0.4	0.6
FH1_S23	< 0.2	0.5	< 6	12	76	7.2	4	0.8	1.7	< 1	12	3.0	< 1	< 0.4	0.4
FH1_S24	< 0.2	0.7	< 6	11	301	8.4	1	< 0.4	0.6	< 1	19	1.9	6.6	< 0.4	0.3
method LoD	0.2	0.001	6	10	1	0.06	1	0.4	0.6	1	0.007	0.2	1	0.4	0.2
method LoQ	0.5	0.004	20	40	5	0.2	4	1	2	4	0.02	0.7	4	1	0.6
RSU (k=2)	9%	4%	--	--*	9%	9%	--*	--*	7%	--*	3%	7%	5%	--*	9%

* all values below LoQ

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6.7. List of equations

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6.8. List of abbreviations

°C	degree celcius
AAS	atomic absorption spectrometry
AES/OES	atomic/optical emission spectrometry
amu	atomic mass unit
B.C.	before Christ
c	concentration
cps	counts per second
D	dentine
DRC	dynamic reaction cell
E	enamel
e.g.	exempli gratia
equ.	equation
FH	Franzhausen
GPS	Global Positioning System
HR	high resolution
ICP	inductively coupled plasma
Int	intensity
juv.	juvenile
(CF/EA/TC)-IRMS	(continuous flow /elemental analyzer/high temperature conversion) isotope ratio mass spectrometry
K	Kelvin
k	coverage factor
L	liter
LA	laser ablation
M1, M2	first/second molar
MC	multiple collector
MS	mass spectrometry
n.d.	not determined

n.s.	not specified
PFA	perfluoroalkoxy
PTFE	polytetrafluoroethylene
QMS	quadrupole mass spectrometry
RF	radio frequency
rpm	revolutions per minute
SD	standard deviation
SEM	secondary electron multiplier
SF	sector field
SU	standard uncertainty
subb.	subboiled
TIMS	thermal ionisation mass spectrometry
V	volt
VIRIS	Vienna Isotope Research, Investigation and Survey
W	watt

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Sprachen

Deutsch	Muttersprache
Englisch	fließend