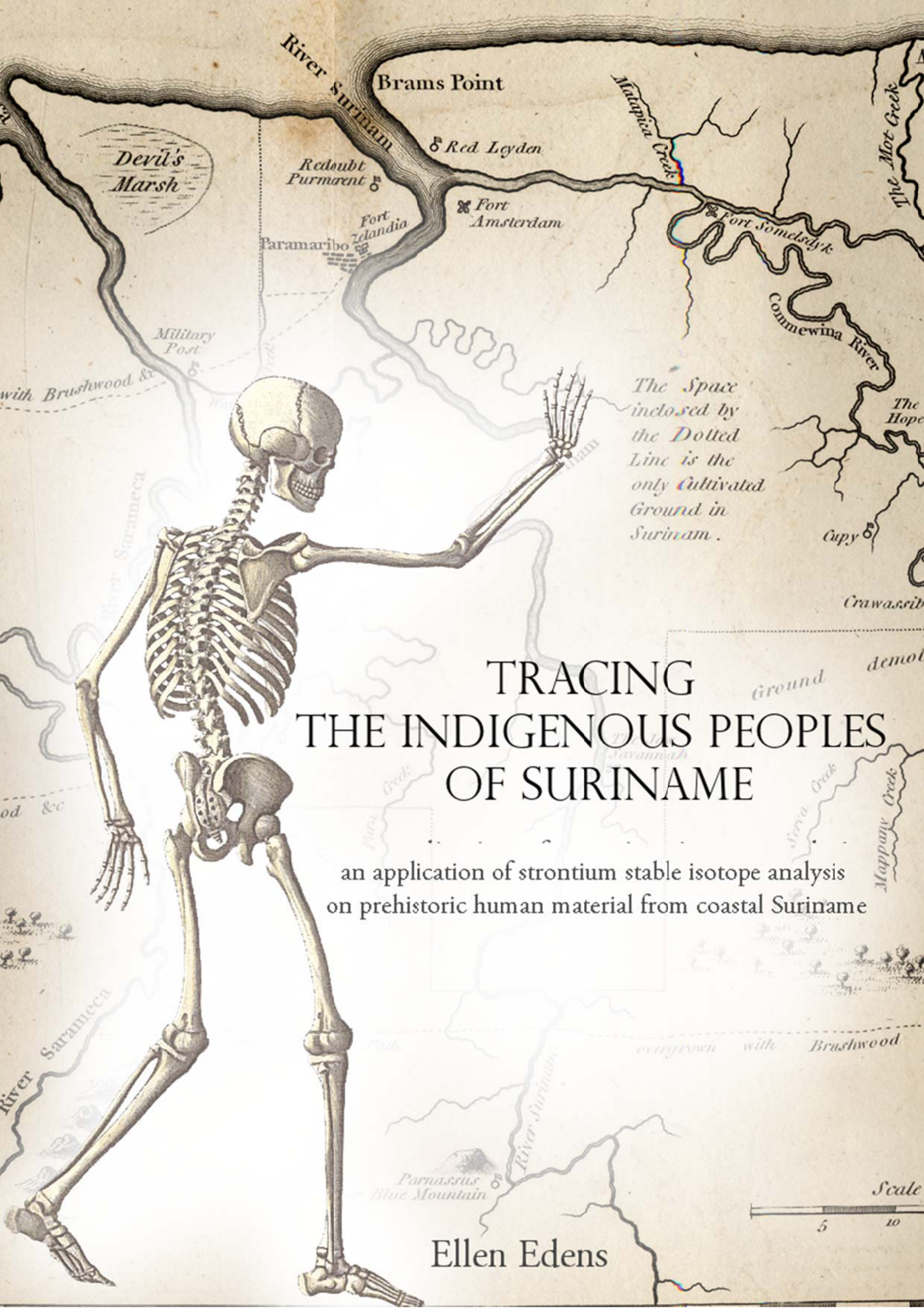

TRACING THE INDIGENOUS PEOPLES OF SURINAME

an application of strontium stable isotope analysis on prehistoric human material from coastal Suriname

Ellen Edens

Picture cover: background is from capt. John Gabriel Stedman's map of Suriname, 1772-1777 (retrieved from: http://consecratedeminence.wordpress.com/2012/06/11/the-narrative-and-the-narrative-cultural-detective-work-with-special-collections-materials/), image of skeleton waving goodbye (retrieved from: http://www.wpclipart.com/holiday/halloween/skeleton/skeleton_waving_goodbye.png). Adjusted and designed by author.

Picture footer: capt. John Gabriel Stedman's map of Suriname, 1772-1777 (retrieved from: http://consecratedeminence.wordpress.com/2012/06/11/the-narrative-and-the-narrative-cultural-detective-work-with-special-collections-materials/)

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Tracing the indigenous peoples of Suriname: an application of strontium stable isotope analysis on prehistoric human material from coastal Suriname.

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University of Leiden, Faculty of Archaeology

Enschede, 11th December 2015

Course: Master thesis

ARCH 1044WY

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Preface/acknowledgements

This research would not be possible without (a lot of) help from Dr. Andrea Waters-Rist and Dr. Jason Laffoon. I would like to thank Andrea for providing me with this research topic. Stable isotope analysis was, before I started with this thesis, an aspect in bioarchaeology which intrigued and fascinated me. Wanting to conduct such analysis myself, Andrea made it possible for me to focus my thesis subject on strontium stable isotopes. And even though collecting the samples was not always easy, I did not regret asking for a thesis topic in this area of bioarchaeology. I also would like to thank her for introducing me to Jason, and especially for all the feedback, input, and suggestions for this thesis. It certainly helped me to put this research in a larger context and study every possible aspect; it certainly helped to discuss the results of the strontium stable isotope analysis.

And, a big thank-you to Jason. This for helping me collecting, cleaning, taking, and processing the samples while explaining to me in the most enthusiastic way what each step of this research meant (and of course, why each step was necessary). I have learned so much about the process of analyzing stable isotopes and about interpreting the values. Your enthusiasm and patience – especially with a wannabe clumsy lab rat – to guide and help me with each step of this research is more than appreciated. And, thank you for providing additional comments and feedback on this thesis. I hope the collected bone fragments of the Geijskes collection will provide some interesting data!

I also want to thank prof. dr. Menno Hoogland for allowing me to conduct this research on the Geijskes collection, as well as his help for trying to get the documentation of the collection so certain things could be clarified.

Last, a thank-you to everyone who had to hear me complaining about the state of the Geijskes collection and its documentation (though I hope this was not all too often..). May we never see orange glue on skulls again!

1. Introduction

Human osteoarchaeology is the study of human skeletal material from an archaeological context. By analyzing various aspects of human skeletal remains, we can produce biological data (though selective) on the age-at-death, sex, and stature of an individual - allowing us to gain data on demography. Understanding the biological profile of an individual will also lead to a better understanding of patterns of health and disease, based on palaeopathology, and other parameters such as diet and mobility. For this study, research on human skeletal remains will take a more technical approach to understanding the past as stable isotope research will be conducted to reconstruct migration and mobility patterns. The study of migration and mobility patterns contributes to understanding the development and movement of past cultures, as well as communication and exchange between cultures (Laffoon 2012, 13). In this thesis, the indigenous individuals from Suriname will be studied. These individuals are from different groups derived from the Arauquinoid Tradition; a culture inhabiting the coastal area of the Guianas between *ca*. AD 600 and AD 1492 (before Columbus).

What are isotopes?

Analysis of stable isotopes in skeletal material offers insight to various aspects of the past life of an individual. It is based on the chemical variation in bones, which gives indications of past diet, migration and mobility, environment, and life history (Katzenberg 2008). Before going into detail about how stable isotopes contribute to these aspects, an understanding of what isotopes are is needed.

A chemical element, for example carbon (C in the periodic table of elements), consists of an atom. Atoms consist of a nucleus (the core) which is surrounded by one or more electrons. It is the nucleus that is of importance when understanding isotopes; the nucleus consists of protons and neutrons. The number of protons defines the chemical element of the atom (e.g. carbon has 6 protons and therefore its atomic number is 6), but the number of neutrons defines the isotope of the element. The term 'isotope' is therefore applied to chemical elements that have the same number of protons, but a different number of neutrons. For example, carbon has 6 protons and there are two stable isotopes of this chemical element: one with 6 neutrons (^{12}C) and one with 7 neutrons (^{13}C). The mass of an atom consists of the protons and neutrons together, thus different isotopes vary in mass (Katzenberg 2008, 415). The mass of the chemical element has consequences for chemical reactions. One oversimplified example is that in chemical reactions the atom with the 'lighter' isotope (e.g. ^{12}C) will react faster than the atom with the 'heavier' isotope (e.g. ^{13}C).

There are two types of isotopes: stable and unstable (or radioactive) isotopes. The unstable isotopes, which are the radioactive isotopes, decay over time. They are not used in stable isotope research. For example, the unstable isotope of carbon, ^{14}C, decays to ^{14}N (Katzenberg 2008, 415). The stable isotopes, which do not decay over time, are the isotopes that are used for analyses of past diet and mobility and migration. This study will conduct research on reconstructing patterns of mobility and migration using stable strontium isotopes.

The application of strontium isotopes in migration studies was originally presented by Ericson (1985), using human bone and enamel. It allowed for a direct approach to study migration in the past, instead of using artefacts and architecture (cultural aspects) as indications of migration. Strontium is now one of the most frequently analyzed isotopes for migration studies (e.g. Eckardt *et al.* 2009; Evans *et al.* 2006; Giblin 2009; Grupe *et al.* 1997; Haverkort *et al.* 2008; Hodell *et al.* 2004; Laffoon 2012; Price *et al*. 2002) often in combination with other isotopes; mainly carbon and nitrogen to reconstruct past diet (DeNiro and Epstein 1978; Katzenberg 2008; Vogel and Van Der Merwe 1977) or oxygen to indicate distance from the shore (Oelze 2012, 18; Pollard *et al.* 2011; White *et al.* 1998).

The use of strontium isotopes in migration studies is based on two of the four naturally occurring isotopes. Strontium is mostly present in rock, soil, and water (groundwater as well as river and ocean water) which gets incorporated into plants and animals (Bentley 2006; Price *et al.* 2002). Of the four naturally occurring isotopes (^{84}Sr, ^{85}Sr, ^{86}Sr, and ^{87}Sr) only ^{87}Sr is radiogenic. It is the product of radioactive decay of ^{85}Rb. This radioactive decay is age related, meaning that older bedrock has a higher ^{87}Sr value than younger bedrock (Faure and Mensing 2005; Fry 2006; Oelze 2012, 16). This also means that various geographic areas have different, often characteristic ^{87}Sr/^{86}Sr values (Oelze 2012, 16), creating a local distinct strontium 'signature' for that area. Because of weathering processes in rocks, the ^{87}Sr/^{86}Sr ratios are passed from the underlying bedrock into the soil, water, and then into plants. The ^{87}Sr/^{86}Sr values do not change considerably during these weathering processes because of the high atomic mass of $^{87}Sr/^{86}Sr$. Therefore, the $^{87}Sr/^{86}Sr$ ratio present in plants and soil reflects the $^{87}Sr/^{86}Sr$ ratio of the underlying bedrock.

The characteristic $^{87}Sr/^{86}Sr$ values of an area can be used to distinguish local and non-local individuals (Evans *et al.* 2009; Laffoon 2012, 61; Wright 2005). The non-local individuals would have a different $^{87}Sr/^{86}Sr$ ratio in either their bone or tooth enamel than the local strontium signature; methods to distinguish local and non-local individuals will be discussed later in this chapter. With the consumption of local foods, which contain the $^{87}Sr/^{86}Sr$ ratio of the underlying bedrock, the strontium signature is deposited in bone and enamel (Ericson 1985). Strontium is deposited in the bone and tooth mineral hydroxyapatite ($Ca_5(PO_4)_3(OH)$), wherein strontium can substitute for calcium in trace amounts (Burton 2008, 444; Slovak and Paytan 2011, 744). The $^{87}Sr/^{86}Sr$ ratio in either bone or enamel will therefore reflect the bioavailable strontium of the environment. The $^{87}Sr/^{86}Sr$ ratio in bone can, however, differ from the $^{87}Sr/^{86}Sr$ ratio in enamel. Most enamel formation occurs during childhood and after completion its chemical composition does not alter substantially (Burton 2008, 455; Hillson 1996). Therefore, strontium ratios in enamel reflect the childhood environment. Bone, however, remodels continuously throughout life and will therefore only reflect the bioavailable strontium from the years before death. Thus, some studies use the strontium values of bone and enamel to determine if an individual migrated in childhood (Grupe *et al*. 1997; Haverkort *et al*. 2008; Price *et al.* 1994). This study will, however, only focus on the strontium isotopes in enamel as the preservation of bone was questionable for the individuals under study, meaning reliable $^{87}Sr/^{86}Sr$ results could not be guaranteed.

Migration

In archaeology, studies on migration allow us to gain insight into the development of cultural groups. Migration is often very broadly defined as any movement of an individual from one location to another; but the definition and concept of migration is a discussion point in some studies (e.g. Adams *et al.* 1978; Kelly 1992). This broad definition of migration, however, implies that all types of movement are migration; indicating movement(s) from, for example, traders, would also be defined as 'migration'. However, the term migration implies a more permanent relocation, whereas any other forms of movement or mobility imply a relocation of a more temporary nature (Laffoon

2012, 21). Laffoon (2012) defines migration as a permanent change of location, excluding any temporary movement(s) from the concept of migration. Therefore, any movement of a culture group of an individual that is without a degree of permanence is considered mobility.

However, it is difficult to differentiate between migration and mobility, and any other type of movement in-between. Kelly (1992) discusses the different types of mobility as established by Binford (1980); residential mobility (i.e. movement of a complete culture; migration), logistical mobility (e.g. traders), and long-term mobility (i.e. movement of a complete culture circulating among a set of areas). In addition, Kelly (1992) mentions seasonal residential mobility; cultures living for a specific time of the year elsewhere. These various types of mobility illustrate also the difficulty in establishing the concept and definition of movement(s). Furthermore, different authors have established different types of migration related to processes, such as colonization, invasions, and pioneering, among others (for discussion of these different types of migration see Laffoon 2012, 21-23). All of these different types of migration, movement, and other processes involving mobility are frequently interrelated; therefore differentiating between migration from mobility and movement is difficult (Kelly 1992; Laffoon 2012; Lightfoot 2008).

As the term 'movement' is a general term for any behavior involving relocation, this study will use the term 'mobility'. The term 'migration' is, as previously mentioned, defined as a permanent relocation of an individual or culture group. However, the term discussed by Kelly (1992), 'residential mobility', also implies a permanent relocation and therefore indicates migration. Furthermore, the other forms of mobility all imply temporary movement (e.g. logistical mobility and seasonal residential mobility); the term 'mobility' can therefore cover both permanent and temporary movements of an individual or a culture group. Therefore, as neither a temporary nor a permanent relocation can be definitely concluded solely based on strontium stable isotopes, and therefore a specific type of mobility cannot be established, this study will use the general term of mobility.

Research on mobility in archaeology has been conducted for many decades, at least from 1950 on, (Laffoon 2012, 14) but the approach to identify mobility in past cultures has changed. Often, the evidence for mobility relies on artifacts and/or architecture (Slovak and Paytan 2011, 743) or the disappearance of a culture (Mans 2012, 6). These approaches are mostly based on culture-history data. After the initial culture-history approach to identify mobility, a more scientific approach was developed. Ericson (1985) used the methods applied in other fields (isotope geochemistry) to focus on the analysis of strontium isotopes for archaeological research on mobility; specifically the analysis of strontium stable isotopes in human tooth enamel and bone. The results of his research, conducted on two Native American sites in California (AD 700-1000), correlated with ethnographic data. More recently, the scientific advances in both bioarchaeology and the understanding within anthropology that mobility is dynamic and complex, has been a factor in the current interest in mobility studies (Laffoon 2012, 18). This study will use the scientific approach to identify mobility in past cultures, with cultural-historical data being used to place mobility into context.

Defining local and non-local individuals

To indicate mobility patterns using stable isotope data, the individuals from the 'local' area need to be distinguished from the individuals that are not from the 'local' area. To do this, various methods exist and Laffoon (2012) summarizes these methods; mentioning the work from, among others, Evans *et al.* (2009) and Price *et al*. (1994; 2002).

First, to distinguish local from non-local individuals, the strontium signature from enamel can be compared to the strontium signature from bone (Price *et al.* 1994). As previously mentioned, the $^{87}Sr/^{86}Sr$ ratio in enamel reflects diet and environment during childhood, whereas the $^{87}Sr/^{86}Sr$ ratio in bone reflects that during the last period of an individual's life. Comparing these $^{87}Sr/^{86}Sr$ ratios in both enamel and bone of the same individual could therefore indicate whether or not the individual migrated to an area with different $^{87}Sr/^{86}Sr$ ratios after childhood; meaning the $^{87}Sr/^{86}Sr$ ratio in enamel differs from the $^{87}Sr/^{86}Sr$ ratio in bone.

Another approach is to use $^{87}Sr/^{86}Sr$ ratios available from either fauna (Price *et al.* 2002) or non-skeletal material (e.g. bedrock or water) (Evans *et al.* 2009; Wright 2005) to distinguish local from non-local individuals. These $^{87}Sr/^{86}Sr$ values from fauna or non-skeletal material will reflect the local strontium signature of a specific area, and can be used to distinguish the non-locals from the locals; the aforementioned will have a significantly different ^{87}Sr/^{86}Sr ratio than the local strontium signature. Local fauna, for example, reflect the range of ^{87}Sr/^{86}Sr ratios of a specific area (Price *et al.* 2002); this is of course limited to fauna that have a small habitat. Evans *et al*. (2009) used a variety of plant and water samples to map the ^{87}Sr/^{86}Sr biosphere variation in the Isle of Skye (Scotland), and could correlate these data to lithological data.

However, mapping local strontium signatures based on ^{87}Sr/^{86}Sr values from fauna or non-skeletal material can be problematic. Price *et al*. (2002) indicated that the strontium signature in local bedrock, soil, and water samples can vary; Bentley *et al.* (2004) presented ^{87}Sr/^{86}Sr values from faunal material which had a wide range, indicating that it was difficult to establish a local strontium signature as there was a small variation locally. These variations in local strontium signatures and the correlating problems with mapping these signatures occur most frequently in areas with complex geology (Evans *et al*. 2009; Laffoon 2012; Pestle *et al.* 2013), as different types of bedrock, with different ages, will have distinct ^{87}Sr/^{86}Sr ratios. In addition, (faunal) bone can be affected by diagenesis (Nelson *et al.* 1986; Price *et al.* 1992), which results in a limited use for establishing local strontium signatures.

The last approach is to compare the values of the samples under study. Assuming most individuals are locals, and are buried in the area where they lived, a comparison of all the ^{87}Sr/^{86}Sr ratios would therefore result in the 'outliers' being the non-locals (individuals with significantly different ^{87}Sr/^{86}Sr ratios) (Bentley *et al.* 2002; Wright 2005).

Laffoon (2012, 61) mentions that the approach using fauna, meaning estimating the 'bioavailable strontium', has the most advantages compared to the other approaches. This is because the fauna samples are often more abundant and more accessible than human bone, and the fauna is generally local; therefore a local strontium signature can be established.

Though the use of stable isotopes to indicate mobility is a direct approach, a few drawbacks exist in using strontium stable isotopes to study mobility. First of all, there should both be enough homogeneity within a geological area and enough heterogeneity between geological areas for any differences in the ^{87}Sr/^{86}Sr of the individual to indicate mobility. Another problem depends on the type of diet that past individuals consumed; individuals living in a terrestrial area with a marine diet would have a coastal $^{87}Sr/^{86}Sr$ ratio (Slovak and Paytan 2011, 744). Strontium stable isotopes in mobility studies are therefore only usable if all, or at least a vast majority of the consumed foods, are local. To overcome these drawbacks, isotopic analysis of other chemical elements is often combined with the analysis of strontium stable isotopes – in particular, the previously mentioned carbon, nitrogen, and oxygen stable isotopes.

Research outline

For this study, strontium stable isotope analysis was conducted on human skeletal material from the Geijskes collection which is housed at Leiden University, Faculty of Archaeology. This collection, from five archaeological sites in Suriname (fig. 1.1), was excavated in the 1950s and 1960s. A total of, at least, 42 individuals are from the sites of “Kwatta Tingiholo”, “Saramacca”, “Hertenrits”, “Okrodam”, and “Paramaribo: Waterkant/Mirandastraat”. All are prehistoric Amerindian sites (Van Duijvenbode 2011). A detailed description of the cultures represented in the archaeological sites is presented in chapter 2.

As the enamel of the teeth is needed to conduct this study, the dental status of the individuals was inventoried. Based on this inventory, the individuals were selected for the research on mobility for this thesis.

Figure 1.1. Locations of the sites included in this study (after Google Earth 2015). 1= Hertenrits; 2= Saramacca (exact location unknown) 3= Kwatta Tingiholo; 4= Okrodam; 5= Paramaribo: Waterkant/De Mirandastaat.

Research goal and questions

Using stable isotope analyses, Laffoon (2012) researched mobility patterns in the Caribbean, focusing on sites from both the Greater and the Lesser Antilles. However, there is a lack of isotope data for the Guianas (Guyana, Suriname, and French Guiana), especially regarding bioavailable strontium (Laffoon 2012, 263), limiting research on mobility patterns in this region. Both stable isotope analyses of human skeletal material as well as fauna/flora are needed to map the bioavailable strontium for the Guianas and to study mobility patterns in this region. The strontium stable isotope analysis of the Geijskes collection will provide the first isotope data for the Suriname region and also for the Geijskes collection itself. As other studies have been conducted on the Geijskes collection, i.e. cranial deformation (Van Duijvenbode 2011), it would therefore be a useful and interesting addition to our knowledge of the prehistory of this area to gain insight into the mobility patterns of its prehistoric cultures.

This thesis consists of a number of research goals. The first and main goal (1) is to establish if there are non-local individuals present in the Geijskes collection, using strontium stable isotope analysis. This goal also has sub-goals: (1a) to analyze variation between $^{87}Sr/^{86}Sr$ results and osteological as well as cultural data, and (1b) to analyze and research if cultural data can establish a point of origin for non-local individuals.

The second goal (2) is to research how strontium stable isotopes can help to establish the approximate location of archaeological sites. It must be noted that often excavations conducted in the past, are either not well documented or documentation is (partially) lost. During the initial inventory of the Geijskes collection, it became clear that the documentation regarding the context of the individuals as well as the location of the archaeological sites was not always sufficient to perform a thorough study. A goal of this study is therefore to research the contribution of strontium analysis regarding establishing a possible location of the archaeological sites. Finally, the last goal of this study (3) is to contribute the first strontium isotope data for the region of the Guianas.

The main research question formulated for this study is: 'Based on stable isotopes of strontium, are there non-locals present among the individuals in the Geijskes collection?' To reach the aforementioned goals, and answer the main research question, sub-research questions have been formulated:

- What is the extent of information on the bioavailable strontium in the surrounding area, and what is the range of the bioavailable strontium in the surrounding area?
- What is the range of $^{87}Sr/^{86}Sr$ ratios in the human skeletal material under study and do any individuals have a $^{87}Sr/^{86}Sr$ ratio that is not within the range of the mean plus/minus two standard deviations, indicating a non-local?
- Is there any intra- or inter-site variation in the $^{87}Sr/^{86}Sr$ ratios?
- Does variation in $^{87}Sr/^{86}Sr$ ratios correlate with osteological (i.e. sex and age at death) and/or cultural (i.e. intentional cranial deformation and burial type) data?
- Using data on the bioavailable strontium, can the possible location of origin and cultural background for the non-locals be established?

For the second research goal, the following sub-research questions are formulated:

- What is the current excavation data on the location of the archaeological sites under study?
- What do the $^{87}Sr/^{86}Sr$ ratios of the individuals suggest as the location of the archaeological sites? Does this correlate with the current data?
- Can strontium stable isotopes contribute to establishing the approximate location of archaeological sites, especially when excavation documentation is lacking or insufficient in this regard?

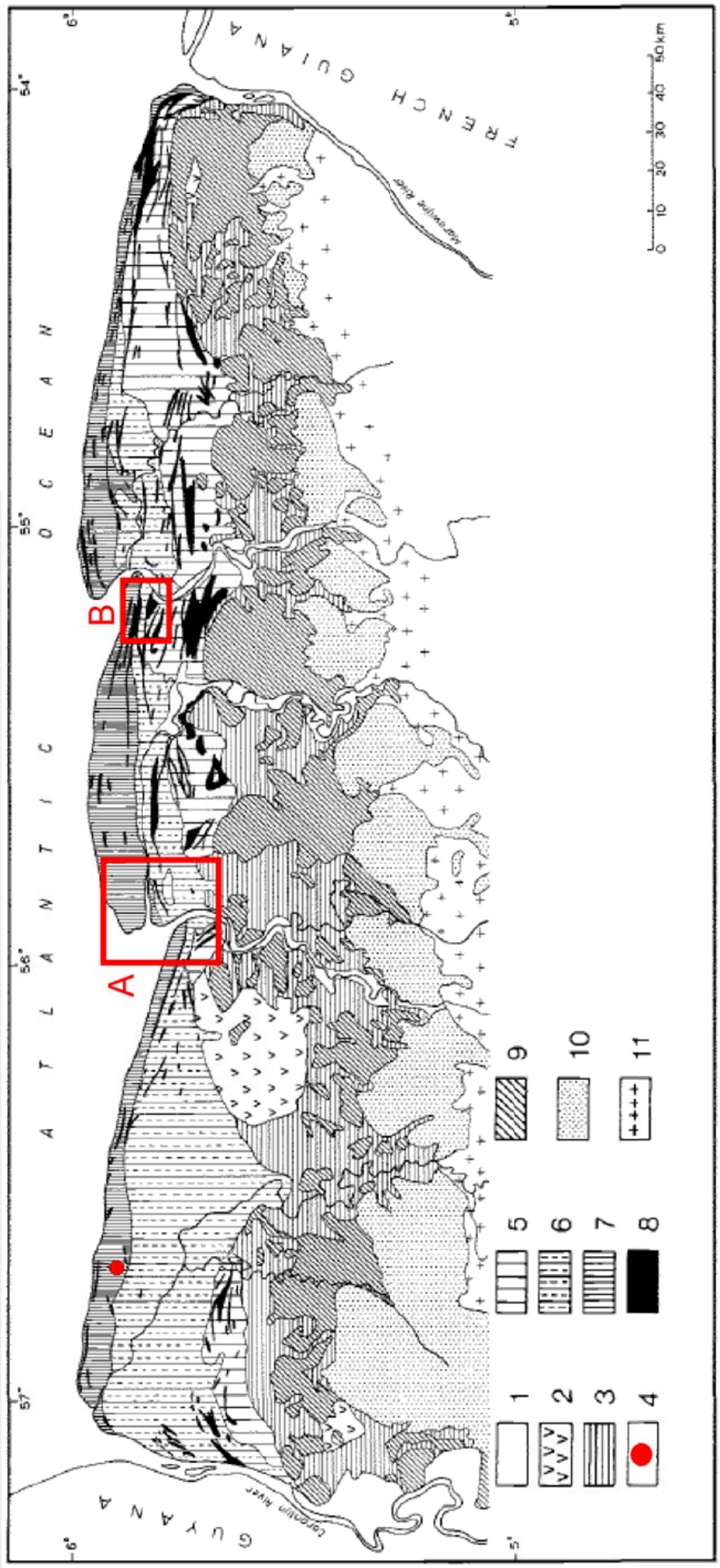
2. Historical context and background information

This chapter provides background for this research. The prehistory of Suriname, as well as the geology and location of Suriname are presented. Also, information on Dr. D.C. Geijskes, his work in Suriname, as well as information on the sites in the Geijskes collection are discussed.

2.1. Suriname: geology

Located in the northern coastal region of South America, Suriname is a country that is bordered by French-Guiana to the east, Brazil to the south, and Guyana to the west. It is a part of the Guianas; this is the name of the region that consists of Suriname, French-Guiana, and Guyana. The northern area of Suriname is a coastal region, with different estuaries that end in large rivers. The largest rivers are the Coppename, Saramacca, Commenwije, and Suriname. The southern area of Suriname is a more mountainous area. The coastal region of Suriname is composed of both young and old coastal plains (Versteeg 2008, 303; fig. 2.1). These geological formations and their sub-formations were formed in different geological ages, which results in variable $^{87}Sr/^{86}Sr$ ratios and therefore a variation in the strontium signature. The locations of the sites under study are spread over the coastal region of Suriname. The different geological zones in Suriname and their depositional phases are therefore of importance for this study.

The Young Coastal Plain (YCP) was deposited during the Holocene, whereas the Old Coastal Plain (OCP) was deposited during the Pleistocene (Versteeg 1985, 660). The YCP consists of the Demerara Formation, which is subdivided into two sub-formations; the Mara Subformation and the Coronie Subformation (Augustinus *et al.* 1989; Roeleveld and Van Loon 1979). The Coronie Subformation is also divided into different depositional phases, the Wanica, Moleson, and Comowine Members (Augustinus *et al.* 1989; Roeleveld and Van Loon 1979). The OCP consists of the Coropina Formation. Two other types of landscape can be distinguished; the cover landscape and Precambrian shield (Guiana Shield). The cover landscape can be found in the more central part of Suriname. The Guiana Shield covers most of Suriname, especially the southern and central region. The Guiana Shield is the northern part of the Amazonian craton, a Precambrian geological formation. It also stretches along the southern regions of Venezuela, the rest of the Guianas, the northern part of Brazil, and the eastern part of Colombia. The sites analyzed in this thesis are all located on the YCP, but on different geological formations within the YCP (fig. 2.1.).



ATLANTIC OCEAN
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GUYANA
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5
6
7
8
9
10
11
0 10 20 30 40 50 km

Figure 2.1 (previous page). The geology of the coastal plain in Suriname (after Versteeg 1985, 660). **Legend**: 1 = Fluvial deposits; 2 = Ombrogenous peat; 3 = Pyrite clays, peaty clays, and peat. Mara Subformation; 4 = **Hertenrits** site / red rectangle A indicates site of **Saramacca**, rectangle B indicates sites of **Kwatta Tingiholo**, **Okrodam**, and **Paramaribo: Waterkant/de Mirandastraat**; 5 = Clays and silty clays, Wanica Member; 6 = Clays and silty clays, Moleson Member; 7 = Clays and silty clays, Comowine Member; 8 = Cheniers; 9 = Silty clays and fine to medium sands, Coropina Formation; 10 = Poorly sorted sands, kaolinitic sands and loams, Upper Coesewijne Formation; 11 = Crystalline Basement. **Note**: The YCP consists of the formations 2, 3, 5, 6, 7, and 8. The OCP consists of the formations 9 and 10.

2.2 Prehistory and archaeology of Suriname

The prehistory of Suriname is divided into three phases, based on how food was gathered: hunter-gatherers, agriculturalists with shifting cultivation, and agriculturalists with a permanent cultivation system (Versteeg and Bubberman 1992). According to Versteeg and Bubberman (1992), the vast majority of cultures living from 2500 BC until colonial times (AD 1492) were mostly agriculturalists with permanent cultivation. The first sedentary agriculturalists (2500-1500 BC) were hunters and farmers, using a slash-and-burn method to clear areas of forest for cultivation. This culture is named the Saladoid Tradition. This tradition began in the central region of Venezuela (Orinoco), migrating towards the east and is therefore also found in the area of West Suriname (Rostain 2008, 284). The earliest findings of the Saladoid Tradition peoples in Suriname are from the Kaurikreek site, dating to 2200-1750 BC (Rostain 2008, 284). Sites of the Late Saladoid Tradition (i.e. the Wonotobo site, AD 70-200) are found in West Suriname, correlating with the migration of this culture to the east (Rostain 2008, 284).

The Saladoid Tradition is replaced by the Barrancoid Tradition, around AD 250; this latter tradition had a very different material culture than the previous one (Versteeg 2003). The origin of the Barrancoid Tradition appears also to be from the central region of Venezuela. Findings of this culture in Suriname are in the western region (Versteeg 2008, 309). In this area, they are named the Mabaruma culture (AD 300-650) and the earliest findings of raised mounds are from this culture (Rostain 2008, 289). In this period, there is evidence for improved agricultural technology, as besides the raised mounds to cultivate crops; there were also irrigation systems to drain the fields (Rostain 2008, 284). In addition, the networks between sites became more intensive and there was probably also an increase in social complexity (Rostain 2008, 284).

After AD 700, changes are noticeable in the archaeological record as in some areas the Barrancoid Tradition disappears, and the Arauquinoid Tradition appears (Rostain 2008, 286). For some other areas, there appears to be a mixture of cultures rather than a disappearance of one and appearance of another (Boomert 1980). The origin of the Arauquinoid Tradition is in the Orinoco area (Venezuela), after which people moved east (Boomert 1980; Rostain 2008, 288). From here, the Arauquinoid Tradition moved in three different directions; one of which was towards the coastal area of Guyana and Suriname. Rostain (2008, 288) mentions two distinct chronological phases in the Arauquinoid Tradition in this area; the first phase was specifically clustered in the area of West Suriname, from AD 700 on. The Hertenrits culture is among this phase, and is also one of the oldest Arauquinoid cultures known in this area (Rostain 2008, 289; Versteeg 1985; Versteeg 2008, 310). It was also one of the first cultures of the Arauquinoid Tradition to build mounds in this area; this because of their habitation on the floodplains.

After AD 1000 there was a population increase in the coastal area, and from this period on there are also differences in the material culture. Along the coast between Guyana and French Guiana, four different Arauquinoid cultures occur simultaneously; Hertenrits (Late Hertenrits, only in West Suriname), Kwatta (East Suriname), Barbakoeba, and Thémire (Rostain 2008, 289). The last two cultures were mainly located in the eastern region of Suriname (van Brakel 2012, 49). These cultures inhabited various sites in the coastal region, up until approximately AD 1250, with some cultures existing even longer (AD 1650) (Versteeg 1985).

However, other cultures in Suriname existed as well, such as the Brownsberg culture. It is not known of which culture the Brownsberg culture derived from, as archaeological data does not indicate an origin in the Arauquinoid Tradition. The Brownsberg culture inhabited sites in central/south Suriname (Boomert and Kroonenberg 1977). This culture (AD 1000-1500) was known for manufacturing cutting tools from stone they mined in their area, and exported these to the coastal area (to the Kwatta peoples), probably using the main rivers as a trade network (Rostain 2008, 292).

Another culture that inhabited the coastal region of Suriname was the Koriabo culture (AD 1200 - colonial period) (Versteeg and Bubberman 1992). Their origin is not clear, but it appears this culture moved from the south to the north, and mixed with the

Arauquinoid sites (Versteeg 2003). From archaeological findings, it seems this culture also had an extensive trade network with the Kwatta culture, but did not have contact with sites in West Suriname (Late Hertenrits) (Rostain 2008, 300; Rostain and Versteeg 2004). An overview of these cultures and their time span is illustrated in figure 2.2. The eras relevant to the Geijskes collection are highlighted. Furthermore, an overview of the archaeological sites of the Arauquinoid Tradition for the coastal area of Suriname is displayed in figure 2.3. The cultures relevant to this thesis will be discussed in more detail in paragraph 2.3.

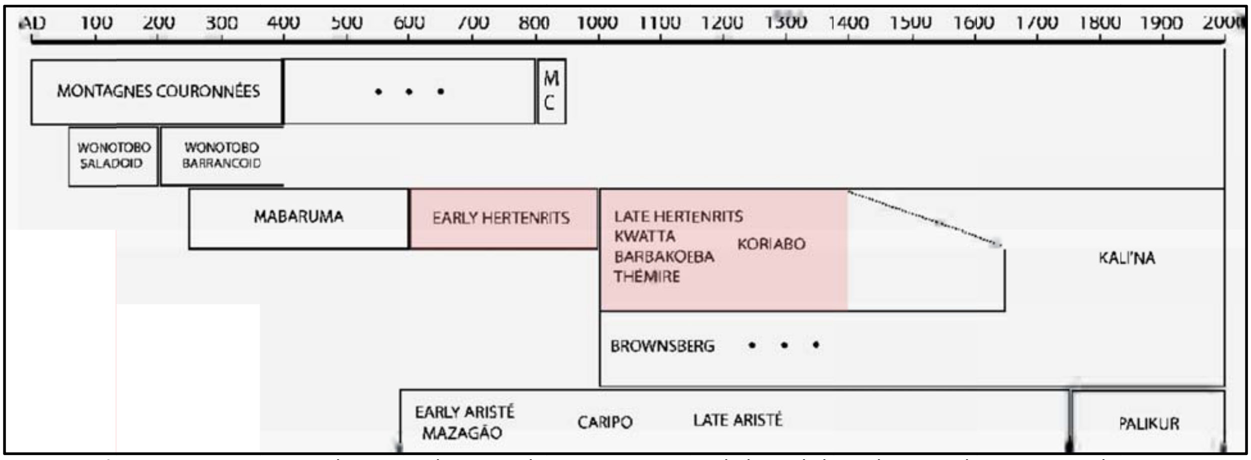

Figure 2.2. Overview prehistoric cultures in the Guianas. Area in light-red show the periods represented in the Geijskes collection (after Rostain 2008, 281).

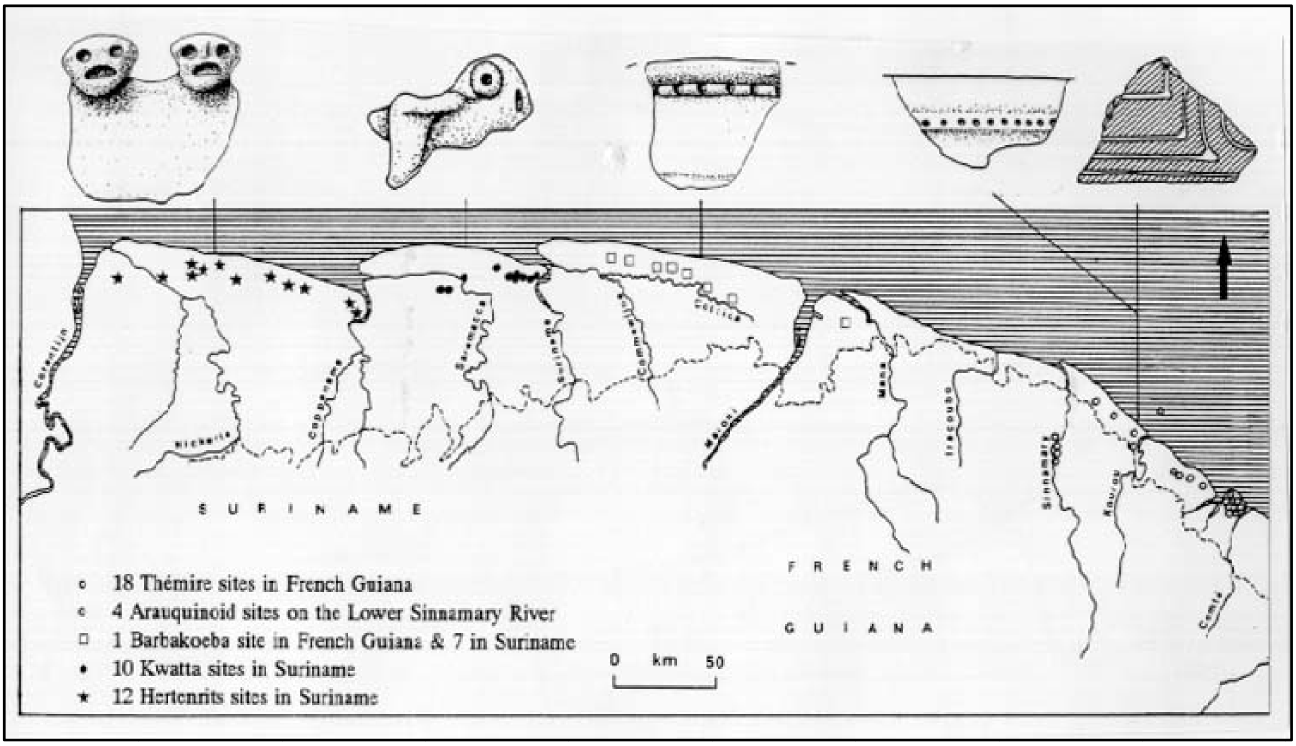

Figure 2.3. Map of archaeological sites of the Arauquinoid Tradition for the coastal area of Suriname (Versteeg and Bubberman 1992, 42)

2.3. Dr. Geijskes and Suriname

In 1947, the Stichting Surinaams Museum (SSM, Suriname Museum Foundation) was founded. Dr. Geijskes, who had already excavated near Paramaribo, was one of the individuals associated with this foundation. In 1954 the SSM had found a location to exhibit excavated artifacts, becoming a small museum. Dr. Geijskes was the first director of this museum, and during the years 1957-1963 led various excavations in Suriname.

One of his earlier excavations, conducted in October 1950, was in Kwatta Tingiholo, near Rijweg 4 (fig. 2.4, #4). The site was 'found' because sand and shell quarrying took place (these materials were used for road improvement) (Versteeg 1998). The quarrying was destroying the archaeological material, and Dr. Geijskes collected the archaeological material from this site. At the Kwatta Tingiholo site, human bones (fig. 2.5) were found among other items (e.g. pottery, stone artifacts). In 1961-62 he excavated Kwatta Tingiholo again, but this time on a larger scale.

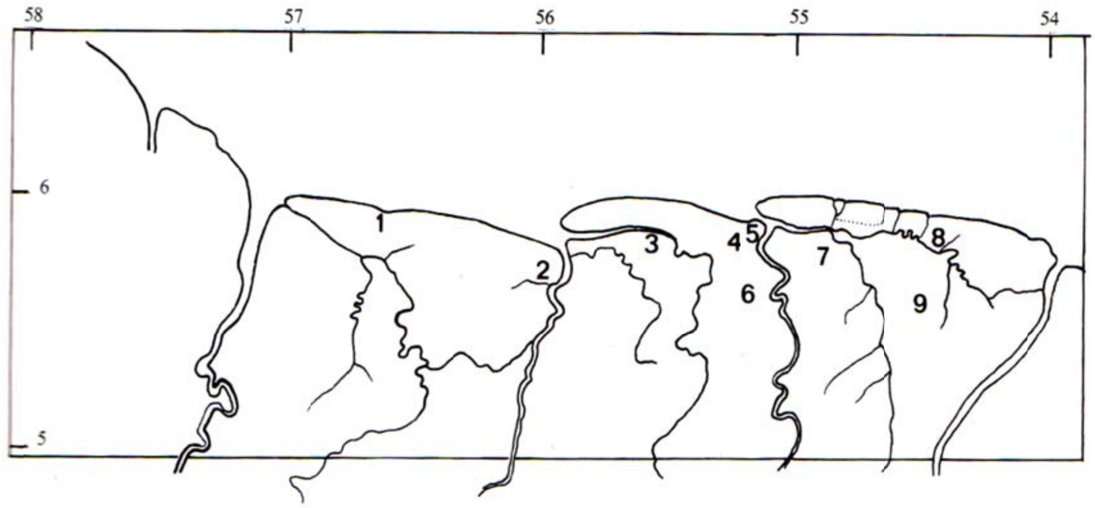

Fig. 3. Archaeological sites in coastal Suriname.
1 = Hertenrits; 2 = Peruvia; 3 = Tambaredjo; 4 = Tingiholo; 5 = Blauwgrond; 6 = Onverdacht; 7 = Commetewane; 8 = Barbakoeba; 9 = Bushmanhill.
Sites 2, 3, 4, 5, 7 and 8 are situated on sandy coastal cheniers. Site 1 is a clay mound.

Figure 2.4. Overview of archaeological sites in Suriname. Not all illustrated sites were excavated by Dr. Geijskes; he excavated #1, 4, 6, 7, and 9. The other sites were excavated after Dr. Geijskes' time in Suriname (Geijskes 1991, 9).

Figure 2.5. Human skeletal material from Kwatta Tingiholo, 4 de Rijweg, excavated in October 1950 by Dr. Geijskes. This material was, however, never stored in the 'Geijskes collection' (Versteeg 1998, 17).

Another early large scale excavation that he led was in Hertenrits (fig 2.4, number 1), in October 1957. This excavation also yielded material like pottery and human bones. Besides these two large-scale excavations, Dr. Geijskes excavated at locations near Paramaribo, but also at small locations such as, among others, near Onverdacht (Para district), Commetewane Kreek, and in the Marowijne district (Bushmanhill) (Geijskes 1991; Versteeg 1998) (respectively numbers 6, 7, and 9 in fig. 2.4). Most of the material was stored and displayed at the SSM. Dr. Geijskes left Suriname in 1965, and his work was continued by members of the SSM board. For overviews of all archaeological research conducted during and after Dr. Geijskes' time in Suriname, the reader can consult Versteeg (1998) and Boomert (1975).

2.4. The Geijskes collection at Leiden University

As noted, human skeletal material was found at various Surinamese sites, but only a small selection of this found its way to the Netherlands and into the 'Geijskes collection' (Van Duijvenbode 2011, 4). The material, mostly from Kwatta Tingiholo, was studied by Tacoma for his dissertation in 1963, in which he also discusses the history and location of the sites. The material from Kwatta Tingiholo was first sent to the Department of Anthropology of the Royal Tropical Institute in Amsterdam. Material from the excavations of Hertenrits (four skulls) and Okrodam (two skulls) was later added, and the complete 'collection' was used for Tacoma's dissertation (Tacoma 1963, 14). In his dissertation, he focuses on intentional cranial deformation and the crania in general (measurements). His study provides an overview of the sex and age at death estimates of the individuals from Kwatta Tingiholo and Hertenrits. The estimation of sex was mostly based on features and morphological differences of the skull, as pelvic remains were scarce. But when possible, the overall pelvic shape, and general robusticity of the postcranial skeleton were also used for sex estimation (Tacoma 1963, 65; 1991, 50). Age at death estimations were based on ectocranial suture closure and dental attrition (Tacoma 1991, 50).

In 2007, the 'collection' was transferred to the Faculty of Archaeology at Leiden University (Van Duijvenbode 2011, 4). Van Duijvenbode (2011) re-analyzed the human skeletal material, and concluded that the collection contained more material than initially thought. This includes a fragmented skull labeled with 'Aruba', but also material from Paramaribo and Saramacca (both Surinamese sites). Material from the Paramaribo site was documented as 'Waterkant/de Mirandastraat'; and material from Saramacca was labeled as 'Sa' and included a note with partial context information. The minimum number of individuals was based on documentation and occurrence of skeletal elements. Van Duijvenbode (2011) created a table with the current composition of the Geijskes collection (table 2.1).

Table 2.1. Overview of the composition Geijskes collection (Van Duijvenbode 2011, 5).

Site	Minimum number of individuals
Kwatta Tingiholo	25
Hertenrits	8
Okrodam	3
Saramacca	4
Paramaribo: Waterkant/De Mirandastraat	2
'Aruba'	1

Individuals from these sites, except the Aruba skull, as this is obviously not from a Surinamese site, are included in this study. A short description about the location as well as time period (and the related culture group) will be presented below for each archaeological site that is analyzed in this study.

Kwatta Tingiholo

The site of Kwatta Tingiholo (fig. 2.6) is dated to the same age as the Late Hertenrits (see *Hertenrits*); between AD 1000 and approximately AD 1400 (Rostain 2008, 289). As mentioned in paragraph 2.3, the site was one of the earliest excavations of Dr. Geijskes (in 1950), and was also excavated by him again later in 1961-62 (Versteeg 1998). Dating of the site is based on radiocarbon results of three charcoal layers (Geijskes 1991, 20). One charcoal layer (970 ± 50 BP (GrN-4552)) is from the excavation conducted by Dr. Geijskes, the other two layers are from a later excavation conducted by Versteeg in 1976 (1140 ± 90 BP (GrN-8250) and 1050 ± 100 BP (GrN8249)) (Geijskes 1991, 20). All of the known sites where material of the Kwatta culture was found were located in the coastal area (Versteeg and Bubberman 1992). The Kwatta are the only Arauquinoid culture that is not associated with the use of raised field mounds, in contrast, for example, to the Hertenrits culture. The Kwatta Tingiholo culture used the technique of slash-and-burn to clear forest areas to live on and for agriculture (Rostain 2008, 290). It was also a culture which had a very extensive trade network, using the large Suriname rivers (Coppename and Saramacca) to trade their artifacts with other cultures to the south and the coastal region. This trade network was probably with the Brownsberg and Koriabo cultures (the latter appeared in the region from about AD 1200 on) (Rostain 2008, 290-292).

Figure 2.6. Locations of the Kwatta Tingiholo and Okrodam site, as well as the Paramaribo: Waterkant/De Mirandastaat site (after Google Earth 2015). The sites are near and in the city of Paramaribo, capital of Suriname (also in figure). Location of Kwatta Tingiholo is based on data from Versteeg (2003) and P-all Projects Supply Suriname N.V. (2013). Location of the Okrodam site is only an indication; no exact location is available. Location of the Paramaribo: Waterkant/de Mirandastraat site is based on the current data of the intersection of these two roads.

Okrodam

The site of Okrodam is close to the Kwatta Tingiholo site (fig. 2.6), but as no objects have been found to indicate a specific culture, nor are any dates available for this site, it is not clear if the Okrodam site is from the same period. The material from the Okrodam site consists of three skulls; one was an accidental find (OK-0-1) and the other two were excavated by Dr. Geijskes in 1957. Versteeg (1998), however, does not mention any Okrodam site in his overview of archaeological research in Suriname. Unfortunately, no other information is available on the Okrodam site.

Paramaribo: Waterkant/de Mirandastraat

The site of Paramaribo: Waterkant/de Mirandastraat (fig. 2.6) is unfortunately another site that is not very well documented. It appears it is from an excavation of Waterkant/de Mirandastraat in Paramaribo, led by Dr. Geijskes in 1960-61. For this site, there are no radiocarbon dates available. Material such as pottery is present in the same storage box as the individuals, but this seems to be from the colonial period and it is not clear if it is related to the human skeletal material/burial or was added to the collection at a later stage. According to Van Duijvenbode (2011, 7) the site is probably from the Kwatta culture, as the location of the site might suggest Kwatta related habitation. At this point no more detailed information is available for this site.

Hertenrits

The Hertenrits site (fig. 2.7) was excavated by Dr. Geijskes in October 1957 (Versteeg 1998). The excavation consisted of seven excavation pits of 2-3 meters in depth. Dr. Geijskes took a total of three samples for radiocarbon dating (Versteeg 1985, 708), but additional samples for radiocarbon dating were taken by Van Der Heide when he excavated near Hertenrits in 1970 (Versteeg 1985, 708). The results of Dr. Geijskes' and Van Der Heide's samples, in combination with the variation in Hertenrits pottery led to the division of different Hertenrits phases. Pottery from the Hertenrits site is in the so-called Hertenrits style, and can be divided into two phases according to Versteeg (1985): the Early Hertenrits (AD 700-1000) and the Late Hertenrits (AD 1000-1250) style (Versteeg 1985, 708; see fig. 2.3). Both are part of the Arauquinoid tradition, which occurs in the area of Guianas from AD 650 on. Findings from the Hertenrits culture occur along the coast of the Guianas, and also specifically the western coast of Suriname. The Arauquinoid tradition spread from the Orinoco area (Venezuela) towards the east (Rostain 2008, 288). The Early Hertenrits is characterized by the building of mounds to live on. Both houses as well as crop cultivation were on mounds of clay, because of their location in the floodplains of the Surinamese coastal area. Versteeg (2008, 310) mentions that the Hertenrits mound is the largest, highest, and also the most impressive mound; at other sites mounds were usually smaller. He therefore suggests that the mound at Hertenrits might indicate that this area was a social or political center for the Hertenrits group (Versteeg 2008, 311). Around AD 1000 a population growth is observed, based on the increase of sites from this area. This population growth along the coastal areas of Guianas is the reason for more cultural diversity in this period (Rostain 2008, 288). The Late Hertenrits pottery group falls into this period, but also the cultural groups called Kwatta, Barbakoeba, and Thémire.

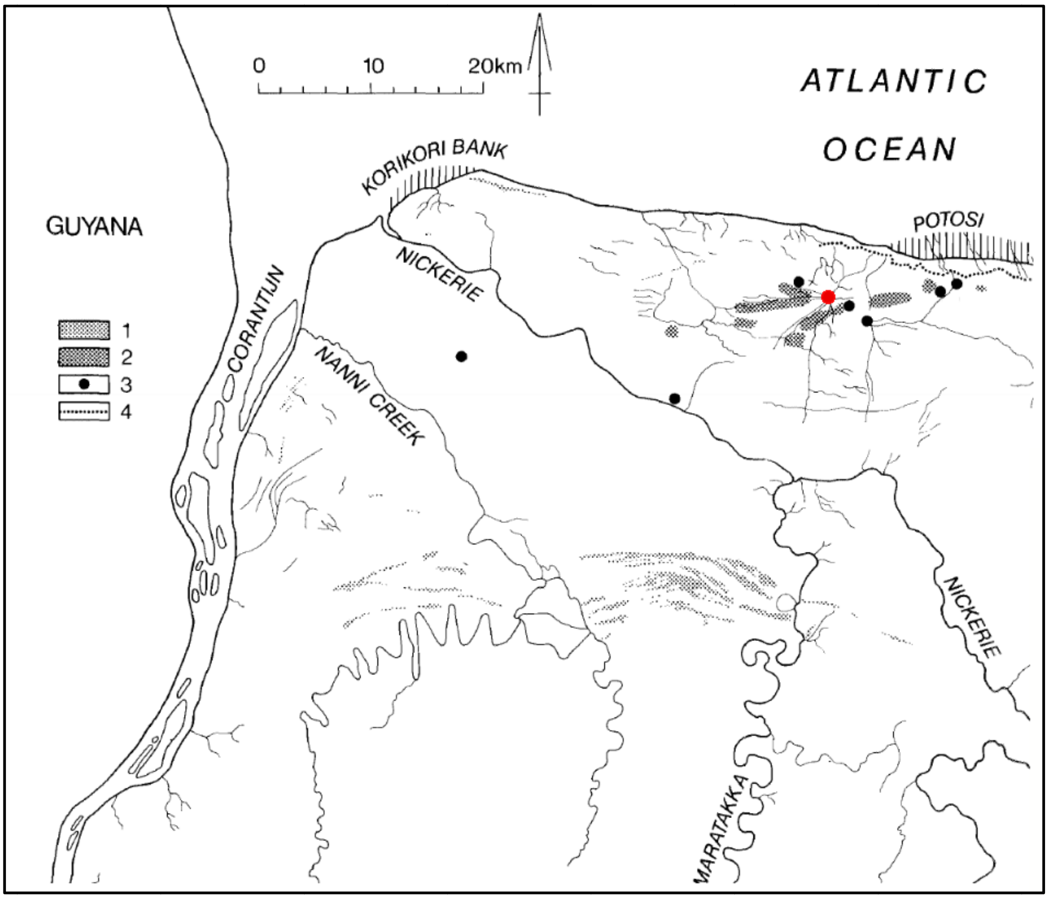

Figure 2.7. Locations of the archaeological sites in west Suriname (after Versteeg 1985, 666). The Hertenrits site is the red dot. **Legend**: 1= Cheniers; 2 = Clusters of raised fields; 3 = Archaeological sites; 4 = former indented coast line

Saramacca

Though Van Duijvenbode (2011) reports four individuals from Saramacca (Sa1 - Sa4), an individual labeled as 'Sa5' was encountered during this study. It would appear then that at least five individuals come from the Saramacca site. Unfortunately, only partial contextual information is available about these individuals. This is because there is a note present with the individuals, but the information does not provide an exact location. Van Duijvenbode (2011) reports that the description of the site and location given on the note does not correspond with any of the excavations mentioned in the overview of archaeological research in Suriname by Boomert (1975). Furthermore, the excavation dates from sites in this area do not correspond with the provided excavation date on the note. Versteeg (1998) does not even mention an excavation in this area conducted by Dr. Geijskes, though he does report on archaeological research in this area before Dr. Geijskes conducted excavations in Suriname (time period of 1900-1945). It is not clear if any human remains were found in this earlier period. At this point, the exact location of the Saramacca site is not clear. According to Van Duijvenbode (2011) it can be assumed that, based on a flexed burial position, the individuals are Amerindian. However, it is not possible to determine the time period for these individuals.

2.5 Contribution of this study

As this chapter illustrates, the prehistory of Suriname is quite diverse. The human skeletal material from Geijskes collection represents various cultures from the pre-Columbian period, and also various locations in the coastal area. Previous archaeological findings and research resulted in knowledge on the origin, material culture, and locations of these cultures, and also communications between cultures in the area (trade networks) (e.g. Rostain 2008; Versteeg and Bubberman 1992; Versteeg 2008). Recent research (Van Duijvenbode 2011) also gave insight into a social-cultural aspect of these individuals, as she studied the presence of intentional cranial deformation (see chapter 4).

Even though our current knowledge on the different cultures from pre-Columbian Suriname is considerable, it is mostly based on archaeological findings. The suggested trade networks are mainly based on artifacts and architecture, or findings indicating trade or communication, as mentioned in chapter 1. Strontium stable isotope analysis may give more insight into mobility – and the probable origin of any non-locals – in these cultures, and therefore also give more insight into possible trade networks.

For most of the material analyzed, the contextual data is sufficient, as this is from either the Kwatta Tingiholo site or the Hertenrits site. However, for the other smaller sites the background information is lacking or limited such that the exact location and time period/cultural group is unknown. As already mentioned in the introduction chapter, strontium stable isotope analysis may contribute to establishing the location of archaeological sites, and the use of the data for this purpose is investigated.

3. Methods and materials

This chapter will present the methods and techniques which were used to conduct this study, which includes the methods for the selection of individuals under study and the methods for the isotopic analysis.

Geijskes collection and selection of individuals

The material under study is from the Geijskes collection, as mentioned in chapter 2. As the stable strontium isotope analysis is conducted on enamel, only individuals with preserved teeth were selected.

To gain more insight in the state of the collection, and which individuals could be selected, an inventory was made to establish the number of individuals and preserved teeth. The collection is stored in different boxes, and each box is labeled numerically. For the inventory, the box number is noted. The find number of each individual(s) present in the box is noted (of course, when this information was possible to extract from the documentation). At the same time, the dentition (if present) of each individual was recorded. The presence of caries, dental attrition, and other features that might indicate the element was not suitable for sampling, were noted.

The notation of each tooth element used in the inventory and throughout this study is according the FDI system (Fédération Dentaire Internationale). The complete jaws (maxilla and mandible) are divided into four quadrants, from the upper right (1), to the upper left (2), and from the lower left (3), to the lower right (4). Each tooth in the quadrant is assigned a second number, beginning from 1 at the mesial side to 8 at the distal side. The quadrant number and tooth number are combined; for example 41 (or 4.1) is the first incisor of the lower right quadrant.

Another remark that was included in the inventory was the presence of glue. Many of the individuals in the Geijskes collection have bone fragments and teeth which were glued together to keep the bones in position (e.g. tooth elements glued into their maxillary or mandibular sockets). This could of course complicate the extraction of the tooth, but also the stable isotope research. It was noted if it was not possible to separate the glue from the enamel and if that was the case the tooth was not sampled.

After the general inventory, individuals with enough enamel for analysis were selected. For each individual, one permanent tooth was selected. Preferably, the permanent premolars were extracted as these teeth form during early childhood. Assuming children are less mobile than adults, the strontium values in the premolars are reflective of the location of origin (Goodman *et al.* 2004; Laffoon 2012, 83). If an individual relocated at a later age to a different area, the local strontium signature of this area would not correlate with the strontium signature of the location of origin (the strontium value in enamel). If no premolars were present or not well enough preserved, then the first or second molars were extracted. The third molars were preferably not taken, as these teeth form relatively late in life (Moorrees *et al.* 1963; Ubelaker 1978) and do not reflect the environment during early childhood. Besides the aforementioned reason to sample premolars, during the inventory it became clear the premolars were well preserved for the majority of the individuals; sampling mostly premolars would also ensure strontium values formed around the same age of the individuals under study.

Table 3.1 displays the age range of enamel formation for the teeth analyzed in this study based on the standard of Holt *et al*. (2012) and Reid and Dean (2006). Both standards are based on European populations. However, Goodman *et al.* (1980) used for the study of enamel hypoplasia in sites from Illinois (AD 900-1300) similar ages for enamel formation (roughly between 2-6 years for the premolars and 0-3.5 years for the first molars). Moreover, Laffoon (2012) used these same age ranges; meaning the presented age ranges in table 3.1 can be used for this study.

Table 3.1. Overview of the age range of enamel formation for the analyzed teeth in this study (premolars and molars).

Tooth	Age of Enamel Crown Initiation	Age of Enamel Crown Completion	Reference
First premolar (upper)	1.7 yrs	4.8-5.3 yrs	Holt *et al*. (2012)
Second premolar (upper)	2.5-2.6 yrs	4.7-5.5 yrs	Holt *et al*. (2012)
First molar (upper)	1.3 yrs	3.0 yrs	Reid and Dean (2006)
First premolar (lower)	2.4-2.5 yrs	4.2-5.2 yrs	Holt *et al*. (2012)
Second premolar (lower)	3.0-3.4 yrs	5.4-5.7 yrs	Holt *et al*. (2012)
First molar (lower)	1.3 yrs	3.3 yrs	Reid and Dean (2006)

The extraction of teeth was done with different methods. For some individuals, the teeth were loose already and could be taken directly for sampling. In some cases, the amount of glue present on the maxilla and/or mandible complicated the extraction of the tooth. Namely, the teeth were glued by their roots into the maxilla and/or mandible, but with the use of extraction forceps and smaller pliers it was usually possible to extract the tooth. In some cases, only a fragment of enamel would fracture and this fragment would then be used for sampling. Because the glue is only present on the roots of the teeth, no glue remnants were present on the crown, ensuring that no glue remnants were present in the sample. Even so, any possible presence of glue was removed during the sample preparation processes (see below).

During the process of extraction, it became clear that previously documented separate individuals (Th21 and Th21/H21) were probably the same individual, but had been divided over two different boxes and labeled inconsistently. The individual with number Th21 is a partially complete skeleton (most of the bones are present), whereas the remains of the individual with number Th21/H21 were found in a bag, containing mostly vertebrae and rib fragments. Between these two individuals there are no duplicate bones, which would have suggested two separate individuals. The documentation included with Th21/H21 indicate that this 'individual' was found near Th17 and Th20. Currently, it is still not entirely clear whether or not these numbers, Th21 and TH21/H21, represent the same individual or two different individuals. For both numbers, enamel was sampled and results will be interpreted keeping in mind that it may be the same individual.

Unlabeled individuals and unidentified teeth were not sampled. The final sample consists of 24 enamel samples, from 23 or 24 individuals, as presented in table 1.

Table 3.2. Individuals selected for stable Sr isotope analysis from the Geijskes collection. The light-blue columns indicate the teeth are probably the same individual. The VU code was the sample code for the strontium stable isotope analysis.

Abbreviations sites: H= Hertenrits, OK= Okrodam, Th= Kwatta Tingiholo, Sa= Saramacca, Pa= Paramaribo.

#code VU	Site	# Individual	# Element	Tooth name	Enamel sample (mg)
W168	H	H0532	3.5	premolar (2nd)	3,5
W147	H	H0394	3.4	premolar (1st)	4,7
W164	H	H0402	3.5	premolar (2nd)	3,4
W156	H	H0393	3.5	premolar (2nd)	5,1
W170	H	H 0-1	2.4	premolar (1st)	4,5
W158	OK	OK-02-2	3.6	first molar	5,3
W161	P	Pa1	3.4	premolar (1st)	3,5
W165	S	Sa1	1.4	premolar (1st)	3,1
W153	S	Sa5	4.6	first molar	3,3
W169	S	Sa4	4.5	premolar (2nd)	3
W155	Th	Th4	3.5	premolar (2nd)	3,4
W167	Th	Th14	3.4	premolar (1st)	4
W157	Th	Th19	3.6 or 4.6	first molar	6,4
W150	Th	Th11	2.4	premolar (1st)	4,1
W154	Th	Th3	3.4	premolar (1st)	3,5
W151	Th	Th9	3.4	premolar (1st)	3,1
W160	Th	Th16	3.4	premolar (1st)	3,1
W162	Th	Th21	??.4	premolar (1st)	3,1
W152	Th	Th18	3.5 or 4.5	premolar (2nd)	3,3
W159	Th	Th17	4.4	premolar (1st)	3
W148	Th	H20	4.5	premolar (2nd)	3,6
W163	Th	H21	4.5	premolar (2nd)	4
W166	Th	Th2	1.4	premolar (1st)	3,2
W149	Th	Th1	3.5	premolar (2nd)	3,4

Preparing and sampling enamel for isotopic analysis

The processes of selecting, extracting, and cleaning the teeth were done at the Thin Sectioning and Bone Processing Laboratory of the Faculty of Archaeology at Leiden University. All of the selected teeth were first collected in plastic zip-lock bags, and each bag was labeled with the corresponding find number of the individual as well as the element number. Protective gloves were worn during the extraction, cleaning, and sampling of the teeth.

To prepare the teeth or enamel fragments for sampling, they were placed in plastic tubes with caps. Each tube was labeled with the find number, then filled with distilled water and sonicated for one hour. This cleaning process removes materials from the enamel surface that are not to be included in the sample (e.g. soil, calculus). After sonication, the teeth were rinsed with distilled water to clean it from the distilled water that was used during sonication, and left to dry.

To start the sampling process, an area of enamel on each tooth was selected; preferably without calculus or fractures (to prevent the enamel from breaking). This surface was then first removed (method specified below); removing the outer layer of enamel. This is done to create a 'clean' surface of enamel from which the sample could be taken, as it prevents any contamination by calculus or soil and surface staining. Removing the outer layer of enamel allows for the sampling of the inner core which is much less prone to diagenetic alterations such as elemental uptake and leeching, influencing the chemical composition (Budd *et al.* 2000; Burton 2008, 454).

To abrade the outer layer and take the inner layer, a Proxxon engraver (model GG12 engraving tool), equipped with a 1.0mm diamond grinding bit was used. Before drilling, the drill was cleaned with 1) distilled water, 2) ethanol, and 3) 1% HCl. This cleaning procedure was repeated between every use.

The enamel sample was collected on a weighing paper, after which it was transferred to a pre-weighed and pre-cleaned 1.5 ml centrifuge tube. Approximately three milligrams is needed for the analysis, and table 3.2 notes the amount of enamel sample collected. The amount of enamel that could be extracted was highly dependent on the tooth (complete element or fragment of enamel), but, minimally three milligrams was obtained for every tooth. The samples were then transferred to the Vrije Universiteit

Amsterdam (VU) for the chemical cleaning and strontium separation processes, as well as the measurement of the samples by mass spectrometry.

The following cleaning processes were done at the laboratory of the Faculty of Earth and Life Sciences of the VU. Each 1.5ml centrifuge tube was placed in a holder, so a sodium hypochlorite solution (NaOCl) could be added. This solution (4.00-4.99%) was mixed with Milli-Q water until the solution was 50/50; meaning the NaOCl concentration was around 2.5%. For each sample, 1 ml of this solution was added with a pipette. After this, the tubes were placed on a vortex mixer to make sure the enamel would be mixed with the NaOCl solution. The NaOCl solution was mixed with the sample for approximately three hours, after which it was removed by centrifuging the mixture for four minutes and pipetting off the supernatant. After this, Mili-Q water was added to the enamel sample, also for three hours. It was then also removed by centrifuging the mixture for four minutes and pipetting off the supernatant. This process was done twice, to ensure there was no trace of the NaOCl solution. In the last step (<1.0 N) acetic acid was added for three hours and also removed using the same process as described for the NaOCl.

The cleaned enamel samples were loaded into pre-cleaned Teflon beakers for drying and the extraction of strontium. These beakers were pre-cleaned first with ethanol and rinsed with demi-water, after which they were placed in (heated) HNO_3 and (heated) HCl, respectively; leached in 6-7M HCl for 48h, and rinsed 5 times with ultra-pure water (Milli-Q).

The strontium extraction from the enamel samples was the next part of the sample preparation. For this, specific equipment as well as a specific solution were used. The separation process (column chromatography) was done with special strontium separation columns; these columns have a small loading reservoir on top and are tapered at the bottom. At the tapered bottom, there is a small glass frit present. The solution is a strontium resin (Eichron Sr-resin) that only binds to strontium. This resin needs to be cleaned first; this is done by adding Mili-Q water (as much as the loading reservoir can hold) and waiting until the Mili-Q is completely through the column. After this, 3M nitric acid (HNO_3) is added to the column. This step of adding Mili-Q water and HNO_3 was repeated three times, in order to alter the pH from low to high and vice versa, which influences the binding-unbinding characteristics of the resin. The sample, nitrated (added HNO_3), was then added with HNO_3 to the column. The HNO_3 (nitration of the solution) enables the binding characteristics of the strontium resin; meaning the strontium of the sample will now bind with the resin. Any other element will not bind to the resin and will pass through the column. After this process Mili-Q water was added, resulting in the resin unbinding with the strontium. The strontium is then released, and this was collected in the sample beaker. The strontium samples were left to dry (on a hotplate) and concentrated HNO_3 was added twice to ensure the samples were clean, and left to dry again.

The dried strontium samples could then be loaded into the mass spectrometer. The first step of the loading process involved adding 10% HNO_3 again to the dry samples, as they are needed in a liquid form to load onto the filaments. The 'filament' is a rhenium ribbon that is used to load the sample on. This small rhenium ribbon is welded between metal loading brackets, which are positioned on a small metal plate. On top of this small plate with the loading brackets a shield is placed, and this whole assemblage can be loaded onto the mass spectrometer. The shields, plates, and brackets were pre-cleaned.

The filaments were placed in a device that enables a specific electric current to run through the filament itself. The process of placing the samples on the filament started with a current of 1.1A and melting some parafilm on both ends of the filament. This is to ensure any liquid placed on the filament (i.e. the sample) will not 'fall off'. At a lower current (approximately 0.9A) both TaCl5 (tantalum pentachloride, 2µl) and H_3PO_4 (phosphoric acid, 1µl) are added, as well as the nitrated sample. After this, the current is increased so the parafilm burns off and the H_3PO_4 evaporates. Again, the current is increased and the filament is heated until the sample is solid; the result is a solid thin residue of the sample on the filament.

The measurement of the strontium samples was done on a Triton Plus Mass Spectrometer. After calibration and configuration the Triton Plus Mass Spectrometer runs the loaded samples automatically; there is no need for configuration after each sample. An electric current (approximately 2.8 amp, sometimes higher) runs through the selected sample, which results in a temperature of around the 1400 degrees Celsius. Each sample was measured in 200 cycles; each cycle is a short measurement of ±10 seconds. In total, the sample is thus measured for approximately 45 minutes. With each measurement, the amount of ^{84}Sr, ^{85}Rb, ^{86}Sr, ^{87}Sr, ^{88}Sr, and hence the ratios of these strontium isotopes, are documented. After 200 cycles, the mean, standard error (% and absolute), and standard deviation (% and absolute) of the 200 measurements are calculated. The standard error is a measurement of precision; the variability of all 200 measurements is calculated. Most of the standard errors (2 S.E.) are approximately 0.000010, or smaller. A higher standard error indicates a less precise measurement.

The resultant data were stored in an export file for Microsoft Excel (.exp), where basic descriptive statistics could be applied. For the descriptive statistical analyses of the $^{87}Sr/^{86}Sr$ ratios and data on the individuals, the Mann Whitney U Test was used in SPSS v. 20.0. The Mann Whitney U test is a non-parametric statistical test. With this test, two samples that are independent can be compared (Corder and Foreman 2009, 57). The Mann Whitney U Test is the equivalent of the parametric t-test (Field 2009, 540). Non-parametric tests use the principle of ranking data. Data is ranked from the lowest value to the highest; resulting in respectively small and larger ranks. The analysis is then conducted on the ranks (Field 2009, 542). The Mann Whitney U test was used for this study as the sample sizes were small and not normally distributed, meaning parametric tests should not be conducted.

4. Results

This chapter will present the results of the strontium stable isotope analysis. The mean, median, and range will be presented for all of the measured samples as well as per site. Both standard deviation (S.D.; σ) as well as standard error (S.E.) are noted. The standard deviation is a measure of variability, whereas the standard error is a measure of internal precision.

4.1 Results of all samples

A total of 24 samples were measured for $^{87}Sr/^{86}Sr$. The ratios range from 0.70923 to 0.716285. A statistical summary of all the $^{87}Sr/^{86}Sr$ ratios with 2 standard deviations is presented in table 4.1.

Table 4.1. Statistical summary of the $^{87}Sr/^{86}Sr$ of all samples.

$^{87}Sr/^{86}Sr$					
	Mean	**Min**	**Max**	**Median**	**2 S.D.**
Individuals from all sites (n=24)	0.709992	0.709230	0.716285	0.709732	0.001369

Table 4.2 shows the results by site. The Paramaribo site has only one sample, with a $^{87}Sr/^{86}Sr$ ratio of 0.710071. It is not shown in the table because mean and range data are not applicable.

The Hertenrits site (n=4) has a $^{87}Sr/^{86}Sr$ range from 0.709230 to 0.709427. The $^{87}Sr/^{86}Sr$ range for the Kwatta Tingiholo site (n=14) is from 0.709478 to 0.710190. The lower end of the $^{87}Sr/^{86}Sr$ range for the Saramacca (n=3) site is 0.709457, whereas the upper end is the highest of all values in these samples at 0.716285. The $^{87}Sr/^{86}Sr$ range for the Okrodam site (n=2) is 0.709727 to 0.709849.

Table 4.2. Statistical summary of the $^{87}Sr/^{86}Sr$ of all samples, sorted by site. The Paramaribo site (n=1) is not listed in the table, but results are noted above.

	$^{87}Sr/^{86}Sr$				
Site	**Mean**	**Min**	**Max**	**Median**	**2 S.D.**
Hertenrits (n=4)	0.709328	0.709230	0.709427	0.709326	0.000094
Kwatta Tingiholo (n=14)	0.709826	0.709478	0.710191	0.709823	0.000236
Saramacca (n=3)	0.711765	0.709457	0.716285	0.709554	0.003914
Okrodam (n=2)	0.709789	0.709727	0.709850	0.709789	0.000087

4.2 Results per site

In this section the results per site will be elaborated upon. This includes the reporting of the $^{87}Sr/^{86}Sr$ values of each individual, after which all $^{87}Sr/^{86}Sr$ values are plotted.

For the Hertenrits site, four samples were measured. The $^{87}Sr/^{86}Sr$ values are presented in table 4.3.

Table 4.3. The $^{87}Sr/^{86}Sr$ of the Hertenrits samples.

# Individual	$^{87}Sr/^{86}Sr$	2 S.E.
H0394	0.709387	0.000009
H0393	0.709427	0.000010
H0402	0.709231	0.000008
H0532	0.709265	0.000008

The $^{87}Sr/^{86}Sr$ values for the samples from the Kwatta Tingiholo site are displayed in table 4.4. The highlighted field indicates a S.E. of more than +/- 0.000010, meaning a less precise measurement.

Table 4.4. The $^{87}Sr/^{86}Sr$ of the Kwatta Tingiholo samples.

# Individual	$^{87}Sr/^{86}Sr$	2 S.E.
Th1	0.709736	0.000009
Th2	0.710191	0.000035
Th3	0.709619	0.000008
Th4	0.709478	0.000008
Th9	0.709957	0.000009
Th11	0.710062	0.000009
Th14	0.709586	0.000009
Th16	0.709862	0.000008
Th17	0.709986	0.000010
Th18	0.709784	0.000008
Th19	0.710001	0.000009
Th20	0.710131	0.000008
Th21	0.709487	0.000008
Th21/h21	0.709678	0.000011

For the Saramacca site, three samples were measured (table 4.5). The individual with number Sa1 has a much higher $^{87}Sr/^{86}Sr$ than observed in the other Saramacca samples.

Table 4.5. The $^{87}Sr/^{86}Sr$ of the Saramacca samples.

# Individual	$^{87}Sr/^{86}Sr$	2 S.E.
Sa1	0.716285	0.000007
Sa4	0.709554	0.000009
Sa5	0.709457	0.000011

The results for Okrodam consist of the measurements of two samples (table 4.6). The highlighted field indicates a S.E. of more than +/- 0.000010.

Table 4.6. The $^{87}Sr/^{86}Sr$ of the Okrodam samples.

# Individual	$^{87}Sr/^{86}Sr$	2 S.E.
OK-0-1	0.709727	0.000009
OK-02-2	0.709850	0.000017

As mentioned earlier, only one sample was available for the Paramaribo site. The results show that the $^{87}Sr/^{86}Sr$ for this individual is 0.710071 with a 2 S.E. value of 0.000008.

The results per site are plotted into graphs to display the variation in $^{87}Sr/^{86}Sr$ values. Figure 4.1 shows the $^{87}Sr/^{86}Sr$ ratios of each individual and grouped by site. The site names are displayed on the X-axis.

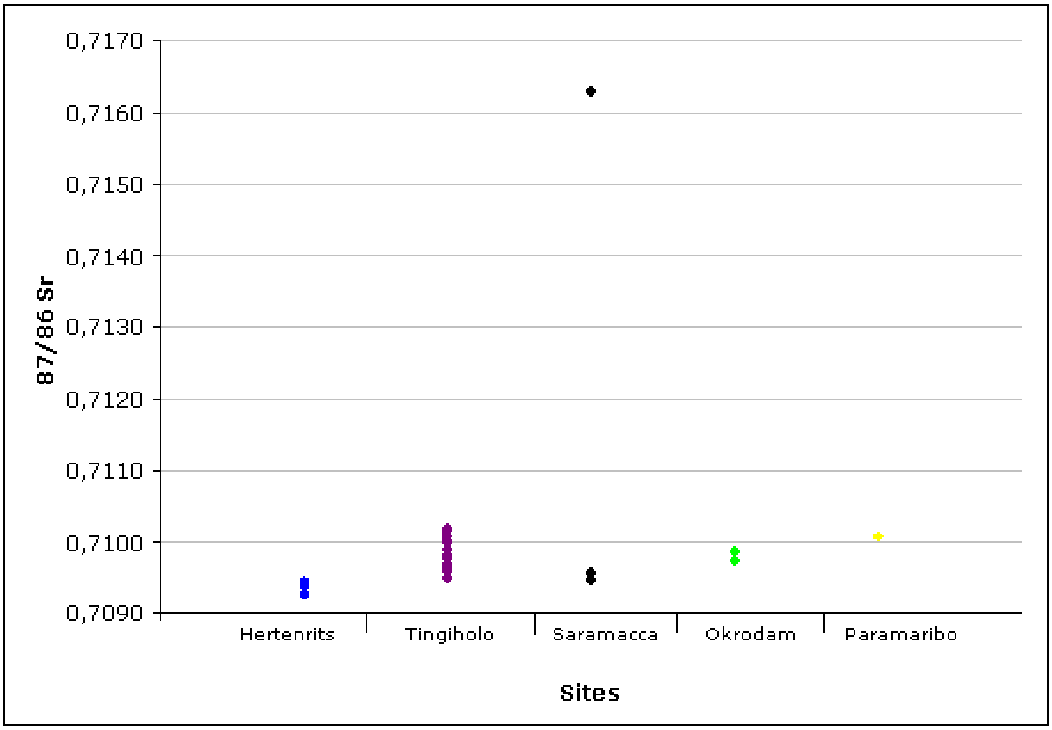

Figure 4.1. The $^{87}Sr/^{86}Sr$ of all samples sorted by site. Note: Tingiholo is Kwatta Tingiholo.

As can be seen in figure 4.1, one individual from Saramacca (Sa1) has a much higher $^{87}Sr/^{86}Sr$ than the other individuals. With the scale used in figure 4.1, the $^{87}Sr/^{86}Sr$ variation between the other individuals is not clear. Figure 4.2 shows the same results at a smaller scale by excluding the outlier.

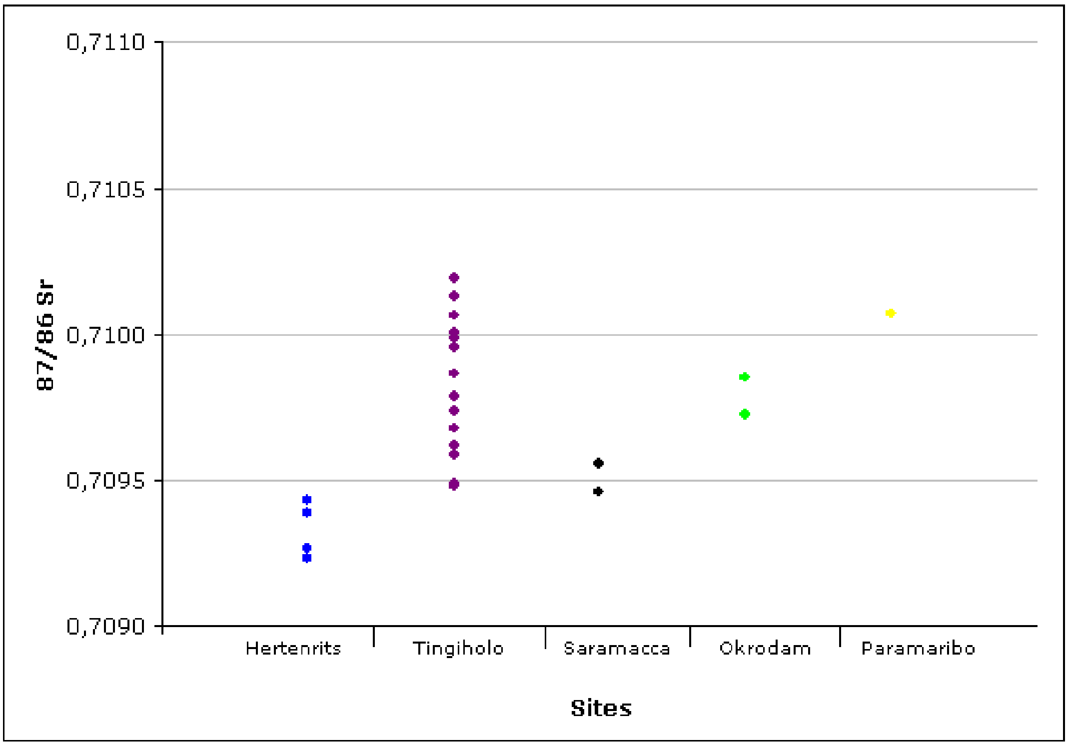

Figure 4.2. The $^{87}Sr/^{86}Sr$ of all samples, excluding Sa1. Note: Tingiholo is Kwatta Tingiholo.

To gain further insight into the $^{87}Sr/^{86}Sr$ variation between individuals, the results were plotted per individual and their number (fig. 4.3). The site names are displayed on the x-axis, and the color encoding for the sites is the same as used in figures 4.1 and 4.2. The numbers shown in table 4.7 indicate the sample's individual designation.

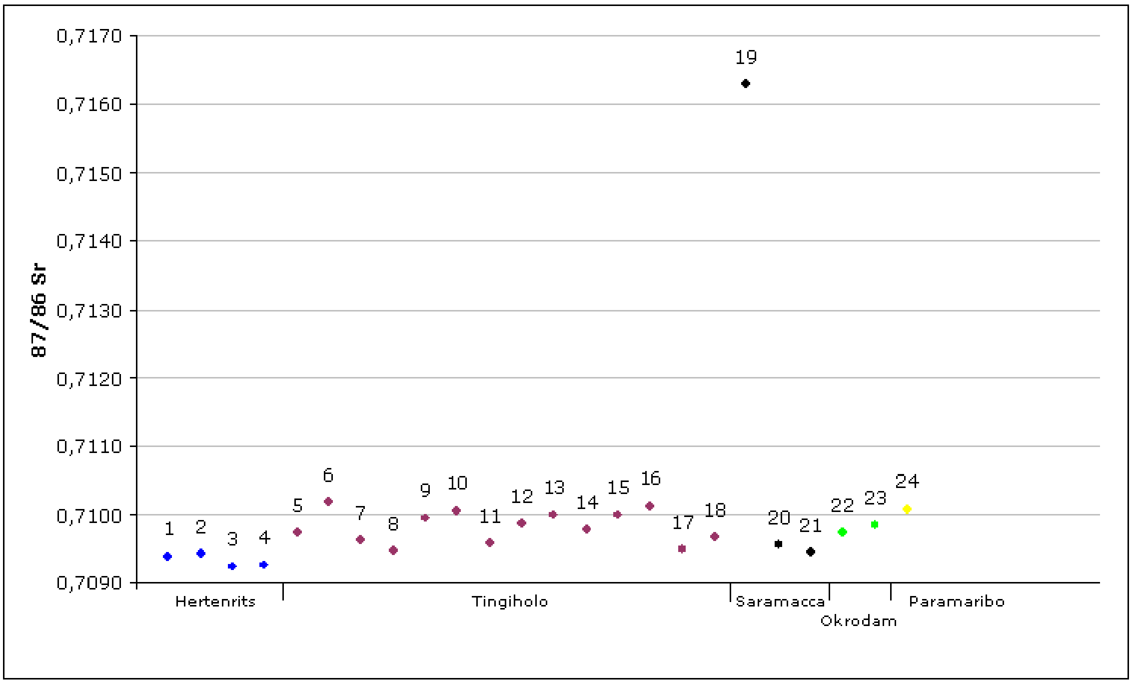

Figure 4.3. The individual $^{87}Sr/^{86}Sr$ of all samples. Note: Tingiholo is Kwatta Tingiholo.

Table 4.7. Numbers displayed in figure 4.3-4.4 and their corresponding individual designation.

# in fig. 4.3; 4.4	# Individual	# in fig. 4.3; 4.4	# Individual
1	H0394	13	Th17
2	H0393	14	Th18
3	H0402	15	Th19
4	H0532	16	Th20
5	Th1	17	Th21
6	Th2	18	Th21/h21
7	Th3	19	Sa1 (not displayed in fig. 4.4)
8	Th4	20	Sa4
9	Th9	21	Sa5
10	Th11	22	OK-0-1
11	Th14	23	OK-02-2
12	Th16	24	Pa1

Figure 4.4 displays the results of each individual with the standard error (2 S.E.) of each $^{87}Sr/^{86}Sr$ value. At this scale, the outlier is not displayed.

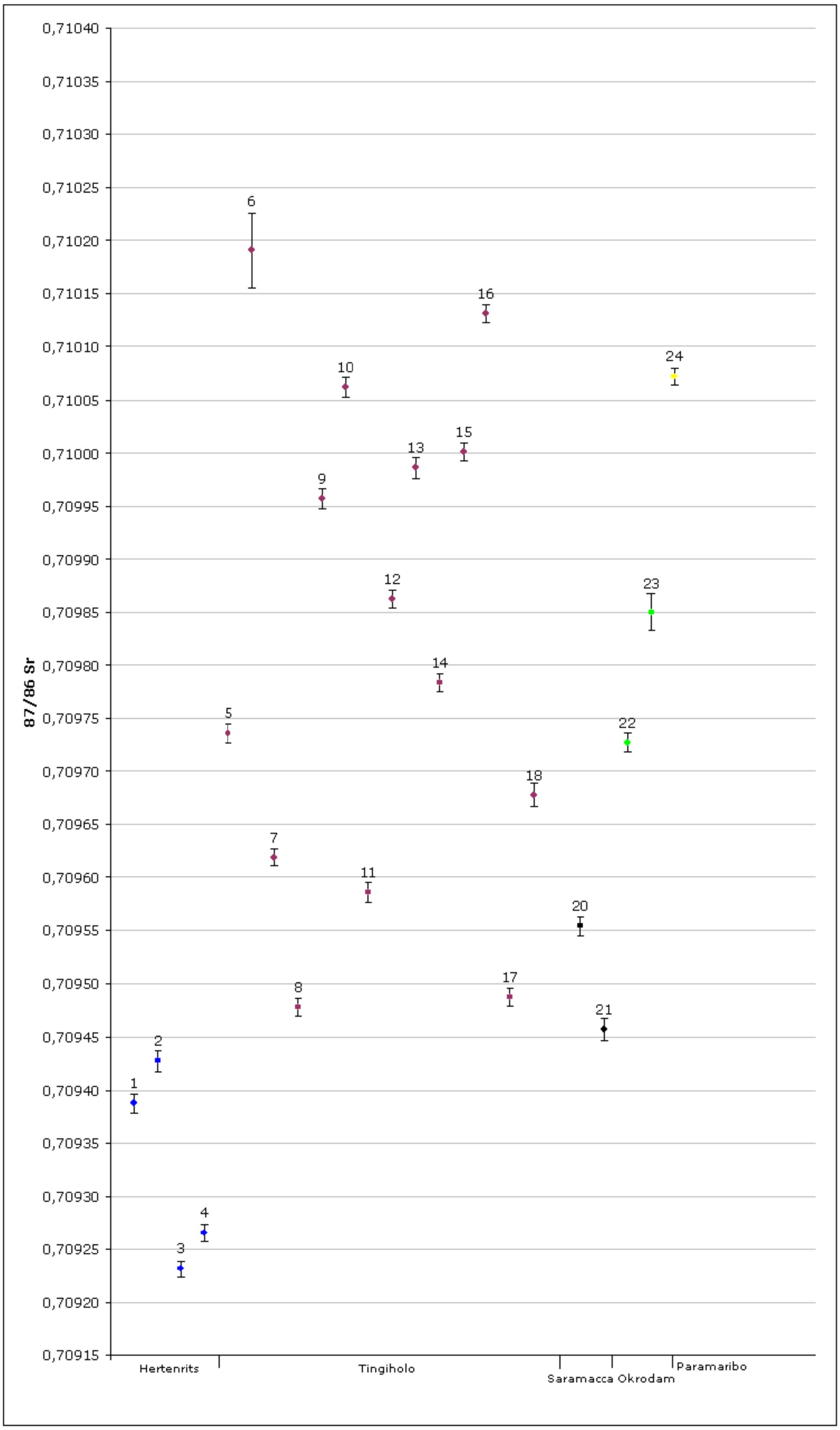

Figure 4.4. The individual $^{87}Sr/^{86}Sr$ of all samples with standard error. Note: Tingiholo is Kwatta Tingiholo.

The interpretation of these results is provided in the subsequent discussion chapter.

4.3 Results statistical tests and data comparison

The $^{87}Sr/^{86}Sr$ results were compared with other data to investigate if there were significant differences between $^{87}Sr/^{86}Sr$ ratios and specific data on the individuals (e.g. sex, cranial deformation). To do this, several statistical analyses were conducted. The interpretation of the results from the statistical analyses will be further discussed in chapter 5.

First, the type of tooth that was selected for this study was either a premolar (n= 21) or a first molar (n=3). As these elements form at different ages (Holt *et al*. 2012; Moorrees *et al.* 1963; Reid and Dean 2006; Ubelaker 1978), which may affect the $^{87}Sr/^{86}Sr$ results, a Mann Whitney U test was conducted on the type of tooth and the $^{87}Sr/^{86}Sr$ ratio to indicate if there was a statistical difference. The test indicated that there was no statistical difference between tooth type and $^{87}Sr/^{86}Sr$ ratios ($U = 30.00$, $z = -.131$, $p = 0.896$).

Next, the $^{87}Sr/^{86}Sr$ ratios for the individuals from the Kwatta Tingiholo site (n=14) and the Hertenrits site (n=4) were compared to see if there was a statistical difference. The Mann Whitney U test indicated that there was a significant difference ($U = 0$, $z = -2.974$, $p = 0.003$). No statistical tests were conducted between the other sites (Okrodam and Paramaribo: Waterkant/de Mirandastraat) because the sample size was too small.

Data on the Kwatta Tingiholo site

Physical anthropological data were only available for the Kwatta Tingiholo and Hertenrits site. The sample of the Hertenrits site was, however, too small to conduct statistical analysis. Tacoma's age-at-death and sex estimates for the Kwatta Tingiholo site (n=14), combined with the $^{87}Sr/^{86}Sr$ ratios, are displayed in table 4.8.

Table 4.8. Individuals from the Kwatta Tingiholo site with estimates of age-at-death and sex (via Tacoma 1963) and $^{87}Sr/^{86}Sr$ ratios. F= female; M=male.

# Individual	$^{87}Sr/^{86}Sr$	2 S.E.	Sex	Age-at-Death (years)
Th1	0,709736	0,000009	F	20-30
Th2	0,710191	0,000035	F	30-40
Th3	0,709619	0,000008	M	30-40
Th4	0,709478	0,000008	M	30-40
Th9	0,709957	0,000009	F	30-40
Th11	0,710062	0,000009	M	30-40
Th14	0,709586	0,000009	M	25-30
Th16	0,709862	0,000008	M	>50
Th17	0,709986	0,000010	M	30-40
Th18	0,709784	0,000008	F	30-40
Th19	0,710001	0,000009	M	20-25
Th20	0,710131	0,000008	M	30
Th21	0,709487	0,000008	F	>40
Th21/h21	0,709678	0,000011	M	>21

The ratio of males and females in the collection of Kwatta Tingiholo - and actually in the complete Geijskes collection - is not equal; females are underrepresented (9 M to 5 F for the Kwatta Tingiholo site). Furthermore, as already noted by Van Duijvenbode (2011), the complete absence of sub-adults in the Geijskes collection is remarkable. Both aspects resulted in limitations regarding statistical analyses for the Kwatta Tingiholo site.

Table 4.8 shows that $^{87}Sr/^{86}Sr$ ratios for males from the Kwatta Tingiholo site (n= 9) vary between 0.7094 and 0.7101, with a mean of 0.709823. The females (n= 5) also have ratios between 0.7094 and 0.7101, with a mean of 0.709831. Using the Mann Whitney U test, there was no statistical difference in $^{87}Sr/^{86}Sr$ ratio between the sexes ($U = 22.00$, $z = -.067$, $p = 0.947$). In addition, due to the fact that during this study enamel was analyzed which was formed during early childhood, no statistical analysis on strontium isotope data and age at death was conducted. The only possible age affect, which is from using different teeth (premolars versus first molars), has already been assessed by statistical analysis.

It must also be noted that even though the burial information (e.g. burial position, grave goods, and grave location) for the Kwatta Tingiholo site was documented, the documentation could not be used to investigate possible differences in burial and $^{87}Sr/^{86}Sr$ ratios. According to Dr. Geijskes (1991, 16), the find numbers for the individuals on the excavation drawing made in 1962 do not correspond with the find numbers that the individuals have currently. On the excavation drawing, the individuals are documented with S-numbers (e.g. S9 or S8) and apparently were later labeled (possibly during Tacoma's research) with Th-numbers. With the change of the find numbers, it was not possible to correlate the data from the excavation drawing with a specific individual; therefore no analysis on burial type and $^{87}Sr/^{86}Sr$ ratio could be conducted.

Cranial deformation

Van Duijvenbode (2011) researched the presence and type of intentional cranial deformation in the individuals from the Geijskes collection. In total, there are four individuals with intentional cranial deformation from the Kwatta Tingiholo site, and one individual from Okrodam site included in this study. Van Duijvenbode (2011) also reports intentional cranial deformation in other individuals from the Geijskes collection, but these individuals were not sampled in this study.

All of the individuals with intentional cranial deformation showed frontal-occipital modification. One individual from the Kwatta Tingiholo site, Th18, shows a deformation that is slightly different. Van Duijvenbode (2011, 8) argues that the deformation was also supposed to be a frontal-occipital modification, but a misaligned board at the back of the skull resulted in a positional plagiocephaly deformation. Her findings indicate that the same type of intentional cranial deformation was present in the cultures of Kwatta (the Kwatta Tingiholo site) and the Hertenrits. Unfortunately, intentional cranial deformation is present in only one individual from the Hertenrits site, and this individual is not sampled in this research. The fact that the same type of intentional cranial deformation is present in two different cultures suggests that cranial deformation was not used to distinguish different cultures (Van Duijvenbode 2011, 10). Van Duijvenbode (2011, 10) suggests that the intentional cranial deformation was probably used for social status differentiation. The data on presence of intentional cranial deformation is therefore combined with the $^{87}Sr/^{86}Sr$ ratios. This might indicate whether or not the individuals with intentional cranial deformation - and therefore possibly also a different social status - were originally from a different location.

The individuals from the Kwatta Tingiholo site with intentional cranial deformation are Th11, Th14, Th17, and Th18. Their type of intentional cranial deformation, age-at-death, and sex, as well as their $^{87}Sr/^{86}Sr$ ratios are displayed in table 4.9; sorted by ascending $^{87}Sr/^{86}Sr$ ratios.

Table 4.9. Individuals with intentional cranial deformation (Van Duijvenbode 2011) with data on sex, age at death (Tacoma 1963), and $^{87}Sr/^{86}Sr$ ratios.

# Individual	Type modification	$^{87}Sr/^{86}Sr$	2 S.E.	Sex	Age at Death (years)
Th14	Fronto-Occipital Parallel	0,709585	0.000009	M	25 – 30
OK-0-1	Fronto-Occipital Parallel	0,709727	0.000009	M	> 40
Th18	Positional Plagiocephaly/ Fronto-Occipital Parallel	0,709784	0.000008	F	30 – 40
Th17	Fronto-Occipital Parallel	0,709986	0.000010	M	30 – 40
Th11	Fronto-Occipital Parallel	0,710062	0.000009	M	30 – 40

As can be seen in table 4.9, individuals with intentional cranial deformation have $^{87}Sr/^{86}Sr$ values between 0.7095 and 0.7100. The same $^{87}Sr/^{86}Sr$ range is represented in the complete sample. The individuals with cranial deformation do not have $^{87}Sr/^{86}Sr$ values that cluster closely together. Statistical analysis was conducted on the Kwatta Tingiholo individuals, and indicates no difference in $^{87}Sr/^{86}Sr$ ratios between individuals with intentional cranial deformation (n=4) and those without intentional cranial deformation (n=10) (U = 18.00, z = −.283, p = 0.777).

Unfortunately, it was not possible to conduct statistical analysis for the Okrodam individual with intentional cranial deformation because of sample size (complete Okrodam sample n=2). Even so, it can be observed that the $^{87}Sr/^{86}Sr$ ratio of the one individual with intentional cranial deformation (OK-0-1) does not differ markedly from the other individual; OK-02-2 (0.709850 ± 0.000017).

4.4 Standard error

One remark that should be made regarding the standard errors is the high standard error for two individuals. The amount of ^{85}Rb was high in one of the samples (individual Th2; #6 in fig. 4.4). This indicated interference from rubidium, which resulted in a very high standard error when compared with other standard errors of the samples (2 S.E. of Th2 = 0.000035), meaning it was not a very precise measurement. However, even with a relatively higher standard error, this strontium value could still be used in this study. When compared with the other $^{87}Sr/^{86}Sr$ ratios of this site, this specific $^{87}Sr/^{86}Sr$ ratio does not fall outside the range of values, even though the standard error is higher. The measurement is of course less precise than the other measurements, but has not affected the result and could be used in this study. Another $^{87}Sr/^{86}Sr$ ratio with a relatively high standard error was from individual OK-02-2 (#23 in fig. 4.4, 2 SE = 0.000017), but this was also still acceptable for the same reasons.

5. Discussion

This chapter will discuss the previously presented strontium stable isotope results and put these data into context. The overall results will be discussed by looking at intra- and inter-site variation, as far as this is possible. Before discussing the results, it should be noted that for this study no local background strontium signature is available; the implications arising from this lack of this information will also be discussed.

5.1. All sites: a brief comparison

The Hertenrits site (n=4) is located in the western region of Suriname and displays the lowest $^{87}Sr/^{86}Sr$ ratios of all sites (n=24); analysis indicates a statistical difference when compared with the $^{87}Sr/^{86}Sr$ ratios of the individuals from the Kwatta Tingiholo site (n=14). Even though the sample size of Hertenrits is small (n=4) and no specific background $^{87}Sr/^{86}Sr$ measurements are available, these lower strontium isotope values are likely due to the region being geologically and thus isotopically distinct compared to the location of the other sites. Using the geological data (see appendix I) and the map provided by Versteeg (1985, presented in chapter 2; fig 2.1), the Hertenrits site is located on a clay and silty clay formation of the Comowine Member. The other sites are also located on a clay and silty clay formation, but these are either from the Moleson Member or the Wanica Member. These are all different depositional phases in the Young Coastal Plain, so the differences in $^{87}Sr/^{86}Sr$ ratios might be related to the ages of these deposits. Brinkman and Pons (1968) describe the deposits of the Comowine Member as the youngest formation (1000 - 0 BP), whereas the Moleson Member (2500 - 1500 BP) and the Wanica Member (6000 - 3500 BP) are older. The variety in age of these sediments may explain the significantly different $^{87}Sr/^{86}Sr$ ratios of the Hertenrits site; it is located on younger sediment when compared with the locations of the other sites.

Excluding the $^{87}Sr/^{86}Sr$ ratio of Sa1 (see paragraph 5.2.1), the $^{87}Sr/^{86}Sr$ ratios of the individuals from the Kwatta Tingiholo, Paramaribo, and Saramacca sites are statistically indistinguishable. All of the ratios fall in the range of 0.709457 to 0.710191. Comparing the $^{87}Sr/^{86}Sr$ ratios, the Paramaribo site has a slightly higher mean $^{87}Sr/^{86}Sr$ ratio than the other sites. The Saramacca site has $^{87}Sr/^{86}Sr$ ratios that are at the lower end of the range - closer to the $^{87}Sr/^{86}Sr$ ratios of the Hertenrits site. Again, based on the geological data, this may correlate with the age of sediments as the Saramacca site is probably located (see 5.2.1 for the discussion on the Saramacca site) in the central coastal region of Suriname; in this area sediments of the Comowine Member are also present. However, additional isotopic data ($^{87}Sr/^{86}Sr$ ratios) for these sediments are needed. These additional data may also determine if the individuals have a geologically local signal.

Also, it must be kept in mind that several comments regarding comparisons of the $^{87}Sr/^{86}Sr$ values between some sites are based on only a few measurements. For example, only one sample represents the Paramaribo site and the Okrodam site is represented by two samples. The addition of more samples is needed for a better representation of the $^{87}Sr/^{86}Sr$ ratio distribution in these sites.

5.2. All sites: data in larger context

Now that the $^{87}Sr/^{86}Sr$ ratios of the sites have been generally discussed these values should be discussed in light of methods to assess which individuals are ‘local’ versus ‘non-local’. Various methods have been developed to distinguish so-called ‘local’ individuals from ‘non-local’ individuals, which were summarized in chapter 2.

For this study there were limitations to the use of some of these previously mentioned methods. No samples were available from non-skeletal material (i.e. soil, plant) to determine the local strontium signature of different regions or sites. Large faunal bones, probably from ox/pig, are present in the Geijskes collection. These bone fragments were selected for sampling by J.E Laffoon and await further processing and analyses. Distinguishing between local and non-local individuals by comparing $^{87}Sr/^{86}Sr$ ratios from both enamel and bone could also not be conducted in this study. At the moment, human bone fragments from the Geijskes collection have been selected for sampling for carbon and nitrogen stable isotope analyses, and also await further processing and analyses. The preservation of skeletal material in the Geijskes collection is poor, which may affect the strontium isotope analysis. The poor state of preservation of bone, as well as the fact that bone is more likely to be affected by diagenesis than enamel (Budd *et al.* 2000; Nelson *et al.* 1986; Price *et al.* 1992; Slovak and Paytan 2011, 745), means there may be difficulties in obtaining biogenic $^{87}Sr/^{86}Sr$ ratios from bone.

As no current data on the local strontium signature were available, results of previous strontium isotope analyses that have been conducted in, near, or around the area of Suriname were analyzed and used to provide an indication of the local strontium signature(s), thus making it possible to distinguish local and non-local individuals.

For example, a study by Veizer (1989) showed that the general strontium signature of a marine environment is approximately 0.7092. This general strontium signature is used to indicate marine environments in archaeological studies (Slovak and Paytan 2011, 744) and has been reported in archaeological studies (e.g. Price *et al.* 1994). This $^{87}Sr/^{86}Sr$ ratio is similar to the $^{87}Sr/^{86}Sr$ of all the sites under study, though the $^{87}Sr/^{86}Sr$ ratios of the sites in the east coastal region of Suriname are slightly higher. This is, as previously mentioned, probably because the east coastal region of Suriname is upon a younger geological formation than the west coastal region.

Another study that gives insight into the possible local strontium signature in Suriname is from Bataille *et al.* (2012). They published a paper on a method for mapping the strontium signature of ecosystems in the circum-Caribbean region. A method to map $^{87}Sr/^{86}Sr$ variation in bedrock and water was already available and was used to interpret $^{87}Sr/^{86}Sr$ ratios from samples in mobility studies, when no strontium signature of a specific area was known. This method relies on the assumption that bedrock weathering is the main source for the strontium signature (Bataille and Bowen 2012), and maps the $^{87}Sr/^{86}Sr$ variation at a large scale. However, taking into account that bedrock weathering is not the only source of a local strontium signature, Bataille *et al*. (2012) 'extended' this method by developing a multiple source model. This model added strontium variability that comes from the atmosphere (based on global climate model simulations). This new model was tested on the circum-Caribbean region (Antilles and Mesoamerica), and the results indicated that the prediction accuracy was higher in the Mesoamerica region than in the Antilles. However, it was concluded that the prediction model is useful for the complete circum-Caribbean region. For the map that was generated with this model see figure 5.1.

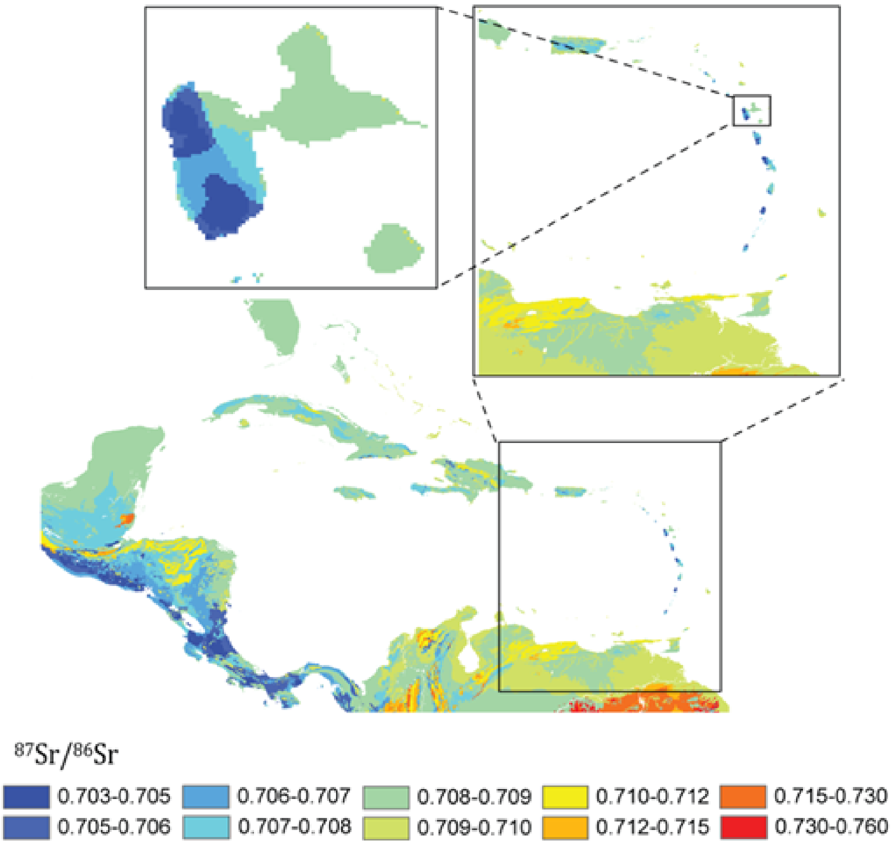

Figure 5.1. Circum-Caribbean region: modeled strontium isotope ratios with the three source mixing model (Bataille *et al*. 2012, 13). Inset panels are the Guadeloupe Islands, which were highlighted by Bataille *et al*. (2012) to illustrate the prediction model working on a small scale.

As is visible in figure 5.1, the map is cut off at the region of Guyana, meaning it does not display Suriname. Even so, based on the geological similarities between Guyana and Suriname, as well as the fact that Suriname is also part of the Guiana Shield, some assumptions can be made about the local strontium signature of Suriname. First, for the coastal region of Guyana, a strontium signature between 0.709-0.710 is predicted. This strontium signature can be found all along the coast of Guyana, but also to the east in Venezuela, as well as the coastal region of Venezuela (Bataille *et al*. 2012). The coastal area of Suriname can be compared to the coastal area of Guyana, as both coastal areas are considered to be from the Young Coastal Plain, deposited during the Holocene (Versteeg 2008, 303). More to the south, both Guyana and Suriname consist of the Old Coastal Plain, which was deposited during the Pleistocene (Versteeg 2008, 303; Zonneveld 1956). As can be seen in figure 5.2, the geology and the location of these different deposits are quite similar for Guyana and Suriname.

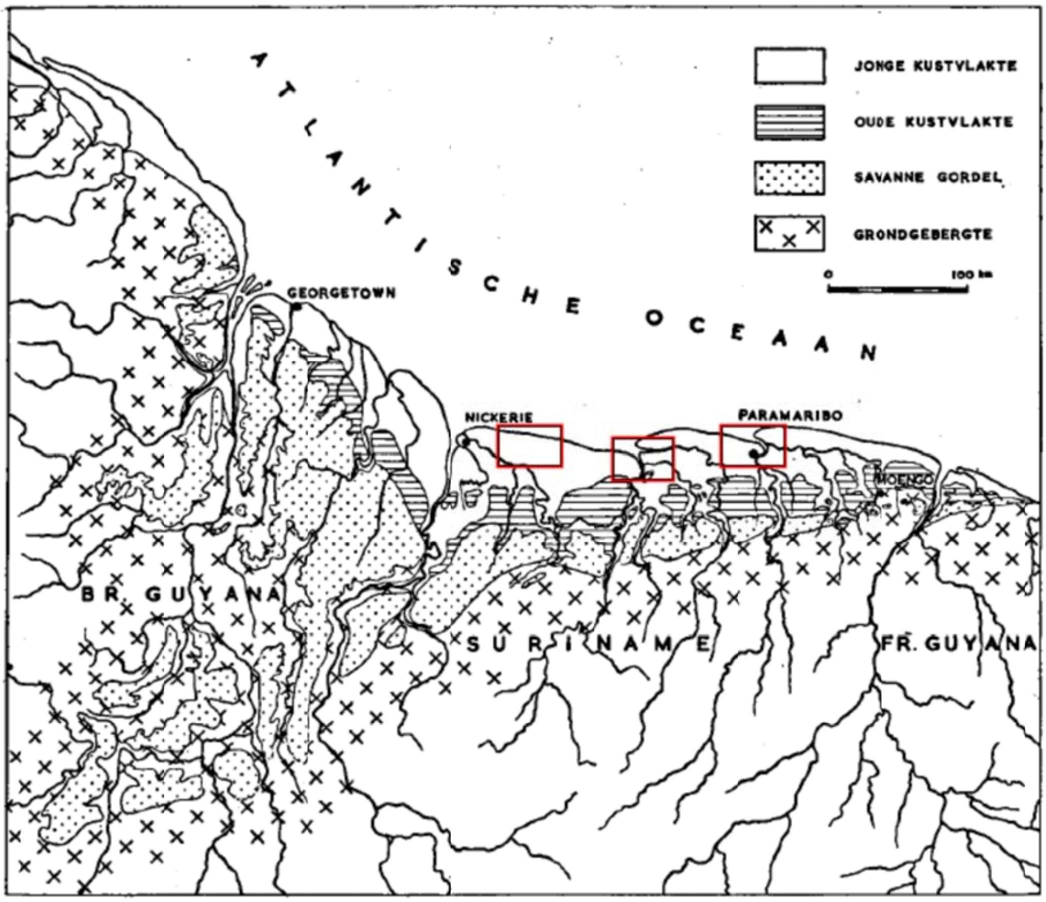

Figure 5.2. Overview geology of the Guianas (after Zonneveld 1955, 215). Left box indicates Hertenrits site, right box indicates the other sites. Middle box indicates the Saramacca site. **Legend** (translated) from top to bottom: Young Coastal Plain, Old Coastal Plain, Savanna, Crystalline Basement.

Based on this, the strontium signature predicted for the coastal area of Guyana (0.709-0.710) can also be expected for the coastal region of Suriname. The $^{87}Sr/^{86}Sr$ ratios of the analyzed individuals, with the exception of one individual (Sa1), all fall within this range, supporting the assertion that this is indeed the strontium isotope range of the coastal bedrock. The map is of course a prediction model, but even though Suriname is not displayed, it is highly unlikely the strontium signature would show extreme variation between Guyana and Suriname, especially in the coastal area.

Thus, the strontium signature for the coastal area of Suriname likely corresponds with the $^{87}Sr/^{86}Sr$ ratios of the individuals under study, with the exception of one, strongly supporting that the vast majority of individuals were locals. Notable are the lower $^{87}Sr/^{86}Sr$ ratios of the individuals from the Hertenrits site. These $^{87}Sr/^{86}Sr$ ratios are quite similar to the previously mentioned ^{87}Sr/^{86}Sr ratio for marine environments (0.7092); but as discussed earlier possibly also correlated with the age of the sediments.

It was also possible to distinguish locals from non-locals based on comparison of ^{87}Sr/^{86}Sr results of different individuals, as previously explained. Based on this, there appears to be one non-local individual. This is individual Sa1 from the Saramacca site, which has, as previously mentioned, a ^{87}Sr/^{86}Sr ratio that is not local based on the predicted local strontium signature for the coastal region of Suriname. This individual will be discussed in the next section.

5.2.1. The Saramacca individual

The context of the Saramacca site is, as previously mentioned, quite unclear. As of now, the only known documentation regarding the context of the Saramacca site is a note that is stored with the individuals in the box. Van Duijvenbode (2011, 7) translated this from Dutch; it provides a short description, date, and location:

Suriname

Saramacca at km 62

Road to Coppename, point Boskamp

February 1960, D.C. Geijskes

District Saramacca in shell ridge near Tambaredjo

Depth 60 cm, legs flexed, head east

No sites matching this description are mentioned in the literature (Boomert 1975; Versteeg 1998), nor do the dates of excavations in the area match the one mentioned in the note. However, based on the information on the note, the location is at least in the Saramacca district (fig. 5.3) and near Boskamp (also visible in fig. 5.3). Van Duijvenbode (2011) mentions that known sites excavated near this ‘possible’ area were both inhabited by the Kwatta as well as the Koriabo cultures. Though a specific time period is not known for the Saramacca site, it is likely to be Amerindian; either a Kwatta or Koriabo culture has been suggested (Van Duijvenbode 2011, 7), the latter at least before the Colonial period. Both cultures did indeed inhabit this coastal region of Suriname

(Rostain 2008). Furthermore, it can be assumed, based on the contextual information that the location of this archaeological site was in the central coastal area of Suriname. Unfortunately, no other information about this archaeological site could be found.

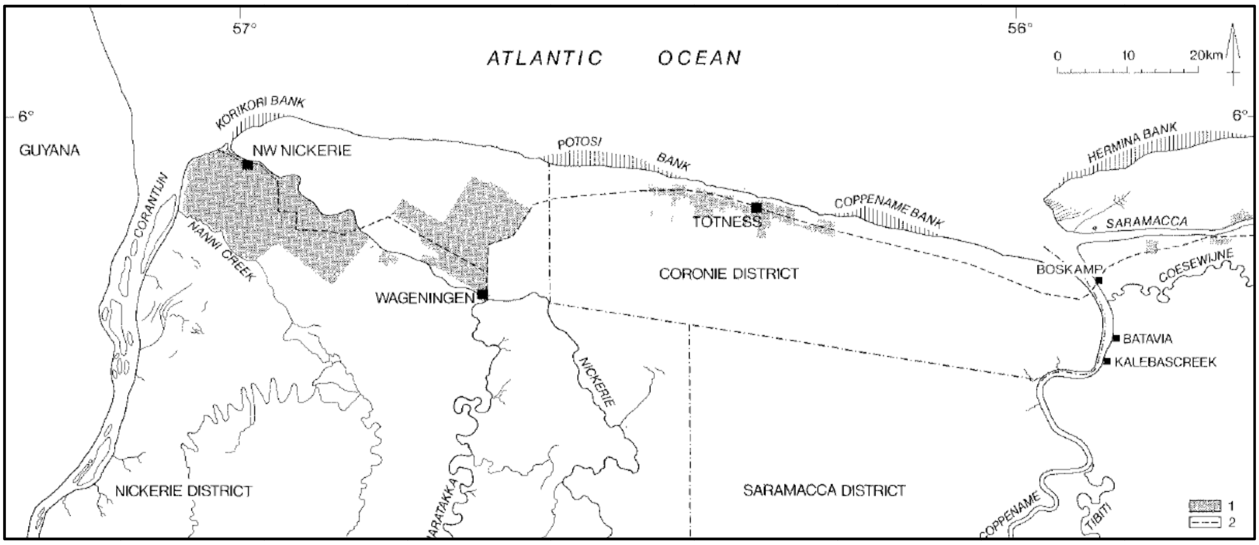

Figure 5.3. Overview of the geology of West Suriname with districts (Versteeg 1985, 665). **Legend**: 1) built-up and agricultural areas; 2) roads.

It is clear that individual Sa1 has a $^{87}Sr/^{86}Sr$ ratio that is much higher than all of the other individuals. It was therefore, using the approach of comparing the $^{87}Sr/^{86}Sr$ ratios to each other, distinguished as the only non-local. Using different approaches, the possible origin area of this individual can be researched; meaning an area with a local strontium signature of approximately 0.716 (the Saramacca individual has a $^{87}Sr/^{86}Sr$ ratio of 0.716285). To do so, the geological composition and therefore the correlating $^{87}Sr/^{86}Sr$ values of Suriname as well as surrounding areas (the Guianas) should be researched.

The prediction model from Bataille *et al*. (2012) could be used to indicate the areas in which the strontium is expected to be higher (>0.710) than the coastal area (0.709-0.710), and therefore a possible location of origin for the Saramacca individual. According to the prediction model, these high strontium ratios can be found in the southern region of Guyana and Venezuela. This area is known as the Guiana Shield (fig. 5.4); of which its geology and geochemistry (focusing on $^{87}Sr/^{86}Sr$) will be discussed below so the local strontium signature of that region can be mapped. This may allow specifying the area in the Guiana Shield the Saramacca may have derived from.

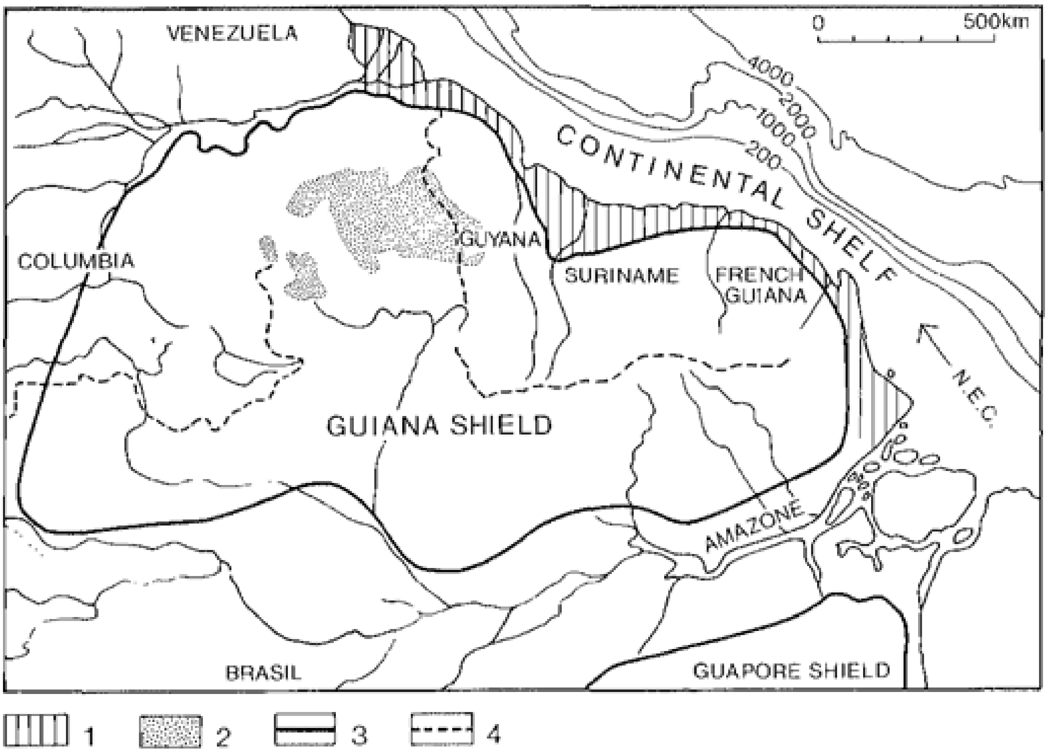

Figure 5.4. Map of the Guiana Shield (Versteeg 1985, 659). Legend: 1 = Coastal plain, 2 = Roraima Formation, 3 = Boundaries of the Shields, 4 = Watersheds

In the Guiana Shield a variety of strontium signatures can be expected, but according to Bataille *et al.*'s (2012) prediction model, all should be higher than 0.712. High $^{87}Sr/^{86}Sr$ ratios for this region are also mentioned by other studies (Kroonenberg and Roever 2009; Laffoon *et al.* 2014). However, according to the prediction model there are also areas in the Guiana Shield where a much lower (0.708-0.709) is expected. The variety in the $^{87}Sr/^{86}Sr$ ratios (high and low ratios) is related to the age of underlying bedrock; the older areas of the Guiana Shield will have higher $^{87}Sr/^{86}Sr$ ratios than the younger areas. The geology of the Guiana Shield in Suriname was discussed by De Vletter and Kroonenberg (1984) who showed that it is a complex geological area, as it consists of different types of formations (fig. 5.5). This is also known for the Guiana Shield in Venezuela (Sidder and Mendoza 1995, B13). De Vletter and Kroonenberg (1984) mention that the Guiana Shield in Suriname consists of two metamorphic belts; but also a greenstone belt and a vast granitoid volcanic complex (fig. 5.5). The two metamorphic belts are divided into the Falawatra Group and Coeroeni Group (De Vletter and Kroonenberg 1984, 163). These groups have $^{87}Sr/^{86}Sr$ ratios of 0.7023-0.7035 and 0.7027 respectively; meaning these areas are younger than the areas with higher $^{87}Sr/^{86}Sr$

ratios. These relatively low strontium isotope signatures were also reported in studies conducted to determine the age of the Guiana Shield (e.g. Priem *et al.* 1973; Sidder and Mendoza 1995), based on isotopes of rubidium and strontium. Most of the measured strontium isotope signatures in these studies are between 0.702 and 0.707, and are all from greenstone belt rocks or metamorphic rocks; again correlating with the fact that these sediments are younger areas in the Guiana Shield.

However, higher $^{87}Sr/^{86}Sr$ ratios such as 0.730 are also common (Laffoon *et al*. 2014, 227), as previously mentioned. It appears that the areas with granitoid complexes have much higher $^{87}Sr/^{86}Sr$ ratios. A recent study on the geochemistry of groundwater in French Guiana showed that the granite areas all have $^{87}Sr/^{86}Sr$ ratios higher than 0.712 (Négrel and Petelet-Giraud 2010). Gruau *et al.* (1985) also reported high $^{87}Sr/^{86}Sr$ ratios in the granite areas (between 0.716-0.770) of the Guiana Shield in French Guiana. A comparison of these values with the strontium isotope signatures of greenstone belt rocks or metamorphic rocks indicates that the granite areas are much older, and therefore have a higher $^{87}Sr/^{86}Sr$ ratio. These granite areas are present in Suriname and are actually quite large (see fig. 5.5; fig. 5.6). Moreover, a study by Hebeda *et al.* (1973) reports $^{87}Sr/^{86}Sr$ ratios of whole-rocks which are also higher than 0.712 and these measurements were taken in the southwest region of Suriname.

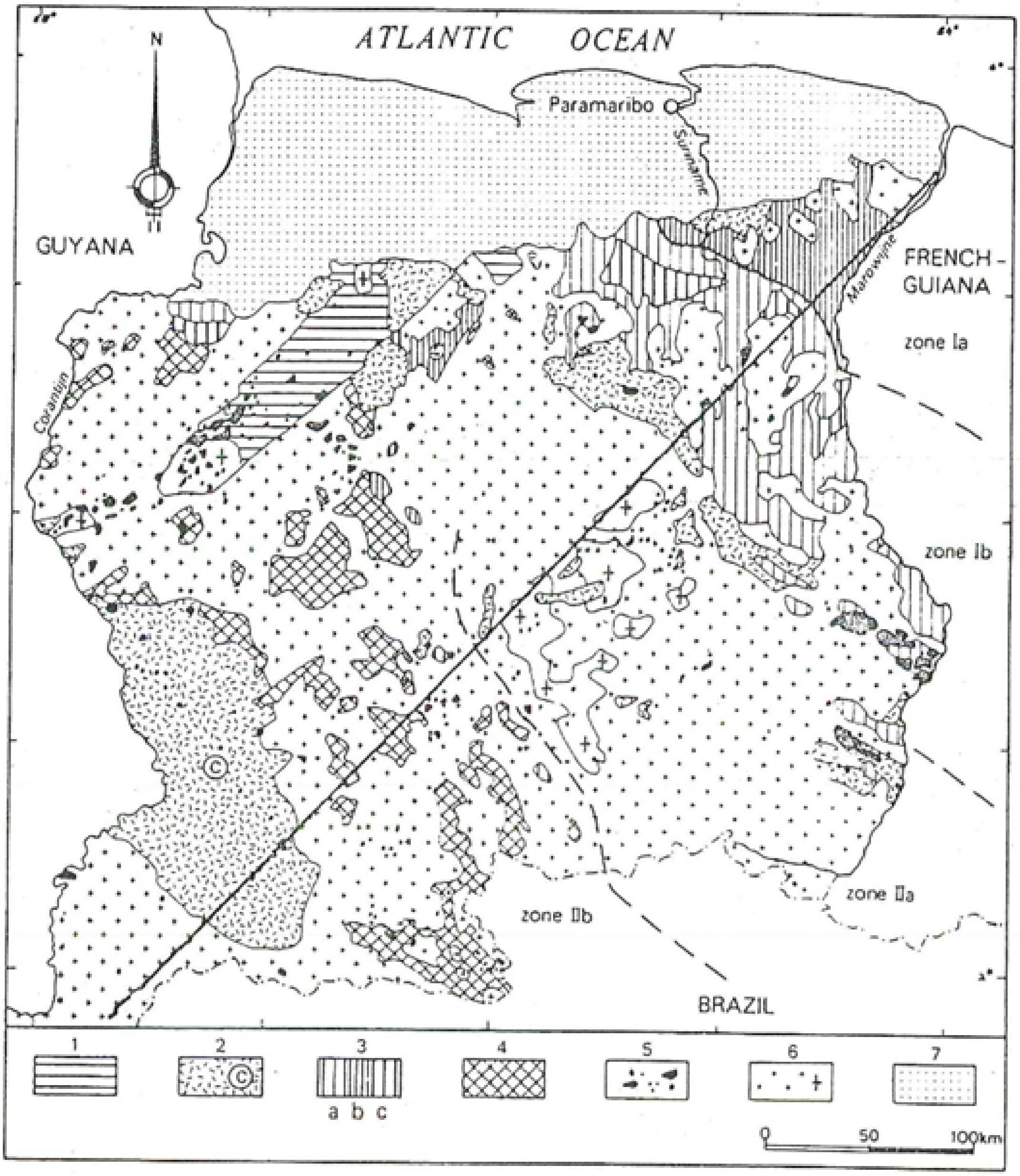

Figure 5.5. Map of the geological formations in Suriname, including the Guiana Shield (De Vletter and Kroonenberg 1984, fig. 1). Line across is a cross section; profile of this cross section is omitted from this figure. **Legend**: 1) Archaean granulate belt; (2) Trans – Amazonian high-grade belts; (3) Trans - Amazonian greenstone belt (a.metabasalts ecc. b.metagreywackes; c.meta-arenite and metaconglomerates); (4,5,6) Trans-Amazonian granitoid volcanic complex (4) acid-intermediate metavolcanics (5) metagabbros (6) granitoid rocks; big crosses: pyroxene granites); (7) Cenozoic sediments. Dolerites and Roraimas and stones omitted. Environmental zonation: Ia:outerturbidite arc; Ib: main basic volcanic arc.

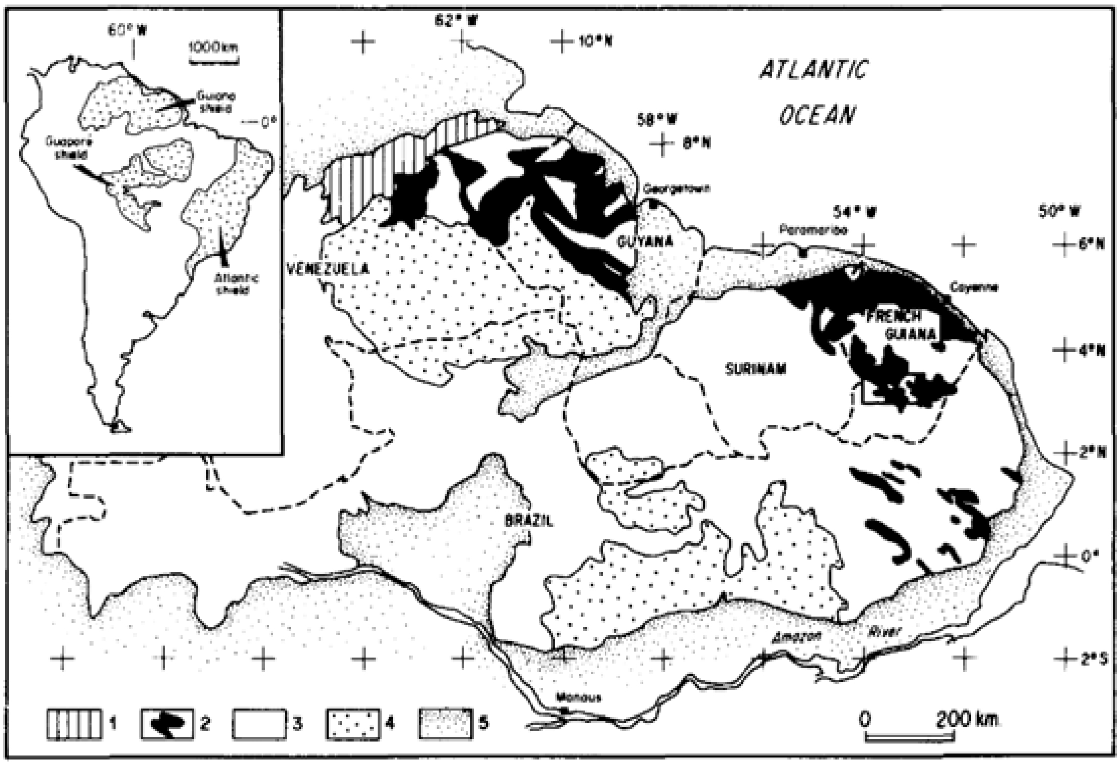

Figure 5.6. Map of the Guianas, indicating geological formations (Guau *et al.* 1985, 65). **Legend**: 1. Imataca granulitic complex; 2. Greenstone belts; 3. Undivided granites, mostly of (?) lower Proterozoic age; 4. Granites and volcano-sedimentary successions of mid-Proterozoic age (Uatuma orogenic cycle, Roraima Group and Urupi Formation); 5. Younger sediments.

Correlating the aforementioned data on geology and corresponding $^{87}Sr/^{86}Sr$ ratios, the $^{87}Sr/^{86}Sr$ ratio of the Saramacca individual (0.716285) would fall into the predicted strontium isotope signature of the Guiana Shield. Establishing the exact location may be problematic because of the heterogeneous geological compositions and ages giving a wide range of $^{87}Sr/^{86}Sr$ ratios within the Guiana Shield. In addition, Suriname is not included in the prediction model; thus remarks on the probable strontium signature in that area are not conclusive. Nevertheless, the region of the Guiana Shield in Suriname is quite similar to Guyana, which is included in the prediction model, and it can be expected that areas with strontium signatures between 0.715-0.730 are present in the southern region of Suriname. Though the Guiana Shield has a heterogeneous geological composition, it appears that some areas correspond with the $^{87}Sr/^{86}Sr$ ratio of the Saramacca individual; suggesting that the Saramacca individual was originally from the southern area of Suriname; probably from the granite areas in the Guiana Shield.

An additional remark is that Bataille *et al.*'s (2012) prediction model also shows other areas besides Suriname where a strontium signature between 0.715 and 0.730 are expected; these areas are the mountainous regions in the west - or even as far away as Belize and Guatemala. Thus, it is possible the Saramacca individual came from one of these farther away areas. However, it is more likely they came from closer-by, therefore making the Guiana Shield - or at least a granite area in the southern region of Suriname - a more likely possibility. Additional isotope analyses, in particular stable oxygen isotopes, may permit a more refined estimate of the individual's location of origin.

With the assumption that the Saramacca individual came from the southern region of Suriname, the prehistory of cultures near and in this area was researched to establish the possible cultural background of this individual; keeping in mind the culture of the Saramacca site was either Koriabo or Kwatta. Data on archaeological sites and findings conclude that two cultures were present in the southern region of Suriname: the Koriabo and the Brownsberg culture, which will both be discussed below.

It should be noted that most archaeological research on the prehistory of Suriname has been conducted in the coastal area, and the dataset on sites from the southern region of Suriname is small (Versteeg and Bubberman 1992). According to Versteeg and Bubberman (1992), the skewed representation of the coastal sites in relation to southern sites might be because of preservation. The acidic soils in the southern region of Suriname do not preserve bone or shell very well; in the coastal areas these types of material are often better preserved. Whether or not it is only related to preservation, the lack of information on cultures in the southern region of Suriname limits the research on the cultural background of the Saramacca individual.

As mentioned, known sites in the southern region are from the Koriabo culture (AD 1200 - Colonial period) and can be seen in figure 5.7. This culture has been found in most areas of Suriname, except for west Suriname. Based on the geological map of De Vletter and Kroonenberg (1984, see fig. 5.5), the majority of inland Koriabo sites (fig. 5.7) are located on granite areas, therefore a strontium signature higher than 0.712 can be expected for individuals from these inland sites. Though the origin of the Koriabo culture is not known, they did migrate from the southern area of Suriname towards the coastal area, suggesting a likely origin in the south (Versteeg and Bubberman 1992). This is based on the fact that most inland Koriabo sites (AD 1200-1350) are older than the coastal sites (AD 1350-1600) (Rostain 2008, 298).

The Koriabo practiced a slash-and-burn agriculture, and are known for inhabiting old, abandoned sites of other cultures (Versteeg and Bubberman 1992). This results in the fact that the Koriabo culture is archaeologically often not very visible (Versteeg and Bubberman 1992). This limits our knowledge about them. The archaeologically known Koriabo sites from the inland (fig. 5.7), meaning the southern region, are all located near riverbanks; probably due to using the rivers as a trade network or to migrate towards the coastal region (Rostain 2008, 299). The Koriabo culture at the inland sites had contact with the cultures of the Arauquinoid Tradition that inhabited the coastal area in that time period, and had specifically close contact with the Kwatta culture. This is based on Koriabo pottery and pottery shape imitations that were found in Kwatta sites (Rostain 2008, 300) suggesting the cultures lived contemporaneously; and also based on the extensive trade network of the Kwatta culture along the rivers.

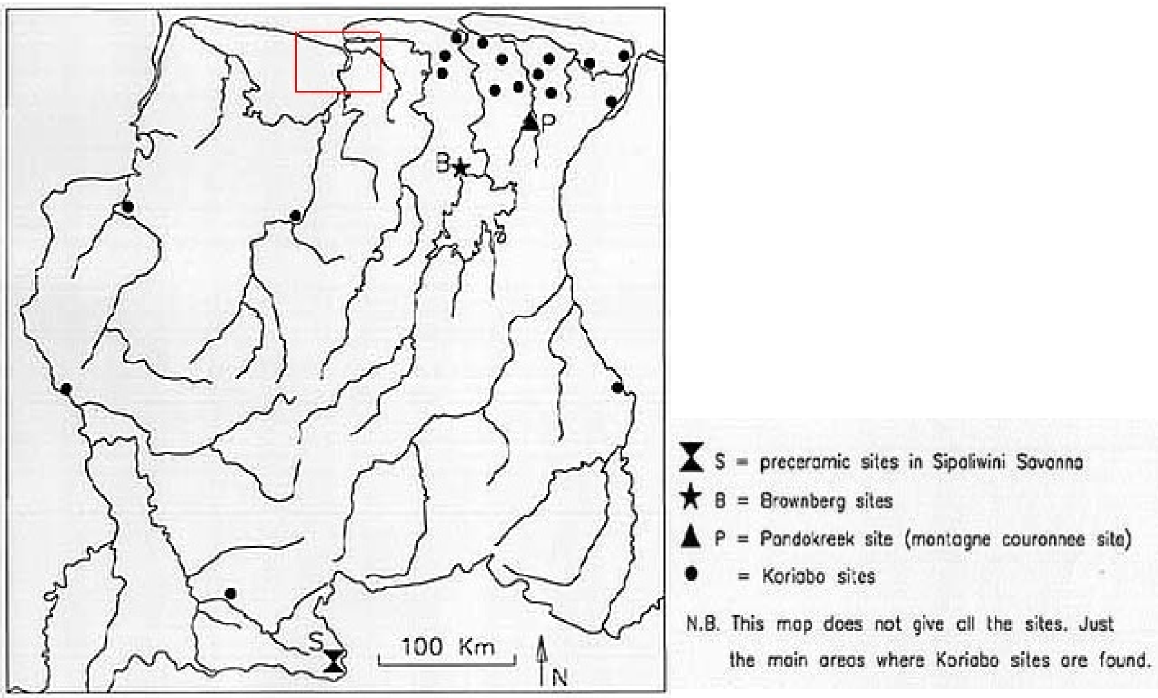

Figure 5.7. Overview of Koriabo sites (among others) in Suriname. Rectangle indicates location Saramacca site (after Versteeg and Bubberman 1992, 44).

As for the cultural origin of the Saramacca individual, it is possible this individual was originally from an inland Koriabo site. The possibility exists that the Saramacca individual lived during his or her childhood at an inland Koriabo site but, based on archaeological evidence for the migration of the Koriabo towards the north, at a later age lived at a coastal Koriabo site. This would correlate with the suggested Koriabo culture for the complete Saramacca site. It would therefore mean that one individual originated from an inland Koriabo site and the other individuals were born locally. This might further suggest the local individuals are from a later time period, but lack of contextual information and time period limits any further speculation on this aspect.

However, as previously mentioned, it was also suggested the Saramacca site could be a Kwatta site. If this is the case, an origin in the Koriabo culture is still then likely for the non-local individual. This is because the Koriabo culture has an origin in the southern region, unlike the Kwatta. The Kwatta culture migrated from the west towards the coastal region of Suriname (Rostain 2008, 289); this would result in $^{87}Sr/^{86}Sr$ ratios correlating with marine environments. The Kwatta culture did have an extensive trade network (Rostain 2008, 290-292), making it very likely they had contact with the Koriabo culture in the south. This is supported by the fact that the inland Koriabo sites are all located near riverbanks, close to the 'cultural highways' of Suriname (Rostain 2008, 300). Based on their contact with the Koriabo culture, it is likely that individuals from inland Koriabo sites had contact with the Kwatta culture. The fact that the non-local individual migrated towards the coastal region, to a Kwatta site, suggests very close contact or perhaps even a social-cultural event like marriage exchange (see paragraph 5.3). However, it might also be possible this type of movement cannot be determined as residential mobility (permanent); the possibility that the non-local individual was present in the coastal region to trade and died at that location should not be excluded (temporary). This, however, still suggests close contact between these two cultures.

Though a possible origin in an inland Koriabo site is likely, there is also another culture that inhabited the southern region of Suriname, namely the Brownsberg culture. This culture is, however, not frequently mentioned in the literature and it appears that only one site for this culture is currently known (fig. 5.7). The location of the site is near the Brownsberg, which is a hill of approximately 500 meters. Based on the soil map (appendix I) and the geological map (De Vletter and Kroonenberg 1984, see fig. 5.5) the area of the Brownsberg is located on the Brokolonko and Bongrowiri landscape; both mountainous landscapes in a granite area. These landscapes are, however, also surrounded by greenstone belt rocks or metamorphic rocks. Though the exact location of the Brownsberg site and culture are not clear, it is likely their location is on a granitoid complex, thus strontium signatures higher than 0.712 can be expected.

Versteeg and Bubberman (1992) describe the Brownsberg culture as an 'extraordinary' one, and Rostain (2008) describes them as a specialized culture. Though not much archaeological data exist for this culture, it seems that the Brownsberg culture was specialized in manufacturing cutting tools. They would mine stone (metabasalt) in the area near the Brownsberg and produce semi-finished products at their habitation site (Versteeg 1998). These semi-finished products were then exported to the coastal areas of Suriname, where the Brownsberg culture traded their cutting tools for artefacts from the Kwatta culture. The Kwatta culture did not have access to stone and could therefore not make cutting tools; they had to receive their stone from the Brownsberg area (Rostain 2008, 292). Artefacts from Kwatta sites support this theory (Boomert and Kroonenberg 1977). The Brownsberg culture probably used the main rivers as a trade network - both the Suriname and Saramacca rivers being the closest - to export their products to the coastal area. Once in the coastal area, Rostain (2008, 292) argues that the trade network along the coast (towards the east as well as the west) was through settlements located on the coastal area. The culture probably lived during the period of AD 1000 -1500 (Rostain 2008, 292), which is in the same period that the Kwatta culture lived in the coastal area.

With the knowledge of the Brownsberg culture and their contact with the Kwatta culture in the coastal region, it may be possible that an individual of the Brownsberg culture lived during his or her childhood in the Brownsberg region but at a later age lived in the coastal area. This would be then in one of the Kwatta sites in the coastal region, again suggesting that the complete Saramacca site is from the Kwatta culture. The possibility that an individual of the Brownsberg culture lived at a later age in the coastal area can be explained by the trade network between the Brownsberg culture and the Kwatta culture, as there are no indications that the Brownsberg culture migrated completely towards the coastal areas. However, it may also be possible that the type of movement of the Saramacca individual was not permanent. Again, it may be possible that this was temporary, for example that this individual was present in the coastal area to trade with the Kwatta culture and died at that location.

Of course, both mentioned possibilities (either an origin in the Koriabo culture or Brownsberg culture) are speculative; they are merely based on the current knowledge of the cultures and their trade networks as well as mobility patterns based on archaeological data. Unfortunately, there is not enough data on the context of this individual to support either theory or point to a different origin for this individual, as well as to further speculate on a possible residential mobility or any temporary movement to the coastal region. Solely based on the ^{87}Sr/^{86}Sr ratio, a southern origin, around the Guiana Shield and specifically a granite area, is the most likely origin of this individual. As of now, the Koriabo and Brownsberg are the only known cultures that originated in the southern region of Suriname, but the possibility that the Saramacca originated from these cultures only based on what is currently archaeologically known about these cultures - which is unfortunately very limited, especially for the Brownsberg culture.

If further research on the Geijskes collection reveals the context of this individual, such as his or her time period and culture, it might improve our understanding of their origin. Further research into both the Koriabo and the Brownsberg culture might also add insight into the interaction between cultures of the south and the coastal area, and will either support or undermine one or both theories on the origin of the Saramacca individual. However, it should be noted that it is not always possible to determine the exact location of origin solely based on strontium isotopes; even with the additional contextual data it may not be possible to determine exactly the location of origin in the southern region of Suriname for the non-local identified in this study.

5.3. Discussion ^{87}Sr/^{86}Sr results compared with other data

As was presented in the results chapter, statistical analyses were conducted using the ^{87}Sr/^{86}Sr data and data on sex and cranial deformation, which will be discussed below. Statistical analyses were also conducted on the ^{87}Sr/^{86}Sr data and tooth type. Both premolars and molars (1^{st}) were sampled, and these elements form at different ages (Moorrees *et al.* 1963; Ubelaker 1978), meaning the ^{87}Sr/^{86}Sr result reflects a different age. There was, however, no statistical difference present. Therefore, results from all teeth can be compared.

Kwatta Tingiholo: comparison of Sr and sex at the Kwatta Tingiholo site

Because of small samples size and lack of data, only a comparison of the strontium stable isotope data and sex could be conducted for the Kwatta Tingiholo site, as presented in chapter 4. The comparison of the strontium stable isotope data with data on sex may give insight into a possible difference between sex and location of origin; which may indicate specific cultural aspects such as marriage exchange (Blanton *et al*. 1993; Keegan and Maclachlan 1989; Laffoon 2012, 244; Tung 2008, 677). Laffoon (2012, 245) mentions that marriage exchange may be an explanation for the slightly higher proportions of non-local females in most of the sites in the Caribbean included in his study. However, a high proportion of non-local males were also noted in some studies (Laffoon 2012, 246; Tung 2008, 677). Either way, marriage exchange is a form of residential mobility, and this type of mobility as a political action has been noted by various studies (Burger 2008, 698; Keegan and Maclachlan 1989; Laffoon 2012, 245; Sharer 1983), and described as an action to create alliances between cultural groups (Burger 2008, 698). If this type of mobility was present in the Kwatta Tingiholo site, more non-local females or males (females with a statistically different $^{87}Sr/^{86}Sr$ ratio than the males or vice versa) would be present. However, analysis indicated that there was no statistical difference between sex and $^{87}Sr/^{86}Sr$ ratio. This suggests no specific social differentiation between location of origin and sex is present within the analyzed sample. In addition, no non-local individuals (either male or female) were found in the site of Kwatta Tingiholo; this would suggest no specific cultural aspect such as marriage exchange. Of course, this would not be visible in the $^{87}Sr/^{86}Sr$ ratios if marriage exchange occurred between cultures in areas with similar local strontium signatures. Furthermore, the females are underrepresented and the sample size is small; thus, no definite conclusions can be made on this aspect.

Cranial deformation and $^{87}Sr/^{86}Sr$ *ratios*

Intentional cranial deformation was frequently used to express personal or group identity (Van Duijvenbode 2011, 2). As intentional cranial deformation is applied during infancy, this identity is present at the time of birth (Van Duijvenbode 2011, 2). The $^{87}Sr/^{86}Sr$ ratio in enamel reflects the environment during infancy and childhood; so approximately during the same period during which intentional cranial deformation is applied. Van Duijvenbode (2011, 10) argues that intentional cranial deformation in the Arauquinoid Tradition is used to differentiate social status and not cultural groups, as the same type of intentional cranial deformation is found in different cultural groups. The $^{87}Sr/^{86}Sr$ ratios of individuals from the Kwatta Tingiholo site with and without cranial deformation were compared in this study, as presented in chapter 4. No statistically significant differences were found. Thus, there was no difference in the presence of intentional cranial deformation and location of origin. This suggests that social status or identity expressed by intentional cranial deformation is not defined by location of origin, at least as indicated by strontium stable isotopes. However, additional research on intentional cranial deformation in combination with mobility patterns, which requires additional isotope data, could further contribute to research about this social-cultural practice and differences in location of origin.

5.4. Limitations of this study

This study yielded useful strontium isotope data that has improved our understanding of mobility in the region of Suriname. However, there are several problems with the sample and limitations to the interpretations, which are outlined below. Future research, as presented in the subsequent conclusions chapter, contains suggestions for the improvement of some of these problems and limitations.

Geijskes collection and human skeletal material information

The first and most important discussion point regards both the sample size and documentation of the collection. For most of the individuals the find number was clear and there was no confusion about the associated documentation. But for some individuals, either the find number was not clear, or commingled material was present. This made it difficult to relate the material to a specific individual, and in one case (Th21) it was possible a duplicate find number was present. In addition to this, it was not possible to sample each individual in the Geijskes collection due to a lack of teeth. For some individuals, teeth were not present (mostly lost post-mortem), or the preferred elements for sampling were not present. The result is that even though the Geijskes collection is quite large, not all individuals could be sampled; thus reducing the sample size. This was mainly problematic for the sites of Paramaribo and Okrodam (n=1 and n=2, respectively). With such small samples conclusions on intra-site variation cannot be made.

Comparing the $^{87}Sr/^{86}Sr$ data with type of burial (position, location, and/or grave goods) was not conducted. Based on the documentation of sites, it would only be possible to do this for the Kwatta Tingiholo site. All other sites were not documented sufficiently enough to extract data about burial ritual. However, even though the burial ritual data (orientation, location, and grave goods) were recorded for the Kwatta Tingiholo site, they could not be used to compare this with the $^{87}Sr/^{86}Sr$. This because, as previously mentioned, the documentation on the excavation drawing does not correspond with the documentation that the individuals have currently.

As previously mentioned, there is a possibility that a duplicate individual was present in the Geijskes collection, and the $^{87}Sr/^{86}Sr$ values may help to confirm or deny this. The $^{87}Sr/^{86}Sr$ ratios of Th21 and H21 are similar (respectively 0.709487 ± 0.000008 and 0.709678 ± 0.000011), but do not match within their standard errors. If the samples were from the same individual, the $^{87}Sr/^{86}Sr$ ratios should have been closer. However, it is not possible to definitely conclude that these two samples represent two different individuals. The enamel sample from Th21 was from a first premolar, while the enamel sample from H21 was from a second premolar. They form at relatively the same age (Holt *et al*. 2012; Moorrees *et al.* 1963; Ubelaker 1978), although the formation phases of the first premolar are earlier than the second premolar. These slight differences in age formation may explain the $^{87}Sr/^{86}Sr$ ratio difference. Additional isotopic data from the enamel sample, such as carbon and oxygen, are needed to determine the relationship between samples. Moreover, isotope data from bone could also contribute to establishing whether or not the samples represent the same individual or two different individuals.

A limitation was the sample size of the sites under study. The sample size for the site of Kwatta Tingiholo was large enough to conduct a comparison of $^{87}Sr/^{86}Sr$ values with sex estimates. All the other sites (Hertenrits, Saramacca, Paramaribo, and Okrodam) were too small to conduct such intra-site comparisons (if data on sex were even available). The small sample size also limited what could be done with inter-site comparisons. Only one individual from Paramaribo was analyzable; if additional data ever become available it would definitely aid in understanding the strontium isotope signature of this site and individual.

But even though the sample size for the Kwatta Tingiholo site was large enough to permit some intra-site comparisons, the underrepresentation of females made statistical results less certain. The lack of sub-adults and underrepresentation of young individuals, of which it would be interesting to have $^{87}Sr/^{86}Sr$ values, limited what could be discerned about the variation of $^{87}Sr/^{86}Sr$ ratios within and between age groups. And, of course, any additional $^{87}Sr/^{86}Sr$ ratios would help in establishing the local strontium signature for that specific archaeological site.

The poor state of documentation was the main and biggest problem for this study. As the section discussing the Saramacca individual already illustrated, the context of the material was not always clear. Especially for the Saramacca site, additional information regarding context and specific location, not to mention at least an indication of time period, would aid further research. The $^{87}Sr/^{86}Sr$ ratio of one of the Saramacca individuals is very distinct, but due to the lack of documentation and information regarding context, definite conclusions about what the $^{87}Sr/^{86}Sr$ ratio might indicate are not possible.

It should not be forgotten that the human skeletal material from the Geijskes collection was excavated in the 1950s and 1960s. Even though at the time the excavation might have been well documented, moving the materials from Suriname to the Netherlands, and afterwards to the various different places to conduct research on the material, might have caused some documentation to be lost and/or the commingling of remains.

Isotopic analysis

For this study only strontium stable isotope analysis has been conducted, which limits any definite conclusions that can be made about palaeomobility. An improvement would be obtaining additional isotope data. By conducting additional isotopic analyses on enamel, such as stable carbon and oxygen, more information on the mobility of the individuals from the Geijskes collection could be obtained. These additional analyses could not be conducted during this study, but will be conducted in the future (see chapter 6). Moreover, the fact that no local strontium signature was available for this study made it difficult to discuss with certainty the locals and the non-local. In this study the local strontium signature was based on geology and a prediction model, which correlated well with the results, but additional isotopic data may help to establish a definite local strontium signature and confirm predictions. This is necessary for the coastal region of Suriname, as studies have indicated that different geological formations, formed at different periods, are present; meaning different strontium signatures are present. It is, however, also necessary for the southern region of Suriname, as studies have illustrated the complex geology of this Precambrian shield and therefore also the variation of associated strontium signatures.

As this discussion has shown, most archaeological research in Suriname has been conducted on coastal areas. The coastal area is known for its habitation in the pre-Columbian period, but the Koriabo culture as well as the Brownsberg culture have, for example, been found in the southern region of Suriname. The lack of knowledge on sites from the southern region of Suriname made it impossible to draw definite conclusions about the non-local in this study. For both the strontium data as well as cultures in this region additional research is needed to provide more certainty on the possible origin of this individual. Again, additional isotopic data should provide more insight in this regard.

Finally, even though the coastal areas have been intensively researched, only the Hertenrits site and Hertenrits culture are frequently mentioned in the literature. The sites of Paramaribo, Saramacca, and Okrodam are not well described or not mentioned at all in the literature; this made research on these specific sites difficult and therefore, no definite conclusions can be made.

5.5 Contribution of this study

Taking the limitations and the need for additional data aside, this study has contributed to quite a few aspects of research on the prehistory of Suriname. Prior to this research, no strontium stable isotope data were available on individuals from the pre-Columbian period in Suriname. Therefore, this study provided the first isotope data upon which a regional database can begin to be built.

Due to the fact that no local strontium signature from fauna or flora was available, other methods were used to establish a local strontium signature and to distinguish local from non-local individuals. These other methods included research on the geology of Suriname, which provided interesting results. The different geological formations and their age in the coastal area of Suriname probably explain the statistically different $^{87}Sr/^{86}Sr$ ratios of the Hertenrits site when compared to the Kwatta Tingiholo site. The west coastal area of Suriname is younger than the east coastal area; so different

^{87}Sr/^{86}Sr ratios can be expected. Another aspect this study contributed to was the prediction model from Bataille *et al*. (2012). This model was extensively used to gain more insight in ^{87}Sr/^{86}Sr variation in specific regions. Though Suriname is not displayed in this model, with the results of the ^{87}Sr/^{86}Sr ratios from this study and the geological data on Suriname and surrounding areas, the prediction model could be used to establish at least an expected strontium isotope range for Suriname. Moreover, the results of the ^{87}Sr/^{86}Sr ratios from this study, with the exception of the non-local individual, support this prediction model; the predicted strontium isotope range for coastal areas in the region of north Mesoamerica correlates with the strontium stable isotope results of this study. This supports that the prediction model for local strontium isotope ranges established by Bataille *et al*. (2012) is very useful and accurate, and is a good model for local strontium isotope ranges and mobility studies in this area. Moreover, by using this prediction model it was possible to research possible locations of origin for the non-local individual in this study.

Using geological data and the strontium result of this study, it was possible to research the contribution of strontium isotope data to establish an approximate location of archaeological sites. Based on geological data and the age of different geological formations, the slight differences in ^{87}Sr/^{86}Sr between the archaeological sites under study could be explained. For example, the location of the Hertenrits site was well documented – in the west coastal area of Suriname, on a young geological formation – and the strontium stable isotope analysis supports this. The exact location of the Saramacca site is unknown, but the ^{87}Sr/^{86}Sr ratio in the Saramacca individuals (with the exception of the outlier) indicate that the location of this archaeological site is on an older geological formation than the Hertenrits site; indicating the middle or east coastal region of Suriname. Though not an exact location, strontium stable isotopes did provide an area for the location of this archaeological site. It can therefore be concluded that strontium stable isotope analysis can contribute to establishing an approximate location of archaeological sites, when this location is unknown.

This study also contributed, as mentioned before, to an understanding of the mobility patterns of the past cultures in Suriname. Past archaeological research indicated that vast trade networks, using the main rivers, existed in pre-Columbian Suriname. This meant a trade network and communication between cultures of the coastal area and the southern region, as well as between coastal areas. The non-local individual identified in this study was probably from the southern region, living in, or visiting at a later point in his or her life, the coastal area of Suriname. This supports the idea of trade networks in Suriname, as well as the communication between cultures living in the south and coastal area of Suriname. Even though it cannot be definitely concluded to which culture group the non-local belonged, or to which culture group the site belonged, it can be said with some certainty that there was, based on strontium stable isotopes, contact between the southern and northern region of Suriname. Using a scientific approach, this study has contributed to research on networks between prehistoric cultures in Suriname.

By comparing the strontium stable isotope results with data on sex and cranial deformation, this study has also provided insight into some social-cultural aspects in relation to location of origin. It provided insight into a possible lack of difference between social-cultural variables (i.e. social status, expressing identity, and possible marriage exchange) and location of origin. This was only analyzable for the Kwatta Tingiholo site, but these data did contribute to the research on social-cultural aspects for the prehistoric sites in coastal Suriname.

6. Conclusions & Possibilities

In this thesis, strontium stable isotope analysis has been conducted in order to gain more insight into palaeomobility of the individuals from the Geijskes collection. The Geijskes collection is a collection of human skeletal material, obtained from different archaeological excavations in Suriname, from the 1950s and 1960s. Before this study, no isotopic data were available for individuals from the pre-Columbian period in this region.

Of the 24 samples, individuals from the sites Hertenrits, Paramaribo, Okrodam, Kwatta Tingiholo, and Saramacca were selected for this study. The sites are from different areas in Suriname; the Hertenrits is located in west Suriname, whereas the other sites are from east Suriname. All are located in the coastal region of Suriname.

Results of the strontium stable isotope analysis indicate mostly local individuals are present amongst the sampled collection. This is based on a comparison of the $^{87}Sr/^{86}Sr$ ratios among individuals. All of the local individuals had $^{87}Sr/^{86}Sr$ ratios between 0.709457 and 0.710191, which correlates with a coastal strontium signature in this region. This coastal strontium signature is based on both a prediction model for the circum-Caribbean region (Bataille *et al*. 2012), as well as geological data (Brinkman and Pons 1968; De Vletter and Kroonenberg 1984; Versteeg 1985; Versteeg 2008; Zonneveld 1956). The $^{87}Sr/^{86}Sr$ ratios between sites show some variation. The Hertenrits site has a lower $^{87}Sr/^{86}Sr$ ratio when compared with the other sites. Based on geological data, the soil formations on which the Hertenrits site is located are younger than the soil formations on which the other sites are located; this likely explains the lower $^{87}Sr/^{86}Sr$ ratios for the Hertenrits site. The other sites either have a slightly higher $^{87}Sr/^{86}Sr$ ratio (Paramaribo) or slightly lower $^{87}Sr/^{86}Sr$ ratio (Saramacca) than the Hertenrits site. However, these variations are very small and fall into the expected $^{87}Sr/^{86}Sr$ ratio range for the coastal region. In addition, the sample size is small for the Paramaribo and Saramacca sites, making it difficult to observe any intra-site as well as inter-site differences in the $^{87}Sr/^{86}Sr$ ratios.

Statistical analysis on sex estimates based on Tacoma's research (1963) and the $^{87}Sr/^{86}Sr$ results from this thesis indicated no difference between males and females. This may indicate that a specific social-cultural aspect, such as marriage exchange - which would require statistically more non-local females or non-local males - is not present in the Kwatta Tingiholo site; unless this occurred between areas with similar $^{87}Sr/^{86}Sr$ ratios (coastal area). Further additional isotopic data may gain more insight on the possible presence of this social-cultural aspect. In addition, females were underrepresented in this small sample, and therefore no definite conclusions can be made.

The $^{87}Sr/^{86}Sr$ ratios were compared with data on the presence of intentional cranial deformation in five individuals. Four of these individuals were from the Kwatta Tingiholo site; one individual was from the Okrodam site. Statistical analysis found no difference between the individuals with and without intentional cranial deformation and their $^{87}Sr/^{86}Sr$ ratios. This indicates that location of origin was probably not a factor for this specific social-cultural practice.

Comparing the $^{87}Sr/^{86}Sr$ ratios among individuals, one person appeared to be an outlier. Most of the $^{87}Sr/^{86}Sr$ ratios range between 0.709 and 0.710, only the individual with find number Sa1 (from the Saramacca site) had a markedly different $^{87}Sr/^{86}Sr$ ratio, of 0.716285. This thesis combined geological data (Versteeg 1985; Versteeg 2008; Zonneveld 1956), Bataille *et al.*'s (2012) prediction model, and previous isotopic research in the area of Suriname (e.g. De Vletter and Kroonenberg 1984; Gruau *et al.* 1985; Hebeda *et al.* 1973; Kroonenberg and Roever 2009; Négrel and Petelet-Giraud 2010), and concluded that a $^{87}Sr/^{86}Sr$ ratio higher than 0.712 can be expected in the southern region of Suriname; specifically in the area of the Guiana Shield. This Precambrian geological formation stretches along the southern areas of Guyana, Suriname, and French Guiana - among others. Other areas where $^{87}Sr/^{86}Sr$ ratios of >0.712 are expected are in Mesoamerica; but it is more likely the Saramacca individual came from a place closer to coastal Suriname. Based on the $^{87}Sr/^{86}Sr$ ratios of the Guiana Shield; it is likely the origin of the Saramacca individual was the southern area of Suriname, possibly from a granite area.

Using the southern region of Suriname as a probable location of origin, existing archaeological data on the cultural groups that inhabited Suriname in the pre-Columbian period were researched to indicate a possible cultural origin. Archaeological research provided data on two cultures that inhabited the southern region of Suriname, at least for a period. These are the Koriabo and the Brownsberg cultures. Even so, lack of contextual information for the Saramacca individual made it difficult to conclude with certainty the cultural origin of this individual. In addition, lack of data on the Brownsberg culture, and to a certain degree on the Koriabo culture, limited research on the possible cultural origin of the Saramacca individual. However, both cultures are known to have had extensive contact with the Kwatta culture in the coastal region using the main rivers in Suriname as a trade and exchange network. Both cultures are a possibility for the origin of the Saramacca individual, and would support the hypotheses established regarding the trade networks between the north and south regions in Suriname. And, as the Saramacca individual lived during his or her childhood in the southern region, but was buried in the coastal area, it would also suggest very close contacts between cultures of the coastal and the southern region. Additional isotope data as well as data on context are needed to confirm or deny this.

This study has provided the first isotopic data for pre-Columbian individuals from the Geijskes collection. Even though additional data are needed, the results of the strontium stable isotope analysis have already given indications of palaeomobility in this area. The documentation on the Geijskes collection was not always sufficient to draw definite conclusions, and therefore a sub-goal of this study was to determine the contribution of strontium isotope analysis to helping to establish the location of archaeological sites. The correlation between $^{87}Sr/^{86}Sr$ differences and the geological formations (and their different depositional phases, thus age) was useful to establish with some certainty the location of archaeological sites. For example, the $^{87}Sr/^{86}Sr$ ratios for the Hertenrits site correlated with the geology and therefore also the location of this site. In addition, the $^{87}Sr/^{86}Sr$ ratios of the Saramacca individuals in combination with geological data also indicated a region for the Saramacca site (of which no exact location is known). It remains, however, difficult to pinpoint an exact location solely based on strontium stable isotopes, but the $^{87}Sr/^{86}Sr$ ratios do contribute to establishing the location of an archaeological site with more certainty.

Future research on the Geijskes collection

To both understand the locals and the non-local better, additional isotopic data are needed. The individuals under study were also selected for both carbon and oxygen stable isotope analyses from dental enamel and carbon and nitrogen isotope analyses from bone, providing additional isotopic data for different ages of the individuals, and this will be conducted in the future. The stable isotopes of carbon and nitrogen are primarily used to study past diet (DeNiro and Epstein 1978; Katzenberg 2008; Schoeninger *et al.* 1983; Vogel and van der Merwe 1977), whereas the stable isotopes of oxygen can indicate latitude, altitude, and distance from the coastal area (Oelze 2012, 18; White *et al.* 1998).

As the individuals under study inhabited the coastal area, carbon and nitrogen stable isotope analysis can allow researching the importance of marine and terrestrial foods in their diet. Furthermore, it may also provide more insight into the diet of the individual now classified as non-local. It is possible that the non-local individual had a different past diet than the local individuals; possibly a more terrestrial diet. However, carbon and nitrogen stable isotope analysis is needed to establish this.

The oxygen stable isotope analysis will provide data on distance from the coastal area or if an individual lived at a higher altitude during its childhood. It can therefore contribute into distinguishing the non-local individuals from the local individuals.

As mentioned before, bone samples were also taken for the individuals of the Geijskes collection. These were taken by J.E. Laffoon and await further analysis. Stable isotope analyses of carbon, nitrogen, and oxygen will be conducted on the bone samples, and these results can be combined and compared with the stable isotope analyses conducted on enamel; this may contribute more to distinguishing the non-local individual from the local individuals. The stable isotope analysis on carbon from the bone sample of the non-local individual may indicate a different diet in later life. If stable isotope analysis on bone indicates marine foods in the diet, it is possible the individual lived for the last years of his or her life in the coastal area. If the non-local individual had a different diet than the local individuals, this may indicate the non-local individual was only for a short period of time in the coastal area. The results from the oxygen stable isotope analysis on bone may indicate if the non-local individual lived during his or her last years closer to the shore than the values from enamel.

Of course, besides the additional data on diet or altitude/latitude from either bone or enamel, to conclude that the Saramacca individual was a non-local, and the remaining individuals were local, the local strontium signature is needed. Future analysis on faunal bone samples may contribute to establishing the local strontium signature. However, as the sites under study are from various locations in the coastal area, plant or soil samples from different geological formations to map the local strontium signature are needed.

Again, the local strontium signature for the west coastal area of Suriname might indicate if this area has indeed slightly lower $^{87}Sr/^{86}Sr$ ratios in comparison with the east coastal area of Suriname. Moreover, to establish a local strontium signature for the Guiana Shield in Suriname, plant or soil samples are also needed for the southern region of Suriname. Because of the complex geology, this is needed for each different geological area (e.g. metamorphic belts, granite areas). These $^{87}Sr/^{86}Sr$ values may contribute into establishing a more approximate location of origin for the individual now classified as non-local.

Last but not least, this study has shown that using geographically dependent stable isotopes are possibly useful to help establish the location of archaeological site when this is not clear through documentation. This may contribute to future research where 'old' excavation documentation is included, but is insufficient to establish the location of an archaeological site.

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List of figures & tables

Figures

Tables

Appendixes

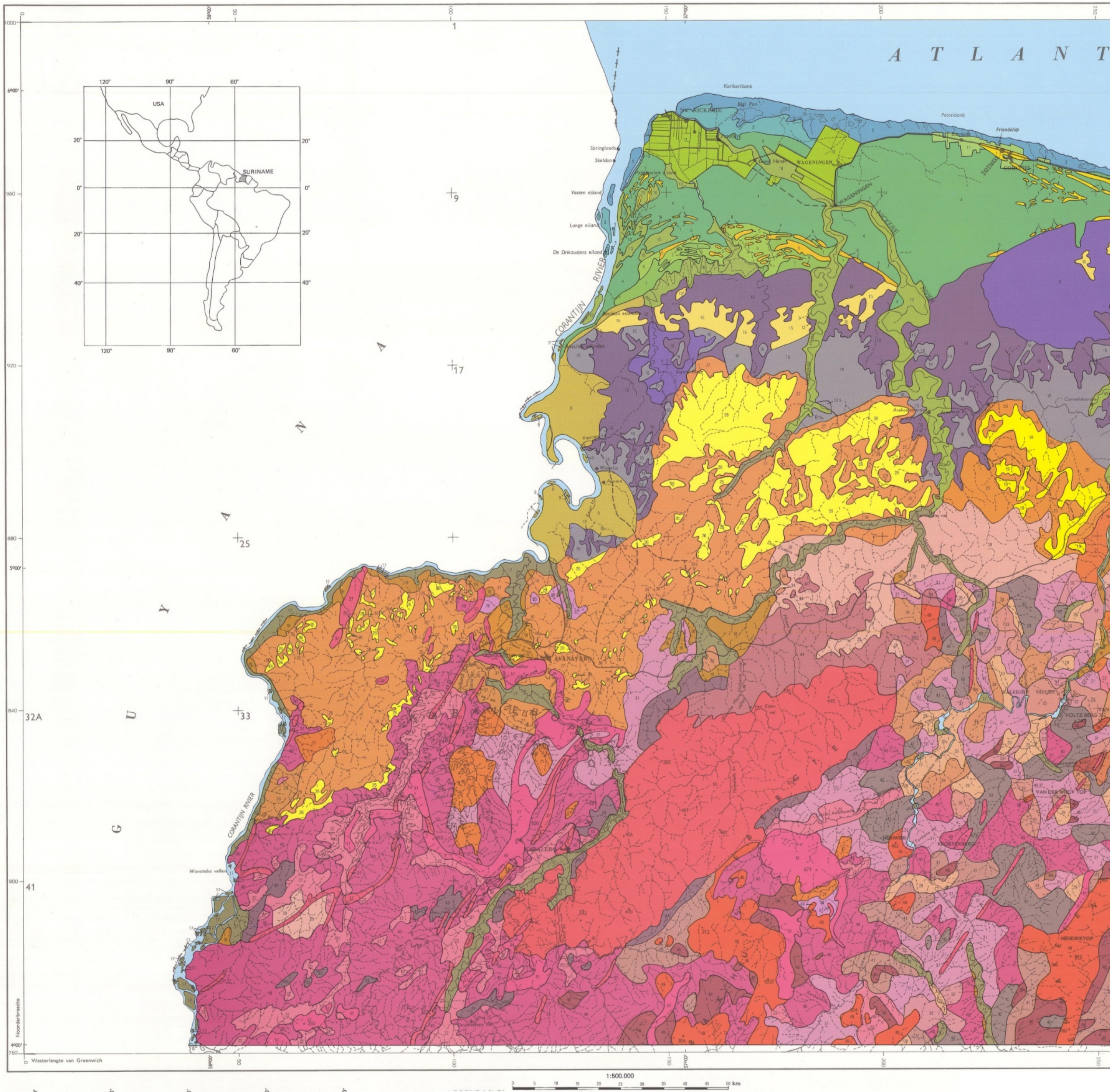
Appendix I: Reconnaissance Soil Map northern region of Suriname (Overzichtsbodemkaart van Noord-Suriname) / scan from Ministry of Development – Soil Survey Department

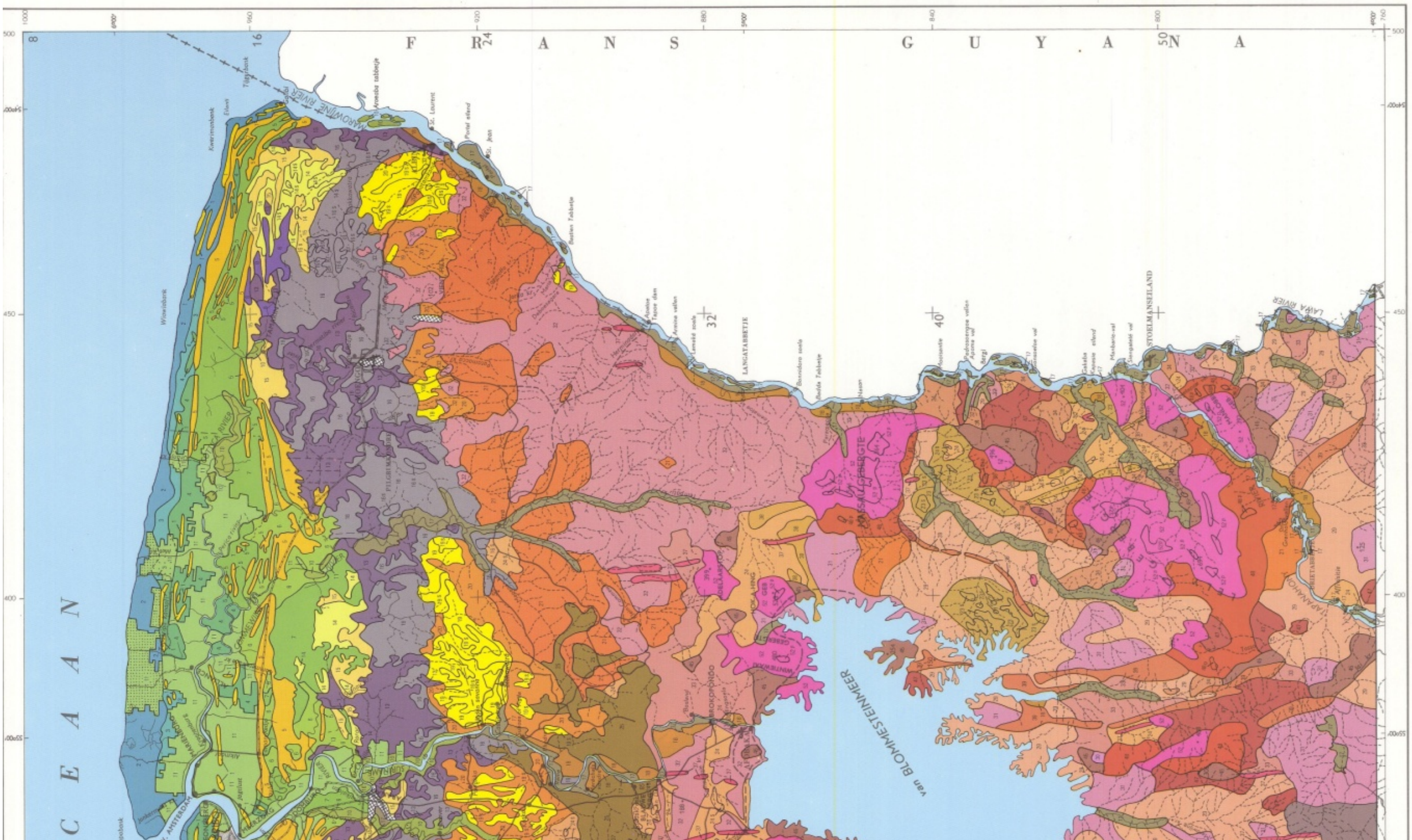
For the original scan (and more detail) see:

Selvaradjou, S-K, L. Montanarella, O. Spaargaren and D. Dent (2005). European Digital Archive of Soil Maps (EuDASM) - Soil Maps of Latin America and Carribean Islands (DVD-Rom version). Luxembourg: Office of the Official Publications of the European Comunities.

Access online:

http://eusoils.jrc.ec.europa.eu/esdb_archive/EuDASM/latinamerica/index.htm


ATLANT
GUYANA
SURINAME
USA
NIEUW NICKERIE
WAGENINGEN
CORANTIJN RIVIER
Springlands
Skeldon
Vossen eiland
Lange eiland
De Driezusters eiland
Kerikoribank
Bigi Pan
Potoribank
Friendship
APANAYEBO
VOLTZ BERG
VAN DER WIJCK TOP
HENDRIKTOP
Wonotobo vallen
Noorderbreedte
Westerlengte van Greenwich
1:500.000
50 km


F R A N S   G U Y A N A
T I S C H E   O C E A A N
MAROWIJNE RIVIER
LAWA RIVER
STOELMANSEILAND
LANGATABBETJE
van BLOMMESTEINMEER
NW. AMSTERDAM
1:500.000

Verantwoording/*References and Justification*

- Samengesteld uit de Overzichtsbodemkaart van Noord-Suriname ten noorden van de 5e breedtegraad, schaal 1:100.000 (1977)
  Compiled from the Reconnaissance Soil Map of Northern Suriname, north of the 5th degree of latitude, scale 1:100,000 (1977)
- Samengesteld uit/*Compiled from Landform and Soil Maps, scale 1:100,000 (1976, 1977).*
- Samengesteld uit Landvormkaart van Suriname tussen 5°00' en 4°00' Noorderbreedte, schalen 1:200.000 en 1:500.000 (1975, 1976).
  Compiled from Landform Map of Suriname between 5°00' and 4°00' Northern Latitude, scales 1:200,000 and 1:500,000 (1975, 1976).
- 1400 — Globaal Aantal Veldwaarnemingen per CBL-kaartblad 1:100.000 (1976)
  Broad Number of Fieldobservations by CBL-map sheet 1:100,000 (1976).

Vanwege het beperkt aantal veldwaarnemingen dient de bodemkundige informatie in het gebied tussen de 5e en 4e breedtegraad grotendeels als voorlopig te worden beschouwd.
Due to the limited number of fieldobservations the soils information in the area between the 5 th and 4 th degree of latitude should for the greater part be considered as tentative

LEGENDA/*LEGEND*

VLAK EN GOLVEND ZEER LAAG LAND
FLAT AND UNDULATING VERY LOW LAND
(steilste helling/*steepest slope* < 8%; 0 - 10 m + NSP)

JONGE KUSTVLAKTE (DEMERARA FORMATIE)
YOUNG COASTAL PLAIN (DEMERARA FORMATION)

CORONIE LANDSCHAP
CORONIE LANDSCAPE

COMOWINE EN MOLESON FASE
COMOWINE AND MOLESON PHASE

1 — Ritsgronden met (zeer) fijn zand, soms midgrof of lemig zand tot zandige leem, schelpgruishoudend zand of schelpen
Ridge soils with (very) fine sand, sometimes medium or loamy sand to sandy loam, sand with shellgrit, or shells

2 — Ongerijpte en bijna ongerijpte zoute zwampkleigronden
Unripe and practically unripe saline swamp clay soils

3 — Bijna ongerijpte en halfgerijpte brakke zwampkleigronden
Practically unripe and half-ripe brackish swamp clay soils

4 — Halfgerijpte en bijna gerijpte zwampkleigronden, meestal ontzilt tot meer dan 1 m diepte
Half-ripe and nearly ripe swamp clay soils, mostly desalinized to a depth of more than 1 meter

WANICA FASE
WANICA PHASE

5 — Ritsgronden met (lemig zeer) fijn zand en soms zandige leem
Ridge soils with (loamy very) fine sand, and sometimes sandy loam

6 — Gerijpte zwampkleigronden, meestal ontzilt tot meer dan 2 m diepte
Ripe swamp clay soils, mostly desalinized to more than 2 meter depth

7 — Bijna gerijpte zwampkleigronden, meestal ontzilt tot meer dan 2 m diepte, soms met lemige bovengrond
Nearly ripe swamp clay soils, mostly desalinized to more than 2 meter depth, sometimes with loamy topsoil

(Noot: De gronden van eenheden 3, 4, 6 en 7 hebben vaak een (dun) pegassedek)
(Note: The soils of units 3, 4, 6 and 7 often have a (thin) peat cover)

ONGECORRELEERD (COMOWINE, MOLESON, WANICA FASE)
UNCORRELATED (COMOWINE, MOLESON, WANICA PHASE)

8 — Zoetwater zwamp en moeras met ombrogeen dik veendek
Fresh water swamp and marsh with ombrogenous thick peat cover

9 — Rivieroever- en estuariumgronden met stof en stofleem
Riverain and estuarine soils with silt and silt loam

10 — Halfgerijpte tot gerijpte rivieroever- en estuarium kleigronden, vaak met dun pegassedek
Half-ripe to ripe riverain and estuarine clay soils, often with a thin peat cover

11 — Gerijpte polderklei (soms leem) gronden (vnl. plantages)
Ripe polder clay (sometimes loam) soils (predominantly plantations)

12 — Halfgerijpte polderkleigronden (rijstvelden)
Half-ripe polder clay soils (rice fields)

MARA LANDSCHAP
MARA LANDSCAPE

13 — Ongerijpte en bijna ongerijpte, meestal pyriethoudende zwampkleigronden, vaak met een dik pegassedek
Unripe and practically unripe mostly pyritic swamp clay soils, often with a thick peat cover

OUDE KUSTVLAKTE (COROPINA FORMATIE)
OLD COASTAL PLAIN (COROPINA FORMATION)

LELYDORP OF OUDE RITSEN LANDSCHAP
LELYDORP OR OLD RIDGES LANDSCAPE

14 — Rits- en plaatgronden met (zeer) fijn (gebleekt) zand en soms klei
Ridge and plateau soils with (very) fine (bleached) sand, and sometimes clay

15 — Rits- en plaatgronden met (zeer fijnzandige) leem en zeer fijn zand over klei
Ridge and plateau soils with (very fine sandy) loam and very fine sand over clay

PARA OF OUDE ZEEKLEI LANDSCHAP
PARA OR OLD MARINE FLAT LANDSCAPE

16 — Scholgronden met stofleem en stoffige zware leem over stugge (stof) klei
Plateau soils with silt loam and silty clay loam over stiff (silty) clay

GOLVEND EN STERK GOLVEND LAAG LAND
UNDULATING AND ROLLING LOW LAND
(steilste helling/*steepest slope* 2 - 16%; 10 - 100 m + NSP)

RIVIER VLAKTES
RIVER FLOODPLAINS

17 — (Zandige) leem en klei oeverwal- en komgronden
(Sandy) loam and clay levee and basin soils

MIDDEN- EN HOOGTERRASSEN
MEDIUM- AND HIGH TERRACES

18 — Zand, zandige leem, zandige zware leem en kleigronden (soms stofklei); lokaal denudatie-terrasgronden met zwaardere textuur
Sand, sandy loam, sandy clay loam and clay soils (sometimes silty clay); locally heavier textured denudation terrace soils

DEK LANDSCHAP (ZANDERIJ)
DEK LANDSCAPE (ZANDERIJ)

19 — Gebleekte midgrof- en grofzand plateau- en hellinggronden
Bleached medium and coarse sandy plateau and slope soils

20 — Ongebleekte midgrof en grof (lemig) zand, zandige (zware) leem tot zandige klei plateau- en hellinggronden
Unbleached medium and coarse (loamy) sand, sandy (clay) loam to sandy clay plateau and slope soils

TIBITI LANDSCHAP
TIBITI LANDSCAPE

21 Plateau- en hellingverweringsgronden met zandige (zware) leem en klei, plaatselijk met grindige bovengrond
Plateau and slope soils with sandy (clay) loam and clay, locally with gravelly topsoil

KARIA LANDSCHAP
KARIA LANDSCAPE

22 Plateau- en hellingverweringsgronden met waarschijnlijk grindige zandige (zware) leem en klei; vermoedelijk plaatselijk veel stenen in en op de grond
Plateau and slope soils with probably gravelly sandy (clay) loam and clay; presumably locally many stones in and on the soil

GONINI LANDSCHAP
GONINI LANDSCAPE

23 Plateau- en hellingverweringsgronden met (lemig) zand, zandige (zware) leem en zandige klei
Plateau and slope soils with (loamy) sand, sandy (clay) loam and sandy clay

COMPAGNIE LANDSCHAP
COMPAGNIE LANDSCAPE

24 Rug-, plateau-, helling- en depressieverweringsgronden met zand, zandige (zware) leem en zandige klei, vaak grindig
Ridge, plateau, slope and depression soils with sand, sandy (clay) loam and sandy clay, often gravelly

RAMA LANDSCHAP
RAMA LANDSCAPE

25 Heuveltop-, plateau- en hellingverweringsgronden met meestal grindige klei
Hill-top, plateau and slope soils with mostly gravelly clay

VERSNEDEN LAGE PLATEAUS
DISSECTED LOW PLATEAUS
(steilste helling/*steepest slope* < 8% en/*and* 16 - 50% en meer/*and more;* 10 - 100 m + NSP)

KAURI LANDSCHAP (ZANDERIJ)
KAURI LANDSCAPE (ZANDERIJ)

26 Gebleekte midgrof en grofzand plateau- en hellinggronden
Bleached medium and coarse sandy plateau and slope soils

27 Ongebleekte midgrof en grof (lemig) zand, zandige (zware) leem tot zandige klei plateau- en hellinggronden; plaatselijk grindig
Unbleached medium and coarse (loamy) sand, sandy (clay) loam to sandy clay plateau and slope soils; locally gravelly

HEUVELACHTIG LAAG LAND
HILLY LOW LAND
(steilste helling/*steepest slope* 16 - 30%; 10 - 100 m + NSP)

FALAWATRA LANDSCHAP
FALAWATRA LANDSCAPE

28 Heuveltop- en hellingverweringsgronden met grindige klei
Hill-top and slope soils with gravelly clay

AWARA LANDSCHAP
AWARA LANDSCAPE

29 Heuveltop-, plateau- en hellingverweringsgronden met zandige zware leem en zandige klei, soms grindig
Hill-top, plateau and slope soils with sandy clay loam and sandy clay, sometimes gravelly

HEUVELACHTIG EN STERK VERSNEDEN LAAG LAND
HILLY AND STEEPLY DISSECTED LOW LAND
(steilste helling/*steepest slope* 16 - 30% en meer/*and more;* 10 - 100 m + NSP)

MATAPI LANDSCHAP
MATAPI LANDSCAPE

30 Heuveltop- en hellingverweringsgronden met zware leem en klei, vaak grindig; ijzersteen komt voor op heuveltoppen
Hill-top and slope soils with clay loam and clay, often gravelly; ironstone occurs on hill-tops

GODO LANDSCHAP
GODO LANDSCAPE

31 Heuveltop-, plateau- en hellingverweringsgronden met (zandige) zware leem en (zandige) klei; plaatselijk weinig stenen aan de oppervlakte
Hill-top, plateau and slope soils with (sandy) clay loam and (sandy) clay; locally a few stones on the soil

TEMPATI LANDSCHAP
TEMPATI LANDSCAPE

32 Heuveltop- en hellingverweringsgronden met grindige klei over klei
Hill-top and slope soils with gravelly clay over clay

DONDERBARI LANDSCHAP
DONDERBARI LANDSCAPE

33 Heuveltop- en hellingverweringsgronden met grindige klei
Hill-top and slope soils with gravelly clay

BROWNS LANDSCHAP
BROWNS LANDSCAPE

34 Heuveltop-, plateau- en hellingverweringsgronden met stoffige zware lemen en kleien; op de plateaus vermoedelijk ijzersteen
Hill-top, plateau and slope soils with silty clay loams and clays; on the plateaus presumably iron-stone

DALBANA LANDSCHAP
DALBANA LANDSCAPE

35 Heuveltop- en hellingverweringsgronden met zware leem, stoffige zware leem en stofklei; vaak grindig en plaatselijk veel stenen op de oppervlakte
Hill-top and slope soils with clay loam, silty clay loam and silty clay; often gravelly and locally many stones on the soil

STON LANDSCHAP
STON LANDSCAPE

36 Heuveltop- en hellingverweringsgronden variërend in textuur van zand tot stof en klei; matig veel stenen op de oppervlakte
Hill-top and slope soils varying in texture from sand to silt and clay; moderate amount of stones on the soil

SMALLE EN STEILE LAGE EN MATIG HOGE HEUVELRUGGEN
NARROW AND STEEP LOW AND MODERATELY HIGH RIDGES
(steilste helling/*steepest slope* 25 - 50% en meer/*and more;* 10 - 300 m + NSP)

LUCAS LANDSCHAP
LUCAS LANDSCAPE

37 Rug- en hellingverweringsgronden met grindige klei; plaatselijk ijzersteen en veel stenen op de oppervlakte
Ridge and slope soils with gravelly clay; locally iron-stone and many stones on the soil

TOM LANDSCHAP
TOM LANDSCAPE

38 Rug- en hellingverweringsgronden met meestal stenige en grindige zware leem en (stof) klei; matig veel stenen op de oppervlakte
Ridge and slope soils with mostly stony and gravelly clay loam and (silty) clay; a moderate amount of stones on the soil

POEKETI LANDSCHAP
POEKETI LANDSCAPE

39 Rug- en hellingverweringsgronden met waarschijnlijk grindige zware leem en (stof) klei; plaatselijk aaneengesloten ijzersteen en veel stenen op de oppervlakte
Ridge and slope soils with probably gravelly clay loam and (silty) clay; locally continuous iron-stone and many stones on the soil

STERK VERSNEDEN (MATIG) HOOG LAND
STEEPLY DISSECTED (MODERATELY) HIGH LAND
(steilste helling/*steepest slope* > 30%; 100 - 300 m + NSP en meer/*and more)*

WONOTOBO LANDSCHAP
WONOTOBO LANDSCAPE

40 Heuveltop-, plateau- en hellingverweringsgronden met zandige zware leem en zandige klei; vaak grindig, met veel stenen op de oppervlakte
Hill-top, plateau and slope soils with sandy clay loam and sandy clay; often gravelly, with many stones on the soil

WILHELMINA RAND LANDSCHAP
WILHELMINA MARGINAL LANDSCAPE

41 Heuveltop- en hellingverweringsgronden met waarschijnlijk (zandige) zware leem en zandige klei
Hill-top and slope soils with probably (sandy) clay loam and sandy clay

TAPANAHONY LANDSCHAP
TAPANAHONY LANDSCAPE

42 Heuveltop- en hellingverweringsgronden met waarschijnlijk meestal grindige zandige klei
Hill-top and slope soils, with probably mostly gravelly sandy clay

BAKHUIS RAND LANDSCHAP
BAKHUIS MARGINAL LANDSCAPE

43 Heuveltop- en hellingverweringsgronden met waarschijnlijk grindige zware leem en klei; vermoedelijk matig veel stenen op de oppervlakte
Hill-top and slope soils with probably gravelly clay loam and clay; presumably a moderate amount of stones on the soil

BLANCHE MARIE LANDSCHAP
BLANCHE MARIE LANDSCAPE

44 Heuveltop-, plateau- en hellingverweringsgronden met grindige klei en veel stenen op de oppervlakte
Hill-top, plateau and slope soils with gravelly clay and many stones on the soil

BONGROWIRI LANDSCHAP
BONGROWIRI LANDSCAPE

45 Heuveltop-, plateau- en hellingverweringsgronden met grindige klei en plaatselijk ijzersteen en bauxiet aan de oppervlakte
Hill-top, plateau and slope soils with gravelly clay, and locally iron-stone and bauxite at the surface

ORANJE LANDSCHAP
ORANJE LANDSCAPE

46 Heuveltop-, plateau- en hellingverweringsgronden met waarschijnlijk stenige en grindige zandige zware leem en zandige klei; zeer veel stenen en plaatselijk vaste rots op en aan de oppervlakte
Hill-top, plateau and slope soils with probably stony and gravelly sandy clay loam and sandy clay; many stones and locally bedrock on and at the surface

AMORO LANDSCHAP
AMORO LANDSCAPE

47 Heuveltop-, plateau- en hellingverweringsgronden met waarschijnlijk grindige zware leem en klei
Hill-top, plateau and slope soils with probably gravelly clay loam and clay

MANSI LANDSCHAP
MANSI LANDSCAPE

48 Plateau-, heuveltop- en hellingverweringsgronden met waarschijnlijk grindige en stenige zware leem en klei; plaatselijk stenig; op de plateaus zeer veel stenen tot aaneengesloten ijzersteen op en aan de oppervlakte
Plateau, hill-top and slope soils with probably gravelly and stony clay loam and clay; locally stony; on the plateaus many stones to continuous iron-stone on and at the surface

BERGACHTIG LAND
MOUNTAINOUS LAND
(steilste helling/*steepest slope* > 50%; > 300 m + NSP)

WILHELMINA LANDSCHAP
WILHELMINA LANDSCAPE

49 Bergtop- en hellingverweringsgronden met waarschijnlijk grindige en stenige zandige zware leem en zandige klei; zeer veel stenen en plaatselijk vaste rots op en aan de oppervlakte
Mountain-top and slope soils with probably gravelly and stony sandy clay loam and sandy clay; many stones and locally bedrock on and at the surface

BAKHUIS LANDSCHAP
BAKHUIS LANDSCAPE

50 Plateau-, bergtop- en hellingverweringsgronden met waarschijnlijk grindige en stenige klei; veel stenen tot aaneengesloten ijzersteen en bauxiet op en aan de oppervlakte
Plateau, mountain-top and slope soils with probably gravelly and stony clay; many stones to continuous iron-stone and bauxite on and at the surface

AVANAVERO LANDSCHAP
AVANAVERO LANDSCAPE

51 Bergtop-, plateau- en hellingverweringsgronden met grindige en stenige stofklei en klei; zeer stenig tot aaneengesloten ijzersteen aan de oppervlakte
Mountain-top, plateau and slope soils with gravelly and stony silty clay and clay; very stony to continuous iron-stone at the surface

BROKOLONKO LANDSCHAP
BROKOLONKO LANDSCAPE

52 Plateau-, bergtop- en hellingverweringsgronden met grindige en stenige zware leem en stofklei; op de plateaus aaneengesloten ijzersteen en bauxiet aan de oppervlakte
Plateau, mountain-top and slope soils with gravelly and stony clay loam and silty clay; on the plateaus continuous iron-stone and bauxite at the surface

Toevoegingen: / *Additions:*
- s = savanne's/*savannas*
- p = *plateaus*
- zout/*saline* — brak/*brackish*

Diversen: / *Miscellaneous:*
- mijngebieden/*Mine Pits*
- wegen/*roads*
- kreken/*creeks*

Opmerking: Kreekdalgronden komen in alle landvormen voor, doch zijn niet apart vermeld

Remark: Valley bottom and footslope soils are present in all land-forms, but are not mentioned separately

Topografische basis Centraal Bureau Luchtkaartering (CBL)
Topographical base Central Bureau of Aerial Survey (CBL)

Abstract

In this thesis, strontium stable isotope analysis is conducted on prehistoric human skeletal material (tooth enamel) from the coastal area of Suriname to research patterns of mobility. The human skeletal material is from the Geijskes collection, material which was collected during various excavations in the 1950s and 1960s. The material derives from 24 skeletons from different archaeological sites and different prehistoric cultures from the Arauquinoid Tradition (*ca.* AD 600 – AD 1492). This study provides the very first strontium stable isotope data for this region and time period.

Strontium stable isotopes from enamel reflect diet and environment during childhood. Therefore, it is possible to research mobility based on a difference in the strontium values present in a person's enamel and the strontium signature of the local environment. While the exact strontium signature of the local environment has yet to be determined from soil, faunal or floral samples, extensive research on the geology and isotope geochemistry of the area, as well as the application of a prediction model, allowed for the establishment of a quite certain local environmental signature. With this local strontium signature, and also by comparing the strontium values of the different individuals, this study identified one non-local individual. The aforementioned data used to establish the local environmental strontium signature was also used to investigate the possible location of origin for the non-local individual. Most likely the individual came from the southern region of Suriname, namely the Guiana Shield. There is a paucity of information about cultures from the southern Suriname region; however, archaeological data has found that a vast trade network was present between the coastal and the inland areas. Though a permanent or temporary movement of the non-local individual cannot be established based solely on strontium stable isotopes, the results suggest close contact between these areas. Therefore, the strontium isotope data from this study has both improved our understanding of mobility in the region of Suriname and supported archaeological evidence of trade networks.

For one of the archaeological sites, Kwatta Tingiholo (*ca.* AD 1000 – AD 1400, n=14), the results of the strontium stable isotope analysis were compared in males versus females and in those with and without cranial deformation. No statistically differences were found, providing insight into a possible lack of difference between social-cultural variables and location of origin.

Future research is needed, particularly additional isotopic data such as oxygen and carbon, and the local strontium signature of Suriname, but this thesis has made the key first step in reconstructing patterns of Suriname paleomobility upon which a regional model can begin to be built.