MOVING TO MEDIEVAL BERLIN: UNDERSTANDING MIGRATION USING SKELETONS AND HISTORICAL RECORDS

by

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# TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................ iv
LIST OF TABLES ................................................................................................................... ix
LIST OF FIGURES ................................................................................................................ x
ABSTRACT .............................................................................................................................. xi

## CHAPTER I. INTRODUCTION ......................................................................................... 1
  Research Context .............................................................................................................. 1
  Research Objectives ...................................................................................................... 2
  Structure of This Thesis ............................................................................................... 4

## CHAPTER II. MIGRATION THEORY AND HISTORICAL CONTEXT ......................... 7
  Migration Theory ............................................................................................................ 7
  Causes of Migration ...................................................................................................... 8
  Examples of Isotope Studies of Ancient Migration ....................................................... 12
  Historical Context ........................................................................................................ 13
  Conclusion ..................................................................................................................... 24

## CHAPTER III. MATERIALS AND METHODS ............................................................... 25
  Sample Composition ...................................................................................................... 25
  Isotope Analysis .......................................................................................................... 28
  Analytical Procedure .................................................................................................... 33

## CHAPTER IV. RESULTS ............................................................................................... 37
  Introduction ..................................................................................................................... 37
  Human Enamel Apatite Results ..................................................................................... 37
  Establishing a Local Range ......................................................................................... 39
  Intrasite Comparisons ............................................................................................... 47
  Intersite Comparisons ............................................................................................... 49
  Conclusion ..................................................................................................................... 51

## CHAPTER V. DISCUSSION AND CONCLUSION ......................................................... 52
  Hypothesis 1: People migrated to Berlin from nearby areas ......................................... 52
Hypothesis 2: Males and females were equally likely to migrate ..........................56
Hypothesis 3: Local people ate local food, whereas migrants likely changed their diet...............................................................................................................................57
Hypothesis 4: Petriplatz is similar to other contemporaneous, nearby sites........57
Future Research ..........................................................................................................59
REFERENCES ..............................................................................................................62
LIST OF TABLES

1. Berlin Sample Demographic .....................................................................................................................26
2. Berlin Sample Demographics and Enamel Weight .......................................................................................34
3. Petriplatz $\delta^{13}$C and $\delta^{18}$O Results from Human First Molar Enamel .............................................37
4. Comparison Between Raw Data and Drinking Water Values .................................................................40
5. Faunal $^{87}$Sr/$^{86}$Sr Measurements from Berlin ....................................................................................44
6. Relevant Bone $\delta^{13}$C and $\delta^{18}$O Values from Zechini (2017) ..........................................................48
LIST OF FIGURES

1. Timeline of the Middle Ages .......................................................... 13
2. Map of Brandenburg ........................................................................ 16
3. Image of immigrants in the *Sachsenspiegel* ..................................... 17
4. Replica of the oldest city map of Berlin/Cölln ................................. 21
5. Ruins of St. Peter’s Church .............................................................. 22
6. Detail of the cemetery plan .............................................................. 23
7. $\delta^{18}O$ isoscape map of Germany ................................................ 32
8. Histogram of oxygen isotope values from first molar enamel from Petriplatz........ 39
9. Histogram of strontium isotope values from first molar enamel from Petriplatz .... 42
10. Geological map of Germany ............................................................ 43
11. Human and faunal strontium range .................................................. 45
12. Human enamel $^{87}$Sr/$^{86}$Sr and $\delta^{18}$O range ............................. 46
13. Map of potential immigrant origins ................................................. 53
ABSTRACT

MOVING TO MEDIEVAL BERLIN: UNDERSTANDING MIGRATION USING SKELETONS AND HISTORICAL RECORDS

Jane E. Holmstrom

The earliest years of modern Berlin are unknown since very few documents from the time have survived. The lives and origins of the settlers are largely unknown. However, the excavation of Petriplatz, a Medieval cemetery in Berlin, allows bioarchaeological research to be done to understand the formative years of this city. This study employs oxygen, carbon, and strontium isotope analysis to understand migration of the earliest settlers of Berlin in order to determine if the city was settled by locals or non-local individuals.

Dental enamel was analyzed from 13 adults dating between the 11th and 13th centuries AD in an effort to identify individuals born locally. This investigation yielded at least five potential immigrants who moved to Berlin during or after childhood, as their oxygen and strontium isotope signatures are outside the local range. Results show that both males and females were migrating to Berlin from nearby areas, all individuals were eating similar foods, and individuals from the Petriplatz cemetery were isotopically similar to other nearby Medieval sites.

This first isotopic study of migration of the earliest settlers provides a glimpse into Berlin’s mysterious formative years and provides the comparative data for future isotope studies at Petriplatz.
CHAPTER I: INTRODUCTION

In a time when our daily lives are documented frequently on various social media platforms, it is difficult to remember the era when cell phones and Facebook were not available. We use websites like Google or digital assistants like Siri to help us navigate life quickly and efficiently. If you do not know something, you can use Google to find an answer. Google provides convenience to people who want a quick answer to something, or need a starting place for researching a topic. However, sometimes it is not possible to find an answer because an answer does not yet exist. For example, when typing into Google “When was Berlin founded?”, Google says 1237. However, Wikipedia’s answer is more in depth, stating “Berlin is mentioned as a town for the first time in 1251 and Cölln in 1261. The year 1237 was later taken as the year of founding” (Stöver, 2013). Little additional information is given about Berlin’s founding date, and essentially nothing is known about the people who settled there. The Wikipedia entry mentions that German merchants settled in the city center by the late 12th century; however, archaeological evidence indicates that the area was settled years earlier (Stöver, 2013; Melisch and Sewell, 2011). This research will help begin to identify through isotope analysis whether Berlin was founded by local settlers or by immigrants.

Research Context

Today, Berlin is a major European capital city located in northeast Germany and has a population of around 3.5 million people. However, since little documentation exists for the area, there is not an official settlement date of the city, and the earliest inhabitants are invisible outside of the archaeological record. Originally, sister cities Berlin and Cölln were built on opposite sides of the Spree River. The double-town foundation (Doppelstadt) was a common occurrence during the eastward expansion of the Medieval period (Melisch and Sewell, 2011). The excavation of St. Peter’s church cemetery, called Petriplatz, located in what was Cölln before it
was integrated into Berlin in the 18th century, allows researchers the opportunity to understand the twin cities’ earliest years through their inhabitants (Melisch and Sewell, 2011). Archaeological research first began at Petriplatz in 1967 by H. Seyer; however, bioarchaeological research did not begin until decades later, when the cemetery was rediscovered after removal of a parking surface. Recent research on the skeletons from the cemetery has been focused on questions regarding kinship, diet, and migration: Rothe et al. (2015) conducted ancient DNA (aDNA) analysis to understand biological relationships within a burial of multiple children; Zechini (2017) focused on adult diet before and after the Black Death; and Killgrove et al. (n.d.) are working on understanding migration through strontium isotopes. My research is focused on learning more about migration and the earliest inhabitants of Berlin through the use of oxygen and carbon isotope analysis in conjunction with Killgrove and colleagues’ strontium isotope analysis. This thesis therefore adds to the fundamental question of the origins of one of the largest European capital cities.

Research Objectives

During the 12th to 14th centuries in Medieval Europe, it was commonplace for individuals and families to move together. In order to gain freedom from oppressive noblemen, Medieval peasants often moved to new areas that were outside of their direct control; migration was also required for certain professions, however (Kleinschmidt, 2003). Migration to Berlin is fascinating because who moved there as well as why they moved there is not known, unlike other major European cities. Archaeological and bioarchaeological methods are well suited for attempting to answer these questions by studying skeletal remains. It is possible to identify immigrants by conducting isotope analysis on dental enamel and comparing those values to known variations in geology and environment and by comparing them with other skeletons from
nearby sites. As people moved, many new settlements formed. Over the centuries, Berlin became a major city; however, other newly formed cities were probably very similar early on. This thesis therefore addresses the following hypotheses:

1. People migrated to Berlin from nearby areas.

After the 7th and 8th centuries, people across Europe who were lower class and tired of being oppressed were moving short distances from urban areas to mostly uninhabited forests in order to gain some freedom from the oppression of the King and district rulers who had minimal control over the forest (Davis, 1986; Kleinschmidt, 2003). Although this pattern of urban-to-rural movement began in the early Medieval period, it became a more popular pattern of migration in subsequent centuries. Therefore, I hypothesize that people likely migrated to Berlin from nearby areas.

2. Males and females were equally likely to migrate.

In patrilocal societies, wives move to where the husband’s family lives. The first farmers to southwest Germany 7,500 years ago were such a society, and through isotopic evidence of the skeletal remains, it was found that females were more commonly the immigrants (Bentley et al., 2002). However, during the Medieval period in Europe, excavations and isotope analysis have shown that males and females were both migrating. Men in certain male-dominated professions, for example clergy, merchants, and apprentices were required to migrate during the Medieval Period (Gregoricka et al., 2017; Schuh and Makarewicz, 2016). Finding out who migrated could indicate what kind of society settled Berlin. Therefore, I hypothesize that people of both sexes migrated to Berlin.
3. Local people ate local food, whereas migrants likely changed their diet. Following the assumption that people were moving to Berlin from nearby areas, the skeletons at Petriplatz should have similar carbon isotope values as locals, suggestive of consumption of a diet based on local food resources. Non-locals would be easily identified by having carbon isotope values outside of the local range. The German diet included foods such as wheat, barley, and oats (Jones 1960; Adamson, 1995; Zechini, 2017), which are isotopically distinct from diets that include non-local foods like sorghum or millet (Brown and Brown, 2011). I hypothesize that the vast majority of the people from Petriplatz were consuming a locally sourced diet.

4. Petriplatz will be isotopically similar to other nearby sites. People were moving eastward in shorter distances during the Medieval Period for jobs and freedom (Kleinschmidt, 2003). Because of this influx of migrants to the east, many settlements were built in eastern Germany and Poland. I hypothesize that the Petriplatz skeletons will therefore show similar ranges of oxygen, strontium, and carbon isotope values as skeletons at other nearby sites. I suggest that people migrated from an isotopically similar location to each other, which can be identified from tooth enamel.

Structure of This Thesis

Chapter 2 discusses migration theory, the historical context of Medieval Europe, and the excavation of the Medieval cemetery site of Petriplatz. Anthropologists have used different theories over the decades for understanding migration. In this chapter, I examine these theories and explain how they can be used to ask questions about the earliest settlers of Berlin. The chapter also lays out historical context of the Medieval period, broadly in Europe and then more specifically in the area that surrounds Berlin. Finally, the history of St. Peter’s church and cemetery is introduced.
Chapter 3 lays out the sample composition of Petriplatz skeletons including dating procedures, demographics, and pathologies as observed by the Museum of London Archaeology team that initially analyzed them. Then, I discuss the use of isotope analyses in answering bioarchaeological research questions. Oxygen, carbon, and strontium isotope analysis are used as indicators of migration. The oxygen isotope ratio found in dental enamel when compared with environmental levels can suggest if a person was ingesting local water during childhood (Schuh and Makarewicz, 2016). Strontium in the body is related to diet, which can be compared to environmental levels based on geological materials (Bentley, 2006; Killgrove, 2010; Schuh and Makarewicz, 2016). Carbon isotopes are generally used for reconstructing diet; however, they also can provide additional evidence for differentiating local versus non-local people (Schuh and Makarewicz, 2016). In this chapter, oxygen, carbon, and strontium isotope analyses are explained and the analytical procedures necessary for obtaining isotope data are described.

Chapter 4 illustrates the isotope data from human remains from Petriplatz received from the Center for Isotope Geoscience at the University of Florida, Gainesville. The local range for Berlin is established for oxygen, carbon, and strontium values, and potential immigrants are identified. Intrasite comparisons in terms of sex are performed using basic statistics, and intersite comparisons are made between Petriplatz and two sites in Southwest Germany (a 6th century site in Dirmstein (Schuh and Makarewicz, 2016), and an 11th century site in Gammertingen (Grumbkow et al., 2013)) and a 17th-18th century site from Drawsko, Poland (Gregoricka et al., 2017).

Chapter 5 hypothesizes where potential immigrants came from based on data in chapter 4 when compared to the isoscape map, the map of strontium signatures, and comparative data from the other German and Polish sites. This chapter also discusses the limitations of using isotopes to
isolate immigrants, especially in a small sample. The chapter concludes with recommended future research needed in order to answer the question of immigrants in Medieval Berlin with confidence.
CHAPTER II: MIGRATION THEORY AND HISTORICAL CONTEXT

Anthropologists use theory to ask the right kinds of questions for their research goals. For this project, migration theory provides the framework for asking questions surrounding the movement of people including the push and pull elements of migration. This chapter describes the different causes for migration and lays out the historical context leading to the foundation of Medieval Berlin.

Migration Theory

Types of Migration.

Migration involves long-term relocation of individuals moving across significant sociocultural, political, or environmental boundaries (Tsuda and Baker, 2015:19). Anthropologists attempt to understand motivational factors influencing individuals and groups leaving their homes for elsewhere. To do this, anthropologists have used different theories in their research to understand what makes people come to and leave from a community.

Modernization theory emerged in the 1950s and 1960s as the way to understand economic and social change. This theory splits the causes of migration into the “push” factors that are typically associated with “traditional” societies, and “pull” factors that are associated with “developed” societies (Kearney, 1986). The assumption of modernization theory is that the city is modern, whereas the country is backward and undeveloped. Through a microeconomic lens, modernization theory focuses on the individual and their process of deciding whether and how to migrate.

By the late 1960s and early 1970s, Latin American political economists realized modernization theory did not work the way that was expected, so a new theory emerged. Dependency theory looks at macroeconomic relationships. Instead of understanding the city and
rural community as separate entities, dependency theory sees ties between urban centers as the core and rural areas as the periphery. The periphery is tied to the core, and this dependency is meant to help the developmental needs of the core rather than the periphery (Frank, 1966; Kearney, 1986).

In the late 1980s and early 1990s, transnationalism became a way to understand modern migrant practices (Vertovec, 2010). Transnationalism looks at macroeconomic relationships and theorizes space and place in new ways (Brettell, 2016). One of the main concepts to come out of transnationalism is diaspora. The diasporic subject straddles two places at once. In their host state, they are considered a hyphenated citizen, whereas in their homeland, they are considered both an insider and outsider as they share allegiance with another nation state (Laguerre, 1998: 8-10, as quoted in Brettell, 2016). Transnationalism examines the social structure of people who tend to go back and forth between their old community and new, as these migrants typically cross geographic, political, and cultural borders (Glick Schiller et al., 1992; Basch et al., 1994; Brettell, 2016). I hypothesized that those who settled Berlin were coming from nearby regions and that both males and females would be immigrating. The concept of transnationalism works well for framing questions about this population because they would have likely maintained ties to their homeland or community.

**Causes of Migration**

Motivations to migrate to a different location can be complex. Major disasters are not sole reasons for people to leave their home. Anthropologists Takeyuki Tsuda and Brenda Baker investigate how disruptive events led to migration across time (Baker and Tsuda, 2015). Disruptive events can be due to conflict, disintegration, and social disorder (Burt, 2007:732; Park and Stokowski, 2009:905-907; Tsuda et al., 2015). Tsuda et al. (2015) identify that disruptions
encompass two groupings of events: environmental disruptions and social disruptions.

Environmental disruptions affect the natural environment; examples include earthquakes, hurricanes, droughts, tornadoes, etc., as well as pathogens and pests that endanger livestock and crops. Social disruptions include economic systems, political systems (such as war, invasions, or conquests), social structures (such as class and kinship), and cultural systems (such as religion, language, and ideology). Before exploring further the different motivational factors for migration, migrants themselves should be defined.

The different types of migrants as described by Tsuda et al. (2015:21) are the following:

- **Conquerors** – those who wish to dominate the host society politically/culturally/socially;
- **Colonizers/settlers** – individual migrants who stay for the long term or permanently, but do not necessarily wish to gain power;
- **Elite migrants** – migrants who are from the ruling class or are economically well-off;
- **Commoner migrants** – those who seek out better economic opportunity and livelihoods elsewhere;
- **Refugee migrants** – those who flee ethnopolitical conflict, persecution, or environmental disaster.

Sometimes the influx of migrants becomes the source of disruption causing conflict and instability, while other times, the receiving society is able to absorb and adapt to the additional population without long-term negative consequences (Tsuda et al., 2015).

**Push and Pull Factors.**

Although modernization theory is not an overall useful theory, it still can help to illuminate individual motivational factors. Motivations for migration can be divided into two overarching categories: push and pull. “Push” factors are generally environmental disruptions but can also be
social disruptions. “Pull” factors are the perceptions of a better opportunity (Cowgill, 2015). Individuals and small groups may choose to migrate for better economic opportunities. Large scale, more organized migrations may occur because of perceived political vulnerability (Cowgill, 2015).

Economists question why some people move and others do not. They describe immigrants as being risk takers, more assertive, entrepreneurial, and healthier than those they tend to leave behind, suggesting that migrants are favorably self-selected to move (Chiswick, 2008). Migrants can be defined as people who may be fleeing poverty, repression, or being pulled by the opportunities of wealth and freedom. Migrants in the past may have had similar motivations as migrants today. Those who move for economic reasons may look for better jobs, education, training, or a more lucrative future for their children. From an economic lens, migrants have been moving for these reasons across time and all over the world. Living closer to urban areas may have also provided an economic benefit, as it could have been more affordable to live outside the city yet still be close enough to hold higher-paying or better types of jobs. This is seen today with individuals and families choosing to live in suburban areas and commute to the city for work. For example, the Medieval town of Bernau, located approximately 20km northwest of Berlin, may have influenced immigration with better opportunities for work and earnings as well as the fact that women were allowed to carry on the businesses of their dead husbands (Faber et al., 2003). These are good incentives for the pull factors that seem to entice people to go where the grass may be greener.

In areas of conflict, two types of push factors are examined. The first type, “push-permit,” is used to describe the process of anticipatory movement, where the individual or group is able to take some time to decide where to flee. Urgent cases where there is no time for
planning are called “push-pressure” (Kunz, 1973). For example, Monsutti (2016) discusses individuals fleeing war torn Afghanistan in the early 1990s and suggests that migration is complex, as he saw Afghans make journeys back and forth between their homeland and their host community.

Droughts or famine are appropriate motives for migration for some groups. Focused on the Epiclassic period (500-900 AD), Beekman (2015) discusses how the Bajío of Northern Mesoamerica abandoned their home due to a climate shift. The once fertile land dried up over time in a centuries-long period of aridity. After farming continued to fail and the drought intensified, farmers had two options: to quit farming and become hunter-gatherers or to migrate. The people began to disperse along well-known paths to areas in which they had trade partners or about which they had information (Beekman and Christenson, 2003).

Religion could be a motivational factor for migration (Beck, 1995). However, religion is also a plastic concept in which expression varies. Since religion is passed along through ritual and tradition, it forms a boundary between different social and cultural groups (Insoll, 2004; Edwards, 2005; Zakrzewski, 2015). For example, Medieval Spain was a religious melting pot (Boone, 2009); however, the Islamic conquest brought invasions to the Iberian Peninsula. The power structure changed among the different faiths, and the ruling party dictated that members of certain religious groups needed to convert to Christianity, be exiled, or become slaves (Lowney, 2005). In 10th century Germany, the German kings, who were also warlords at this time, were anointed by the Christian church. It was during King Otto I’s reign (936-973) that the Slavs and Wends that lived to the east were conquered, suppressed, and converted. The eastern expansion that took place therefore expanded the boundaries of not only Germany but also Latin Christianity (Brown, 1972).
Examples of Isotope Studies of Ancient Migration

Since the beginning of humankind, people have left home to migrate to new areas. The Linearbandkeramik (LBK) is the term used to describe the first central European farmers from approximately 7,500 years ago who moved into the area of southwest Germany from the Hungarian Plain. Bentley et al. (2002) used strontium isotope analysis on skeletons from three LBK cemeteries in southwest Germany to understand migration. In addition to finding that movement of people was taking place during this time, they also found that the females were immigrants to the area, which is consistent with a history of patrilocality in European prehistory (Bentley et al., 2002).

Killgrove and Montgomery (2016) used biogeochemical analysis at two ancient cemeteries to find immigrants to Rome, Italy. Their research found that men and children were migrating to Rome; however, as women were underrepresented in their sample, it cannot be ruled out that families were migrating together, as suggested by Prowse et al. (2007).

Knudson and Torres-Rouff (2015) used biogeochemical analyses on individuals in the South-Central Andes to investigate migration due to environmental and political disruption. They used strontium and oxygen isotopes to try to isolate immigrants during the Middle Horizon and Late Intermediate periods. They found that during the Middle Horizon period, there was an influx of people migrating to the area; however, at the end of the Middle Horizon, there was political upheaval and a long-term drought, which caused fewer people to migrate to the region. They also found that after the drought and political disruption ended, people did not return to the area, suggesting that people who left likely stayed in their new home to continue to strengthen their social and economic networks (Knudson and Torres-Rouff, 2015).
Schuh and Makarewicz (2016) used carbon, oxygen, and strontium isotopes to investigate migration in southwest Germany that had territorial conquests in the 5th and 6th centuries. Their study identified among the skeletons immigrants who contributed to the settlement of the area; however, they were unable to determine if migration was the result of political factors. I will be using this study as one of my comparative sites for this thesis.

**Historical Context**

*Medieval Period.*

The Medieval Period can be divided into the early, middle, and high middle ages (Figure 1).

![Timeline of the Middle Ages](www.gowiththeflo.blogspot.com/2015/03/design-history-medieval-period.html)

**Early Middle Ages (4th-10th C AD).**

The climate in Europe north of the Alps from the 4th to 8th century was cold and wet and likely contributed to poor harvests. People struggled greatly to make a living (Koenigsberger,
1987), which may have been an early contributing factor for mobility during the beginning of the Early Medieval Period. In the 4th to 6th centuries, long-distance movements were made by organized groups attempting to reach areas under Roman rule. The migrants usually integrated into the settlements; however, sometimes they would contribute to the preexisting economic, political, or cultural conflicts. Movement during this period was not unidirectional. Migrations taking place back and forth across the English Channel have been identified through linguistic and topographical evidence such as the names of towns and cities (Kleinschmidt, 2003).

During the 7th and 8th centuries, kings or multiple noblemen ruled districts across Europe. Coexistence of many different groups could have been due to the norms enshrined by Christian church institutions. It was necessary for individuals to join the settlements and remain integrated. From this, kin based and neighborhood based groups would migrate together. Sometimes migrants would need permission from the Frankish kings in order to relocate (Kleinschmidt, 2003). Tired of being controlled by the rulers, the kin based and neighborhood groups chose to move into the nearby woodlands and away from the main settlements because the rulers did not have direct control over the woods (Davis, 1986; Kleinschmidt, 2003). These groups cleared the trees and created new settlements, generating a new pattern of migration that became dominant a few centuries later. It is possible that there could have been small forest dwelling groups that may have been forced out when the settlers came, or they could have been welcomed in the newly forming villages. Migrants during this time were more likely to move shorter distances near their previous settlements rather than moving long distance. Due to a lack of historical evidence, motives are not clear for these short-distance migrations; however, it is thought that people did not migrate with the intention to elevate their status, but rather to gain freedom from the rulers. These new woodland settlements did eventually cause the district rulers
to take direct control over the wooded areas and begin to allocate rights over the usage of the forest (Kleinschmidt, 2003).

In the 9th and 10th centuries, political changes occurred. Although Germany was subject to Viking attacks, the largest threat at this time was from the Magyars. Because of the Frankish king’s inability to cope with the Magyar raids, regional officials had a resurgence of power (Hollister, 1982). In the early 10th century, the German magnates elected the new German king, Henry I. He was able to organize an effective defense against the Magyars; however, it was the king’s son Otto who was able to defeat the Magyars’ advance through Italy, Germany, and France. The Magyars settled in Hungary, keeping their own language (Koenigsberger, 1987).

German colonization grew during feudalism, which is a social order that has obligations that include the peasant, the vassal, and the lord. Here, central authority is weak or non-existent, the peasant can work for themselves, and the economy is self-sufficient; however, the system was cruel. In exchange for land usage, labor or service was required. German colonization provided the peasant an opportunity to leave dense populations and oppressive obligations for an area with much more freedom (Rugg, 2000).

*High Middle Ages (11th – 15th C AD).*

A slow and steady push to colonize eastern Germany occurred from 1125-1350, most notably by the Slavs. The Slavs had already moved into eastern Germany in the 10th and 11th centuries, creating fortified settlements. One such place is in Görzke, which is located about 80km or 50 miles west of Berlin. Görzke was first mentioned in 1161 AD and gained town status in 1283 AD (Brande, 2007). The Germanic military, however, extended the boundaries of German settlements back to the east at the Slavs’ expense. From this, a large migration of
German peasants came from the west and built countless small agrarian villages in the new eastern lands (Hollister, 1982).

In the 12th century, Brandenburg (Figure 2), a territory in northeast Germany where Berlin was founded, became occupied. The original Slavic settlements began to be occupied by Flemish and German colonists from the west (Brown, 1972; Brande, 2007). This migration during the 12th century was a permanent one, forever changing the shape of European maps (Brown, 1972).

![Figure 2: Map of Brandenburg. (Brown, 1972)](image)

In the 13th century, the Middle Low German law book *Sachsenspiegel* ruled that the law was only for the settlement’s permanent residents and not for resident aliens. This is the first recording of the segregation of immigrants from permanent residents in the middle ages. However, as of the late 13th century, there was no generic German word for foreigners or
resident aliens. The book described and illustrated the outsiders based on the clothing they wore (Figure 3). The English word “foreigner” was created from a Medieval Latin root in the 15th century and the German word “Ausländer” was first recorded in the 16th century. This shows that the separation of immigrants was a salient feature of Medieval Europe. Segregation was also seen in 12th century France, Syria, and Palestine (Kleinschmidt, 2003).

Figure 3: Image of immigrants in the *Sachsenspiegel* (Wikimedia Commons/Public Domain).

After the 12th century, people in Europe began moving into more urban regions as towns and cities grew, in large part because local governments required migration for certain groups of professionals, especially apprentices. Eventually, aristocrats and clergy joined this pattern of long-distance migration. However, due to war, plague, and other disasters, by the 14th century, up to twenty percent of France’s population was on the move; areas that were minimally populated attracted agriculturalists from nearby regions as immigrants (Kleinschmidt, 2003). Between 1200 and 1350, 1,200 new villages were founded in Silesia (a small area now part of Germany, Poland, the Czech Republic), and 1,400 new villages were founded in Prussia (both east of Brandenburg), bringing around 300,000 peasants to the area. These migrants came seeking new land, wealth, opportunities, and status (Brown, 1972).
**Push/Pull Factors.**

Europe saw a period of mild weather, known as the Medieval Warm Period (MWP), from 950 AD to 1400 AD. During the 11th century, Western Europe developed technological advances that brought about an increase in population (Davis, 1986). It is believed that this warm period and a change in technology created a sudden abundance of resources (Kendall et al., 2013). It was in the 13th and 14th centuries that grain became a dietary staple, allowing for a major increase in agricultural production (Piskorski, 1999).

In the 12th century, areas in western Europe began running out of easily accessible land. During this time, the Flemish and Dutch peoples (currently the region of Brussels and the Netherlands) moved to inhabit Eastern Germany and Slavic regions (Davis, 1986; Koenigsberger, 1987). Additionally, at the beginning of the 12th century, people began moving eastward, starting in Holland and Flanders, and occupying territories across the Elbe River, including Polish, Czech, and Hungarian lands. German emigration in the 12th and 13th centuries reached annual counts of 2,000 to 2,500 people (Piskorski, 2008).

The high and late middle ages saw another motivational force for migration: religious self-determination. This period saw a few large, long distance migrations. One was the Vikings (8th-12th centuries), who settled in areas of Iceland, Sicily, Russia, and Canada. Another group was the Magyars (9th-11th centuries), Asian nomads who settled in central and southern Europe. Lastly, there were the German-speaking groups (12th and 13th centuries) in the Baltic region and in Poland (Brown, 1972; Kleinschmidt, 2003). The mid-13th century began the German settlement of the Eastern Holstein. Here settlers came from northern Germany and the Netherlands. During this time, the Germans did not come as conquerors, but were invited to
come and settle by the local lords. By the 14th century, Germans lived on the Gulf of Finland and on the Swedish coast of the Baltic (Piskorski, 1999).

**Brandenburg.**

The area of Brandenburg (see Figure 1) was a primeval beech-oak forest from 550 AD – 1200 AD when the forest began to be cleared (Brande, 2007). Based on pollen analysis conducted by Brande (2007), a small amount of human impact was found by the Germanic population of Semnones (Brande, 2006). After the 9th century, the temperatures warmed slightly and harvests improved (Koenigsberger, 1987).

During the early Medieval period, the area of Brandenburg was occupied by the Semnones, who were eventually pushed out and replaced by the Slavs. The German conquest began with the capture of the Slavic capital of Havelli by German King Henry I the Fowler (919-936) of Branibor (Encyclopedia Britannica, 2006). Frankish King Charlemagne brought about the earliest eastern expansion as he took the Germans to the river Elbe. The mark or borderland of Brandenburg was established under Charlemagne which originally was for protection from the Wends and the Slavs. The mark was subdivided, and trade developed with the Wendish neighbors. Although there were isolated instances of brutality in nearby regions, Germans and Wends along with other immigrant groups such as Flemings (natives of northern Belgium), Walloons (natives of southern Belgium), northern French, Englishmen, and Piedmontese (northwest Italy), were gradually integrating and becoming a melting pot.

In Brandenburg, colonization began to increase because of Albrecht von Ballenstedt, also called Albert the Bear. He began to lead colonization after 1157, as the margrave of Brandenburg, when he invited settlers into the territory from all parts of Germany and the Low Countries (modern day Belgium, Netherlands, and Luxembourg). During this period of growth,
Berlin was one of the new towns that was founded, and Brandenburg enjoyed prosperity in the 13th century (Encyclopedia Britannica, 2006). By the early 13th century, many of Brandenburg’s settlements were founded or were expanded into townships. It is not clear if Cölln was founded or expanded in 1232 with Berlin following in 1242; however, based on existing documents, it is likely that these cities were not founded during this time but expanded. The region of Brandenburg was not an agriculturally rich area, later being called the Holy Roman Emperor’s sandbox. The colonists had to exert a lot of effort to transform the sandy soil and vast forests into arable land. Within the protective walls of the towns, the goal was to build as many houses as possible, all surrounding a central market (Koch, 1978).

Immigrants came to the area, either settling at a previous Slavic village or building a new town on an uninhabited site. These towns were under the direct rule of the margrave. Brandenburg Mark had over 60 towns; over half had Slavonic names, with 25 percent of the towns having already been major settlements prior to the Germanic immigration.

**History of Berlin and St. Peter’s Church.**

The twin cities, Berlin and Cölln, were built on opposite sides of the Spree River during the Medieval period (Figure 4) (Melisch and Sewell, 2011). Although Berlin and Cölln began as two distinct settlements, Cölln has since been integrated as part of the modern city of Berlin. There is currently no evidence to suggest whether these two cities formed at the same time, and there are very few contemporaneous written accounts that reference the settlements. Berlin and Cölln settlers are essentially invisible to the written record until the documentation of births in the 1600s (Melisch and Sewell, 2011). Based on archaeological evidence, the foundation of sister cities Berlin and Cölln likely occurred in the late 1100s or early 1200s.
The earliest historical reference, a charter, dates to 1237. This document discusses a meeting at the Latin school to resolve a dispute about the church tax. The witness to the document signed as Symeon, Plebanus de Colnia (pastor of Cölln). The next document, from 1285, references a Cölln church building specifically (Manuel et al., 2014). Per a 1308 town document, Berlin and Cölln joined a “union” of Brandenburg towns vowing mutual help against violence and injustice. The following year, the same towns agreed to also share expenses when resisting injustice before the margrave’s high court or due to violence done to one of the towns (Carsten, 1943). Many towns in Brandenburg during this period were only considered fortified places, not having their own privileges of self-government or other benefits acknowledged by rulers. However, Berlin and Cölln were granted these special privileges in 1317 (Carsten, 1943). Finally, a discharge letter from 1379 states that St. Peter’s church received a new choir. The church documents all reference the same one, St. Peter’s church of Cölln (Melisch and Sewell, 2011).
Melisch and Sewell (2011) described the few hundred years’ worth of mishaps St. Peter’s church (Figure 5) underwent. In the late 1600s, the church partially collapsed due to structural instability. In 1730, the church was struck by lightning and subsequently burned to the ground. As soon as it was close to being rebuilt, the tower collapsed under its own weight. The tower was rebuilt and caught on fire again in 1809. Eventually, it was rebuilt and was again destroyed during WWII. The church site was ultimately demolished for the expansion of a road and the site was turned into a parking lot. It remained this way until 2007, when a team of archaeologists, led by Claudia Melisch and Jamie Sewell, removed the parking surface and uncovered the cemetery under St. Peter’s square or Petriplatz.

Figure 5: The ruins of St. Peter’s Church on 6 Nov. 1960. The demolition of the church is already in progress (Photo: Wolfgang Gehrke).

Archaeology and Petriplatz.

Petriplatz was excavated from 2007-2010 by Claudia Melisch and Jamie Sewell. Their team found 3,124 graves holding the remains of 3,718 individuals (Melisch and Sewell, 2011). The Petriplatz cemetery was used from the early 1200s until the closure of the cemetery in 1717,
representing a 500-year period of continued use. Individuals recovered range from the potential founders of the city to the final individuals interred at the time of its closure. The cemetery seemed to lack organization, with the exception of rows attributed to the later stages of use. The graves were oriented from west to east, with little variation (Figure 6). In many cases the burials were made on top of those below; in some instances, there were mere millimeters between individuals. Although the site has been disturbed over the years, the burials were so well preserved that the skeletal remains of well-developed fetuses were uncovered in good condition (Melisch and Sewell, 2011).

Figure 6: Detail from the cemetery plan. (Plan: Claudia M. Melisch)

Melisch, interested in the foundation of Berlin, invited Dr. Kristina Killgrove and myself to conduct isotope analysis on some of the earliest skeletons uncovered at Petriplatz to identify migrants and better understand migration. Doing this work will help modern Berliners better understand their origins and the history of the city. This isotopic study on migration is the first to be done at Petriplatz and Medieval Berlin.
Conclusion

Migration theory helps to form questions about the movement of people through time. Modernization theory focuses on the push and pull elements that motivate people to uproot their lives and relocate, requiring them to make and maintain new social networks, and possible old ones as well, while transnationalism explains how immigrants can maintain ties between old and new home areas. The Medieval period was full of political instability and many groups tried expanding their boundaries. The German eastern expansion began around the 10th century and pushed the German boundaries east through conquest and colonization all while spreading Christianity. Before Berlin became a modern major metropolis, it began as minimally inhabited forest in the early Medieval period with agriculturally poor soil. Its largest cemetery, located next to the ruins of St. Peter’s Church and known as Petriplatz, may hold the key to understanding the foundation of the city in its skeletons. In the following chapters, I will determine through stable isotope analysis whether any of the skeletons I sampled were immigrants and from where they may have migrated.
CHAPTER III: MATERIALS AND METHODS

Isotopic studies conducted on teeth and bone are used to answer research questions relating to residence and migration studies as well as diet. The primary focus of this study is to understand the migration patterns of individuals who represent some of the earliest settlers of Berlin, so oxygen isotope analysis was conducted on the apatite from the carbonate portion of enamel. Dental enamel is formed during early childhood and is essentially unaltered after eruption, preserving its biochemical structure (Pollard et al., 2007). Enamel samples were taken from first molars because these teeth begin forming at birth and are completed by age 4 (White et al., 2012).

My research employs oxygen isotope analysis by initially using dental enamel from 21 individuals: ten adult females and eleven adult males. Based on burial location and radiocarbon dating, these individuals represent some of the earliest inhabitants of Berlin/Cölln, with dates ranging from the 11th to the 17th centuries. The majority of the skeletons date to the approximate period of the town’s settlement between 1200-1300. This chapter lays out the osteological context and methods used for the Petriplatz skeletons.

Sample Composition

Dating.

A user-friendly database was developed for the Petriplatz site to assist in the compilation and management of data produced. Additionally, a graphically interactive Harris Matrix module was programmed for the database to interpret relative chronology of the site’s stratigraphic units capable of assisting in absolute dating of contexts. For graves without contextual finds (ceramics or other grave goods), a provisional date range was given. The results of the stratigraphic
sequence also assisted in selecting individuals for $^{14}$C dating samples (Melisch and Sewell, 2012).

The females for this study date from 1057 to 1300. The males date from 1047 to 1600. The majority of individuals (N=17) fall in a date range between 1170 to 1300, which was likely around the time of the formation of the town (see Table 1).

Table 1: Berlin Sample Demographic. M = Male, F = Female, PM = Probably Male, PF = Probably Female.

<table>
<thead>
<tr>
<th>Skeleton Number</th>
<th>Sex</th>
<th>Date Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2724</td>
<td>F</td>
<td>1200-1300</td>
</tr>
<tr>
<td>3381</td>
<td>PM</td>
<td>1188-1244</td>
</tr>
<tr>
<td>4029</td>
<td>F</td>
<td>1200-1300</td>
</tr>
<tr>
<td>4407</td>
<td>F</td>
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<tr>
<td>4411</td>
<td>F</td>
<td>1200-1300</td>
</tr>
<tr>
<td>4439</td>
<td>M</td>
<td>1200-1300</td>
</tr>
<tr>
<td>4636</td>
<td>F</td>
<td>1200-1300</td>
</tr>
<tr>
<td>4785</td>
<td>M</td>
<td>1400-1600</td>
</tr>
<tr>
<td>5039</td>
<td>F</td>
<td>1200-1250</td>
</tr>
<tr>
<td>5311</td>
<td>M</td>
<td>1279-1376</td>
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<tr>
<td>5328</td>
<td>M</td>
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<td>ID</td>
<td>Gender</td>
<td>Age Range</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>5453</td>
<td>PF</td>
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<td>5454</td>
<td>M</td>
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</tr>
<tr>
<td>5468</td>
<td>M</td>
<td>1188-1264</td>
</tr>
<tr>
<td>5477A</td>
<td>M</td>
<td>1200-1250</td>
</tr>
<tr>
<td>5496</td>
<td>PF</td>
<td>1191-1264</td>
</tr>
<tr>
<td>5504</td>
<td>M</td>
<td>1200-1300</td>
</tr>
</tbody>
</table>

**Age and Sex Estimation.**

Age-at-death and sex estimations were accomplished in Berlin prior to our receipt of samples in the United States. Researchers in Berlin used the Museum of London Archaeology (MOLA) methods (Powers, 2012a). In order to determine adult age-at-death, multiple methods were employed including pubic symphysis degeneration (Brooks and Suchey, 1990; Buikstra and Ubelaker, 1994), auricular surface degeneration (Buikstra and Ubelaker, 1994; Lovejoy et al., 1985), sternal rib morphology (İşcan et al., 1984; İşcan et al., 1985), and dental attrition data (Brothwell, 1981). Broad age groups were used when ascribing age estimates. In cases where remains were fragmentary or incomplete, adulthood was determined by the complete fusion of the epiphyses and the complete eruption of the third molars (Powers, 2012b).

Sex estimation was based on macroscopic assessment of the skull and pelvis. Features used from the skull were supraorbital ridges, inion protuberance, nuchal crest (Brothwell, 1981), mastoid process, slope of forehead (Bass, 1987), and zygoma root (Ferembach et al., 1980). Using the mandible, the gonial angles were assessed according to Brothwell (1981). Pelvic features included the ventral arc, medial portion of the pubis (Phenice, 1969), greater sciatic notch, preauricular sulcus, subpubic angle, subpubic concavity, and median ischiopubic ramus ridge (Bass, 1987). Present features were graded on a five point scale: 1 = male, 2 = probably
male, 3 = indeterminate, 4 = probably female, 5 = female. If a feature was not observed because it was damaged or was missing, a grade of 9 was given (Bekvalac, 2012).

**Pathologies.**

In 2013, Museum of London Archaeology (MOLA) began working with the archaeology team at Petriplatz. The MOLA researchers were interested in comparing the Petriplatz skeletal assemblage with the St. Mary Spital cemetery in England as a way to evaluate the comparability of existing data. One of the researchers at MOLA, Natasha Powers (2013), chose a sample of 148 skeletons from Petriplatz for additional assessment beyond estimating age-at-death and sex. Additional assessment included, in some cases, radiocarbon dating, stable isotope analysis, aDNA analysis, and a rapid assessment of gross pathologies. Some of the individuals that were selected for MOLA’s additional evaluation are part of the research presented in this thesis. When a skeleton was labeled at the site with a number and a letter (e.g., 5477a), MOLA changed the letter to a decimal (e.g., 5477.1) in order to maintain compatibility with their database (Powers et al., 2013).

**Isotope Analysis**

An isotope is a variant of an element that has the same number of protons, but a different number of neutrons (Katzenberg, 2008), giving it a different atomic mass. The isotope’s atomic mass changes with the number of neutrons. For example, the $^{16}$O isotope contains eight protons and eight neutrons whereas $^{18}$O has eight protons and ten neutrons (Pollard et al., 2007). Isotopes are important in archaeological research: while some are important because they decay over time (e.g., $^{14}$C), the stable isotopes are important because they do not decay and are unchanged from when the organism was alive. Archaeochemists can measure the stable isotope abundance ratios
with reference to the isotope standard ratios (Katzenberg, 2008), which are reported in delta notation:

\[
\delta^{18}\text{O‰} = \left( \frac{^{18}\text{O}/^{16}\text{O} \text{ sample} - ^{18}\text{O}/^{16}\text{O} \text{ standard}}{^{18}\text{O}/^{16}\text{O} \text{ standard}} \right) \times 1000
\]

where the delta value (\(\delta\)) is permil (‰), meaning per thousand. The ratio of two isotopes is measured in the mass spectrometer and compared to a standard (Katzenberg 2008). Carbon is compared to a standard called Peedee belemnite measured in Vienna (VPDB). Oxygen ratios are also able to be compared against VPDB, or with standard mean ocean water measured in Vienna (VSMOW) (Brown and Brown, 2011).

**Oxygen.**

The most abundant oxygen isotope is \(^{16}\text{O}\) (99.759%). The heavier isotopes are less abundant \(^{17}\text{O}\) (0.037%) and \(^{18}\text{O}\) (0.204%) (Katzenberg, 2008). The abundance of oxygen isotope ratios in rainwater shows geographical patterning based on climate, altitude, latitude, and distance from the coast (Dansgaard, 1964; Katzenberg, 2008; Brown and Brown, 2011). The oxygen ratio found in human teeth, when compared with environmental levels, can suggest if an individual was ingesting local water or not during enamel development (Schuh and Makarewicz, 2016). When local water sources used by a community are known and distinctions in \(\delta^{18}\text{O}\) between regions are present, oxygen composition from dental enamel can be used to evaluate the movement of individuals during childhood (Chenery et al., 2010; Müldner et al., 2011; Schuh and Makarewicz, 2016).

**Conversions.**

In order to isolate immigrants from my data set, it is necessary to know what the local \(\delta^{18}\text{O}\) values are. Because human \(\delta^{18}\text{O}\) values go through a fractionation process, they cannot be
compared directly to local water. Therefore, I compared the data to themselves, then compared δ18O to modern drinking water, and finally compared the data to other studies. Mathematical conversions need to be used to transform the data into appropriate values for comparison. Linear regression equations help to describe mathematical relationships between data sets. Conversions are useful in order to compare data with other studies and data sets; therefore, a conversion needs to occur before isotope values from human tissue can be compared to geochemical data (Pollard et al., 2007). For example, to compare data between the VPDB and VSMOW standards, a mathematical formula is necessary. Using the following regression equation resolves any confusion from laboratories using different scales to report δ-values (Coplen et al., 1983; Lightfoot and O’Connell, 2016).

\[
\text{VSMOW} = 1.03091 \times \text{VPDB} + 30.91
\]

Conversion of the Petriplatz human data from the VPDB standard to the VSMOW standard will be presented fully in chapter 4. Additional conversions are necessary to compare human enamel δ18O values to modern drinking water.

After the conversion is made from the VPDB standard to the VSMOW standard, the next mathematical equation converts carbonate apatite values to phosphate values. Structural carbonate apatite is less resistant to post-depositional change than phosphate is; however, both carbonate apatite and phosphate are better preserved by crystallized enamel than by poorly crystallized dentine or bone phosphate (Iacumin et al., 1996). Phosphate in biological carbonate apatite is correlated with the oxygen isotope makeup of body water. This is linked to the δ18O of ingested water, which is ultimately associated with the δ18O of local precipitation (Longinelli and Peretti-Padalino, 1980; Longinelli, 1984; Luz and Kolodny, 1985; Ayliffe and Chivas, 1990; Luz
et al., 1990; Bryant et al., 1994; Iacumin et al., 1996). Here, the fractionation relationship between δ^{18}O_c and δ^{18}O_p can be calculated with the regression equation by Iacumin et al. (1996):

\[ \delta^{18}O_p = 0.98 \delta^{18}O_c - 8.5 \]

The δ^{18}O values closest to the calculated best fit are considered unmodified values, while δ^{18}O values further from the best fit line slope would indicate a modification by diagenetic processes (Iacumin et al., 1996).

The ratio of oxygen isotopes in mammalian bones and teeth reflects the origin of the water consumed (Daux et al., 2008). Since humans are mostly omnivores, we ingest less water from food than do herbivores. Our δ^{18}O largely reflects our drinking water, which is related to environmental water (Longinelli, 1984; Luz et al., 1984; Levinson et al., 1987; Daux et al., 2008). There is a relationship between human phosphate and meteoric water that can be calculated with a fractionation equation as described by Daux et al. (2008):

\[ \delta^{18}O_{dw} = 1.54(\pm 0.09) \times \delta^{18}O_p - 33.72(\pm 1.51) \]

Drinking water only represents 0.6% to 0.75% of the total water ingested, but it has a large influence on δ^{18}O_p. Cooking food with water (e.g., boiling or brewing) can change the value of δ^{18}O by enriching it. Water ingested from solid foods should not be richer in ^{18}O than the total water ingested by local herbivorous animals (Daux et al., 2008). Once the δ^{18}O_c values are converted to δ^{18}O_p and then to an approximate δ^{18}O_{dw} value, they can then be compared with known values on an isoscape map in an attempt to determine whether an individual was an immigrant to the region in which their skeleton was found and potentially where immigrants may have come from.
This isoscape map shows the general environmental $\delta^{18}O$ values across Germany (Figure 7). These values vary from -11.2‰ to -6.9‰ with the highest levels in the north and the lowest in the south (Sjögren et al., 2016). These values and the map will be revisited in chapter 4 following presentation of the data.

![Figure 7: $\delta^{18}O$ isoscape map of Germany (Sjögren et al. 2016)](image)

**Strontium.**

In an attempt to locate a more precise region of origin for the early settlers of Berlin, the results from the oxygen analysis are integrated with an unpublished strontium isotope study conducted by Dr. Kristina Killgrove of the University of West Florida and Dr. Marion Tichomirova of the University of Freiberg.

The utility of oxygen isotopes to estimate region of origin is enhanced when combined with strontium isotope ratios. Strontium isotope signatures come from eroding geologic
materials, through soil and the food chain, into the skeleton, where they are incorporated into hard tissue as a substitute for calcium (Bentley, 2006; Schuh and Makarewicz, 2016). Since the strontium in body tissue is related to diet and the geological environment, it is possible to analyze the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio and compare it directly to environmental values (Killgrove, 2010). Strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) in rock and sediment depend on their age and composition. $^{87}\text{Sr}$ is formed from the radioactive decay of $^{87}\text{Rb}$; therefore, higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratios will come from older rocks such as travertine, and lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios will come from younger formations such as volcanic rock (Sjögren et al., 2016). Since strontium levels can vary for a number of reasons, including the weathering of minerals, it is important to find the bioavailable isotope signal in the local food chain. This can be done by testing archaeological fauna at or near the excavation site. Gathering these baseline data is useful for comparing human strontium levels (Sjögren et al., 2016). Bentley and Knipper (2005) suggest testing archaeological low-mobility herbivores for the local strontium baseline as their $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are generally consistent, rather than using modern faunal remains.

**Carbon.**

Carbon is primarily used for paleodietary reconstruction; however, it can also be used as an additional line of evidence to differentiate between local and non-local people (Schuh and Makarewicz, 2016). Like oxygen, carbon is a light isotope that is measured to the standard VPDB. Although carbon was not the focus of this study, $\delta^{13}\text{C}$ was obtained from the enamel apatite, which will be discussed later in this chapter.

**Analytical Procedure**

As part of Dr. Killgrove’s Medieval Berlin project funded by the UWF Florida Research Fellowship, I traveled to Georgia State University (GSU) where Dr. Beth Turner instructed me
and two other graduate students on methods for treating bone and teeth for light isotope analysis. Dental enamel carbonate apatite was isolated for δ¹³C and δ¹⁸O characterization using methods adapted from van der Merwe, Tykot, and Hammond (1995), Ambrose (1993), and Schoeninger et al. (1989) as described in Turner et al. (2005; 2009).

The first part of the pre-treatment process began in one of the anthropology lab spaces at UWF. Dental enamel was taken from the first molar using a dental drill to grind the enamel off of the tooth. Each sample was then packaged in 2 ml plastic vials and labeled with the skeleton number. The second part of the pre-treatment process took place at GSU. Each sample was removed from the 2 ml vial and evenly ground with an agate mortar and pestle. The enamel powder was then weighed using sample papers and a scale. Enamel carbonate requires a minimum sample weight of 5mg. The sample weights for the oxygen analysis ranged from 5.62mg to 41.87mg as seen in Table 2.

Table 2: Berlin Sample Demographics and Enamel Weight

<table>
<thead>
<tr>
<th>Skeleton Number</th>
<th>Sex</th>
<th>Date Range</th>
<th>Sample Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2724</td>
<td>F</td>
<td>1200-1300</td>
<td>8.05mg</td>
</tr>
<tr>
<td>3381</td>
<td>PM</td>
<td>1188-1244</td>
<td>13.59mg</td>
</tr>
<tr>
<td>4029</td>
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<tr>
<td>4407</td>
<td>F</td>
<td>1200-1300</td>
<td>19.93mg</td>
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<td>10.40mg</td>
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<td>7.06mg</td>
</tr>
<tr>
<td>4636</td>
<td>F</td>
<td>1200-1300</td>
<td>18.2mg</td>
</tr>
<tr>
<td>4785</td>
<td>M</td>
<td>1400-1600</td>
<td>17.15mg</td>
</tr>
</tbody>
</table>
In between samples, the mortar and pestle were cleaned first with acetone then with double distilled water. After the enamel powder was weighed, it was then placed in a 15 ml Falcon™ tube and soaked in a 2% NaOCl (bleach)/ddH₂O (double distilled water) solution until all inorganic material was removed, about 24–48 hours. Then each sample was centrifuged at 4000rpm with double distilled water until the sample became pH neutral. The samples were centrifuged six times. A pipette was used to get as close to the sample as possible to test for pH. After the samples were at pH neutral, they were soaked in 0.2% acetic acid for up to 4 hours at 4°C to remove any exogenous carbonates or other contaminants (Garvie-Lok et al., 2004). Samples were centrifuged again and rinsed to pH neutral using ddH₂O. Samples were then freeze
dried overnight and digested in 100% phosphoric acid on an automated prep system at 50°C, interfacing with a VG prism mass spectrometer at the Center for Isotope Geoscience in the Department of Geological Sciences at the University of Florida, Gainesville. Isotopic values are reported as per mil (‰) relative to the international VPDB standard for carbon and for oxygen. The analytical precision for the mass spectrometer used is ±0.05‰ for δ¹³C and ±0.11‰ for δ¹⁸O (Turner et al., 2005; Turner et al., 2009).

Oxygen, strontium, and carbon isotope analysis was attempted on the enamel apatite of 21 individuals from the Petriplatz cemetery. This chapter discussed the conversions necessary to compare measured δ¹⁸O to environmental water. The next chapter will include isotope results, conversions, and comparisons.
CHAPTER IV: RESULTS

Introduction

For this research, I conducted oxygen isotope analysis on dental enamel of the first permanent molar to address migration and mobility in Medieval Berlin, Germany. An initial sample of teeth from 21 individuals was used; however, eight samples failed to produce data. Oxygen isotope analysis was successfully completed on 13 individuals. Results for δ^{13}C, δ^{18}O, and 87Sr/86Sr are shown in Table 3. In order to interpret the data, they need to be compared to local signatures, and mathematical conversions that facilitate this comparison follow. Strontium results are compared with baseline local faunal data, and finally isotope data from Petriplatz are compared to human data from two southwestern German sites and a site in western Poland.

Human Enamel Apatite Results

Table 3 shows the corresponding isotope ratios for each individual. Eight of the samples did not produce any data, but there is no obvious bias or taphonomic reason evident. These individuals are illustrated by a “-“ in the table and will from here on be omitted from further analysis and discussion.

Table 3: Petriplatz δ^{13}C and δ^{18}O Results from Human First Molar Enamel (“-“ indicates an absence of data). *87Sr/86Sr results from Killgrove et al. (n.d.).

<table>
<thead>
<tr>
<th>Burial Number</th>
<th>Sex</th>
<th>Age</th>
<th>Date Range</th>
<th>Sample Weight (mg)</th>
<th>δ^{13}C ‰VPDB</th>
<th>δ^{18}O ‰VPDB</th>
<th>87Sr/86Sr*</th>
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</thead>
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<td>Age</td>
<td>Enamel δ¹⁸O (‰)</td>
<td>Teeth δ¹³C (‰)</td>
<td>δ¹³C Stdev</td>
<td>Age Stdev</td>
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<tr>
<td>-------</td>
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<td>Adult</td>
<td>9.35</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

The enamel δ¹⁸O values (N=13) range from -6.1‰ to -2.8‰, with an average of -4.4‰ and a standard deviation of 1.0‰. At one standard deviation from the mean, the enamel oxygen values illustrate five individuals falling outside the sample range: males 5454, 5311, 3381 and females 5039, 5413. Analysis of enamel apatite also provided data for δ¹⁸O and δ¹³C. The sample
population (N=13) has a first molar $\delta^{13}$C range of -14.9‰ to -12.5‰, with an average of -13.7‰ and one standard deviation of 0.6‰. For these data, two individuals fall outside of the range of one standard deviation: females 5444 and 4407. The Petriplatz strontium study, conducted by Killgrove et al. (n.d.), found that the sample population (N=13) had a $^{87}$Sr/$^{86}$Sr range between 0.71015 to 0.71440 with a mean of 0.71113 and a standard deviation of 0.00112. One individual falls outside of the range of one standard deviation: male 5311.

**Establishing a Local Range**

**Oxygen.**

Oxygen isotope data are shown in a histogram in Figure 8. These data are not normally distributed, as is expected for a small population.

![Figure 8: Histogram of oxygen isotope values from first molar enamel from Petriplatz](image)

However, this histogram is reasonably symmetric with the exception of the individuals represented in the lower range. Most people fall between -5‰ and -2.5‰, whereas the second
group falls between -6.5‰ and -5.5‰. Typically in stable, non-moving populations, the local range is approximately 2‰ (White et al., 2004; Killgrove, 2010). This may indicate that individuals at the lower end may be immigrants.

In order to more fully understand what the local oxygen range is, after the raw data were received, I compared the human values to expected local environmental values. To do this, I used regression equations (see chapter 3) to convert from δ¹⁸Oₚ VPDB (measurements from enamel) to δ¹⁸Oₜ VSMOW (expected drinking water values) in Germany. Table 4 shows these conversions.

Table 4: Comparison between Raw Data and Drinking Water Values δ¹⁸Oₚ VPDB to δ¹⁸Oₜ VSMOW

<table>
<thead>
<tr>
<th>Skeleton Number</th>
<th>Sex</th>
<th>Age</th>
<th>Date Range</th>
<th>δ¹⁸O VPDB</th>
<th>δ¹⁸Oₚ VSMOW</th>
<th>δ¹⁸Oₚ VSMOW</th>
<th>δ¹⁸Oₜ VSMOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3381</td>
<td>PM</td>
<td>Adult</td>
<td>1188-1244</td>
<td>-5.9</td>
<td>24.8</td>
<td>15.8</td>
<td>-9.3</td>
</tr>
<tr>
<td>4029</td>
<td>F</td>
<td>Adult</td>
<td>1200-1300</td>
<td>-3.8</td>
<td>27.0</td>
<td>18.0</td>
<td>-6.1</td>
</tr>
<tr>
<td>4407</td>
<td>F</td>
<td>Adult</td>
<td>1200-1300</td>
<td>-4.3</td>
<td>26.5</td>
<td>17.5</td>
<td>-6.8</td>
</tr>
<tr>
<td>4411</td>
<td>F</td>
<td>Adult</td>
<td>1200-1300</td>
<td>-4.0</td>
<td>26.8</td>
<td>17.8</td>
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<tr>
<td>5039</td>
<td>F</td>
<td>Adult</td>
<td>1200-1250</td>
<td>-6.1</td>
<td>24.6</td>
<td>15.6</td>
<td>-9.6</td>
</tr>
<tr>
<td>5311</td>
<td>M</td>
<td>Adult</td>
<td>1279-1376</td>
<td>-5.4</td>
<td>25.4</td>
<td>16.3</td>
<td>-8.6</td>
</tr>
<tr>
<td>5413</td>
<td>F</td>
<td>Adult</td>
<td>1169-1256</td>
<td>-2.8</td>
<td>28.0</td>
<td>19.0</td>
<td>-4.5</td>
</tr>
<tr>
<td>5444</td>
<td>PF</td>
<td>Adult</td>
<td>1057-1244</td>
<td>-3.8</td>
<td>27.0</td>
<td>18.0</td>
<td>-6.1</td>
</tr>
<tr>
<td>5446</td>
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<td>Adult</td>
<td>1047-1217</td>
<td>-4.6</td>
<td>26.2</td>
<td>17.2</td>
<td>-7.3</td>
</tr>
</tbody>
</table>
After the final conversion into estimated drinking water values, measured human oxygen values are able to be compared to an isoscape map (see Figure 7). This map reveals that each isoscape or band of environmental oxygen values varies along the southwest-to-northeast axis of Germany.

Based on the latitude, longitude, and elevation of Berlin, waterisotopes.org estimates the average annual $\delta^{18}O$ value as -8.1‰ (Bowen, 2016; IAEA/WMO, 2015; Bowen and Revenaugh, 2003). Six of the individuals have higher values than this and fall just outside of Germany’s highest $\delta^{18}O$ isoscape range: male 5454 and females 4029, 4407, 4411, 5413, 5444.

A 17th to 18th century cemetery in Drawsko Poland located 272 km east of Berlin had a $\delta^{18}O$ range of -6.1‰ to -3.1‰ with an average of -4.5‰ (Gregoricka et al., 2017). The skeletal sample from Petriplatz ranges from -6.1‰ to -2.8‰, with an average of -4.4‰. These ranges and averages suggest that these cemeteries have similar $\delta^{18}O$ values and may have similar water characteristics.

**Strontium.**

Strontium isotope data produced by Kristina Killgrove in 2013 are plotted in a histogram in Figure 9. This histogram shows that most people have strontium isotope values between 0.71000 and 0.71300, values that are fairly consistent with the geology found in Berlin and faunal $^{87}\text{Sr}^{86}\text{Sr}$ values found from Petriplatz. At one standard deviation, all but one individual is
inside the local range. The individual falls within the range at the third deviation. The histogram is skewed to the right indicating that the individual farthest to the right (male 5311) is likely an immigrant.

![Histogram of strontium isotope values from first molar enamel from Petriplatz (data from Killgrove, n.d.)](image)

The strontium values can also be roughly compared to a geological map of Germany (Figure 10) in order to investigate the expected Sr range for Berlin. Compared to the map, on which geological Sr isotope ranges are displayed, two individuals are outside the local range for Berlin: male 5311 and female 4407. Their strontium values suggest they grew up in southwest Germany, or somewhere with similar geology. Germany’s geology is diverse and complex; therefore, the map provides only a rough estimation of strontium values found (Grumbkow et al., 2013).
It is also worth comparing the Petriplatz Sr isotope data with those from other sites in the same general time and place. Schuh and Makarewicz (2016) conducted strontium isotope analysis on skeletons from a 6th century cemetery in Dirmstein, located in southwest Germany. The biologically available $^{87}\text{Sr}/^{86}\text{Sr}$ range was between 0.7088 and 0.7104. Grumbkow et al. (2013) excavated an 11th century cemetery in Gammertingen, located in Southwest Germany. The excavated skeletons had a strontium range between 0.7070 and 0.7097. A 17th to 18th century cemetery in Drawsko Poland located 272 km east of Berlin had $^{87}\text{Sr}/^{86}\text{Sr}$ values ranging from 0.70999 to 0.71301 (Gregoricka et al., 2017). Although these sites are not located near
Petriplatz, the differences in Sr isotope results confirm what is expected based on the geological map in Figure 10.

The Petriplatz skeletons had a $^{87}\text{Sr}/^{86}\text{Sr}$ range between 0.71015 to 0.71440. This too is fairly consistent with the map in Figure 10, indicating that the majority of data recorded from skeletons were within the local range geographically.

Finally, in addition to the geological and bioavailable background data, the strontium values of a few animals from the immediate surrounding area of Berlin were analyzed by Prof. Marion Tichomirova of the University of Freiburg (Table 5) (Killgrove et al., n.d.). Bones and teeth from small animals usually show homogeneous values within a given area, thus providing a regional average of bioavailable strontium. These values should be comparable to human values (Price et al., 2002; Grombkow et al., 2013). Faunal strontium data points from Petriplatz (N=5) range from 0.71168 to 0.71274.

Table 5: Faunal $^{87}\text{Sr}/^{86}\text{Sr}$ Measurements from Berlin

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
<th>$^{87}\text{Sr}/^{86}\text{Sr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep/Goat/Deer</td>
<td>1345-1</td>
<td>0.71174</td>
</tr>
<tr>
<td>Pig</td>
<td>4540-1</td>
<td>0.71181</td>
</tr>
<tr>
<td>Sheep/Goat/Deer</td>
<td>1351-1</td>
<td>0.71274</td>
</tr>
<tr>
<td>Sheep/Goat/Deer</td>
<td>1346-1</td>
<td>0.71189</td>
</tr>
<tr>
<td>Pig</td>
<td>3668-2</td>
<td>0.71168</td>
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<tr>
<td>Mean</td>
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</tr>
<tr>
<td>Stdev</td>
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<td>0.00044</td>
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</table>
When human strontium values are compared against the faunal strontium range (Figure 11), it is clear that only one human falls within the faunal range at one standard deviation: female 4407. Six individuals are included within the second deviation: males 3381, 5454, 5468 and females 4407, 5039, 5413. Six individuals fall outside of the faunal range at the third deviation. This result likely indicates that: a) the animals were eating foods imported to the area; b) the animals were transported to the area; c) the animals were pastured in other geological areas; or d) some combination of these. As no small animals with local home ranges were tested, the faunal Sr data are unfortunately of little utility in constructing a local Sr isotope range.

Figure 11: Human and faunal strontium range. Box represents faunal strontium range at one standard deviation. $^{87}$Sr/$^{86}$Sr error bars = .00001.

**Local Range.**

Figure 12 illustrates that at the first standard deviation from the mean, five individuals are outside the local range for oxygen (males 5454, 3381, 5311 and females 5039 and 5413) and could have been immigrants; however, at two standard deviations, all individuals are within the local range. This indicates that all 13 individuals may have been drinking from the same water
source or drinking water from regions that had isotopically similar precipitation. Still, the variation is intriguing.

![Figure 12: Human enamel $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}$ range. Box represents one standard deviation. Error bars for $\delta^{18}\text{O}$ = .07, $^{87}\text{Sr}/^{86}\text{Sr}$ = .00001.](image)

In comparing the predicted $\delta^{18}\text{O}_{\text{dw}}$ VPDB to the isoscape map of Germany, six people fall outside the German range (male 5454 and females 4029, 4407, 4411, 5413, 5444). Male 5311 is the only individual to fall within the Berlin range according to the map (Figure 7). According to waterisotopes.org, Berlin’s $\delta^{18}\text{O}$ value is -8.1‰ (Bowen, 2016; IAEA/WMO, 2015; Bowen and Revenaugh, 2003). This may indicate that these six individuals were emigrating from a location similar in geology to Germany and drinking water that closely resembles local water, but had a slightly different $\delta^{18}\text{O}$ composition.

In addition to falling on the edge of the estimated local range for oxygen, one individual, male 5311, was outside of the local range for strontium. His $\delta^{18}\text{O}_{\text{dw}}$ value, however, was within the range of Berlin based on the conversions. This may mean that his drinking water was most similar to that of Berlin’s based on $\delta^{18}\text{O}$ composition; however, he is the most likely candidate for being an immigrant based on his high $^{87}\text{Sr}/^{86}\text{Sr}$ value.
Intrasite Comparisons

Sex Differences.

I hypothesized that males and females were equally likely to migrate. In order to test this, I employed a Mann-Whitney $U$ test of the sample means for both oxygen and strontium. There was no statistical difference in average $\delta^{18}$O values between six males ($\bar{x} = -4.8\%$) and seven females ($\bar{x} = -4.2\%$) during childhood (Mann-Whitney $U = 13.5, p = 0.283$). This result is expected based on data from sites that are similar in geographical location and time period. For example, Gregoricka et al. (2017) performed a similar test on their population from Drawsko and reported no statistical significance either (Mann-Whitney $U p = 0.31$). The interpopulation comparison of $\delta^{18}$O values from enamel indicates that males and females were consuming isotopically similar water. There was also no statistically significant difference in strontium values between the six males ($^{87}$Sr/$^{86}$Sr $\bar{x} = 0.71141$) and seven females ($\bar{x} = 0.71089$) from Petriplatz (Mann-Whitney $U = 17.0, p = 0.567$).

I also hypothesized that local people would most likely be eating local food. I tested the hypothesis that males and females would be eating similar, local cuisine by using $\delta^{13}$C data. I found that there was no statistical difference in the average carbohydrate portion of the diet between six males ($\delta^{13}$C$_{ap} \bar{x} = -13.5\%$) and seven females ($\bar{x} = -14.0\%$) (Mann-Whitney $U = 12, p = 0.195$). This result is expected based on data from sites that are similar in geographical location and time period. For example, Gregoricka et al. (2017) reported Mann-Whitney $U p = 0.28$ at Drawsko and suggested that males and females consumed similar foods. Nitrogen isotopes can provide information on the protein portion of the diet but cannot be measured in enamel apatite. Zechini (2017) found in doing nitrogen isotope analysis on bone from Petriplatz.
that there was no statistical difference (Mann-Whitney \( U_p = 0.101 \)) between male and female diets during this time period.

**Life Course Analysis from Childhood to Adulthood.**

Zechini (2017) studied Petriplatz skeletons for diet before and after the Black Death. Her sample data came from \( \delta^{13}C \) and \( \delta^{18}O \) obtained from bone apatite of rib fragments. There was some overlap between her sample and mine, allowing me to understand how \( \delta^{18}O \) and \( \delta^{13}C \) changed from childhood (dental enamel) to adulthood (bone) (Table 6).

Table 6: Relevant Bone \( \delta^{13}C \) and \( \delta^{18}O \) Values from Zechini (2017) ("-" indicates an absence of data)

<table>
<thead>
<tr>
<th>Skeleton Number</th>
<th>Sex</th>
<th>Date Range</th>
<th>Bone ( \delta^{13}C_{ap} ) ( %_{VPDB} )</th>
<th>Bone ( \delta^{18}O_{ap} ) ( %_{VPDB} )</th>
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</tr>
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<td>1200-1300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4407</td>
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<td>-4.2</td>
</tr>
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<td>1047-1217</td>
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<td>PF</td>
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<tr>
<td><strong>Mean</strong></td>
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<td><strong>-14.7</strong></td>
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<td><strong>Stdev</strong></td>
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<td><strong>0.3</strong></td>
</tr>
</tbody>
</table>
I hypothesized that, if people were migrating to Berlin after childhood, a statistical difference in oxygen values between the enamel values and bone values would be found. When enamel and bone δ\(^{18}\)O values from 10 individuals from Petriplatz were compared, however, they were not statistically different (enamel average = -4.6‰; bone average = -4.2‰; Mann-Whitney \(U = 52.5, p = 0.197\)). This result indicates that during childhood, they were drinking from water sources similar in δ\(^{18}\)O composition to the water sources they were using as adults. It is possible that even though they mostly share δ\(^{18}\)O values that are within the range of the Berlin area, they may not be from the Berlin area, but another area that overlaps in oxygen range.

I also hypothesized that, if a significant number of individuals were migrants, it might be possible to see a change in diet from childhood to adulthood. To test this, I compared δ\(^{13}\)C\(_{ap}\) from dental enamel apatite and bone apatite for 10 individuals (enamel mean = -13.72‰; bone mean = -14.72‰; Mann-Whitney \(U = 4.5, p < 0.001\)). This result was statistically significant, indicating a different diet in childhood. In a study by Fuller et al. (2006), \(^{13}\)C was found to be enriched by 1‰ due to exclusive breastfeeding. It is likely that the δ\(^{13}\)C values from the enamel sample are indicating a diet of breastmilk.

**Intersite Comparisons**

Petriplatz data were compared with the Dirmstein site in southwest Germany (Schuh and Makarewicz, 2016) and the Drawsko site in Poland (Gregoricka et al., 2017), as these are the two geographically and temporally closest published sites. Data gathered by Schuh and Makarewicz (2016) came from adult canines, premolars, and molars. The data gathered by Gregoricka et al. (2017) came from adult first, second, and third molars.

In comparing the oxygen isotope data from human enamel from Petriplatz (\(\bar{x} = -4.5\text{‰}\)) and Drawsko (\(\bar{x} = -4.5\text{‰}\)), no statistically significant differences were found (Mann-Whitney \(U\)).
Petriplatz and Dirmstein ($\bar{x} = -4.6\%$) were also not statistically different (Mann-Whitney $U = 247.0, p = 0.606$). This result indicates that individuals at these three sites were all consuming water with similar $\delta^{18}$O composition.

The Petriplatz ($\bar{x} = 0.71113$) and Drawsko ($\bar{x} = 0.7112$) samples were also not significantly different (Mann-Whitney $U = 292.5, p = 0.209$) in terms of strontium isotope value (Gregoricka et al., 2014). This is likely because Drawsko and Berlin were built on similar Quaternary geology. However, Petriplatz and Dirmstein ($\bar{x} = 0.7113$) were statistically different (Mann-Whitney $U = 119.0, p = 0.002$). Although the means for Drawsko and Dirmstein are very similar, the range for Dirmstein is quite large (0.7089 to 0.7294). These results were expected because southwest Germany, where Dirmstein is located, was made of Triassic rock, thus having a higher expected strontium value than Berlin (see strontium map above Figure 9).

Finally, I hypothesized that Petriplatz individuals would have a similar diet to others nearby. The carbohydrate portion of the German diet consisted of wheat, barley, oats, and sometimes millet (Jones, 1960; Adamson, 1995; Zechini, 2017). Petriplatz ($\bar{x} = -13.7\%$) and Drawsko ($\bar{x} = -13.6\%$) were not statistically different (Mann-Whitney $U = 355.5, p = 0.749$) in terms of average carbon apatite values. Like Petriplatz, Medieval Drawsko was an agricultural society that incorporated rye, wheat, and barley into their regular diet (Debińska, 1999; Żyromski, 2003; Gregoricka, 2017). Similarly, Petriplatz and Dirmstein ($\bar{x} = -13.6\%$) were not statistically different (Mann-Whitney $U = 248.0, p = 0.619$). Schuh and Makarewicz (2016) found that individuals were eating typical C$_3$ foods, such as wheat, barley, rice, and potato, which are found in temperate regions such as Europe; C$_4$ plants, on the other hand, include sorghum and millet (Brown and Brown, 2011). Although people from Petriplatz presumably had access to C$_4$ foods such as millet, they appear not to have been a large part of the diet. It would
not be expected that people separated by hundreds of kilometers were eating such a similar diet, yet surprisingly they were.

**Conclusion**

Before finding potential immigrants among the Petriplatz skeletons, the local range needed to be established for oxygen, strontium, and carbon. Histograms were created for oxygen and strontium to further illustrate population distribution. The oxygen isotope values were then converted from δ\(^{18}\)O\(_{ap}\) VPDB to δ\(^{18}\)O\(_{dw}\) VSMOW in order to compare values with the German isoscape map. Although this method includes a significant margin of error, it provides a better visualization of data. Strontium values were compared to the German geological map, which also helps to visualize rough estimates of strontium values in relation to the rest of the country.

It was therefore possible to get an idea of who might have been an immigrant to Medieval Berlin. It is probable that one Petriplatz individual, adult male 5311, is an immigrant based on his high strontium value. It is possible that four additional individuals (males 5454 and 3381, and females 5039 and 5413) were also immigrants based on higher and lower oxygen isotope values than expected for Berlin. Chapter 5 will further discuss the potential immigrants and address my hypotheses.
CHAPTER V: DISCUSSION AND CONCLUSION

With knowledge constantly at our fingertips, it can be difficult to believe that sometimes there might not be information about something we are searching for. Luckily, for many questions about the past, archaeology and bioarchaeology can help fill in the blanks that history has forgotten.

The story of the foundation of Berlin is largely unknown due to a lack of historical documents from the earliest period of the Medieval city. This thesis took first molars from individuals buried at the cemetery of Petriplatz between the 11th and 14th centuries in order to answer questions about migration to and the settlement of Berlin. I used oxygen and carbon isotope analysis in combination with strontium isotope data from a previous study in order to test four hypotheses. The data gathered were presented in the previous chapter. Here I answer my research questions as follows:

Hypothesis 1: People migrated to Berlin from nearby areas.

My first hypothesis in the project was that people migrated to Berlin from nearby areas. It has been suggested by Kleinschmidt (2003) and Rugg (2000) that European migrants began moving short distances for freedom from the local rulers in the 7th century, which established a new pattern of migration for later centuries. Isotopically, the sample from Petriplatz seems to agree. Most of the individuals studied from the Petriplatz site are considered locals to the Berlin area, meaning that they were living in or near Berlin during childhood or that they lived in regions geologically and isotopically similar to Berlin. Five people require some extra investigation due to their anomalous ratios compared to the local strontium and oxygen ranges, which were established in Chapter 4 (Figure 13).
5311: This male stood out as an outlier for strontium (0.71440); however, he is within the local range for both enamel $\delta^{18}$O (-5.4‰) and $\delta^{13}$C (-14.3‰). This indicates he was coming from an area with a similar diet and climate as the local population but from an area with different geology. He is within the local range for bone $\delta^{18}$O (-4.6‰) at the second deviation and within the range for bone $\delta^{13}$C (-14.6‰) at the first deviation, which suggests that, as an adult, he was consuming a similar diet as others in Berlin. Although he was eating similar foods and drinking water that had a $\delta^{18}$O composition similar to the rest of the sample population at death, he is the mostly likely candidate for being an immigrant as his enamel strontium levels are much higher than the rest of the study. It is possible he moved to Berlin from western Germany, as his strontium measurement is consistent with the geology in that region and his estimated $\delta^{18}$O$_{dw}$
value is consistent with the environment there, compared to the isoscape map. It is also possible
that he came from elsewhere with similar geology, precipitation, and food resources.

3381: This male had the lowest enamel $\delta^{18}O$ value (-5.9‰) of the male population and
the second lowest $\delta^{18}O$ value overall. Although his $\delta^{18}O$ enamel value was still within the local
range (at the second deviation from the mean), the low value could mean that, as a child, he was
consuming water with a slightly different $\delta^{18}O$ composition. His $\delta^{13}C$ enamel value (-13.4‰)
was within the local range for carbon, indicating he was eating a diet isotopically consistent with
the sample population during childhood. His strontium value (0.71111) is within the range for
the population as well. $\delta^{18}O$ (-3.8‰) and $\delta^{13}C$ (-14.3‰) bone values are within the range at the
second deviation from the mean, but are the highest values of the population during adulthood.
After comparing his values to the maps in chapter 4, this person most likely moved to Berlin
from nearby, possibly south of the city, or from a location outside of Germany that is quite
similar in geology, precipitation, and food resources.

5039: This female had the lowest $\delta^{18}O$ enamel value (-6.1‰) out of the sample
population during childhood. As an adult, she had the highest $\delta^{18}O$ bone (-3.9‰) value of the
overall population, while being within the local range. This wide spread between $\delta^{18}O$ enamel
and $\delta^{18}O$ bone may indicate she is an immigrant. Her $\delta^{13}C$ enamel (-13.2‰) and bone (-14.5‰)
values were within the local range, indicating she was likely eating a similar diet during
childhood and adulthood as the others in the study. Her strontium measurement (0.71118) was
within the local range. Although it may seem as though this individual was a local, it is possible
that, like male 3381, she too may have come from a place very similar geologically to Berlin, but
with a slightly warmer and/or drier climate as a child. After comparing her strontium value and
her $\delta^{18}O_{dw}$ to the maps shown in chapter 4, it is possible that this woman moved to Berlin from an area in eastern Germany, possibly just southeast of the city.

**5413:** This female had the highest $\delta^{18}O$ enamel value (-2.8‰) out of the sample population during childhood. Her $\delta^{13}C$ enamel (-14.2‰) and bone (-14.8‰) values were within the local range, indicating she was eating a similar diet during childhood and adulthood as the others in the study. Her strontium measurement (0.71120) was within the local range. Although it may seem as though this individual was a local, it is possible that, like male 5454, she too may have come from a place very similar geologically to Berlin, but with a slightly cooler and wetter climate as a child. After comparing her strontium value and her $\delta^{18}O_{dw}$ to the maps shown in chapter 4, it is possible that this woman moved to Berlin from an area similar to western or northwest Germany.

**5454:** This male had the highest enamel $\delta^{18}O$ value (-3.2‰) of the male population and the second highest $\delta^{18}O$ value overall. Although his $\delta^{18}O$ enamel value was still within the local range (at the second deviation from the mean), the high value could mean that, as a child, he was consuming water with a slightly different $\delta^{18}O$ composition. His $\delta^{13}C$ enamel value (-13.1‰) was within the local range for carbon, indicating he was eating a diet isotopically consistent with the sample population during childhood. His strontium value (0.71099) is within the range for the population as well. $\delta^{18}O$ (-4.3‰) and $\delta^{13}C$ (-14.6‰) bone values are within the range at the second deviation from the mean, but are the highest values of the population during adulthood. After comparing his values to the maps in chapter 4, this person most likely moved to Berlin from an area similar to northwestern Germany.
Hypothesis 2: Males and females were equally likely to migrate.

In addressing the second hypothesis that males and females were equally likely to migrate, it is important to look at the type of society people were living in and understand the context of their willingness or ability to move. Modern matrilineal societies like the Minangkabau of west Sumatra experience migration, where single men and women move, but also family units move together. Men typically migrate further distances than women, and those who are better educated typically move before they are 30 years old (Santow, 1982). During the LBK period in ancient Europe (as mentioned in chapter 2), isotope analysis indicated that females were more likely to be non-local due to patrilocality (Bentley et al., 2002). Europe, since prehistory, has largely been a patrilineal society; however, by the high middle ages, kinship groups were disbanding and nuclear families were becoming the norm. While individuals were moving for work, such as apprentices, clergy, and merchants, it seems plausible that families would be moving together during the Eastward expansion (Kleinschmidt, 2003).

While one male (5311) was most likely an immigrant based on his strontium values, four other individuals are also possibly immigrants (males 5454 and 3381 and females 5039 and 5413). This indicates that males and females were equally likely to migrate. To further test this, I compared males and females statistically for strontium, oxygen, and carbon. The results, outlined in section 4.2, showed that there was no statistical difference, indicating that they were all very similar and therefore equally likely to move.

However, in this sample, it is not clear if individuals migrated or if people came in family groups. The archaeologists excavating at Petriplatz did uncover non-adult burials, but it is not known if they were born in Berlin or if they moved there before death. It is possible, however, that the earliest individuals of Berlin were migrating eastward to gain some freedom from the
Frankish rulers. This study focused on 13 individuals and may not fully represent the population distribution of the earliest individuals.

**Hypothesis 3: Local people ate local food, whereas migrants likely changed their diet.**

I hypothesized that immigrants could be identified through their carbon isotope signatures as they likely were eating different foods, particularly as children, than were the locals. As agricultural technologies improved, grain became more of a staple in the European diet (Piskorski, 1999). Locals ate a varied diet that included locally sourced foods as well as items acquired through trade, if they were affordable.

Isotopically, the individuals at Petriplatz were eating a diet typical for the region, heavy on carbohydrates like wheat, oats, and barley (Zechini, 2017). Two individuals, male 5454 and female 5039, had high childhood $\delta^{13}C$ values, suggesting they may have been eating millet or something the locals were not. There were no statistically significant differences between male and female diets during childhood or adulthood, as noted in section 4.4.1 and 4.4.2, indicating that males and females were all eating similar food at different stages during life. There was a statistical difference between that of children and adults in section 4.4.2., but that was likely due to breastfeeding practices (Fuller et al., 2006).

**Hypothesis 4: Petriplatz is similar to other contemporaneous, nearby sites.**

If during the Medieval period people were migrating shorter distances, then those sites should show similar isotope values and ranges. I hypothesized that the Petriplatz population would be similar to other nearby sites, as people were likely not moving far from their homeland (see section 4.5). One site used for comparison was Drawsko, Poland. Drawsko is located about 240 km northeast of Berlin. Both locations are along the Northern European Plain, geologically homogeneous lowlands with glacial gravel deposited from the Quaternary period (Buko et al., 2013; Gregoricka et al., 2017). In terms of geographical location and geology, they are very
similar. If people were migrating eastward during the German migration, I would expect that skeletons found at both locations would be isotopically similar.

Berlin and Drawsko both had oxygen means of -4.5‰, indicating that people were drinking water with very similar $\delta^{18}O$ composition. When following the isoscape map from chapter 4 (Figure 7), Drawsko would be within the same boundaries for the oxygen range as Berlin. These two sites also had very similar average strontium (Berlin = 0.71113, Drawsko = 0.71112) values, which agrees with their location along the North European Plain. Finally, carbon values for Petriplatz (-13.7‰) and Drawsko (-13.6‰) were not statistically different. This shows that people at these locations were likely eating the same or similar available foods.

Anthropologist Lesley Gregoricka and colleagues (2017) explain that people migrated east to Poland between the 10th and 16th centuries to leave behind economic and religious oppression. Scots, German and Flemish craftsmen, printers, and artists, Mennonites from north Germany and the Netherlands, and Jews all migrated eastward for religious freedom and better economic opportunities (Borowy, 1949; Guldon, 1990; Guldon and Stępkowski, 1982; Gierowski, 1984; Topolski, 1992; Kopczyński and Tygielski, 2010; Witkowski, 2011; Gregoricka et al., 2017). Although these groups of people made new settlements or joined existing cities in Poland, it would not be unreasonable to believe that some of these migrants ended their journey in or around Berlin.

Berlin was also compared to a cemetery in Dirmstein, Germany. There was no statistical difference in oxygen means (Berlin = -4.5‰, Dirmstein = -4.6‰). Looking at the isoscape map in chapter 4 (Figure 7), the two cities should have water with similar oxygen composition. Unlike Berlin and Drawsko, Dirmstein was built on older geology, so the strontium values are statistically different (0.7113), signifying the different geologies; or perhaps indicating the
strontium range for individuals at Dirmstein was large. Carbon values at Dirmstein (-13.6‰) were not statistically different from Berlin, suggesting that people were eating the same foods. Although the cemetery at Dirmstein represents a time period from the Early Middle Ages, it was discovered that males and females were both likely moving and migrants were moving from eastern areas or regions with higher altitude than the Upper Rhine (Schuh and Makarewicz, 2016). Because Petriplatz was not statistically different from Drawsko and Dirmstein, hypothesis 4 is upheld.

**Future Research**

Lightfoot and O’Connell (2016) suggest that it is difficult if not impossible to isolate immigrants from a small sample population, and this analysis of a small sample of the large Medieval Petriplatz cemetery in Berlin upholds that conclusion. Much more work needs to be done to confidently identify immigrants to Berlin. Specifically:

1) In order to fully understand migration within context of Berlin’s foundation, it would be beneficial to test all individuals from the earliest period of the cemetery, including juveniles who have their adult teeth, as a larger sample can combat small sample-size effects.

2) Conducting isotope analysis on additional teeth besides first molars, such as canines, second, and third molars, would provide a series of biological time capsules that could indicate migration. Because teeth develop and erupt at different ages, they are good for understanding migration during childhood. Each tooth could provide environmental clues indicating a region of origin. If an individual moved across large geological boundaries over many years, those isotopic signatures could be determined, and it may be possible to determine their movement pattern.

3) Continuing to combine strontium and oxygen isotope analysis from enamel and bone also provides a glimpse into life history. Since dental enamel is formed during childhood, and
bone samples show values from the last few years of life, comparing the two biological tissues can show if the person immigrated after tooth formation or later in life and how their diet compares to the rest of the population. Additionally, carbon isotopes measured from enamel and bone can compare diet at two different stages in a person’s life, and therefore this method is useful in investigating whether a change in diet may signify an individual that is more likely to be an immigrant.

4) Although faunal remains were available at Petriplatz to characterize the strontium isotope range, they were from omnivores. Testing additional local fauna, especially animals that are predominantly herbivores and animals with a small home range, would help provide a more accurate local range of strontium.

This thesis has demonstrated, through stable light isotope analysis of 13 adults buried in the early Medieval cemetery of Petriplatz in Berlin, Germany, that immigrants moved to Berlin from nearby regions. These results are important because they are the first migration study to be conducted on the earliest skeletons at Petriplatz. Although this study had a small sample population, it lays the foundation for additional research that can be compared and added. Isotopic studies on additional skeletons will allow us to be able to conclude with more certainty who founded the city.

Finally, this research complements other research done at Petriplatz. The analysis of overlapping individuals between this study and Zechini’s (2017) provides more clues about the lives of the early inhabitants of Berlin. It also provides more information of potential origins complementing the aDNA research done by Rothe et al. (2015). This isotopic study offers comparative data for current and future Medieval site studies. Furthermore, this
bioarchaeological research adds to the historical knowledge of the city. Now when people are using Google to ask, “When was Berlin founded?”, a more thorough answer will be found.
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