Early Agricultural Lives: Bioarchaeological Inferences from Neolithic and Early Copper Age Tombs in the Central Po Valley, Italy

by

Christopher J. Eck Jr.

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Doctor of Philosophy
Department of Anthropology
College of Arts and Sciences
University of South Florida

Major Professor: Robert H. Tykot, Ph.D.
Jonathan D. Bethard, Ph.D., D-ABFA
Diane Wallman, Ph.D.
Andrea Vianello, Ph.D.
Zachary Atlas, Ph.D.

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DEDICATION

This dissertation is dedicated to the lives and remains of those who enabled the pursuit of archaeological science. Through you, we see.

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ABSTRACT

The current project seeks to illuminate the diets of the earliest farming societies in central Northern Italy. Neolithic peoples who first began settling in the Central Po Valley sometime at the end of the seventh and beginning of the sixth millennium BCE forever changed the landscape from one of expanding sub-continental forests to one of intensive agricultural production and anthropogenic influence. A total of 109 individual burials from 24 separate infrastructure project excavations of 17 sites surrounding the modern city of Mantua, Italy were analyzed utilizing a biochemical approach and a bioarchaeological explanatory theoretical framework based within embodiment and life history theory. Small group life histories were produced unique to the three phases of the Middle and Late Neolithic Square-Mouthed Pottery (SMP) culture or *Vasi Bocca Quadrata* (VBQ) and the Chalcolithic or Copper Age Lagozza cultures that settled around Mantua. Differences and similarities in Middle Neolithic diets and mobility were explored by period and culture and among different sex and age cohorts utilizing a series of cluster, ANOVA, and discriminate function analyses.

A radiocarbon chronological model was produced for the analyzed assemblage and spans from approximately 4700 cal BCE to 3100 cal BCE bridging the transition from the Early to Middle Neolithic to the Copper Age. Isotopic life histories were constructed in order to address key questions in the region regarding the subsistence strategies specific to the three phases of the SMP culture and the Lagozza. The results of the current project provide direct support to previous scholarly work in the region which has partially characterized the palaeobotanical and zooarchaeological records for the time period of interest, initially described by an intensive shift to crop agriculture and land clearance activities by the SMP. Bone and tooth root results of the current project have resulted in tight clustering of SMP individuals around known environmental and human values for C3 plant cultivars, with mean $\delta^{13}C_{ap}$, $\delta^{13}C_{co}$, and $\delta^{15}N$ bone values of -12.8‰ ± 0.6, -20.8‰ ± 0.3, 9.9‰ ± 0.6 respectively, and mean $\delta^{13}C_{ap}$, $\delta^{13}C_{co}$, and $\delta^{15}N$ tooth root values of -12.6‰ ± 0.9, -20.2‰ ± 0.4, 10.2‰ ± 0.7 respectively. Similarly, the Lagozza cultural groups around Mantua continued the intensive agricultural lifestyles of the SMP into the Copper Age, with an increase of only about 1.0‰ $\delta^{13}C_{co}$ in dietary protein source variation than what was observed in the Middle Neolithic population. Stable Oxygen isotopic analysis was also conducted in order to assess the overall mobility of individuals within the two major periods, the four cultural phases, and by sex. Slightly more individual mobility was observed in the Middle Neolithic than the Copper Age with associated $\delta^{18}O$ VSMOW mean values of -8.7‰ ± 1.3 for the Middle Neolithic and -7.3‰ ± 0.6 for the Copper Age. The results of the current study contribute to the collective scholarly understanding of the Neolithic and Copper Ages in Northern Italy and advance knowledge on the legacies wrought by contemporary Italian populations with respect to food culture, Italian identity, and landscape instability and change.

CHAPTER ONE:

INTRODUCTION

INTRODUCTION

This dissertation explores life histories of Neolithic and Copper Ages peoples from the Central Po Valley in Northern Italy. The specific focus of the research presented here is the reconstruction of dietary and mobility profiles utilizing biochemical methods and a chronological radiocarbon model to assess the presence or absence of differences between the Middle Neolithic and the Copper Age, followed by more fine-grained analyses of specific cultural groups, the Square Mouthed Pottery (SMP) or *Vasi Bocca Quadrata* (VBQ), and the Copper Age or Chalcolithic Chassey-Lagozza or Lagozza culture. Demographic and paleopathological data (sex, age-at-death, and non-specific stress markers) were obtained through the bioarchaeological analysis of 111 individual tombs from 17 unique sites situated to the north and east of the modern city of Mantua, Italy.

The data collection and scientific analysis of the assembled skeletal collection was made possible by the award of the Archaeological Institute of America (AIA) through the John R. Coleman Traveling Fellowship (2019) and the AIA and National Endowment for the Humanities (NEH) Grant for Post-Fieldwork Research and Publication (2020). Permissions to conduct destructive analyses on all the tombs was provided by the Superintendency for Archaeology in Mantua and carried out in 2019 at the Museo delle Civiltà in the Biological Anthropology Laboratory in Rome, Italy. The assembled skeletal collection containing 111 tombs across 17 different sites was compiled by Dr. Andrea Vianello (dissertation committee member) with

Cristina Longhi (Mantua Superintendence), with help from Dr. Lamanna (Mantua Superintendence) in accessing the available original excavation reports. The excavated materials represent nearly a decade of Neolithic and Early Copper Age salvage excavation work conducted by private Italian cultural resources firms within an 8 km range from the center of Mantua, Italy.

BACKGROUND

This dissertation explores questions regarding the Neolithic and Copper Age or (Late Neolithic or Chalcolithic) specifically in one of the most important agricultural zones in the world, the Po Valley in Northern Italy. From V. Gordon Childe's initial studies (Childe, 1925), the European/Eurasian Neolithic is widely considered one of the most important periods in human history, due to the departure of human groups from broad spectrum wild subsistence economies in favor of crop agriculture and animal husbandry (Barker, 2006; Dennell, 2006; Price, 2000b; Watson, 2003). The development of domesticated taxa allowed previously mobile Mesolithic populations to settle in one place and create their own food, first through rudimentary horticulture and eventually more formalized crop cultivation and animal domestication. In conjunction with emerging agricultural systems polished stone tools with new and more complex forms were manufactured, mostly utilizing locally available flints and hard jadeites and basalt rocks, characteristics that John Lubbock utilized to characterized the period as the Neolithic or "New Stone Age" (Lubbock, 1904). The first iteration of the Neolithic was observed in the Near East in the Levant in a region known as the Fertile Crescent, so named due to the abundance of wild progenitor species of plants and animals that would later give rise to the first true domesticated taxa because of anthropogenic manipulation (Zeder, 2011). The earliest Neolithic peoples are believed to have been spurred into experimenting with growing wild plants near camps and small seasonal villages due to a drastic shift in climate around 12,000 years ago known as the Younger Dryas (Colledge, 2010; Hillman, et al., 2001). This period was characterized by a return to glacial like conditions at the beginning of the Holocene when warmer and wetter climates, gave way to a colder and dryer climate for a little over 1,000 years (Moore and Hillman, 1992). Afterwards, between 11,000 and 10,000 years ago the Neolithic had begun in the Near East (Zeder, 2011).

Quickly after the beginning of the Neolithic, human populations began to grow quickly due to the increased availability of food produced through crop agriculture and readily available meat-on-the-hoof in form of the first barnyard species, sheep, goats, cattle, and pigs (Bocquet-Appel, 2011; Price, 2013). As populations grew people began to expand and farm more arable lands and as a result created a patchwork of interconnected villages and the first true cities across the Near East (Zeder, 2011). This period has been described as the Neolithic revolution, when less and less human labor was required for food procurement or production, but with similar yields from crop agriculture, with focuses turned increasingly to non-food producing activities, such as architecture, religious worship, craft production, and trade (Childe, 1951). At this time the domesticated varieties of plants and animals were collectively called the Neolithic package, as grain from domesticated plants could be easily transported within ceramic storage containers and domesticated animals could be taken easily to new places and introduced while they were young and later bred (Bogucki, 1996; Colledge, et al., 2007; Pluciennik and Zvelebil, 2008). Neolithic agriculturalists began to expand outward from the Fertile Crescent with seed crops and animals as part of the Neolithic package utilizing both land and sea routes and would eventually colonize the entire Mediterranean by around 4,000 BCE (Ammerman and Cavalli-Sforza, 1979; Bocquet-Appel, et al., 2009; Zvelebil, 1989). Within 6,000 years, nearly all modern Europe had been exposed to the Neolithic way of life as a result of the rapid spread of agriculture (Robb, 2013).

Contemporary scholars have begun to explore the origin and spread of agriculture through the application of novel and emerging genomic methodologies seeking to trace the first farmers and their Neolithic descendants across Europe (Marchi, et al., 2022) – interrogating the previously mentioned Neolithic advancement models proposed in the 1970s and 1980s.

Neolithic seafarers were the first to reach Italy sometime in the late 7th millennium BCE when Impressed Wares were discovered on the islands just off the coast of Apulia in southeastern peninsular Italy (Brown, 1997; Brown and Alexander, 2013; Lightfoot, et al., 2011; Skeates, 2003). These earliest groups of Neolithic agropastoralists brought with them the Neolithic package of ancient varieties of domesticated wheat and barley as well as cattle, sheep, goats, and pigs (Natali and Forgia, 2018). The simplest forms of ceramic containers often found plain or with patterned impressions made with finger tips, stone, shell, or reeds collectively known as impressed wares, mainly Cardial Impressed Wares, were associated with the spread of the Neolithic via the Mediterranean Sea (Aubán, et al., 2017; Barnett, 2000; Capelli, et al., 2017). These impressed wares were first observed in northern Italy in Liguria among Neolithic remains located within many of the area cave complexes along the rocky shoreline, with the earliest dating to about 6,000 BCE (Pearce, 2013). But as for the arrival of the Neolithic in the Central Po Valley, there was nearly a 500-year gap between the earliest dated Neolithic sites in Liguria. The Neolithization of the Po Valley has been highly contested in the scholarly literature with some suggesting a resistance by the last Mesolithic hunter-gatherers or more likely a more complex interaction and meeting of Ligurian, Adriatic, and Central Italian agriculturalists in the Central Po Valley (Bagolini and Biagi, 1990; Barfield, 1971; Biagi and Cremaschi, 1981; Biagi, et al., 2020; Binder, 2000; Jarosław, 2010; Pearce, 2013; Starnini, et al., 2017).

The first Neolithic settlements within the Central Po Valley belonged to two distinctive groups, the Vhó and the Fiorano, with the current project area near Mantua, relatively on the southeast (Fiorano) and northwest (Vhó) dividing line between the two cultural groups, but with more Fiorano sites known near Mantua (Biagi, et al., 2020). These early groups became established sometime around 5,500 BCE took advantage of the numerous tributaries of the Po River and the Po River itself and established settlements along major waterways and began clearing land and establishing arable land on elevated areas (Biagi and Cremaschi, 1981; Biagi, et al., 2020). Major problems with establishing reliable radiochronologies has plagued scholars, due to a distinctive lack of human burials and continually occupied sites including both Late Mesolithic and Early Neolithic remains (Starnini, et al., 2017). These problems have resulted in a limited amount of bioarchaeological literature or research on Early Neolithic or even later burials. Most of the literature concerning the Early Neolithic period is confined to the analysis of lithics, ceramics, and plant and animal remains, with almost the entire northern Radiocarbon chronological sequence based on palaeobotanical remains of charcoal and seeds(Pearce, 2013). It was the hope at the outset of the current project that at least a few Early Neolithic burials would be present, of which less than ten have ever been recovered, mostly from the early 20th century, with no information published on any.

The Neolithic is divided into the Early, Middle, and Late phases. These periods become increasingly complex because previously established Early Neolithic populations begin to grow and expand giving rise to new technologies, more complexity, and diversity that are later codified by ceramic typological research projects throughout the region (Guidi and Piperno, 1992). The Middle Neolithic in Northern Italy is defined primarily by the emergence of the VBQ, which was divided into three phases by Lawrence Barfield and later refined by Bernardino Bagolini and Paolo

Biagi, the first two associated with the Middle Neolithic and the last phase with the Late Neolithic (Barfield, 1971; Mottes, et al., 2009; Pessina and Tiné, 2018). The first phase of the VBQ emerged sometime around 5,000 BCE and significantly overlapped with the earlier Vhó and Fiorano groups that persisted well after 5,000 BCE (Guidi and Piperno, 1992; Mottes, et al., 2009; Pessina and Tiné, 2018). Many of the sites included in the current project likely date to this period, with only two suspected to be potentially earlier, based on contextual evidence reported by the excavators. The VBQ was extremely unique, due to the square-mouthed ceramics from which the name derives. Some scholarly debate surrounds the exact functional use of the square-mouthed pots vs. the typical circular ones but the origin of the forms was likely linked to the Balkans, specifically the Danilo culture from modern day Croatia and Slovenia (Bagolini and Biagi, 1985; Mottes, et al., 2009; Pessina and Tiné, 2018). The VBQ has been characterized as highly mobile with specific regard to the use of caves and rock shelters, likely seasonally for pasturing primarily cattle (Mottes, et al., 2009). This was followed by increases in the sheepherding at the end of the second phase and into the third phase of the VBQ. Sometime around the beginning of the 5th millennium BCE, the VBQ migrated to the Central Po Valley and established many open-air sites, likely replacing or possibly supplanting Vhó and Fiorano groups and constructing pitted-floor villages and hamlets. The VBQ were active farmers, cultivating wheat, barley, poppy, pulses, and flax, likely connected to species from the Levant (Rottoli and Castiglioni, 2009). During the second and third phases of the VBQ, new forms of wheat and barley were becoming more increasing visible, including the "naked" and "new glume" wheats and spelt, possibly due to the increased connection with the Balkans as evidenced by stylistic changes to the ceramics similar to those observed in Balkan cultural groups (Rottoli and Castiglioni, 2009). Between the 5th and 4th millennium BCE, much of

Northern Italy was dominated by VBQ sites, likely leading to a homogeneity of resources and agropastoral practices.

The Late Neolithic and Copper Age witnessed the last phase of the VBQ as three separate but related ceramic cultures emerged in Southeastern France, the Chassey culture, in Northern Italy, the Lagozza, and in Switzerland and Austria, the Cortaillod culture, which all shared common dark or black plain rounded pottery types (Borrello, 2015). This regional connection is critically important in understanding the mobility of the Alpine Iceman, Ötzi, that dates to the Copper Age and was from the current project area around the base of Lake Garda, but found high in the Alps near the modern Italian and Austrian borders (Kutschera, et al., 2014; Müller, et al., 2003). The period began sometime near the end of the 5th millennium and beginning of the 4th millennium BCE (Pessina and Tiné, 2018), with the Iceman dating to around 3,300 BCE (Müller, et al., 2003). The key feature of the period is found within the name and marked the first use of copper by humans. It is likely that the Chassey-Lagozza were prospecting copper and beginning to trade it throughout Northern Italy, but the first true Copper Age culture, the Remedello culture, developed near Lake Garda, just north of the project area (Artioli, et al., 2017; Artioli, et al., 2015; Pearce, 2019). The Copper Age lasts until around 2,200 BCE when the Bronze Age begins in Northern Italy, but facets persist, including copper metallurgy and human burials within caves across the North (Dolfini, 2019).

APPLIED RESEARCH QUESTIONS

This dissertation specifically focuses on applying contemporary bioarchaeological methods and theories to explore a region that has received very little previous bioarchaeological research. Previous research has indicated a need for more comprehensive radiocarbon chronologies to uncover potential rare Early Neolithic remains and to shore up or refute previously untenable dates at related sites. Additionally, many of the studies involving the Italian Neolithic and Copper Age have lacked any discussion or analysis of human burials with a distinct lack of stable isotopic analyses of human remains. Research questions were developed to capture some of the current weak points of the current literature and to elucidate specifically differences in diet and mobility by period, cultural group, and demographic. The Neolithic and Copper Ages have previously been shown to be extremely egalitarian with males and females sharing equal and similar responsibilities for food and material production, but it is unclear if the northern Italian Neolithic meets this assumption. Additionally, the relative importance of wild and domesticated food sources is only currently understood through previous zooarchaeological research, and the addition of human isotopic values could help clarify the roles of hunting, fishing, and animal rearing in the Neolithic and Copper Ages. Finally, these questions culminate in a life history framework and as such can help inform on landscape changes and legacies left by the Neolithic and Copper Age among contemporary populations. Thus specific points of inquiry include the following questions: 1) Are there any uniquely Early Neolithic burials within the assembled collection?; 2) Did dietary life histories differ from the Neolithic to the Early Copper Age, between the VBQ phases and the Lagozza, or between males and females?; 3) Is there evidence of dietary and mobility life histories shifting due to changes in technology, specifically the arrival of new domesticated taxa in the second phase of the VBQ?; 4) Did Neolithic or Early Copper Age peoples continue to supplement their diets with wild and local food sources? If so, is there any indication as to which foods were consumed over others?; 5) Is there any evidence for the consumption of freshwater or marine fishes and shellfishes?; and 6) Do the Neolithic and Early Copper Age dietary life histories inform on any of the anthropogenic changes to the contemporary landscape?

METHODOLOGICAL AND THEORETICAL FRAMEWORK

A biochemical methodological framework involving measuring radiocarbon and stable isotopes from human bone and tooth root samples was selected for the current project due to a limited use of this current method in prior research within the region. Thus, a need existed within the region to seek additional evidence from human burials that would be of comparative value with previous palaeobotanical and zooarchaeological reconstructions. The radiocarbon chronological model for the area can also be incorporated into larger radiocarbon modeling studies of the Neolithic and Copper Ages in Northern Italy. Permissions for data collection and destructive methods was provided by the Superintendency for Archaeology in Mantua, with the strict limitation of tooth root sampling and not tooth enamel.

Isotopic methods are of tremendous value to archaeologists because they can be utilized to create dietary and mobility profiles from human skeletal material (Katzenberg, 2008; Pollard, 1998). Biochemical methods have a unique advantage when applied to human remains in that the results directly translate information on the types of plants and animals the humans were eating during life (Katzenberg, 2008). Once created these dietary profiles can be applied to information gleaned from human skeletal analyses to include the estimation of sex, age, ancestry, stature, and skeletal lesions which can inform on the life histories of individuals and groups (Larsen, 1995). Specifically, how these individuals expended energy, their health status, childhood stress events, level of individual or group mobility, migration, and socioeconomic status (Ambrose, et al., 2003; Bentley, 2013; Cohen and Armelagos, 2013). Palaeobotanical and zooarchaeological analyses assume that remains located at sites were indeed consumed by the people that lived there; however, isotopic analyses of human remains can provide a more complete picture of the whole diet of individuals and communities. Stable isotopic values from carbon and nitrogen, for example, are unique in that they share a relationship with photosynthetic pathways of plants in case of carbon and trophic level of consumers in the case of nitrogen (DeNiro and Epstein, 1981; van der Merwe, 1982). That makes them extremely useful in identifying the presence or absence of plants with different photosynthetic pathways that are common domesticates, like C_3 (wheat and barley) or C_4 plants (millet and sorghum) (Tykot, 2018). The later plants in prehistory were often considered poorer plants for human consumption and were often left for the poorest people and animals to eat, while wealthier individuals often ate a more balanced diet of mixed plants and animal proteins (Reitsema and Vercellotti, 2012). Specific to the Neolithic, stable isotopic analysis of protein sources using carbon and nitrogen can be used to determine the addition of marine or freshwater fishes in the diet and the importance of wild vs. domesticated animals when proxy samples are available (Katzenberg, 2008). Lastly, oxygen isotopes are extremely useful at identifying potential latitudes, elevations, and water sources consumed during life, as oxygen isotopes in potable water is reflected in human bone and enamel apatite (Katzenberg, 2008). These isotopes can be used in conjunction with environmental values to examine mobility and region of origin, when testing long bones and teeth from the same individual that form or remodel at different points during life, with bone reflecting the last decade or more of life and teeth reflecting early childhood to adolescence (Katzenberg, 2008). The same principle can be applied to dietary questions as well.

This dissertation utilizes radiocarbon and stable carbon, nitrogen, and oxygen to create radiocarbon chronologies and dietary and mobility profiles for the assemblage of Neolithic and Copper Age burials. Embodiment theory is used to describe the basic principle of “you are what you eat” regarding the simple fact that all humans require food and water to survive and as a result of consumption involuntarily incorporate an isotopic signature from food and their remains embody their dietary environments during life (Schrader and Torres-Rouff, 2021). In funneling the results from the biochemical analysis through an embodiment foundation, isotopic life histories can be constructed to describe individuals or small groups. Previous work has shown that life histories when combined with isotopic methods can be an effective way at interpreting how individuals and groups were living and thus what effects production of food had on the landscape, how climate or crop failure impacted decisions on fall back foods, social stratification, political economies, and individual health outcomes (Bell, et al., 2001; Cheverko, 2021; Eriksson and Lidén, 2013; Sealy, et al., 1995; Temple, 2019; Torres-Rouff and Knudson, 2007). Through the sampling of bone and tooth roots and the estimation of sex and age from the skeletal population, general adult and childhood dietary trends can be explored and mobility, including region of origin, can be evaluated given the tissues samples and the methods applied.

APPLIED IMPACTS OF RESEARCH

The tombs and associated archaeological sites in this study were under direct threat from numerous planned infrastructure projects around the city and such were required by Italian law to be excavated prior to construction and groundworks. Mantua and the Po Valley more broadly is an extremely fertile region of the world and is known as one of the great "bread baskets" or highly productive agricultural areas throughout the world (Fortis, 2016). As such, much of the region is devoted to agricultural production, with most of the rural population earning a living through farming. The Po Valley is punctuated by numerous small cities, villages, and hamlets that are renowned for numerous world-famous agricultural products. These include products like Parma ham, pecorino and parmesan cheeses, pastas, risotto quality and variety rice, wines, and many other beloved Italian specialty products. These contemporary industries are strictly controlled, monitored, and protected by the Italian government via the Protected Designation of Origin (PDO) and Protected Geographic Origin (PGI) designations that are the result of rigorous inspections of production and products within Italy by teams of professional agricultural inspectors (Aprile, et al., 2012). The specialty Italian foods industry on average exports more than 500 billion euros worth of goods throughout Italy and the world annually (Carbone, et al., 2015; Giovannetti and Marvasi, 2016). As such, modern Italian agricultural identities are intimately tied to the production and consumption of these specialty foods, which have ancient roots in prehistory like the earliest forms of animal husbandry practiced in the Neolithic and Copper Ages (Wilson, 2006).

As a major food producing region of the world, contemporary Italian farmers and shepherds have deep prehistoric connections to the first farming and herding communities of the region. But the landscape also retains legacies of Neolithic and Copper Age agricultural systems which have both adverse and beneficial consequences for modern northern Italian communities. Intensive crop agriculture in the Neolithic and Copper Age was centered around the cultivation of wheat and barley which were heavily cultivated in raised areas throughout the Po Valley that were a clear cut of understory and trees to make way for crop fields (Valese, et al., 2014). Overtime, these now exposed areas would experience soil destabilization and heavy erosive activity due to the loss of vegetative root structures that provided greater stability and prevented loss. Subsequent periods continued to shape and manipulate a growing anthropogenic landscape to create ideal growing conditions for key crops that preferred wetter and waterlogged soils, which included Neolithic plants like millet and later plants such as rice (Tafuri, et al., 2009). As a result of the soil destabilization begun in the Neolithic and Copper Ages and continued by later groups much of northern Italy became a greater risk for severe flooding, which has resulted in loss of life, property, and soils. Floods in northern Italy are becoming more prevalent and intense because of climate change dropping more rain throughout the region (Bocchiola, 2015; Dada, et al., 2021).

Conversely, with the flattening out of the topography and increased presence of waterlogged soils uniquely Italian specialties like risotto became staples in the Middle Ages and remain beloved all over the world. So much so that today Italy is the highest producer of rice in Europe (Carbone, et al., 2015). These contemporary environmental and cultural trends have a deep connection with the Neolithic and Copper Ages and specifically with the commitment to intensive crop agriculture.

CHAPTER ORGANIZATION AND SUMMARIES

This dissertation is organized into nine chapters and were written at various stages of the research process between 2018 to 2022. The introduction has provided a brief overview of the history of the region of interest and the time periods and peoples from which the analyzed assemblage of burials originates, and a brief overview of the methods and theoretical framework utilized to collect, analyze, and interpret the subsequent bioarchaeological data. The other eight chapters are briefly summarized here and follow a general outline beginning with the summative discussions of the field of bioarchaeology and the relevant methods and theories to the current project, backgrounds of current relevant archaeology and bioarchaeology of Neolithic northern Italy, and finally the presentation of the materials, results, and interpretations and conclusions of the research.

Chapter Two specifically presents a history of bioarchaeology and the prevailing scholars, works, and theories that have shaped it since in origins in the 1960s. The chapter discusses the major watersheds including influential work from the fields of biological anthropology and archaeology, such as the New Physical Anthropology and Middle Range Theory, respectively, that were foundational in establishing the field. This chapter includes a novel view of embodiment theory as a form of middle range theory within bioarchaeology and suggests that two separate types of embodiment must be created so as higher level theories can be applied and supported within an embodiment framework. As such, the chapter concludes with the initial use of embodiment as a conduit for the application of life history theory as an explanatory model for the research.

Chapter Three discusses the foundation of isotopic methods in archaeology and later uses in bioarchaeology, beginning with the discovery of radiocarbon as a useful radioisotope for dating organic materials such as plant and animal remains from archaeological sites. The chapter outlines the origin of radiocarbon research and early instrumentation and presents current and on-going issues with the use of radiocarbon. Additionally, the chapter discusses the subsequent origins and utility of stable isotopes in the study of ancient diets and mobility. The chapter included seminal examples of the application of stable isotope methods in bioarchaeology and research that has employed life history frameworks in the past.

Chapter Four presents the archaeological context of the central Po Valley that was initially outlined in the introductory chapter. First, this chapter describes the environment found in Northern Italy, with special emphasis placed on ecological zones and the natural resources exploited first in the Paleolithic and Mesolithic and then by Neolithic agriculturalists. The chapter continues with an overview of the theories regarding the Neolithization process of northern Italy, which as previously discussed is still generally contested among the scholarly community. Finally, the chapter concludes with a general overview of the cultural groups, first mentioned in the introduction, and their material remains and associated sites near the project area and Mantua.

Chapter Five summaries the limited available bioarchaeological literature regarding Neolithic human remains found at sites within Northern Italy. A dearth of publications on human remains exists for much of the north apart from Liguria, where well documented Neolithic sequences which included Neolithic tombs have been carefully excavated and preserved since the 1950s. Much of the available bioarchaeological literature concerns the health status of these Neolithic individuals. The chapter also discusses the relevant Middle Neolithic VBQ and Late Neolithic Lagozza mortuary practices, including body placement and typical material remains. Lastly, the chapter discusses two famous discoveries, the Lover of Valdaro and Ötzi the Alpine Iceman, which date to the periods represented here by the analyzed collection of tombs.

Chapter Six is a detailed overview of the materials and methods utilized to analyze the 111 individual sets of remains included in the project. This chapter begins with an overview of the sites, the available Italian project reports, and number of individuals from each site. The bulk of this chapter is comprised of a detailed translation of each burial in situ from the available project reports. The descriptions are accompanied by photo graphic and sketches of the remains in situ if available. The chapter continues with a summary of the macroscopic methods utilized to estimate sex, age, and observe major macroscopic pathological lesions. Lastly, the biochemical preparation and sampling methods are discussed with respect to the preparation of human bone and tooth root collagen and apatite aimed at measuring carbon, nitrogen, and oxygen isotopic ratios.

Chapter Seven utilizes the obtained radiocarbon dates and isotopic values from the human bone and tooth root samples and presents a chronological model and statistical results for 107 of the values. Three of the burials were discovered to date to the Bronze Age and one was potentially non-human so only the Neolithic and Copper Age burials were analyzed. The chapter begins by detailing the results from the radiocarbon dating specifically with models for the Neolithic and Copper Age tombs that were tested. The remainder of the chapter is devoted to statistical tests and plots that are organized in order of the research questions presented in the introduction and according to exploration of life histories divided into results by period, cultural group, and demographic when relevant.

Chapter Eight is an organized interpretation that follows the layout of the research questions from the introduction and the order of statistical tests from chapter seven. The chapter explores the meaning of the chronological model and how the dated tombs relate to established radiocarbon and relative chronological frameworks and bioculturally how the tombs date and burial goods inform cultural group affiliation. Additionally, specific archaeological features and artifacts are associated with the dated tombs to explore cultural and geographical connections meaningful to trade and mobility. The second half of the chapter postulates on the dietary and mobility results and how the members of each cultural groups likely lived in the Central Po Valley during the Neolithic and the Copper Age. The chapter concludes with some applied applications of the key findings from the research and seeks to connect modern Italian landscapes and identities with Neolithic and Copper Age life histories.

CHAPTER TWO:

ORIGINS AND THEORIES OF BIOARCHAEOLOGY

INTRODUCTION

Bioarchaeology is a relatively young sub-discipline which aims to synergize biological anthropology and archaeological methods and theories to conduct targeted dual faceted biological and archaeological studies of anatomically modern humans, that are not of forensic interest. Larsen aptly defines the field as such “the study of human remains from archaeological contexts” (Larsen, 2015a). Yet this definition is simplistic in how it is applied in practice. Buiksta 1977 suggests that bioarchaeology must encapsulate a holistic bio-cultural approach, where social and critical theory are central to reconstruct past behaviors, lifestyles, and lifeways when combined with material cultural contexts, including human skeletons (Buikstra, 1977; Zuckerman and Armelagos, 2011). Thus, the most apt definition defines bioarchaeology as the bio-cultural study of human remains from archaeological contexts.

In practice, bioarchaeologists are specialists in the excavation of human remains, mortuary interpretation of individuals, groups, and mass and comingled human burials, and a host of subsequent scientific analyses that aim to reconstruct biological and life histories of excavated assemblages of osseous remains. The bioarchaeological literature has been largely focused on human remains from the last 12,000 years, or from the late paleolithic to the beginning of the 20th century, while earlier periods are still primarily studied by paleoanthropologists, including the emergence of anatomically modern humans to the late Paleolithic and hominin ancestors (Larsen and Walker, 2010).

The present study thus is bioarchaeological in its nature, where an excavated assemblage of probable Neolithic and Early Copper Age human remains were analyzed scientifically utilizing modern bioarchaeological theories and practices to bridge information gleaned from biochemical and biological profiles and radiocarbon chronologies with archaeological data and material culture. The modern empirical analysis of human remains, and overall treatment of human remains as material culture has its roots in the mid-20th century theoretical and scientific shifts in both archaeology and biological anthropology. The purpose of this chapter is to describe the trajectory of modern archaeology from the genesis of bioarchaeology, summarize the establishment of bioarchaeology as a critical sub-field, and explore supporting theories in bioarchaeology that are sought as an explanatory framework for the present study.

HISTORICAL OVERVIEW

Biological Anthropology in the Nineteenth and Early Twentieth Centuries

The roots of bioarchaeology can be traced back to the early to mid-19th century works by Samuel George Morton, Washington Matthews, Frank Hamilton Cushing, and Thomas Jefferson (Buikstra, 2006a). Morton's work in the 1830s survives today as a cautionary example to contemporary bioarchaeologists due to the complete lack of contextual and provenience archaeological data of human crania studied (Little and Kennedy, 2010). His research objectives are classified heavily as eugenic and racist, due to his unsupported assertion that a biological superiority of races existed between Caucasian or white humans and Native Americans, with the former having clear biological advantages and supremacy compared to the latter (Buikstra, 2006a; Marks, 2010). Critiques of Morton's work aptly point out that the collection of skulls used to formulate his conclusions contain no spatial or temporal information, making his conclusions impossible to support, and more importantly rendering the assemblage itself mostly meaningless to biological anthropologist (Buikstra, 2006a; Cook, 2006). Samuel Morton's work stands as a warning to contemporary bioarchaeologists that human skeletons are archaeological artifacts and cannot be divorced from the archaeological contexts in which they originate. Further, any analyses and subsequent interpretations regarding human remains should be specific to the site-of-origin and be related or inclusive of associated burial goods and artifacts and other archaeological interpretations of the specific region, culture, and time period, so meaningful reconstructions of the lives of individuals and populations can be inferred.

Frank Cushing's work at the Los Muertos site in Tempe, Arizona is another example of misguided interpretations that have since been critiqued heavily as controversial regarding proposed reconstructions of ancient southwest Native American lives (Buikstra, 2006a). However, the excavation report and methodologies authored by Washington Matthews were nuanced in his approach to detailing the archaeological context at Los Muertos as a primer for his bioarchaeological analyses. Matthew's report successfully distanced itself from Cushing's more inflammatory views and ushered in the first robust biomechanical interpretations of human behavior at Los Muertos. He described changes in many preserved tibial shafts that demonstrated heavy load stresses carried over dynamic environments, which resulted in permanent boney changes (Buikstra, 2006a). Matthew's work is a vital precursor to contemporary bioarchaeology regarding the integration of both cultural and environmental observations for the first time into bioarchaeological analytical outcomes while maintaining a contextually sensitive framework grounded in the archaeology of the site (Buikstra, 2006a).

Finally, Thomas Jefferson's work on Native American mound sites in northern Virginia utilized a problem-oriented approach questioning the use of the mounds in Native American societies as either structures for dead warriors or community ossuaries, which was sophisticated for the period and even underlies current approaches in the field (Lehmann-Hartleben, 1943). Much of the development of biological anthropology after the Jefferson into the late 19th and early 20th centuries unfortunately bifurcated into further devolutions of race science seeking a biological foundation to race, mostly in European biological anthropology and European anthropologists coming to America (Little and Kennedy, 2010). However, a second wave of biological anthropologists starkly opposed race science and biological foundations of race and rather set to build on Matthew's work on discreate formulations of skeletal analytical methodologies for sex, age, and stature estimations and championed biomechanical observations to reconstruct human behavior and environments (Buikstra, 2006b).

The early 20th century was a time for expansion and more formalization of biological anthropology in the United States and Europe, with the field increasing saturated by formally trained physicians and anatomists. The most prominent figure of the period was undoubtable Aleš Hrdlička, a Czech physician who practiced in America and engaged in typological morphological studies of the human skeleton. Hrdlička's research propelled functional adaptation approaches from previous German medical literature to center stage in biological anthropology, with innovative approaches such as comparative non-human primate studies of long bones and morphological characterization of landmarks on the human femur (Ortner, 2010; Pearson and Buikstra, 2006). He was notably hired as the first curator of Physical Anthropology by the Smithsonian's National Museum of Natural History in Washington, D.C., in 1903. While there he established the *American Journal of Physical Anthropology* in 1918, and later was a founding member of the American Association of Physical Anthropologists in 1930 (Ortner, 2010). Despite his enormous contributions to the field, Hrdlička could not escape the enormity of race science of the period polluting and tainting the discipline, even going as far to name Samuel Morton a founder of American physical anthropology, and praising his work (Pearson and Buikstra, 2006).

Aside from Hrdlička's contributions to the field, the most influential biological anthropologist of the early 20th century was Earnest Hooton. A British trained anthropologist, Hooton's influence looms large, primarily due to his groundbreaking work at Pecos Pueblo and the numerous students he trained during his tenure at Harvard, including, but not limited to J. Lawrence Angel, Sherwood Washburn, and T. Dale Stewart, all of whom will be discussed later in this chapter (Pearson and Buikstra, 2006). Hooton worked closely with Hrdlička and was a founding member of the American Association of Physical Anthropologists and served as editor for the *American Journal of Physical Anthropology*. His work specifically at Pecos Pueblo in the late 1920s and early 1930s remains exemplified as a gold standard of detailing and integration of archaeological and skeletal data in a bioarchaeological framework and essentially established a model for future excavations and bioarchaeological work (Buikstra, 2006a; Hooton, 1930). As with many disciplines, work and publication frequency in biological anthropology was heavily affected by the outbreak of World War One and Two in the early 20th century but witnessed a strong resurgence in scholarly vigor, and a drive towards specialization within biological anthropology in the 1950s. The early 20th century witnessed an increasing relationship between typological biological anthropologists and traditional archaeologists creating a ripe environment for the emergence of a more formal bioarchaeology in the post-world war period.

The New Physical Anthropology and New Archaeology

In the 1950s-60s a collision of ideas reverberated throughout both biological anthropology and archaeology. Both fields were redefining the fundamental nature of theory and methods and the subsequent philosophies inferred from analyses. Biological anthropologists began an integration of more scientifically rigorous methods in detailing biomechanical stress markers to infer behavior, largely due to the accession of more physicians and anatomists into the field as previously discussed. The desire to move both fields into a more scientific realm culminated in multiple symposia beginning with the Cold Spring Harbor Institute Symposium on the "Origin and Evolution of Man," organized by Sherwood Washburn in 1950, which culminated in broader population-based discussions, rather than more common race or typological themes (Stini, 2010). The symposium successfully served as a springboard for Washburn's "New Physical Anthropology," with novel tenets of processual evolution of primates, human variation, Darwinian genetics, population-based race rather than types, migration, genetic drift, and selection (excluding mutation), and finally adaptation of forms linked to functions (Stini, 2010; Washburn, 1951). Washburn emphasized the need for scientifically rigorous experiments and strict adherence to the scientific method. The New Physical Anthropology provided an avenue for biological anthropologists to successfully integrate with the biological science amid the growing discoveries involving human and hominin DNA and aDNA beginning in 1952 and continuing today - further enhanced with contemporary discoveries by paleoanthropologists in the Rift Valley and South Africa (Weiss, 2018).

A decade later, largely American archaeologists sought to change the direction of archaeology similarly toward a more evolutionary and systems-based lens towards the past. Cultural history dominated the field prior to the New Archaeology movement in the 1960s, where archaeological sites were simply excavated, cataloged, and artifacts ordered and analyzed without much regard to the actual populations or systems that created them. Archaeologists began advocating that material culture in form, use, and function was highly variable within different contexts (Binford, 1965). The movement mirrored shifts a decade earlier in the New Physical Anthropology, with the emphasis on the application of the scientific method and hypothesis testing via deductive reasoning, to describe contextually sensitive behaviors of individuals, societies, and populations (Binford, 1962). Lewis Binford championed the ideas of cultural evolution and more scientific rigor within archaeology and was the key figure in forming a new space for archaeology among the other life and natural sciences (Cheverko, et al., 2021). The New Archaeology was also aptly positioned in the 1960s in the United States within Anthropology departments on college campuses, which was a clear departure from European models of stand-alone archaeology departments or nesting within history departments (Hammond, 1971). This positionality of the field for students of archaeology in the 1960s and of the formal New Archaeology critique of cultural history allowed for the incorporation of more sociocultural and anthropological perspectives within the discipline (Binford, 1968; Willey, 2001). The culmination of the New Physical Anthropology and the New Archaeology, as it relates to this dissertation, was the creation of bioarchaeology as a formal sub-field in the 1970s (Armelagos, 2011; Buikstra, 1977; Zuckerman and Armelagos, 2011). Finally, the linear, systems-based analysis of cultural evolution emerged formally as "processualism" during the New Archaeology movement, incorporating ecological and environmental influences on the generation of material culture and societies (Binford, 1968; Kushner, 1970).

The Biocultural Approach

Since the foundation of the sub-field a biocultural approach has been central to successful and meaningful bioarchaeological research (Armelagos, et al., 1982; Buikstra, 1977). Initially bioarchaeologists and biological anthropologists neglected a biocultural framework and it sometimes remained absent even into current contemporary work. In modern research, the biocultural approach recognizes that human variation is a product of both culture and biology (Dufour, 2006; Goodman, 2013; Zuckerman and Martin, 2016). The development of a biocultural approach directly translated to an increase in specialization within biological anthropology and bioarchaeology with increasingly technical and sophisticated methods such as ancient DNA, isotopic, and paleopathology analyses (Buikstra, 2006b; Little and Sussman, 2010). Arguably, the biocultural approach was instrumental in early paleopathological research in the 1980s and 90s focusing on the health and life ways contributing to epistemological origins of human illnesses (Armelagos, et al., 2005; Cook and Powell, 2006; Martin and Zuckerman, 2016). Paleopathological research combined with paleodemographic inferences also helped usher in post-processual theoretical developments with bioarchaeology, to expand the theoretical scope beyond simple linear Darwinian and processual explanations for disease propagation and migration (Bocquet-Appel and Masset, 1982; Goldstein, 2006). The post-processual critique of skeletal assemblages reached a watershed with the Osteological Paradox (Wood, et al., 1992), which formally addressed issues surrounding demographic nonstationarity, selective mortality, and heterogenous frailty within archaeological populations and has since been further enhanced and critiqued by contemporary scholars (DeWitte and Stojanowski, 2015; Wright and Yoder, 2003). The development of the New Physical Anthropology and New Archaeology, coupled with a biocultural approach in bioarchaeology, has resulted in a contemporary holistic approach, generating multiple "bioarchaeologies" (examples include, the bioarchaeology of disease, health, violence, demography, etc.) (Baker and Agarwal, 2017; Stojanowski and Duncan, 2015). These bioarchaeologies are emphasized by a multidisciplinary platform for research to position bioarchaeology within the scientific academy and are an outcropping of the increased drive towards more specialized approaches seen in the 1980s through today and is currently generating a more collaborative environment for modern bioarchaeological research.

EMBODIMENT – THE BIOARCHAEOLOGICAL MIDDLE RANGE

Embodiment Theory in Bioarchaeology

Embodiment theory in biological anthropology has been widely employed to explain the variety of boney responses to environmental and social stresses placed on individuals during the life course (Battles and Gilmour, 2021; Geller, 2008; Gowland, 2015; Gregoricka, 2021; Mays, et al., 2017; Nystrom, 2014; Shuler, et al., 2012; Stojanowski and Duncan, 2015; Temple, 2014; Zuckerman and Crandall, 2019; Zuckerman, et al., 2014). When viewed from an archaeological perspective, embodiment appears to be situated between the static data obtained from skeletal analyses and the lived experiences of dynamics of an individual's life, or what processual archaeologist would define as the middle range. This connection between middle range archaeologies and embodiment was not explicitly outlined in the complimentary contextual and multidisciplinary approaches to middle range applications, but the importance of skeletal data was certainly becoming a priority of early practitioners (Trigger, 2006). Contemporary bioarchaeologists utilize embodiment theory to bridge the gap between skeletal data and the biocultural environment sought to be reconstructed and explained. In archaeology, this middle range is seen as static data from artifacts such as pottery sherds or stone points, and how that static data is used to create an interpretation of the *chaîne opératoire* or the cultural processes involved in creating, using, and disposing of objects (Johnson, 2019). The cultural process begins with raw material sourcing, followed by manipulation of raw materials either into other materials or by combining multiple raw materials into one form and, then the creation of templates, which leads to the creation of a new object, followed by the use and reuse of the object, and finally the process of recycling or disposal – the point typically at which archaeologists find objects during excavation. Similarly, skeletons follow a developmental trajectory where skeletal development begins at conception through neonate stages of life, where the individual is wholly reliant on the cultural system and parents for survival, followed by a period of growth and burgeoning independence until skeletal maturation is complete in early adulthood. After skeletal maturation an individual's skeleton begins a longer period of skeletal degeneration. Ultimately, death occurs, and the individual is either buried or left unburied and soft tissue decomposition occurs followed by taphonomic interactions where one of two things can occur, the first is the skeleton fully decomposes or, second, is rediscovered either as human skeletal remains often with associated artifacts or the skeletal elements become artifacts or cultural objects for decoration, tools, etc. The body assumes a dual role in bioarchaeology as either an artifact or a once living human, both of these conditions engage directly with embodiment theory in very specific often loosely defined ways and are not mutually exclusive. Both physical archaeological artifacts and bodies embody sociocultural conditions acted upon them. Those embodied traits can then be translated by bioarchaeologists as static data and are utilized to reconstruct the past dynamics from which they could have originated.

Embodiment in bioarchaeological research has rarely been explicitly defined or explained regarding its application to the reconstruction or interpretations of skeletal data. This issue within the field is often seen as a more cursory use of embodiment as a structural component of a larger theoretical framework but is never fully fleshed out in its application. A greater misstep, perhaps, is the use of embodiment wholly as a theoretical framework, which when utilized alone cannot fully explain or reconstruct past biocultural environments. Embodiment theory is the middle range for bioarchaeological research and functions as a lower-level theory and must always be paired with a higher-level theoretical perspective such as life history, human behavioral ecology, structural violence, niche construction, etc. It strictly serves as a theoretical conduit to move skeletal data from a salient space into a more theoretically elevated interpretive framework for more meaningful applied applications (Krieger, 2005). Yet, it is not enough to simply state that, for example, a traumatic event or pathological condition was simply just "embodied" via the presence or absence of corresponding skeletal lesions. Thus, I suggest embodiment must be defined as either implicit or explicit in its application in bioarchaeological research.

Implicit and Explicit Embodiment

Implicit embodiment corresponds with any activities required for living such as eating, reproducing, surviving, moving, etc. undertaken by an individual, but the traces of which are present as boney changes or preserved biomarkers. Implicit embodiment, as I define it, its related to previous theoretical literature concerning "unconscious embodiment" (Schrader and Torres-Rouff, 2021), where the individual by virtue of existing, biologically incorporates aspects of their ecological and cultural environments which can be translated into skeletal data by bioarchaeologists. Stable isotopes are an example of implicit or unconsciously embodied feature as they are actively incorporated into the skeleton in life through the digestion of food. Thus, inevitable biological incorporation of stable isotopes from the human diet imparts information about the agricultural or subsistence systems from which the food originated. However, implicit embodiment extracts information or values from skeletal remains, seen as prior living organisms to reconstruct the biocultural environments. Implicit embodiment is by its nature a more inductive endeavor, where specific skeletal evidence is utilized to generally reconstruct the dynamics that resulted in their possible presence or abundance within the skeleton.

Explicit embodiment is defined first by the archaeological contexts of the skeletal remains, and later by specific lesions on osseous remains that are indicative of a loss of individual agency, typically because of a power imbalance. This is more easily understood from the perspective of institutional bioarchaeology, where individuals recovered from these contexts were explicitly embodying features of the experience of being institutionalized. This type of embodiment builds on previous implicitly embodied information that originated from the cultural system where a given individual originated. Institutionalized individuals take on biocultural aspects of both the culture from which they originated and their institutional experiences, where implicit embodiment of generalized biocultural traits are shared across the population of origin, but the individual biomarkers of institutionally derived boney lesions are explicitly connected to the institution and sperate from the larger population. For example, if an individual was institutionalized later in life, their diets may look drastically different, where their early childhood isotopic composition would have been implicitly acquired from the subsistence system shared by the community or parents, but the adult or institutional diet is explicitly embodied as it was strictly controlled by the institution. Explicit embodiment often describes boney manifestations that occur due to a loss in agency or niche cultural norm in life. These contexts often require a much more deductive approach, where the general context is unique and known and results in the specific creation of evidence of treatment and living conditions that are atypical of the implicitly embodied boney changes shared by populations of origin. If implicit embodiment is unconscious and the skeletal remains represent an organism, then conversely explicit embodiment must be conscious, meaning the body is interpreted as material culture. Examples include, but are not limited to, foot binding, teeth filing, cranial vault modifications, and of course institutionalization (Agarwal and Glencross, 2010b; Nystrom, 2014; Tiesler, 2014; Zuckerman, et al., 2014).

The road to understanding or reconstructing past population dynamics and sociocultural systems can be complicated when utilizing embodiment theory. As previously stated, human skeletons occupy a dual space as both person and artifact and thus can retain both implicit and explicitly embodied lesions or features. Explicit embodiment is grounded within philosophical thought, specifically, Foucault's ideas concerning power and agency and the effects on bodies (Foucault and Gordon, 1980), while implicit embodiment is more closely related to Merlaeu-Ponty's reasoning that bodies can record lived experiences (Merleau-Ponty and Smith, 2002). For this reason, researchers must be as specific as possible regarding how embodiment theory is applied. There are latent issues with embodiment that confound the suggested implicit and explicit dichotomy. The first is the cultural system itself. All bioarchaeology as previously described above must be local and bioculturally sensitive to the archaeological context in which human skeletons originate (Buikstra, 1977). That facet of bioarchaeological research results in the uneven application of embodiment. For example, if one cultural group is generally interpreted archaeologically as more peaceful and another cultural group is seen as more war-like, then traumatic lesions would been seen as possibly explicit in one but implicit in the other, depending on if mechanisms of violence are either more systemic or episodic within each respective group. The second is non-stationarity of people. As previously stated, a given individual can embody more than one biocultural set of conditions due to migration in life. Often seen in the literature as differences between locals and non-locals where those features implicitly embodied within a non-local could be seen as explicit within a different cultural context, and described as "other", but, both cultural manifestations are implicitly embodied as they occurred through the act of living and moving around, despite potential clear contrasts in embodied features. Despite these issues, if the use of embodiment is specific, they can be avoided by adequately describing the archaeological contexts from which the individuals originated, how the researcher is utilizing data obtained from the skeleton, and what types of interpretations are being made based on the results provided by skeletal data. In this way, research becomes more localized to the groups under scientific scrutiny. Bioarchaeologists can avoid over-emphasizing the dichotomy between the dead and the mortuary context through appropriate description of the application and scrutiny of the types of embodied traits observed, which in turn can preserve the cultural actions of the living within the mortuary sequence (Buikstra and Scott, 2009). Careful description and consideration of the applicability of specific types of embodiment can ground research within a richer theoretical environment and engage research questions with more foundational archaeological theoretical perspectives regarding personhood, agency, and identity (Joyce, 2007). By middle ranging embodiment theory, researchers can then allow higher level theories to position or define more fully hypothesized embodied traits from skeletal analyses into comprehensive archaeological theoretical narratives that seek to describe human behavior, social and political systems, and environmental and ecological settings.

LIFE HISTORY THEORY AS AN EXPLANATORY FRAMEWORK

The Life History Approach

The archaeological foundation for the use of life history approaches derives largely from new archaeology and processual thought, including middle range theory as it relates to the embodied skeleton, but also to evolutionary and ecological archaeology. Beginning in the 1950s and the lead up to the New Archaeology movement, Julian Steward and Leslie White began laying the groundwork for what would become processual ecological theory. White was particularly concerned with how human behaviors were largely driven by energy input and output regarding first the evolutionary needs for survival and reproduction, and second how cultural systems absorbed human energy to meet those goals through the production of technologies aimed at providing for primal needs defined as food, shelter, and defense (White, 1943). Around the same time, Julian Steward began pondering how local ecological conditions could affect the generation of materials and technologies, and ultimately shape human behavior (Steward, 2020). Both perspectives were critical in the formation of processual archaeology by Lewis Binford and the shift to archaeology as anthropology. The energy expenditure hypothesis and cultural ecology, created a ripe theoretical landscape for middle-range expansion where archaeological data were utilized as a bridge to both higher level theories and as an avenue to make more meaningful insights into human environmental interactions relating to subsistence, resilience, and adaptation (Binford, 1962). Once middle-range theory had been introduced, archaeologists could begin to build a greater appreciation for site formation processes, fine-grained archaeological techniques that garnered greater contextual control, and start to elucidate the complex interaction between human behaviors in localized environmental settings and specific definitive cultural components across time.

Since the development of processual archaeology human behavioral ecology has been the theoretical meeting point of evolutionary and ecological archaeology and middle-range theory. Emerging from evolutionary ecology, HBE views human behavior as adaptive when humans are subjected to environmental stimuli, so as to enhance individual fitness concerning primarily survival and reproductive success. Behavioral ecology, a sub-field of evolutionary ecology, seeks to define behavioral trade-offs and determine why certain behaviors are abandoned and why others persist. In archaeology, humans interact with our environments through socioecological and cultural mechanisms or the generation of technology and tools, so our trade-offs are often seen as changes in cultural materials or tool kits, in response to certain conditions or challenges. HBE utilizes a systems-based approach to examining contextually sensitive human adaptations to their environments through cultural mechanisms that increase survival via hunting and foraging success or food production in agricultural contexts. Further, HBE also equally considers culturally adaptive behaviors that increase reproductive success and decrease infant mortality. Nesting life history theory within an HBE framework was a natural progression of the field from a strictly biological perspective. Early literature initially was constrained to investigations regarding reproduction, maturation, dispersal patterns, mortality, and senescence throughout non-human primate, hominin, and human evolution (Dean, et al., 2001; Hawkes, et al., 1998; Hill and Hurtado, 1996; Hill and Kaplan, 1999; Kaplan, et al., 2000; Smith and Tompkins, 1995; Winterhalder and Smith, 2000). Much of this work utilizes Eric Charnov's models for behavioral variation which defines reproduction, weaning, and growth as dependent on adult mortality (Charnov, 1993). Charnov argued that adult mortality and longevity and not delayed maturity in early humans directly resulted in changes to human life histories. Life history has since been utilized by bioarchaeologists to help understand how specific embodied evidence, emerging from human skeletons, could indicate trade-offs made in life, assist in reconstructing sociocultural systems and environments, and how the human life course continues to evolve and adapt under different conditions.

Life history theory itself originally developed within the biological sciences, and it is firmly rooted by evolutionary approaches to natural selection and the development of traits, as previously discussed. Life history specifically interrogates the cumulative development of adaptive traits across the lifespan that directly increase the fitness of individuals and small groups (Zvelebil and

Weber, 2013). Since life history developed in the biological sciences, typically researchers are able to observe organisms with relatively short lifespans compared to humans, which allows for a more intensive list of traits such as, weaning, sexual maturity, number of offspring, day-to-day diet and activity levels, and menopause and senescence (Hill, 1993; Stearns, 2000). Bioarchaeologists are retroactively applying life histories to human skeletal remains, the life history frameworks are built first upon age-at-death and sex estimations and can include any number or combinations of data such as paleopathological lesions, biomechanical responses, paleodemographic changes, family size and relatedness, and diet and mobility reconstructions, and/or more recently aDNA, microbiome, or proteomic results (Cheverko, 2021). An aggregate of these data provides the foundation for life history interpretations regarding the level of plasticity of individuals or groups in terms of resource allocation, trade-offs, interpersonal and sociocultural interactions, and agency. Life histories provide an avenue for meaningful descriptions of sociocultural and ecological conditions and resulting mortality and morbidity. The acceleration of current bioarchaeologies of childhood have increased the use and applicability of life history approaches in bioarchaeological research due to the need to examine changes across the lifespan from childhood to adulthood, of both groups and individuals (Fernández-Crespo, et al., 2020; Fournier, et al., 2022; Goude, et al., 2020; Temple, 2019).

One of the primary structural components of life history theory revolves around age. Human lifespans are much longer in comparison to other non-human primates, which leads to increased parental investment of resources to child rearing, and longer childhood and sexual maturity (Cheverko, 2021). In bioarchaeology, three distinctive age categories have been developed to encapsulate the individual more holistically, these are chronological, biological, and social age (Halcrow and Tayles, 2008; Knudson and Stojanowski, 2008). Chronological age refers to exact time since birth, commonly measured in Julian calendar years in western society. Biological age in bioarchaeology is the condition or level of development or degeneration of specific landmarks that exhibit age-related changes, such as the pubic symphysis, vertebral bodies, or the epiphyseal ends of long bones, etc. (Clark, et al., 2020). Social age refers to the behaviors or cultural norms assigned to distinctive maturity levels – which are much harder to see in the archaeological record (Agarwal and Glencross, 2010b). These age categories have been heavily critiqued, as bioarchaeologists typically create a social dichotomy that is heavily influenced by western cultural norms regarding social age and maturity. These groups are most commonly sub-adults or juveniles and adults. Bioarchaeologists typically report biological age as part of construction of the biological profile of skeletons. Life history approaches often partition implicitly embodied traits such as isotopic composition of teeth and biomarkers of physiological stress occurring over the life course and those same types of implicitly embodied traits associated with adulthood reservoirs and landmarks. The primary goal of examining embodied evidence across the lifespan in bioarchaeology is to create a platform for interrogating variations in human behavior and how those behaviors can be utilized to reconstruct past environments within dynamic archaeological contexts.

To discourage confusion, life course theory is related but not epistemologically the same as life history theory - the former developed within the social sciences and has retained a more sociological bend. The purpose of life course theory is to navigate developmental processes, personal and sociocultural conditions, and social pathways in order to illuminate age and socioeconomic class-graded patterns central to studies surrounding institutionalization, health and aging, mortality and morbidity, and work and family histories (Ben-Shlomo and Kuh, 2002; Hardy and Tilling, 2016; Mayer, 2009). The utility of life course theory alone requires the explicit use of previously developed models and theoretical framing for the application and interpretive framework to be applicable in sociological literature. Similarly, to life history theory, an emphasis is placed on age-related changes through time, with future life outcomes directly impacted by cultural and socioeconomic dimensions across the lifespan. This theoretical approach is summarized by five exclusive principles: (1) human development, degradation, and aging are lifelong processes; (2) humans have individual agency for decision-making within sociocultural and environmental constraints; (3) lives are products of historical time and space; (4) the timing of events throughout the life course affect development; and (5) interpersonal and social relationships impact development of individual life courses (Cheverko, 2021; Elder, et al., 2003). This rigorous framework often requires larger longitudinal or cohort level studies, which are difficult to obtain in bioarchaeological research outside of strictly paleopathological or paleodemographic studies – where life course approaches have primarily been applied historically (Gowland, 2015). Facets of the life course perspective have been adopted within bioarchaeology as the field begins to further evolve and grow towards a more "social bioarchaeology" space as part of the on-going biocultural development of the discipline (Agarwal, 2016; Agarwal and Glencross, 2010a; Cheverko, 2021). However, this distinction is necessary because throughout the current the literature life course theory and life history theory are often described or even utilized simultaneously and interchangeably but remain distinct due to their theoretical origins.

In 2013 a special issue of the *Journal of Anthropological Archaeology* (vol. 32, issue 3) was published and edited by Marek Zvelebil and Andrzej Weber (Zvelebil and Weber, 2013), focusing on the bioarchaeology of individuals and group identities utilizing both life history and life course frameworks, sometimes used interchangeably as previously mentioned. The articles largely surrounded three main bodies of data, isotopic analyses for dietary and mobility reconstructions, mortuary analyses examining trade and status, and biomechanical analyses interrogating past activities. The purpose of this special issue was to demonstrate the applicability of an individual or combined life history and life course explanatory framework in elucidating the biocultural identities of individuals and small groups from a variety of time periods. Several of the articles are of direct relevance to the current study as they interrogate peoples from the Neolithic period (Bentley, 2013; Eriksson and Lidén, 2013; Le Bras-Goude, et al., 2013; Zvelebil and Pettitt, 2013), many with specific use of biochemical analyses to reconstruct mobility and diets.

This dissertation utilizes life history to reconstruct the biocultural and ecological environments via implicitly embodied dietary profiles of Neolithic and Early Copper Age agriculturalists from the Central Po Valley. Implicit embodiment complements and enhances life course and life history theoretical frameworks, such as the perspective utilized by the present study, through the translation of static stable isotope and radiocarbon data obtained from skeletal remains into a space appropriate the reconstruction of cultural subsistence strategies, settlement patterns, ecologies, and chronologies, and identities. Life history theory is utilized here as a descriptive and explanatory tool to examine the level of evolutionary plasticity of primarily small cultural groups, when possible, individual identities of Neolithic and Early Copper Age peoples from the Central Po Valley. Theoretical perspectives in bioarchaeology should equitably draw from both human and evolutionary biology and archaeology. At the current time lifespan approaches in bioarchaeology are weighted heavily towards biosocial epistemological frameworks, as previously mentioned, without much consideration for how archaeological theories concerning material culture evolution, personhood, and identity can strengthen and possibly create a more holistic approach that is appropriate for bioarchaeological contexts. An applied theoretical framework for biocultural lifespan theories should include facets from embodiment, cultural evolution, and ecological and social archaeology that form the basis for contemporary processual and post-processual thought in archaeology.

CHAPTER THREE:

ISOTOPES IN BIOARCHAEOLOGY

INTRODUCTION

The discovery of the atom and subsequent development of atomic theory in both chemistry and physics has revolutionized science and the way we view and study the natural and ancient world. Towards the end of the nineteenth century the atomic world was being used to define the previously understood limits of matter through the characterization of the atom and its associated structures, the nucleus with positively charged protons and neutral neutrons, to the negatively charged electrons surrounding atomic nuclei in clouds or shells (Pollard and Heron, 2008b). This early work involved the development of the first periodic table of elements each defined as the atomic level by unique collections of atoms with equally unique and measurable atomic weights and masses. These elements were assigned atomic numbers based on their number of protons equal to their number of electrons and ordered by their masses for the first time (Katzenberg and Waters-Rist, 2019). At the turn of the century, Henri Becquerel revealed that uranium samples he was studying were emitting invisible radiation, a phenomenon later defined as radioactivity by Pierre and Marie Curie (Taylor, 2014). The property of radioactivity of certain elements resulted in the proposal by Frederick Soddy that nuclear properties of some elements were variable and thus he coined the term isotope to define those atoms that share an atomic number but have variable atomic masses (Taylor, 2014). This assertion was further elaborated on in the 1930s when it was discovered that the atomic masses of isotopes differed not because of differing numbers of protons or electrons but rather because of the variable number of neutrons.

Radiocarbon (^{14}C) is a radioisotope of carbon and is commonly utilized in archaeology to date human bone and other organic remains from archaeological contexts. Radiocarbon analyses first began in the late 1950s, when Willard F. Libby, James R. Arnold, and Ernest C. Anderson developed a technique to measure residual carbon-14 isotopes via naturally occurring nuclear decay counting techniques for the isotope in organic samples (Libby, 1961). This technique quickly became the gold-standard for providing absolute chronometric dates from a variety of carbon-rich samples such as bone, wood, charcoal, shell, and plant remains and earned the collaborators the Nobel Prize in Chemistry in 1960 (Kern, 2020). The application of radiocarbon techniques utilizing carbon isotopes was a watershed moment when archaeology was also experiencing a cultural shift from strict cultural history reconstructions to a more scientifically rigorous field. In the 1970s, researchers began experimenting with the stable isotopes of carbon to understand the biochemical nature of carbon isotopes and how they related to human diet (van der Merwe and Vogel, 1978; Vogel and Van Der Merwe, 1977). This chapter will summarize the emergence and use of isotopic methods for absolute dating, dietary, and mobility reconstruction through organic biochemical analyses. In this section, I will summarize the development of isotopic methods and theory focusing on the utility of human remains in the creation of absolute chronologies and dietary profiles.

RADIOCARBON

Production, Distribution, and Decay

As mentioned above, in the experiments by Libby and colleagues in the 1950s began a cascade of research concerning isotopic utility in the archaeological record. It was understood at the time that carbon occurred naturally in three forms (^{12}C, ^{13}C, and ^{14}C) with ^{12}C and ^{13}C being stable, discussed later in this chapter, and ^{14}C defined as a radioisotope (Taylor, 2014). Stable isotopes, as the name suggests, remain a subset of isotopes and do not decay and form other elements. Radioisotopes do decay over time and form other elements at relatively regular intervals known as half-lives. Carbon-14 contains eight neutrons and six protons and undergoes beta decay and one of the neutrons becomes a positively charged proton and the atomic number is increased resulting in the creation of nitrogen-14 (^{14}N) (Taylor, 2014). The nucleus of ^{14}C is thus naturally unstable and decays with a known half-life, when the total concentration of ^{14}C in any given sample is reduced by half via beta decay, of about 5,700 years (Taylor, 2014). This allows ^{14}C to be measured in decaying organic material through counting or by way of novel instrumentation, discussed below.

Prior to ^{14}C decay, it must first be produced through natural stratospheric level reactions. Cosmic rays consist primarily of protons from hydrogen and helium nuclei that are accelerated from the sun toward the Earth, with some being deflected by the Earth's magnetic field and some reaching the upper atmosphere. Within the upper atmosphere, cosmic rays collide with a number of primary and secondary particles of atmospheric gases and produce spallation products, which include free neutrons. The free neutrons slowly lose energy and as they do they begin to react with atmospheric gases forming secondary molecules. When these free neutrons react with the nucleus of ^{14}N they form ^{14}C. The resulting ^{14}C is quickly oxidized via hydroxide ions and forms both ^{14}CO (carbon monoxide) and $^{14}CO_2$ (carbon dioxide). These newly formed molecules are rapidly dispersed around the globe via atmospheric wind currents and begin to sink onto the troposphere where they are incorporated into various plant life via photosynthesis or dissolved into water as inorganic and organic carbonates (Figure 3.1) (Taylor, 2014). A smaller percentage of atmospherically available ^{14}C is incorporated into the plant biomass on Earth, compared to the marine environments on the planet.

All life on Earth is reliant on complex and interconnected food webs that are all founded on the consumption of plants as primary producers. As such, all life on Earth absorbs ^{14}C bonded within biologically available molecules within consumed plants and proteins (Taylor, 2014). As ^{14}C is metabolically incorporated into the living tissues of all organisms, the concentration of ^{14}C remains in an approximate equilibrium for most organisms with the relative concentration of ^{14}C in the Earth's atmosphere, regardless of trophic level (Taylor, 2014). Upon the death of an organism, all metabolic activity ceases and ^{14}C concentrations cannot actively be maintained through consumption and thus negative beta (β^{-}) decay of ^{14}C begins. As previously mentioned, the half-life ($t_{1/2}$) is the expression used to define the exact time-period that a radioactive isotope concentration within an object will decrease by half. Negative beta decay of the remaining ^{14}C within an organism after death results in ^{14}N. Radiocarbon dating methods seek to quantify the remaining ^{14}C within organic artifacts from purified sample matrices of those without external sources of carbon introduced during sample preparation (Longin, 1971).

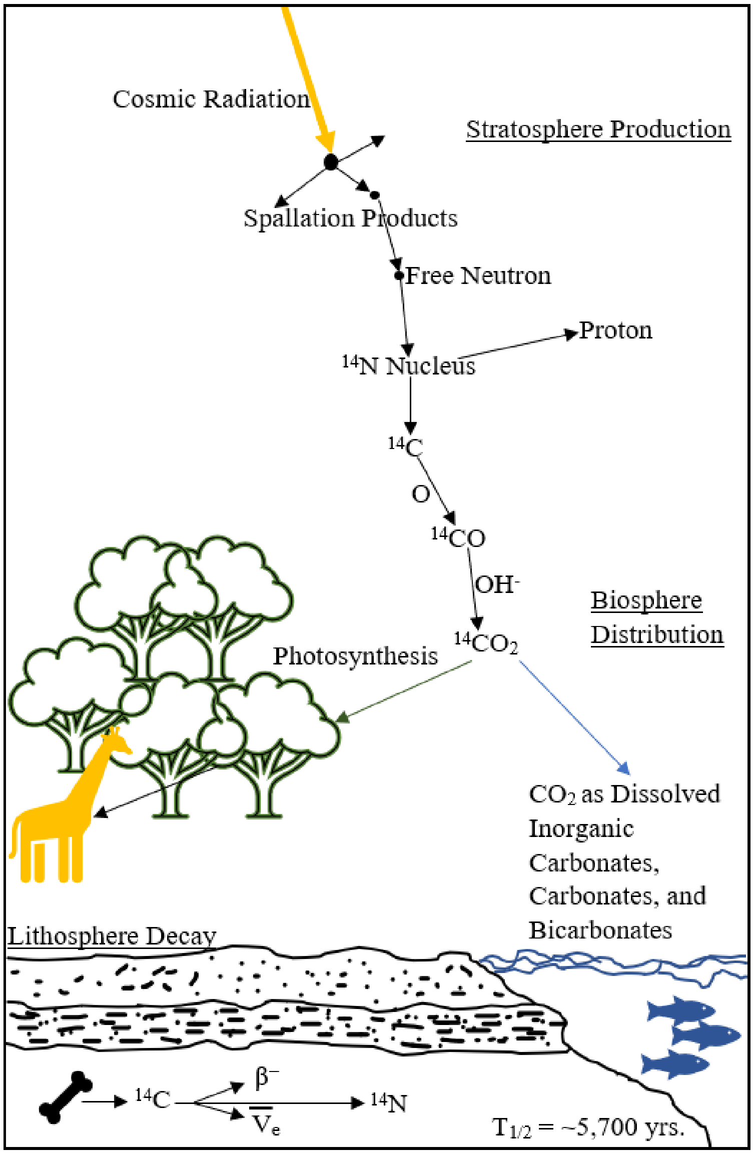

Figure 3.1: Radiocarbon model of production, distribution, and decay

Measurement and Precision

Since the radiocarbon revolution began, absolute dating via ^{14}C has often served as the arbiter in settling uncertainties regarding the age of famous objects such as the Shroud of Turin, and famous human skeletons such as the Kennewick Man (Damon, et al., 1989; Owsley and Jantz, 2014). Radiocarbon dating relies on a set of assumptions that allow for accurate dating: (1) ^{14}C reservoirs have remained constant over the last 100,00 year; (2) complete global mixing of ^{14}C

reservoirs is achieved within only a few decades; (3) isotopic sample matrices are purely representative of ^{14}C decay only; (4) the ^{14}C half-life has an appropriate level of precision; and (5) control samples containing ^{14}C can be measured accurately and provide an appropriate level of precision (Taylor, 2014). Scientists relying on optimal results from ^{14}C dating methods also must reliably document the contextual provenance of all samples. Samples originating from archaeological sites are typically associated with materials that can be relatively dated to a specific time-period such as ceramic or lithic remains, which can help provide further precision to chronological models using returned radiocarbon dates (Manning, et al., 2014). An important note here is that the term accuracy refers to the validity of a returned date, and precision refers to a degree of uncertainty greater than or less than any returned date.

Over the years the instrumentation and accompanying methodologies for quantifying the residual ^{14}C in organic samples has evolved. The first type of instrumentation used to detect and count ^{14}C decay events were traditional devices used to measure radiation called the Geiger-Müller (GM) tube (Kromer and Münnich, 1992). GM tubes functioned by introducing internal or external gases to a counter gas producing ionized charged free electrons that are electromagnetically sensitive (Kromer and Münnich, 1992; Taylor, 1987). These electrons would be attracted to a charged wire passing through a gas chamber which results in the production of secondary electrons (Kromer and Münnich, 1992). As the electrons pass along the charged wire they can be connected with detection devices that detect decay events, more specifically for ^{14}C the detection of beta particles or negatively charged electrons producing during decay (Taylor, 1987). Several factors determined the ability of researchers to obtain accurate counts which include the nature and pressure of the gas, detector dimensions, and amount of voltage between the tube wall and the wire (Taylor, 1987). These early devices functioned primarily through the manipulation of voltages to detect and count alpha and beta particles produced in proportional or Geiger regions, which effect the energy of the ionized radiation (Taylor, 1987).

By the time Libby began his work in the 1950s, three generations of these detection devices for different radioisotopes had been manufactured. These included decay or beta counting of elemental carbon, decay counting via gas or liquid scintillation devices, and direct counting utilizing particle accelerators. Libby and colleagues largely utilized a “screen-wall” type of counter which required solid carbon samples (Libby, 1955; Taylor, 1987). The gas and liquid scintillation instruments gained popularity quickly after Libby’s work. The gas systems converted samples to CO_2 gas where the gas was utilized directly inside a counting instrument. Liquid systems similarly converted samples to CO_2 gas but then synthesized the gas via a series of chemical reactions to produce benzene (C_6H_6), which is added to a scintillator solution resulting in measurable light pulses of ionizing radiation (Taylor, 1987). These instruments began to phase out with the introduction of mass accelerator spectrometers with direct and or ion counting capabilities in the late 1980s.

The overall sensitivity of ^{14}C counting was dramatically increased via the direct atom-by-atom detection capabilities made possible by mass spectrometers. The reason mass spectrometers have become the standard technology employed for measuring isotopes is because of their precision and functionality, which takes direct advantage of the naturally occurring atomic mass differences between isotopes and elements to measure their concentrations in organic samples. The process requires that nuclides be ionized, adding, or removing electrons, typically occurring via an ion beam of a noble gas such as argon (Beukens, 1992). Once ionized, the sample gases become sensitive to electromagnetic fields. These ions are accelerated through a vacuum inside of the mass spectrometer. As ions are accelerated, they are deflected and directed via a magnetic field applied and calibrated to the appropriate strength necessary to collect and measure the isotopes of interest (Taylor, 1987). This is accomplished by accelerating the ions around a bend in the mass spectrometer where the magnetic field is applied. This physical attribute of the instrument allows only those ions of interest to be directed rapidly around the bend where they enter a collector in the larger concentrations than the other larger or smaller ions that are deflected by the magnetic field. These undesired ions are pumped out of the mass spectrometer as they are deflected via the magnetic field and lose energy inside the machine (Beukens, 1992; Taylor, 1987). Traditional mass spectrometers work very well at measuring stable isotopes, for example ^{13}C and ^{12}C, but function poorly at measuring ^{14}C due to the low relative abundance of the isotope compared to much more abundant ions. However, this problem was solved by Hans Oeschger and colleagues in the 1970s, by accelerating high energy ions in particle accelerators which strips many of the unwanted molecules away allowing for the detection and direct counting of ^{14}C and ^{14}N in a sample (Taylor, 1987). This was accomplished within an accelerator mass spectrometer (AMS).

AMS instruments are available in two types that each have unique properties and functions for direct counting of ^{14}C, one is a cyclotron accelerator and the other is an electrostatic accelerator (Beukens, 1992; Taylor, 1987). The cyclotron accelerator acts on a critical ratio between charge and mass where when ionized ^{14}C is the target and the only other ion present is ^{14}N, while the other unwanted ions are eliminated quickly from the ion beam. Cyclotron accelerators accelerate ions through two semi-circular electrodes that are subjected to a high-voltage charge within a magnetic field, with an alternating accelerating voltage applied between them. The separation of ions of interest and those not of interest occurs simultaneously during acceleration. The process of separating the ^{14}C and ^{14}N involves range separation where the overall distance traveled within the machine of ^{14}C is about 70% greater than ^{14}N. This allows for the individual detection and counting of ^{14}C ions via total energy and energy loss of the ions. The electrostatic type AMS instruments utilize a voltage mediated acceleration provided by either a moving belt or chain or by a solid-state voltage multiplier (Beukens, 1992; Taylor, 1987). Here only negatively charged ions are accelerated into a positively charged terminal and passed through a gas stripper, which results in positively charged ions. No molecules at charge states greater than 3+ survive the gas stripping process. Total energy measurements are achieved via the ions first moving towards the positively charged terminal and then away from it after the gas stripping process (Taylor, 1987). This means that the measurement occurs in two stages, known as tandem acceleration or tandem accelerator mass spectrometry (TAMS). There are advantages to TAMS units, specifically the lack of survival of ^{14}N ions after the gas stripping process and the simplicity of measuring various stable carbon and radiocarbon ratios ($^{14}C/^{13}C$ and $^{13}C/^{12}C$) within a short period of time (Taylor, 1987). Gas rather than solid samples are preferred for analysis due to the ability for combustion of solid samples to occur within the machines producing CO_2 gas, reducing the risk of external contamination of the sample. AMS instruments have continued to evolve since their initial introduction in the mid- to late twentieth century, with specific regard to hardware modifications to detectors, housing, and magnetic field producing equipment as well as the ion source, and the treatment and pretreatment of solid and gas samples for analyses. As a result of the development and utility of radiocarbon dating technology, several radiocarbon specific academic publications, such as the academic journal entitled *Radiocarbon*, and many academic conferences have been developed specifically to share and collaborate on issues, research, and technological advances within the study of radiocarbon.

The greatest issue with obtaining accurate and precise radiocarbon dates that are reflective estimates of calendar dates is international calibration. Radiocarbon dates are always reported directly from the AMS measurement instruments in terms of years "before present" or BP and do not reflect a 1:1 relationship with calendar years (Stuiver and Pearson, 1992). Years BP refers directly to the proportion of radiocarbon contained within a sample in relation to the "present" which refers to the year 1950, prior to the first atomic bomb tests that forever altered atmospheric radiocarbon concentrations (Kern, 2020). Additional consideration for the use of calibrated calendar dates from reported BP dates is due to variable and measurable based shifts in the proportion of atmospheric carbon available throughout the past for active incorporation into carbon-based organisms (Bronk, 2008). For accurate and precise measurements or "true ages" to be reported, dates must be calibrated utilizing a suit of international environmental standards produced regularly by the IntCal working group since 2004 (Becker, 1992; Reimer, et al., 2020). This group collects and analyzes a variety of materials of known ages, such as tree rings, speleothems, marine corals, and sediment cores, to produce a calibration curve which is consistent with the environmental availability of radiocarbon. The most consistent and reliable environmental reservoir for accurate calibrations has been tree rings collected from both very old and dead, waterlogged trees throughout the world, which has resulted in a data set of different overlapping calendar ages that are useful in translating BP dates to calibrated AD or BC dates (Becker, 1992). Programs such as OxCal, provide a method for calibrating BP dates from AMS laboratories to more useful calibrated dates more reflective of calendar years (Bronk, 2009). Calibrations are always provided in a range as the amount to radiocarbon available at any given period, based on available tree rings data which overlaps a provided BP period, is variable and thus samples do have constraints on the precision of any given date. This can also result in multiple ranges for some samples for any provided date due to the variation in atmospheric radiocarbon. For example, in Figure 3.2 the obtained BP date for tomb one at Bagnolo San Vito Dalmaschio, a project site, is provided as an example of how the calibration process is carried out via a single plot of the date. Most modern radiocarbon labs currently report all analyzed radiocarbon dates with both a 1-sigma (68%) and 2-sigma (95.4%) confidence interval. In addition to the confidence intervals dates are commonly reported with respect to the overall precision of the base measurement which is typically at least ± 25. In the present study, the BP date provided is accompanied by the USF sample number and the BP date provided within a 2-sigma probability and ± 25 base measurement variation as reported by the AMS laboratory at the University of Georgia. This BP date is plotted on the y-axis of the single plot in red and is reported at the top of the graph as 5890 ± 25 BP. Along the x-axis is the calibrated BC date range that corresponds with the two blue lines traversing the graph, which represents the closest tree ring dates or estimations obtained for the time period of interest by the IntCal group. The calibrated range also has two date ranges provided, while others may have only one as previously discussed, but in this instance the two ranges indicate that there is reasonable statistical probability that the date range in calibrated BC calendar time could fall between 4840 cal BC and 4700 cal BC. The total amount of precision for any radiocarbon dates to calendar dates are wholly dependent on the quality and range of corresponding environmental samples or estimates provided by the IntCal working group.

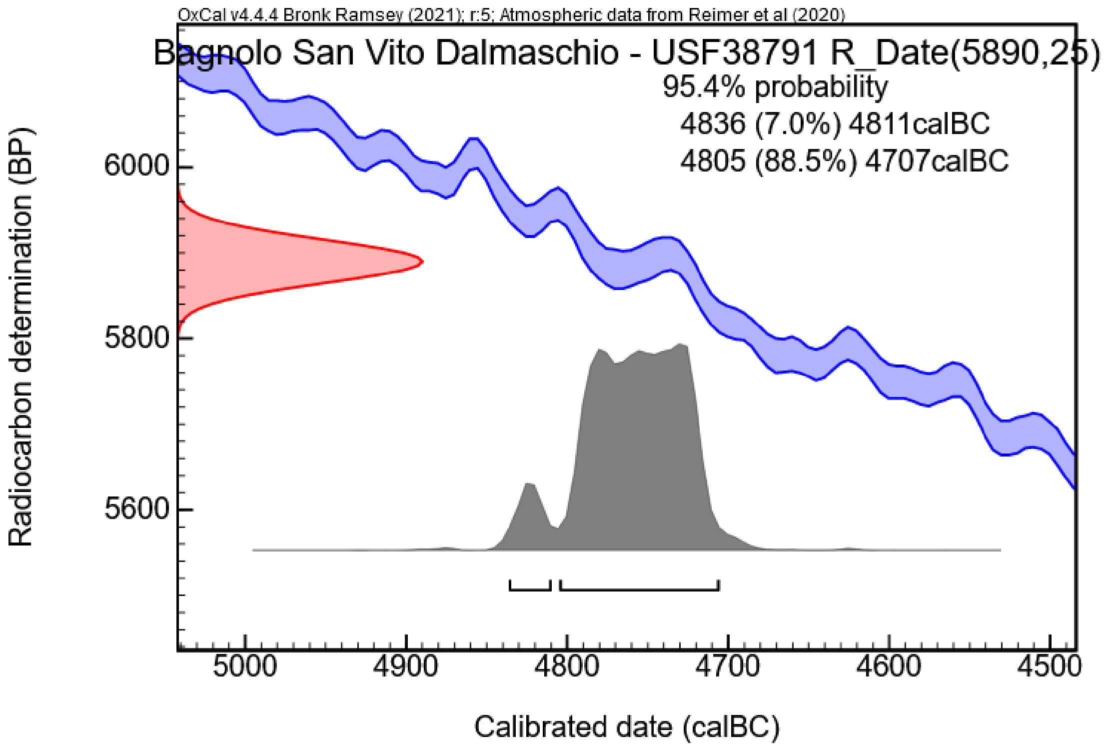

Figure 3.2: Bagnolo San Vito Dalmaschio tomb 1 single plot

Additional Issues with Radiocarbon

Some of the more notable publications in recent years have been focused on issues surrounding sample types, calibration sequences, costs, and sample preparations pertaining to contamination of archaeological samples (Adolphi, et al., 2017; Becerra-Valdivia, et al., 2020; Blaauw and Christen, 2005; Guilderson, et al., 2005; Parkinson, et al., 2021). The use and utility of AMS technology has continued to develop and is largely undisputed in its reliability to provide accurate and precise dates of ancient organic samples. This trust is built by routine blind comparative studies of the same material submitted to multiple laboratories to gauge the reliability of each laboratory and to detect possible issues before they interfere with large and expensive research projects (Beramendi-Orosco, et al., 2006; Boaretto, et al., 2002; Jackson, et al., 2015; Pearson, et al., 2020). Traditionally radiocarbon instrumentation has only been housed and made available on large research campuses throughout the country like those at the University of Arizona and the University of Georgia. Within the past few decades however, independent research firms such as BETA Analytic and Direct AMS have emerged as industry competitors to campus laboratories (Boaretto, et al., 2002). However, the use of traditional research laboratories or independent contracting companies remains the researcher's preference. A major impetus for the creation of multiple laboratories both public and private is the cost for radiocarbon services which average anywhere from $300-600 dollars or more per sample for AMS and can be variable based on laboratory and number of samples with batch discount options (Wood, 2015). Having the ability to choose a laboratory for radiocarbon sampling typically involves a combination of previous user trust or reputation and price. Cost-per-sample can become extremely important when research projects, such as the current project, involve multiple radiocarbon dates or the production of radiocarbon models of time-periods, cultures, and settlement patterns.

Beyond the overall cost and reputation of independent and private labs the types of radiocarbon samples have been a consistent topic of debate among scholars. Many different types of organic remains occur on archaeological sites, to include plant remains such as seeds and burnt cobs or husks, human and animal bones, wood and charcoal, and shells. Some of these materials are relatively straight forward to prepare for radiocarbon dating and remain relatively unchanged by diagenetic forces in the environment. Plant remains, seeds, shells, and bones are among the materials preferred by scientists for their ability to deliver reliable dates, due to their resilience within the lithosphere after death (Taylor, 2014). However, wood and charcoal have often been used, especially early in the development of radiocarbon dating techniques and have often come under fire for issues surrounding their ability to absolutely date archaeological features, layers, and sites (Becerra-Valdivia, et al., 2020; Blaauw and Christen, 2005; Schiffer, 1986). One of the primary issues with wood samples is known as the "old-wood effect," or when the wood remains are of structures like houses or boats or burned wood now charcoal that represents the living tree itself and may not represent the period of its anthropogenic use (Schiffer, 1986). The result of the old-wood effect means that radiocarbon dates obtained from charcoal or wood represent the life of the tree itself, especially when trees that have since died or have fallen naturally are utilized by humans. Good examples of this are fallen trees typically used for fuel for fires. Utilizing fallen trees and drying out wood eliminated the need to fell the tree itself and saves time in collecting wood for cooking fires, furnaces, or hearths. Additionally, fallen trees are also extremely popular building materials for pile dwellings as they often are waterlogged and can be easily sunk into mudflats or ponds and lack bottoms and roots more slowly than green wood alternatives, preserving the life of the dwelling (Čufar, et al., 2015; Hafner, et al., 2020; Martinelli, 2014). This is important in the current study as many pile dwelling communities emerged during the Bronze Age in Northern Italy, but the development of the practice of producing pile dwellings began in the Late Neolithic and Early Copper Age (Martinelli, 2014). The old-wood effect can render wood and charcoal samples unreliable as proxies for dating practices, layers, and objects. Recent work; however, suggests that the old-wood effect can be mitigated by targeting short lived species for radiocarbon dating rather than longer lived hard-wood counterparts when available (Kim, et al., 2019). The current study only utilizes human bone for radiocarbon dating purposes so the "old-wood effect" will not affect the data. Additionally, all chemical preparation methods for the human bone collagen utilized to obtain ^{14}C dates, discussed in materials and methods, did not introduce any modern carbon into the samples. Lastly, all radiocarbon dates obtained from skeletal materials in the current study were analyzed via AMS technology and will be compared later with previous Italian Neolithic AMS and non-AMS ^{14}C dates, with respect to laboratory offsets and precision as described above.

STABLE ISOTOPES IN HUMAN BONE

In the use of stable isotopes to construct human and animal dietary profiles, the adage "you are what you eat" is most apt in describing how isotopic ratios are translated from human and animal osseous remains to measurable and understandable values. Applying the key biological principles of photosynthesis, trophic levels, and the water cycle allows researchers to appreciate the diversity in environmentally and animal derived isotopic values and those extracted from human bones, described more below. The consumption of food is a basic biological function that must be carried out by humans and animals to meet the metabolic needs required to produce energy and sustain life and manage bone and other tissues with blood supplies. Archaeologists are interested in not only what was consumed, but how reflective the consumed foods are of the surrounding natural environment or the anthropogenic environment. A variety of direct sources of data, to include animal and plant remains, organic residues from pottery and lithics, and coprolites and soil sediments have been utilized to reconstruct human diets. Additionally, indirect evidence from human skeletal remains, such as paleopathological conditions and biomarkers, dental wear, and biomechanical entheseal changes as well as iconographic and written sources and ethnographic observations of modern populations can also help inform on past human diets.

The foundation of stable isotopic methods in archaeology certainly has its roots in the radiocarbon revolution and the popularization of mass spectrometers utilized to measure their abundance in a variety of materials. However, similarly to radiocarbon, stable isotopic research has evolved into a niche of its own in archaeology and often functions alongside chronological reconstructions provided by radiocarbon, but since the very first studies in the 1970s have been leveraged to reveal ancient diets and provenience human remains (van der Merwe and Vogel, 1978; Vogel and Van Der Merwe, 1977). These early pioneering studies have significantly increased the precision in which archaeologists are able to characterize the diets and adaptations of past populations when compared with the traditional methods mentioned above. This section will focus specifically on specific stable isotopes of carbon, nitrogen, and oxygen, and how they are used in the production of dietary profiles of humans and animals as well as mobility and provenience studies.

Skeletal Biology

The foundation of isotopic theory in bioarchaeology is grounded in skeletal biology and the molecular framework of skeletal tissues. Bone is the primary component of the human skeleton and is comprised of two primary tissues, the first is a mineralized portion of bone called hydroxyapatite ($Ca_{10}(PO_4)_6OH_2$) and the second is a long chain carbon molecule known as collagen comprised of carbon, hydrogen, nitrogen, and oxygen (Katzenberg and Waters-Rist, 2019). Bone apatite is constructed from two main minerals, calcium and phosphorous, which combine with bone collagen, a fibrous matrix of four amino acid chains, to form bone. Collagen is not just found in bone, but is a prominent extracellular structural component of cartilage, tendons, ligaments, and skin (Burr and Allen, 2019). Additionally, tooth roots are comprised of a material known as dentin, which is similar to bone, but is calcified after formation and is slightly more mineralized than bone, but less than tooth enamel. Tooth enamel is a specialized tissue that caps the tooth roots (dentin) that is heavily mineralized with about 96% of its composition being hydroxyapatite and only 3-4% organic (Hillson, 1996).

Tooth roots are covered by a connective tissue called cementum, that is highly organic and is responsible for securing the tooth in the sockets of the alveolar processes of the mandible and maxilla respectively (Hillson, 1992). The cementum is innervated by nerves and a vascular network that penetrates the tooth root within a hollow space known as the pulp cavity (Burr and Allen, 2019). Critically, tooth dentin and hydroxyapatite are both avascular, meaning that neither tissue remodels, or replenishes both hydroxyapatite and collagen matrices at regular intervals, and thus the molecular structure functions as a time capsule, only reflecting the time period the tissue was formed. Bone apatite and collagen have vascular networks and thus undergo constant iterations of breakdown and buildup known as remodeling (Burr and Allen, 2019). Archaeologically, the vascularization of bone tissues is important in understanding what isotopic values derived from those tissues represent. Specifically, stable isotope values obtained from tooth enamel and dentin will represent adolescent dietary histories, but bone collagen and apatite will reflect primarily the diet of the last decade of life(Pollard, 1998; Tykot, 2004). Trabecular or spongey bone found in the ends of long bones and medullary cavities, does remodel faster than cortical bone, which is found along long bone shafts and covering bone. The average remodeling rate is about 10 years but can vary depending on the composition of a sampled bone (Burr and Allen, 2019). These reservoirs of stable isotopes are particularly useful in answering archaeological questions relating to childhood vs. adult diets, sex-based differences, socioeconomic status, weaning cessation, stress events, and provenience and mobility. Without a vascular network in bone, injuries to bone would be unable to form boney calluses and heal; however, the avascular nature of dentin and enamel means that damage to either tissue will not repair and could become infected if not removed or treated (Burr and Allen, 2019; Hedges, 2002). Together, hydroxyapatite and collagen function to provide bone its rigidity and strength, and its plastic and elastic traits respectively. All together about 70% of bone is hydroxyapatite, 20% is collagen, and the other 10% is a mix of other proteins, fatty acids chains, and water (Burr and Allen, 2019).

Bone collagen and dentin both contain molecular carbon (~35%) as well as nitrogen, hydrogen, oxygen, and sulfur (~11-16%) (Katzenberg and Waters-Rist, 2019). Primarily bone will allocate a larger percentage of essential amino acids (diet derived from proteins) to the formation of bone collagen and dentin, but when diets are low in protein sources, the body will incorporate higher percentages of carbohydrates and lipids, which can diminish the effectiveness of collagen in bone (Ambrose and Norr, 1993). An example of the effect of compromised collagen in bone is a condition known as scurvy or vitamin C deficiency, which disrupts the formation of bone collagen, leading to brittle bones and increased risk of injury (Brickley and Mays, 2019). Non-essential amino acids play a lesser role in collagen formation, as they are naturally synthesized by our bodies, but in high protein diets, research has shown that the body will allocate non-essential amino acids from the diet to bone as well (Clementz, et al., 2009; Schoeller, 1999).

Bone apatite contains both carbon and oxygen within an inorganic mineral matrix. The apatite is formed and remodeled in life primarily through dissolved bicarbonates and carbon dioxide originating from digested proteins, carbohydrates and lipids (Krueger, 1991). Bone apatite formation will mobilize amino acids when diets are extremely protein heavy, but primarily reflect the whole diet given the primary incorporation of carbon derived from carbohydrates and fats (Ambrose and Norr, 1993; Tykot, 2018). The oxygen contained in hydroxyapatite is bound in either structural carbonate (CO_3^-) or phosphate (PO_4^-), with the later containing a higher percentage, but requiring more intensive chemical preparation methods to isolate the oxygen for processing on a mass spectrometer (Bryant, et al., 1996; Chenery, et al., 2012). The oxygen bound within the structural carbonate is more accessible via weak acid dissolution, covered in more detail in materials and methods. Structural phosphate only binds oxygen from enzyme reactions and body water, while structural carbonate binds oxygen from dissolved bicarbonates, dissolved carbon dioxide, and body water (Bryant, et al., 1996). Oxygen found in both boney reservoirs will reflect both meteoric water sources, primarily, and water contained within food stuffs.

Lastly, sample preparation methods for these various boney tissues have been developed and quality tested specifically to address issues originating from the burial environment, mainly diagenesis. Human bone when in contact with the soil can be physically, chemically, and biologically changed during the decomposition process (Hedges, 2002). The effects of these decomposition processes can impact the preserved isotopic ratios reflective of those during life. As bone degrades it is exposed to a variety of contaminants, such as soil carbonates and humic acids, that can result in losses in apatite and collagen integrity (Eiler, et al., 2018; Lopez-Costas, et al., 2016). A decomposing body is a source of nutrients to the surrounding environment including plants, microorganisms, and animals, where the bodies soft and hard tissue are recycled into the living biomass. Micronutrients like carbon and nitrogen are leached into the soil by numerous bacteria and fungi species, which can result in significant alterations to isotopic ratios (Damann and Carter, 2014). Bone collagen that is tightly bound within deep cortical and dense trabecular structures typically remains unaltered and can accurately reflect the diet during life (Nelson, et al., 1986). Diagenetic changes to bone apatite primarily involve surface level interactions between soil carbonates and bone surfaces. Deeper layers of bone apatite protected by thick cortical and trabecular bone typically remain relatively unaltered (Sillen, 1989). Numerous studies and scientific methods for extracting true stable isotopic values from compromised bone samples have been shown to be successful at mitigating the effects of diagenetic processes in the burial environment (Brown, et al., 1988; Burman, et al., 2005; Koch, et al., 1997; Nielsen-Marsh and Hedges, 2000b; Sealy, et al., 2014; Szpak, et al.; Yoder and Bartelink, 2010). Human tooth enamel and dentin largely resist diagenetic changes in the burial environment and resist physical and chemical degradation, with tooth enamel remaining the most unaltered tissue (Kinaston, et al., 2019). Chemical preparation and evaluation methods outlined in the materials and methods chapter, seek to obtain true isotopic values from the boney tissues relevant to this dissertation.

Carbon

As previously discussed ^{14}C is useful to archaeologists and bioarchaeologists in determining the length of time an organism has been deceased and when active metabolic replacement of living ^{14}C ceases. Carbon also has two stable isotopic forms, that do not decay over time, that are critically useful in the reconstruction of dietary profiles of both ancient animals and humans, ^{12}C and ^{13}C (Katzenberg and Waters-Rist, 2019). Stable carbon isotopes in bone collagen have previously been shown to reflect natural sources through careful feeding studies utilizing animal proxies (Ambrose and Norr, 1993; DeNiro and Epstein, 1978). The relative ratio of $^{13}C/^{12}C$ in nature is low and thus standard delta notion (δ) expresses concentrations in parts per thousand (or parts "per mil" or ‰) in relation a standard value, typically obtained from the marine fossil *Belemnitella americana* which originates from the Pee Dee (PDB) limestone formation in South Carolina in the United States (Larsen, 2015b). The standard notation can be considered a scientific convenience that facilitates the communication and comparison of very small numbers, where multiplying returned isotopic values by 1,000 makes them easier to read. Typically, with lighter stable isotopes, especially carbon, nitrogen, and oxygen, the lightest isotope is usually more naturally abundant than the heavier isotope. The standard notation of isotopes can be explained in two brief formulas (Pollard, et al., 2007), the first representing the isotopic ratio itself, R, which is typically the proportion of a rare isotope to the most abundant:

$$R = I_{r(rare)}/I_{a(abundant)}, \text{ ex. } (^{13}C/^{12}C)$$

Delta notation (δ) is slightly more complex and represents the isotopic ratio of any given sample relative to a known standard (STD) with a known isotopic composition:

$$\delta \frac{sample}{stanard} = \frac{\left(\frac{(R_{sample} - R_{STD})}{R_{STD}}\right) \times 1000}{\left(\frac{R_{sample}}{R_{STD}}\right) - 1) \times 1000}$$

The delta notation, as formulated above, communicates that the ratio is reported in parts per thousand (‰) or "per mil", where the relative difference, in parts per thousands, is represented or reported between the isotopic ratio of the sample and standard (Pollard, et al., 2007; van der Merwe, 1982).

Biochemical analysis of carbon begins with photosynthesis and the three separate pathways in which specific types of plants, including agricultural crops, produce their energy. It is understood that three separate photosynthetic pathways exist within the biological world and include, the C_3 (Calvin-Benson), the C_4 (Hatch-Slack), and the CAM (Crassulacean Acid Metabolism), which allows different plants occurring in different environmental conditions to produce energy (Katzenberg and Waters-Rist, 2019). The first group, the C_3 plants, include trees, shrubs, tubers, and grasses that are typical of temperate environments. This group extends further into agricultural crops of special interest to archaeologists, to include wheat, barley, and rice, which make up a large portion of ancient and modern cereal crops (Tykot, 2018). The second group, the C_4 plants, include tropical grasses, sugar cane, amaranth, and chenopods that are typical of hot and arid environments. These also include widely used cereal crops such as maize (corn), millet, and sorghum, which are staple cereal crops that often followed the more temperate cereal varieties within populations transitioning to agriculture and whose spread across Europe, Africa, and Asia has been of interest to archaeologist for decades (Tykot, 2018). The CAM plants are largely succulents like cacti, that share overlapping growing conditions and carbon isotopic values with C_3 and C_4 plants. Carbon isotopic fractionation, or the partitioning of heavier vs lighter isotopes between coexisting phases, occurs kinetically because of differences in metabolism during each of these plant's photosynthetic pathways and is derived primarily by the treatment of the heavier carbon isotope (^{13}C) contained within CO_2 gas that is respired by plants. C_3 plants discriminate more against the heavier carbon isotopes than do C_4 plants resulting in C3 plants being more isotopically negative regarding the ratio between $^{13}C/^{12}C$. (Bender, 1968; Chisholm, 1989; Craig, 1954). The resulting fractionation is reflected in the natural ratios ($^{13}C/^{12}C$) of ancient and modern C_3 and C_4 plants respectively, with C_3 plants being more naturally depleted in ^{13}C, the resulting carbon values result in an average of -26.5‰, while C_4 plant carbon values reflect less ^{13}C depletion and average about -12.5‰ (Figure 3.3) (Tykot, 2018). CAM plants, as previously mentioned, overlap both C_3 and C_4 plant values, which is controlled primarily by environmental conditions where they are found (Tykot, 2018). Carbon fractionation is a critical factor in understanding first the bioavailability of carbon in the environment, and second the expressed values of tissue ratios obtained from consumers. Isotopic fractionation is a term that describes a gradient difference in isotopic values before and after a chemical reaction, such as photosynthesis or digestion (Figure 3.3) (Pollard, 1998; van der Merwe, 1982). Stable isotopes tend to fractionate by mass, called "mass dependent fractionation," whereas stable isotopes share the same chemical behaviors as the element, they differ in the rate at which reactions can occur due to their larger mass, thus the heavier the isotope the slower it will chemically react compared to lighter isotopes of the same element (Pollard, et al., 2007). The previously discussed differential treatment of ^{13}C

vs. ^{12}C in C_3 and C_4 plants is a good example of mass dependent fractionation. Fractionation occurs readily in the human gut and during the formation of tissues of intertest in archaeological studies such as bone collagen and apatite (Pollard and Heron, 2008a; van der Merwe, 1982). In bone collagen in particular, carbon values are often metabolically enriched due to fractionation by as much as +5‰ relative to the diet (Pollard and Heron, 2008a). Bone apatite is enriched by +9.5‰, and as much as +12‰ in large herbivores and humans (Tykot, 2018).

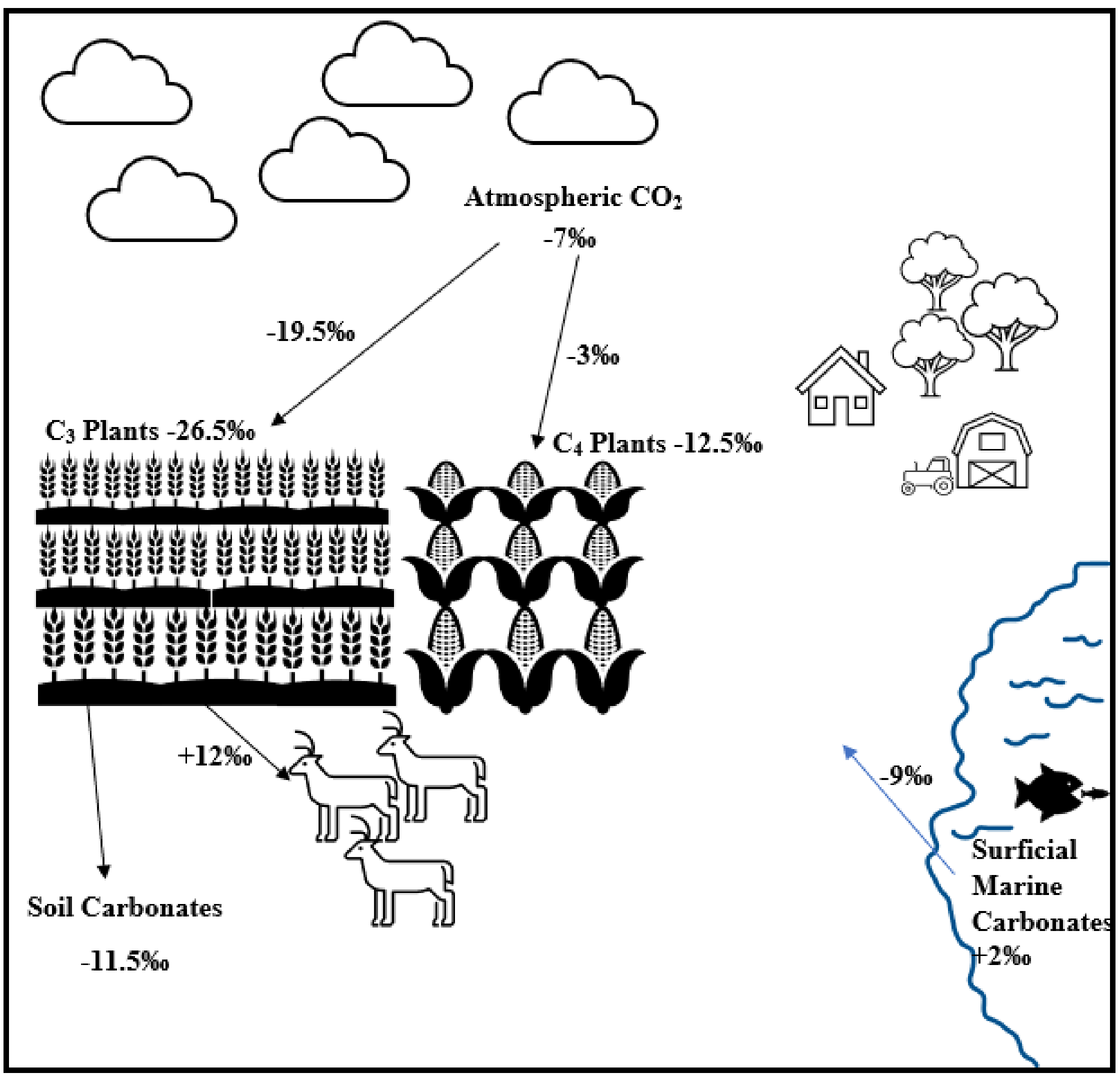

Figure 3.3: Illustration of the carbon cycle and carbon fractionation

Variation in carbon enrichment can occur due to the amount of protein vs. carbohydrates or fats in the diet or the amount of $\delta^{13}C$ biologically available to consumers (Tykot, et al., 2009). For example, the "canopy effect" or the effect of heavily developed or dense forest foliage on atmospherically available carbon can deplete atmospherically plant values due to indirect atmospheric mixing (Tykot, 2018). The canopy effect can also affect oxygen isotopic values, as discussed later in this chapter. As previously mentioned, bone collagen is primarily constructed and remodeled in life by primarily utilizing digested proteins resulting in collagen $\delta^{13}C$ values representing about 60% of the protein portion of the diet. On the other hand, bone apatite is constructed and remodeled utilizing a greater range of digested foods, which results in apatite $\delta^{13}C$ values being more reflective of the whole diet (Ambrose and Norr, 1993). Fractionation events caused by chemical reactions related to digestion are often referred to a "diet-tissue-spacing" and describe the overall enrichment or depletion of a given isotope within a tissue related to the dietary sources from which it is formed (France and Owsley, 2015). This means that the diet-tissue-spacing of $\delta^{13}C$ between human collagen and apatite samples, as mentioned above, is also a function of dietary sources, proteins vs. carbohydrates and fatty acids, that form tissues of interest (Tykot, 2018).

Marine plants typically have $\delta^{13}C$ that typically fall between that of C_3 and C_4 terrestrial plants due to the carbon reservoirs within marine environments consisting of dissolved bicarbonates and CO_2. Marine fishes and mammals typically have less negative carbon values than animals strictly feeding on C_3 based terrestrial plants, but freshwater fish have slightly more negative carbon values than that of terrestrial animals consuming C_3 plants (Figure 3.4) (Tykot, 2018). The $\delta^{13}C$ values typically become more enriched as the trophic level increases within marine environments (Katzenberg and Waters-Rist, 2019). However, simply examining the relationship between apatite and collagen derived $\delta^{13}C$ values respectively can aid in determining the primary source of carbon in the diet, either terrestrial or marine. This can be especially helpful when examining general dietary preferences between C_3 and C_4 plants.

Nitrogen

Like carbon, nitrogen ratios obtained from human and animal tissues have been shown to closely reflect the diet. There are two stable isotopes of nitrogen (^{14}N and ^{15}N), with the lightest being more naturally abundant (Katzenberg and Waters-Rist, 2019). The international standard for organic samples yielding nitrogen is Ambient Inhalable Reservoir (AIR) or atmospheric nitrogen (N_2), expressed in parts per thousand (‰) again in delta notation $\delta^{15}N$ (Pollard and Heron, 2008a). Plant and animal nitrogen values are largely determined by their trophic level or position within a local or regional food web. It is generally understood that as you progress through a food web, the producers or plants at the bottom of the web will have the lowest nitrogen values, while the consumers above become increasingly nitrogen enriched at each level (Tykot, 2018).

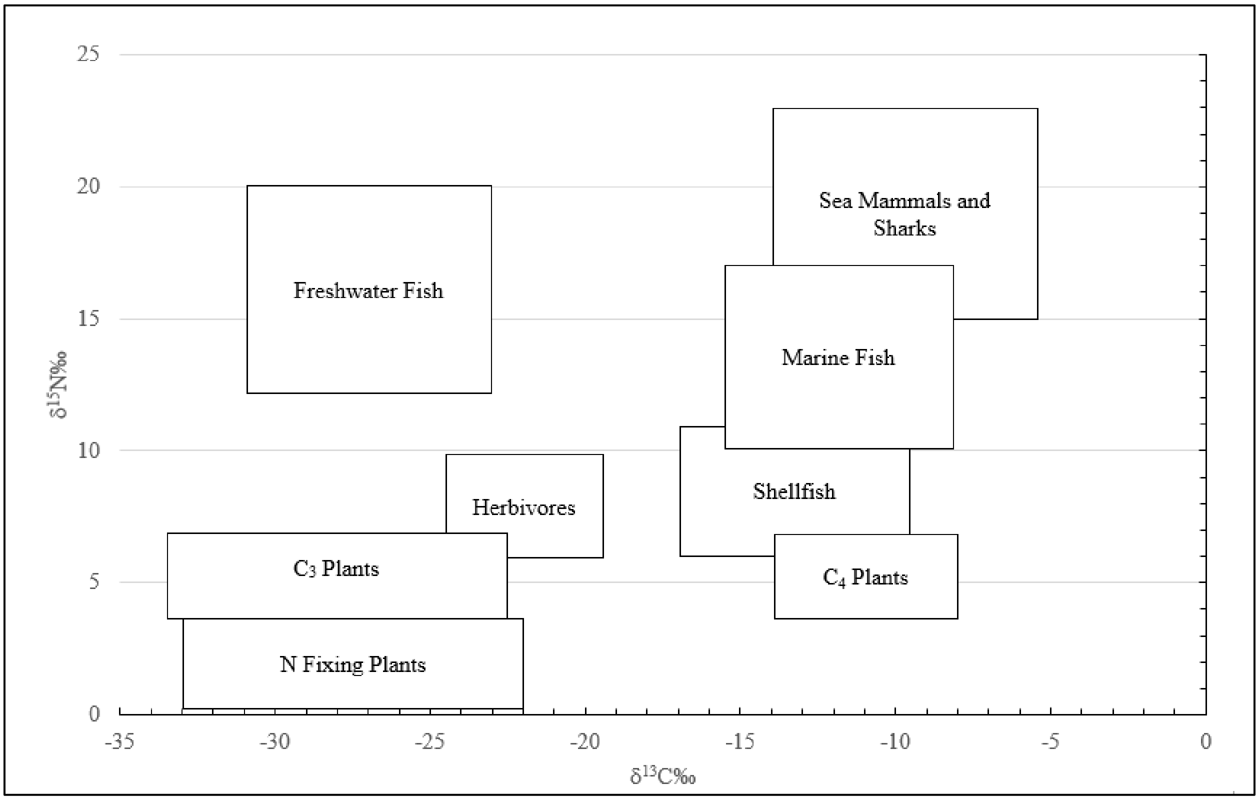

Figure 3.4: Isotopic food web illustrating general carbon and nitrogen ratios by consumer.

Isotopic fractionation between ^{14}N and ^{15}N primarily causes quantifiable differences in ^{15}N in particular as the heavier isotope, ^{15}N, reacts more slowly than ^{14}N, which allows for the greater rate of excretion of ^{14}N than ^{15}N in life (Pollard and Heron, 2008a; Schoeninger, 1985; Schoeninger and DeNiro, 1984). This results in the retention of more ^{15}N in consumers than what was contained in each consumed organism. At the producer trophic level, two groups (legumes and non-legumes) of plants utilize two different methods to obtain the nitrogen they need from the environment to carryout metabolic processes (Katzenberg and Waters-Rist, 2019). Legumes derive their nitrogen either directly from the air via symbiotic relationships with bacteria living among the roots of the plant and reflect a closer ratio with atmospheric nitrogen (Brill, 1977). Non-legumes or nitrogen fixing plants derive their nitrogen also through symbiotic relationships with bacteria, but uptake nitrogen released from decomposition of organic material in the soil (Brill, 1977). These plants have higher $\delta^{15}N$ values (+3‰) due to natural fractionation of nitrogen in the soil (Figure 3.4) (Larsen, 2015b). Fractionation during the natural decomposition or organic matter produces changes in the nitrogen reservoir through the leaching of nitrogen oxide, which incorporates the lighter ^{14}N isotope more frequently than the heavier ^{15}N isotope (Larsen, 2015b). This nitrogen-tissue spacing is commonly referred to as manuring or fertilizing. Natural manuring occurs via the typical growth and decay processes active in nature, allowing nitrogen fixing plants to thrive in areas with actively decomposing materials. Anthropogenic manuring with animal or plant manures that are high in nitrogen, typical of ancient societies, and more contemporary chemical fertilizers can further affect the producer tissue spacing of nitrogen values and result in higher consumer nitrogen values (Bogaard, et al., 2007; Fraser, et al., 2011; Treasure, et al., 2016). Terrestrial herbivores typically have $\delta^{15}N$ values about +6‰, while terrestrial carnivores average about +9‰ (Katzenberg and Waters-Rist, 2019; Schoeninger and DeNiro, 1984). Omnivores such as humans will typically have values between +6‰ and +9‰ depending on the composition of the diet (Figure 3.4) (Katzenberg and Waters-Rist, 2019). Animal feeding studies have also been conducted to determine nitrogen tissue spacing, with about +3‰ to +4‰ suggested as typical average trophic level enrichment for archaeological dietary studies (Ambrose, 2002; DeNiro and Epstein, 1981; O'Connell, et al., 2012). Marine enrichment appears to also follow the same average trend of +3‰ to +4‰ per trophic level increase (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984).

Marine plants can incorporate dissolved nitrates from seawater and are often slightly nitrogen enriched when compared with terrestrial plants (Walker and DeNiro, 1986). For the most part, marine food webs are much more complex than terrestrial ones with many more consumers within food chains leading to greater nitrogen enrichment of marine foods on average than terrestrial foods. Marine plants will have the lowest values (sea weeds and grasses) at 2‰ to 5‰, followed by shellfish (mussels and abalone) at 8‰ to 10‰, and marine fishes at 11‰ to 16‰ (Figure 3.4) (Larsen, 2015b). Marine mammals would have the highest nitrogen values at the top of the food chain (seals and large fishes), between 11‰ and 23‰ depending on the species (Larsen, 2015b). It is expected that humans consuming either marine or freshwater fishes or shellfish will be significantly more nitrogen enriched (~12-22‰) compared with a more terrestrial diet rich in terrestrial proteins (~6-10‰) (Schoeninger, 1985; Tykot, 2004).

Nitrogen values can be impacted by several factors such as climate, rainfall, altitude, salinity of the soil, and fertilization, as previously discussed (Ambrose, 1991; Fraser, et al., 2011; Tykot, 2018). Typically, hot, and arid environmental conditions can inhibit nitrogen fixation in the soil, leading to depleted nitrogen values in the producer plants (Ambrose, 2002). In coastal environments sharing hot and humid conditions, plants will often substitute soil nitrogen for nitrates bound in sea spray, which can lead to plants reflecting more mixed marine and terrestrial values (Göhring, et al., 2017). Conversely, temperate forest areas retain lower nitrogen values due to increased nitrogen mobilization from abundant nitrogen fixing plants (Tykot, 2018). Some specific drought tolerant plant species have specifically adapted to secrete nitrogen depleted urine, which can increase $\delta^{15}N$ values compared to more water dependent species (Ambrose, 1991). Understanding the environments from which the plants and animals consumed were potentially sourced can inform researchers as to expected variations in nitrogen values relating to derived $\delta^{15}N$ values from human and animal bones. Ancient climate data obtained from soil and ice cores can supplement archaeological investigations into paleodiet by providing evidence for specific environmental conditions reflective of the time period of study.

Oxygen

Oxygen has three naturally occurring stable isotopes (^{16}O, ^{17}O, and ^{18}O), with the lightest being the most abundant, followed by ^{18}O and ^{17}O, with the latter having the lowest natural abundance (Katzenberg and Waters-Rist, 2019). The standard notation for oxygen isotopic ratios is $^{18}O/^{16}O$ ($\delta^{18}O$), with ^{17}O typically not included due to its extremely low natural abundance (Katzenberg and Waters-Rist, 2019). As previously mentioned, oxygen is bound within both hydroxyapatite structural carbonate and phosphate respectively and specific extraction methods for each have been independently developed (Bryant, et al., 1996; Chenery, et al., 2012). Thus, oxygen isotopes are only extracted and studied from inorganic or mineralized tissues, with bone hydroxyapatite having the ability to remodel or reflecting water sources from the last decade of life and tooth enamel and dentin reflecting adolescent sources of water only (Katzenberg and Waters-Rist, 2019; Luz and Kolodny, 1989). Between these two tissue sources, oxygen isotopes are utilized by archaeologists primarily to study seasonality, such as the movements of animals between higher and lower altitudes, anthropogenically known as transhumance (Balasse, et al., 2002; Makarewicz, 2017; Zavodny, et al., 2014), mobility of individuals between childhood and late adulthood (Bentley, 2013; Gregoricka, 2021), including provenance or region of origin from enamel and dentin, and diet, to a lesser extent than carbon and nitrogen isotopic systems.

These studies are possible because oxygen isotopic values typically reflect meteoric water values available to humans during life that have been digested and become a major component of body water (Katzenberg and Waters-Rist, 2019). This often includes water from anthropogenic sources such as cooking or dairying, as those activities and animals are typically sharing the same sources water also utilized for drinking. However, cooking can result in $\delta^{18}O$ enrichment due to increased evaporation during boiling (Daux, et al., 2008). Daux et al. (2008) found that raw food water and cooking water fractionation values could range from 1.2‰ to 6.2‰, with a typical maximum enrichment of 1.1‰ that accounts for balanced diets of cooked proteins and cereals and raw fruits and vegetables (Daux, et al., 2008). These fractionation events can be muted, because humans are not only consuming cooked foods, they are also consuming non-boiled meteoric water and raw foods, with human values becoming more reflective of those consumed sources rather than cooked signatures alone (Chesson, et al., 2008). Oxygen isotopes are naturally environmentally variable due to mass dependent fractionation events within the water/precipitation cycle and reservoir effects in lakes, ponds, and other natural water bodies. During the water cycle, as surface water is evaporated into the atmosphere to form clouds and later falls as precipitation, lighter oxygen isotopes tend to evaporate more quickly than the heavier isotopes (Wright, 2017). This process can be affected by extraneous factors such as humidity, temperature, and increasing latitude (Longinelli, 1984; Pederzani and Britton, 2019). This is the first instance of mass dependent fractionation of oxygen isotopes, where the second and arguably the more critical event occurs when atmospheric water falls as precipitation. As newly formed weather systems that typically form over oceans and larger bodies of water move over land, they release trapped water as precipitation. Oxygen isotopes bound within water molecules of precipitation are also distributed within precipitation but fractionate depending on their mass with the heavier isotopes preferentially falling in precipitation faster than the lighter isotopes as precipitation producing systems move across land (Dansgaard, 1964; Katzenberg and Waters-Rist, 2019). This results in more positive isotopic ratios within coastal environments and more negative values in higher latitudes and mountainous areas as ^{18}O becomes more depleted (Dansgaard, 1964). Environmental testing stations for meteoric water sources, both from natural reservoirs and contemporary tap water, are continual monitored and measured to produce oxygen isoscapes, or interpolated maps of oxygen isotopic values for a given region between each monitoring station (Bowen, 2010). In Italy in particular, oxygen isotopic values are particularly useful in Alpine and near Alpine environments like the Po Valley, due to the extreme and sometimes rapid changes in elevation (Cavazzuti, et al., 2019; Longinelli and Selmo, 2003; Trentacoste, et al., 2020).

Anthropogenic sources of mass dependent fractionation have also been well documented, especially the reservoir effect, where oxygen values can become depleted or enriched depending on the source (Luz, et al., 1984; Pederzani and Britton, 2019). In water retaining reservoirs with little to no mixing or recharge from lakes and rivers, ^{18}O will naturally sink lower than ^{16}O with surface water becoming more depleted and deeper water becoming more enriched (Pollard and Heron, 2008a). This effect can also occur in cisterns where ^{18}O enrichment occurs at the bottom of the container (Wright, 2017). The reservoir effect can impact oxygen isotopic values of bioapatite, for example if water is scooped from the surface of a reservoir vs. obtained from a spout or outlet on the bottom of a cistern (Wright, 2017). Oxygen isotopic values can also be affected by digestion, where metabolic fractionation can occur between body water sources and bioapatite (Longinelli, 1984; Luz, et al., 1984; Pollard and Heron, 2008a). This typically occurs due to the slower reactivity of the heavier ^{18}O, allowing more of the heavier isotope to be retained, enriching body water compared to ingested water (Pollard and Heron, 2008a). More of the lighter ^{16}O isotope is lost to the environment via urination, sweat, and exhalation than ^{18}O (Luz, et al., 1984). The relationship between specifically between structural phosphate vs. carbonate appear to be linear with meteoric water, as the structural phosphate is less effected by enzyme reactions and extracellular oxygen sources and is more reflective of body water (Longinelli, 1984; Pollard and Heron, 2008a). Thus studies, such as the present study, that obtain oxygen isotopic values from structural carbonate, should utilize available conversion equations to convert carbonate values, first to phosphate $\delta^{18}O$ and second to drinking water values. This way oxygen isotopic values are reflective of meteoric values by accounting for metabolic fractionation and can be more easily compared to locally available oxygen isoscapes.

A few environmental standards exist for oxygen isotopes typically depending on the material being studied which include the Vienna Standard Mean Ocean Water (VSMOW) which are derived from purified water sources to reduce to possibility of measuring dissolved carbonates, the previously mentioned marine fossil *Belemnitella americana* which originates from the Pee Dee (PDB) limestone formation in South Carolina in the United States (Pollard and Heron, 2008a; Wright, 2017). In this dissertation, PDB and VSMOW are used because bone and tooth root samples extracted oxygen from the carbonate portion of hydroxyapatite, with the values later converted to VSMOW and phosphate values via standard conversion equations covered in the materials and methods chapter.

Lighter elements such as oxygen and hydrogen create a greater concern for diagenesis in the burial environment because they react easily in the presence of many different compounds and molecules (Hedges, 2002). This is especially important because within the carbonate portion of bone oxygen is more weakly bound to calcium and hydrogen than the oxygen found within the phosphate portion of hydroxyapatite (Chenery, et al., 2012; Nielsen-Marsh and Hedges, 2000a). The weaker bonds within structural carbonate are more easily broken in the burial environment by weak acidic leaching and can result in mixing of burial oxygen and structural carbonate oxygen, especially on the surface of bone (Nielsen-Marsh and Hedges, 2000a). Tooth enamel and dentin largely resist chemical and physical degradation in the burial environment and as a result often exhibit much less diagenetic change (Kinaston, et al., 2019; Lee-Thorp, 2008). For this reason, both sampling and processing procedures have been developed to reduce the effects of diagenesis in bone, which have been utilized for this dissertation and outlined in the materials and methods chapter.

CONCLUSION

Much of the scholarly work surrounding isotopes in archaeology has been focused on differentiating food sources in ancient populations, with a particular emphasis on tracing the origins and spread of C_4 plants, millet in the old world and Asia, and maize in the new world and South America (Schoeninger, 2009; Tafuri, et al., 2009; Tafuri, et al., 2018; Tykot, 2006). As previously discussed, only a few cereal crops, millet, maize or corn, and sorghum, follow the Hatch-Slack of C_4 photosynthetic pathway and can be easily distinguished from the larger suite of C_3 domesticated varieties of wheat and barley. In addition, most of the terrestrial vegetation also potential available as food sources, including most fruit or nut bearing shrubs and trees, all follow the Calvin-Benson photosynthetic pathway. Within the C_3 group, however, there can be slight variations in ^{13}C values between wheat and barley and nuts, fruits, and vegetables that can be further elucidated by combining regional palaeobotanical data with stable isotopic values. These natural variations combined with natural shifts in cereal crops in ancient populations between wheat and barley to millet or maize dominated agricultural systems, provides the basis for comprehensive isotopic studies that can easily identify these changes in carbon sources. Beyond C_3 and C_4 plant differentiation, stable and radiogenic isotopes have also been heavily employed in isolation and in concert with other evidence in archaeological studies which examine trophic levels and mobility of human populations. Bioarchaeological research is simply one piece of a larger archaeological puzzle, as previously discussed through the biocultural approach, skeletal data is additive to the scholarly understanding of the past and must be framed in way that contributes to the larger region and time period.

CHAPTER FOUR:

ARCHAEOLOGICAL CONTEXT

INTRODUCTION

This chapter summarizes the ecology and environments of the Neolithic and Copper Age peoples of Northern Italy. The Po Valley is known as one of the world's great "bread baskets" and remains a highly agriculturally productive area in modern times due to its unique topography, climate, and ecological zones. Further, this chapter explores how farmers first arrived and dispersed across the Italian peninsula and mainland through a review of the Anglo-American and Italian literature sources. Early archaeological cultures are briefly summarized here from the wide variety emerging in the early Neolithic to the more wide-spread definitive utilitarian into the Late Neolithic and Early Copper Age. Finally, typical mortuary treatments of the central Po Valley specific to the Early and Middle Neolithic and the Early Copper Age are explored. Lastly, previously constructed bioarchaeologies from the primary literature are also discussed, including the sites and tombs of the project area surrounding Mantua, Italy.

ENVIRONMENT

The dynamic environments of the north required newly permanent settlements and residents to adapt their subsistence practices to meet seasonal and variable environmental differences. Lines of evidence explored here, but are not limited to, distinctions in burial practices, skeletal lesions, and compositions of the zooarchaeological and archaeobotanical records documented at key sites throughout the region. The dissertation project region is contained within the Central Po Valley, in Northern Italy, from which human burials were recovered from within 10 kilometers (km) of the modern town of Mantua. Mantua, along with other contemporary Italian cities and provinces, will be used as references throughout the dissertation, to orient the reader on the ancient landscape (Figure 4.1). The region of interest is characterized by the Po River, which is in the center of the northern valley, and is bordered to the north by the rugged Alps, and the south by the ancient Apennine Range, the mountainous spine of peninsular Italy. The Friuli Plain is an additional area to the northeast, partly geographically separated from the Po Valley, and makes up most of the modern region of the Friuli-Venezia Giulia. This area forms a critical land-based link between the Po Valley and the Balkan region. The dissertation will focus on the rich alluvial landscape enriched by the Po and its many tributaries, the two ancient mountain ranges, and the bountiful natural resources available to the last hunter-gatherers and the first agriculturalists that lived there.

The Po River

The Po River flows west to east, beginning in the western alpine foothills southwest of Turin and bisects the landscape, eventually emptying into the Adriatic Sea just south of Venetian Lagoon. Several tributaries feed the Po River, flowing both north to south from the Alps and south to north from the Apennine Range. Mantua and the project sites rest along one of these capillary tributaries, the Mincio River, which flows from Lake Garda, south to the Po within the Lombardy region (Figure 4.1). The modern course of the Po River is largely a product of human agricultural activity that dates back to the Neolithic and continues to the modern day (Houston, 1967; Wiman, 2013). Over the course of approximately 6000 years, humans have tamed the course of the river by constructing a vast network of irrigation canals on both the tributaries and the river itself. By controlling the flow of water entering and leaving the system, humans have been able to minimize previously frequent seasonal floods and dry out the vast alluvial fan, which prior to anthropogenic hydroengineering was a lacustrine wetland dotted with several raised alluvial terraces (Vannière, et al., 2013). Prolonged periods of flooding resulted in an enormous amount of sedimentation and infilling of the ancient valley, known as the "Apennine or Po Foredeep," between the end of the last glaciation and the modern period (Houston, 1967; Starnini, et al., 2017). The result has been a vast deposit of arable land, ripe for agricultural production for crops favoring both free draining conditions, like those found on the alluvial terraces, and soggy conditions, found throughout the valley. The Neolithic agriculturalists were largely confined to free draining crops, such as wheats and barley, and thus preferred the alluvial terraces nearest the Po and its tributaries for settlements and agricultural areas. These types of areas would have been abundant around Mantua during the Neolithic (Zanon, et al., 2019).

Figure 4.1: Map of relevant regions and rivers to current project

Eco-zones, Climate, and Natural Resources

Italy contains a wide variety of landscapes and ecozones that provide ample and diverse opportunities for resource exploitation. These distinctive environments provide a mixed array of microclimates and stark regional differences, with the strictest explanation invoking basic topography and geography, but bioculturally highlighting regional biodiversity and the seasonal availability of wild resources. Approximately three-quarters of the land can be described as hilly or mountainous, only one-quarter of the area is semi-flat lowland plains suitable for agricultural production (Houston, 1967). This characterization also includes Sicily and Sardinia, the major islands of modern Italy. The first farmers arriving to the Italian Peninsula would have valued lowland environments that contained easily tillable and free draining soils with access to fresh water and open areas for planting crops and foddering animals (Barker, 2005; Krauß, et al., 2018). However, later in time, the narrow high-altitude pastures become critical refuges for spring and summer pasturing (Barker, 2005; Carrer, 2015; Zavodny, et al., 2014). Three such areas existed in antiquity and proved attractive to early Neolithic farmers: the Tavoliere in southeastern Italy, the Catania plains of Sicily, and the Po Valley in the north. In addition to these inland environments, no part of the modern country is more than 150 miles from the sea (Houston, 1967). The rocky shorelines of the peninsula, as well as the Alpine and Apennine ranges, are home to many karst caves that have witnessed variable seasonal and annual human occupation beginning in the Middle and Upper Paleolithic periods (Angelucci, et al., 2009; Mussi, 2002). The mountain ranges and the piedmont regions contain a variety of mineral and stone resources such as flint, greenstone (jadeite and nephrite), chert, obsidian in the far eastern alps, and metals like copper and iron (D'Amico, 2005; Tykot, et al., 2005; Williams Thorpe, et al., 1979). The most well-known of these troves are the flint outcrops in the Lessini Mountains, just southeast of modern Verona, that have been exploited as early as the Lower Paleolithic by *Homo erectus* and *Homo neanderthalensis* through contemporary time when Napoleon sourced gun flints for his army from the area (Barfield, 1999; Barker, 1985; Longo and Giunti, 2010; Migliavacca, et al., 2015).

Considering this regional biodiversity, such unique ecozones allowed Mesolithic hunter-gatherers to develop a subsistence economies that were broad in terms of potential prey selection, and diverse in terms of actual species predated (Barfield, 1971; Mussi, 2002). Beginning in the late post-glacial Mesolithic period, the Adriatic Sea was beginning to in-fill towards the north, and form the modern coastline (Houston, 1967; Mussi, 2002). The ancient coastline was much further south, creating a larger expanse of land connecting the western Balkans with what would become the Italian Peninsula, known as the Great Adriatic Plain (Bertolini, et al., 2016). The Paleolithic and Mesolithic estuary environment provided by these prehistoric exposed areas, that now form the bottom of the near-coastal Adriatic Sea floor, would have provided an additional resource area for these earliest human groups (Fontana and Visentin, 2016). Opposite the Adriatic, the Ligurian Sea and coast, which is considerably steeper than the Adriatic coast, only differed slightly prehistorically from the modern coast due to a negligible rise in sea level along the rocky shoreline over time (Barfield, 1971; Mussi, 2002). During the melt period of the last glacial maximum (LGM) when the infilling of the Adriatic occurred, Mesolithic hunter-gatherers would have been sequestered onto the Friuli plain region, the Central Po Valley, and the karst caves in the east, all of which would have been much further inland were becoming coastal environments because of sea level rise (Spataro, 2009). Extremely large glacial lakes, such as Lake Garda, filled and created sub-tropical microclimates along the immediate southern shorelines, which also provided additional food rich environments and a potential means for transportation for Mesolithic peoples in an out of the high-altitude alpine environments. The narrowing of this region provided greater access to both marine and higher latitude species simultaneously (Binder, 2000). Ultimately, the mixed Mesolithic subsistence economies preserved in the occupational horizons found in the karst caves, inland piedmont, and lowland camps and have provided a clear picture of the earliest food gathering prior to the arrival of the first Neolithic wave.

In terms of climatic change, the period directly succeeding the LGM has been documented as one that drastically shifted the previous cool and dry climate to one that was warmer and wetter (Furlanetto, et al., 2018; Tomasso, et al., 2019). Italy is characterized as sub-continental and sub-Mediterranean and on average is more humid than other Mediterranean localities (Houston, 1967). As previously noted, sea levels were rising, rivers were rapidly moving melt waters into the seas, and more moisture increased the average amount of annual rain fall in the Po Valley to between 24 and 40 inches per year, with the most precipitation in mid-autumn and the least in mid-summer (Furlanetto, et al., 2018; Houston, 1967). Areas previously on the fringes of glaciers were now experiencing rapid green forest growth (Badino, et al., 2018) and Pleistocene cold-climate megafauna such as the bison and *megaloceros* were abandoning the region, with the latest evidence found in Emilia Romagna at *Settepolesini di Bondeno* approximately 11,000 years ago (Petronio, et al., 2007). Spurred by climatic change, the disappearance of megafauna at the end of the Pleistocene allowed lowland species to readily populate the new-growth forests. Red and roe deer, and wild boar were the most numerous, being found as sites across the entire region (Barfield, 1971; Barker, 1985; Conwy-Rowley, 2003; Pearce, 2013). In addition to the large cervids and sus species, the auroch has also been documented well into the Neolithic and Early Bronze Age at sites like *Barche di Solferino* (Petronio, et al., 2007). Smaller species including hares, hedgehogs, beavers, weasels, and squirrels were also present and accompanied by large predators that followed these prey animals into the valley, including brown bear, foxes, wolves, badgers, and lynxes

(Petronio, et al., 2007; Romandeni, et al., 2015). While the lowland species made their way into the expanding valley, taxa that prefer colder temperatures were being sequestered into more mountainous and high-altitude regions in the Alps and Apennines such as the ibex, chamois, marmot, martin, and mountain hare (Loison, et al., 2003; Petronio, et al., 2007). As temperature fluctuated, leading to seasonal extremes, high-altitude species could be found lower in the piedmont and valley during the winter months, while low-land species could be found at higher latitudes in spring and summer months, grazing on alpine grasses and wildflowers (Barker, 1985). In addition to shifting terrestrial fauna, freshwater fishes, such as European eels, carp, and sturgeon, and shellfish such as limpets and clams could be found in large numbers in the Alpine Lakes, the Po River, and small streams (Barfield, 1971; Ravazzi, et al., 2013). The coasts maintained the most seasonal consistency with available shellfish, such as abalone and bivalves, and fishes such as European pilchard, grouper, and sea bream (Angelucci, et al., 2009; Barfield, 1971; Mussi, 2002).

The marked changes in terrestrial fauna coincide with dramatic shifts in vegetation, from largely sparse hardy pine forests and open grass land in the Pleistocene, to an increase in biodiversity, specifically and especially among hard wood trees and deciduous shrub plants in the Neolithic period (Mercuri, et al., 2015). These major shifts in vegetation on the landscape were primarily due to above-mentioned climate change between the late Pleistocene and Early Holocene (Tomasso, et al., 2019); however, as agricultural groups began settling in the Po Valley, the scale of anthropogenic influence on the regional biodiversity began to rival naturally occurring shifts in climate (Vannière, et al., 2008). Early Holocene vegetation included beech, oak, chestnut, poplar, hornbeam, and mixed evergreens along with classic Mediterranean shrubs and bushes, such as alder, juniper, rhododendron, and stunted beech (Mercuri, et al., 2015; Mussi, 2002). In addition to these species, spring-emerging alpine grasses and wildflowers also occurred along the narrow valleys in the highland Alps and Apennines (Barker, 1985). These seasonal resources were important to spring-foraging herbivores in both the lowlands and highlands, such as red deer and ibex respectively, and have become a major impetus for early transhumance of domesticated ovicaprines in the Neolithic and Copper Ages (Barker, 2005; Carrer, 2015; Putzer, et al., 2016). As humans began to formally cultivate the Po Valley and piedmont areas of northern Italy, ample palaeobotanical evidence shows a propensity for the use of fire to clear land for cultivation (Valese, et al., 2014; Vannière, et al., 2013). When the use of slash-and-burn methods of land clearance are combined with routine sourcing of hardwood species such as oak and beech for building materials, humans slowly decrease the density of slower-growing hardwood trees and increase the number of faster-growing evergreens like pines and furs (Vannière, et al., 2008). This trend is extremely prevalent in the Early Copper Age with the documented expansion and increase in hornbeam, potentially linked to the overall effectiveness of previous Neolithic groups clearing land via fire and also felling trees with abundant numbers of stone axes which in turn allowed less desirable species like hornbeams to expand (Zanon, et al., 2019). Overall, the transformation of the Po Valley into one of the most agriculturally productive regions in Europe began in the Neolithic, and permanently changed the landscape, its biodiversity, and topography.

The Last Hunter-Gatherers

Given the broad-sweeping environmental and ecological change previously discussed, the advent of agriculture and its subsequent impact on human lifeways and health is of critical archaeological importance. The Neolithic transition has been viewed by scholars as one of the seminal transitions in human history (Barker, 2006; Harris, 2003; Pluciennik and Zvelebil, 2008;

Price, 2000b; Shennan, 2018). It is categorized by a shift in human subsistence strategies away from pursuit hunting, opportunistic scavenging, and wild foraging to regular consumption of domesticated plants and animals. Previously, the variety of food resources encountered by hunter-gatherers was described as a broad spectrum of nutrient-dense and vitamin-rich seasonal varieties of terrestrial and aqueous proteins, and wild fruits, tubers, and plants (Barfield, 1971; Lewthwaite, 1986; Mussi, 2002). A highly mobile lifestyle was required to reach seasonally rich areas, which provided greater opportunities for successful hunting and foraging encounters. This way of life was far from a pristine harmonious balance with nature, it was highly dependent on major climatic shifts, fruitful payoffs in hunting large prey animals, and high potentials for injury or death in navigating difficult environments (Pluciennik, 1994). These factors restrained the size of hunting groups to small-sized bands, and drastically shortened the average age at death to under 40 years of age (Mussi, 2002). Mesolithic bands of hunter-gatherers mostly occupied seasonal camps near reliable resource areas, resulting in a high degree of mobility between highland, lowland, and coastal environments (Mussi, 2002). Although such a diet was nutritionally rich and diverse, the costs of contending with natural phenomenon would sometimes result in reliance on fallback foods when the primary food source was not plentiful or unavailable, expensive in terms of energy expended during hunting and gathering, or deadly when confronted by injury, climatic extremes, or aggressive predators (Larsen, et al., 2019; Shennan, 2018).

Some literature points to the late Mesolithic as being a prime time for ecological niche construction, which could have been the driver behind permanent settlement at sites like those occurring earlier in the Fertile Crescent and other western localities (Stutz, 2020; Zeder, 2016). These explanatory frameworks rely on the changes in climate and productive wild habitats, which include the expansion of vegetation that thrived in the warmer and wetter Holocene. In Italy, differences between the Early Mesolithic and the Late Mesolithic can be seen through a stronger reliance on terrestrial resources in the early period, and a resilient movement towards marine resources during the later periods (Biagi, 2003; Biagi and Spataro, 2002; Binder, 2000). Utilizing an environmental framework to explain this type of subsistence trend in the Adriatic region, a shift in food preference could have been due to the reduction of terrestrial prey availability during the Younger Dryas, as cooler and dryer conditions affected wild food resources which sustained large populations of animals (Petronio, et al., 2007). Late Mesolithic hunter-gatherers, in the absence of naturally abundant wild progenitor grasses of known domesticates like wheat and barley, would have relied on stable ecosystems like coastal marine zones and opportunistically hunted terrestrial animals, including small mammals, sea birds, and cervids. These differences are clearly seen in the north between early sites, including *Riparo Tagliente* in the Veneto and the Gaban Rockshelter in the Adige Valley (Barfield, 1971; Cristiani, et al., 2009). At these inland and elevated sites, there was consistent consumption of primarily red and roe deer with occasional ibex, with earlier levels clearly showing a preference for ibex and chamois, coinciding with the colder and dryer periods. Many early occupational phases are missing in the many cave sites in the east and west, such as *Arene Candide* in coastal Liguria and the Trieste Karst Caves such as *Grotta Azzurra* or *Grotta Benussi* (Angelucci, et al., 2009; Biagi, 2003; Maggi, 1997; Starnini, et al., 2017). It is believed that the earliest Mesolithic sites may have been concentrated on the previously mentioned Great Adriatic Plain, or were largely open-air sites across the entire region, briefly occupied during seasonally rich periods (Mussi, 2002). However, the late Mesolithic horizons across northern sites include marine foods, coinciding with terrestrial protein, as evidenced by the propagation of shellfish middens, pond tortoises, mollusks, and fishes in these newly coastal sites (Angelucci, et al., 2009; Barfield, 1971; Mussi, 2002; Tagliacozzo, 1993). The mixed diversity in late Mesolithic diet would continue until the arrival of the first farmers in the region in the late 7th and early 6th millennia BCE.

THE NEOLITHIC REVOLUTION IN ITALY

Introduction

Prior to the mid-20th century, peninsular Italy and the north were treated discretely from one another (Peet, 1909), until the "New Archaeology" movement and the emergence of post processual thought (Hodder and Hutson, 2003), were imported into the Italian archaeological community. During the last 60 years, Italian archaeologists specializing in prehistoric periods have developed bodies of literature that narrowly describe regional archaeologies, such as those occurring in the central Po Valley and the north (Bagolini, 1980; Barfield, 1971; Bernabò Brea, 1957; Guido, 1963; Trump, 1966). These regional archaeologies have more recently been woven into the larger holistic Italian narrative of movement, trade, and cultures of the prehistoric world (Guidi and Piperno, 1992; Pessina and Tiné, 2018). These integrative approaches are best exemplified through the emphasis on producing accurate and continuous systems of absolute and relative ceramic chronologies across the entire northern region, peninsular Italy, and major islands. The Italian archaeological scholarly community has diligently typified many well-known cultural groups throughout the 20th century, which has provided a solid foundation for the advancement of more modern work and scientific approaches to the study prehistoric periods. Several well-known radiocarbon regimes have been published and are heavily referenced in the primary literature (Bagolini and Biagi, 1990; Pearce, 2013; Skeates, 1994). Traditionally, a reliance on standardized Italian approaches have dominated, but recently, within the last 20 years, as western scholars of prehistory have been utilizing previous work and have been publishing new studies that are founded within broader theoretical paradigms, including, identity, gender, and landscape frameworks (Carrer, et al., 2015; Harris and Hofmann, 2014; Holmes and Whitehouse, 1998; Robb, 2007; Zuffetti, et al., 2018). Modern processual and post-processual approaches are grounded within the Italian tradition of relative typological studies that have painstakingly typified the cultural landscape via fine grained ceramic and lithic analyses, which has resulted in an expansion of contemporary theories and ideas regarding the neolithization of Italy. This chapter will explore the Neolithic cultures of Northern Italy, survey important central northern sites and mortuary traditions, and summarize the limited bioarchaeological research related to the Neolithic and Early Copper Age throughout the Po Valley.

Neolithization of Italy

The changes in subsistence and trade economies between the Mesolithic and Neolithic periods can be characterized generally by the rise of subsistence preferences favoring domesticate species over wild seasonal taxa. Additionally, the Neolithic witnessed an increasing materiality and complexity, including the amplified sourcing, production, and wider exchange of polished lithic tools such as flint, chert, and obsidian blades, greenstone axes, jewelry, and idols, and the emergence of major individual ceramic cultures, or unique cultural groups, throughout the region. These distinctive changes were first witnessed at southern coastal sites in Apulia within the Tavoliere Plain and coastal islands (Brown, 1997; Tafuri, et al., 2014; Whitehouse, 2014). Two distinctive Early Neolithic cultures currently define the initial Neolithization of southern Italy, the Adriatic Impressed Ware (Figure 4.3) and Advanced Impressed Ware. These first groups are believed to have crossed the Adriatic Sea from coastal settlements along the Dalmatian Coast of Croatia and farther afield within the eastern Mediterranean (Lightfoot, et al., 2011; Tafuri, et al., 2014). Interspersed with the impressed wares were aspects of the Dalmatian Danilo Neolithic ceramic group along eastern coastal Italy and especially as the culture migrated into the karst caves in Western Slovenia and the Eastern Friuli Plain (Bagolini and Biagi, 1985; Lelli, et al., 2012; Lightfoot, et al., 2011; Spataro, 2001a).

Once the Neolithic package had arrived in Southeastern Italy it began to spread over the peninsula into central Italy and eventually arrived in the north. The full neolithization of Northern Italy is very poorly understood, with the prevailing theory of introduction introduced in the 1990s, which relies heavily on demic diffusion and folk migration (Pearce, 2013). The primary reason for the lack of information is the availability of any Early Neolithic sites or burials that can be systematically studied in association with Late Mesolithic occupations of the same areas (Starnini, et al., 2017). Among the Late Mesolithic sites and Early Neolithic sites a near 500-year gap appear to separate the two time periods, with no sites having preserved contiguous layers of both Late Mesolithic and Early Neolithic occupation (Biagi and Spataro, 2002; Pearce, 2013). Most Italian scholars believe that demic diffusion was the primary driver of Neolithization (Starnini, et al., 2017), as opposed to other indigenist or arrhythmic theories that suggest Late Mesolithic and Neolithic peoples forming complex relationships eventually leading to greater adaption of the Neolithic package and simultaneous efficient exploitation of rich environmental resources (Berger and Guilaine, 2009; Binder and Maggi, 2001; Guilaine, 2018).

Figure 4.2: Example ceramic sherds of the Early Neolithic Adriatic Impressed Ware

The expansion of the Neolithic via maritime technologies appears to be the earliest possible mode of introduction of the Neolithic package throughout coastal Italy and the islands of Sicily and Sardinia as evidenced by the broad dispersal of Adriatic and Ligurian Impressed Ware respectively (Biagi and Spataro, 2002; Capelli, et al., 2017). Based on available radiocarbon dates, the first agriculturalists arrive in southern Italy nearly 500 years before they reach the Northern coasts (Skeates, 2003). These coastal groups appear to have first established small settlements that utilized a mix of open air and coastal karst caves, which was followed by expansion into more inland localities later in time (Angelucci, et al., 2009; Bernardini, et al., 2016). The most prominent coastal Early Neolithic culture was the Cardial Impressed Ware culture, which witnessed eastern Adriatic Impressed Ware and western Ligurian Impressed Ware variants, as previously mentioned. The Central Po Valley groups consisted of the Vhò and the Fiorano (Biagi, 2003), described in more detail in this chapter.

As identified previously by regional scholars, the Neolithic transition in northern Italy has provided a complex testing arena for delineating the start of the Neolithic (Bagolini and Biagi, 1990; Barfield, 1971; Biagi, 2003; Biagi and Spataro, 2002; Binder, 2000; Binder and Maggi, 2001; Pearce, 2013; Starnini, et al., 2017). There is little to no evidence within the Po Valley of continually occupied sites with both Mesolithic and early Neolithic sequences (Biagi and Spataro, 2002; Palmer, et al., 2009; Starnini, et al., 2017); however, it is possible, as previously examined, to see very clear Late Mesolithic layers at cave sites in the far east and west, as well as among the mountainous borderland in the Adige in the Alps and Emilia Romagna in the Apennines (Baroni and Biagi, 1997; Cristiani, et al., 2009; Mussi, 2002). The relative dating of the period has relied on the identification of major Neolithic material such as ceramic cultural groups as defined by traditional lithic or ceramic typologies (Barfield, 1971). Radiocarbon dating has been carried out primarily on associated charcoal, seeds, and animal bones, with less than 10 human bone samples for the entire area (Starnini, et al., 2017). Only the previously mentioned site of *Arene Candide* has more than 10 human burials that have been extensively radiocarbon dated (Lucchese, 1997; Pearce, 2013; Starnini, et al., 2017).

Specifically, the Neolithic package appears to arrive first in the north along the Ligurian coast during the early 6th millennium BCE, as seen in the earliest impressed-ware layers at *Grotta Pollera* (5970 cal BCE), and *Arene Candide* (5960–5570 cal BCE) (Pearce, 2013). These layers are directly above Late Mesolithic horizons, but occur separately at other sites along the coast, a trend that has been used as evidence for "leapfrog" settlements and introduction by maritime agriculturalists (Barnett, 2000). The maritime groups within the Adriatic first introduced domesticate species along the previously mentioned Eastern Dalmatian coats in the late 7th millennium BCE with little Mesolithic-Neolithic transitional evidence appearing along the western coast (Borojević, et al., 2008; Lightfoot, et al., 2011). The Trieste Karst and Friuli areas see Neolithization during the middle of the 6th millennium BCE with *Grotta dell'Edera* (5530–5340 cal BCE) and *Sammardenchia* (5610–5380 cal BCE) yielding some of the earliest ceramic and extensive botanical evidence (Pearce, 2013; Rottoli and Castiglioni, 2009). Lastly, the Po Valley and the middle Apennine and Alpine foothills see sparce components of the Adriatic Impressed Ware groups alongside primary Vhò and the Fiorano settlements in the middle to late 6th millennium BCE (Biagi, 2003). They first arrive in Emilia Romagna with *Fornace Cappuccini* providing an early date of 5450–5080 cal BCE and later in the central Po Valley and Adige at *Vhò* (5365–4836 cal BCE) and *Romagnano Loc III* (5060–4800 cal BCE) respectively (Pearce, 2013). The Early Neolithic settlement of the Po Valley has changed very little in nearly 30 years of research, due to the previously mention sparse Early Neolithic sites located on the alluvial plain (Biagi, et al., 1993; Starnini, et al., 2017). These few sites provide very little regarding the process of Neolithization of highly mobile maritime agriculturalists and traders westward across the Po Valley and the later slower migration and interactive introduction from groups diffusing across the Friuli west and the Ligurian coast east. Lastly, groups originally occupying the central northern region of what is now Tuscany and Emilia Romagna were also migrating north. The convergence of these groups in the central Po Valley is specifically what is extremely vague archaeologically and can only be hypothesized to have produced the Vhò and the Fiorano cultural groups and the agricultural landscape that would become more visible with the arrival of the Square Mouthed Pottery Culture (SMP) or *Vassi Bocca Quadrata* (VBQ) signaling the beginning of the Middle Neolithic (Pessina and Tiné, 2018; Starnini, et al., 2017).

The issues of the Neolithization of the Po Valley are outlined well by two well-known Italian scholars, Paolo Biagi in 2003 (Biagi, 2003) and Elisabetta Starnini and colleagues in 2016 (Starnini, et al., 2017). One of the primary critiques of previous archaeological work in the region highlights the need for a more reliable radiocarbon dating regime for the earliest sites in the central Po Valley, which relied heavily on charcoal sampling and were conducted prior to the advent of

AMS dating technology (Starnini, et al., 2017). This issue is exacerbated by the compounding issue of interlaboratory ^{14}C variation because of different published research utilizing different labs, variable levels of precision (1-sigma or 2-sigma) when reporting dates, and the most obvious difference being among dating methods for radiocarbon. Starnini and colleagues were able to display a cross-section of radiocarbon dates for sites in the central Po Valley that overlap the research area and define a clear temporal juxtaposition between the traditionally dated charcoal material and modern advanced AMS-dated material from a collection of sites detailing inconsistencies of about 200 to 300 years and assert that the AMS dates cluster more tightly than do the traditional dates (Starnini, et al., 2017). It is therefore imperative that any future research in the region should budget for a rigorous AMS radiocarbon dating regime to ensure a more accurate and precise chronology of the Mesolithic-Neolithic transition, and middle and later Neolithic cultural development and introduction.

Beyond dating methodology, the second issue of Po valley research relates back to the land-use history of the region, as well as the action of natural processes. The northern parts of the Po River, in the project area, have been largely flattened out throughout time from intensive farming and irrigation activities, where the Neolithic landscape would have been less flat and more undulating (Biagi, 2003; Starnini, et al., 2017). The southern or Apennine side of the river has natural rocky rises that occur periodically along tributaries that have largely survived this intense anthropogenic manipulation overtime (Starnini, et al., 2017). As a result, southern Neolithic sites in Emilia Romagna tend to be better preserved than those potentially now destroyed north of the Po River in Lombardy and the Western Veneto, due to intensive modern agricultural activity (Starnini, et al., 2017). The influence of heavy agricultural production throughout the region has likely resulted in the loss of many Late Mesolithic and Early Neolithic settlements; only those that were exposed and potentially inundated with silt and colluvium likely remain deeply preserved (Starnini, et al., 2017). Additionally, given the rise in modern erosion and depletion of topsoil, (Zuffetti, et al., 2018), those few remaining sites may now be under active threat of destruction by agricultural machinery. This legacy of agriculture and flooding in the region has limited the number of sites uncovered and has resulted in the enumerable loss of material unknowingly disturbed by modern farming operations.

The third research issue is innately tied to the proposed dissertation. As outlined by Biagi and Starnini et al., there is a general lack of human burials outside of protected cave sites in the central Po Valley (Starnini, et al., 2017). Burials provide a wealth of information to excavators given their concentration of burial goods and bioarchaeological significance; however, as previously discussed, many of the tombs of Early Neolithic individuals have likely been lost due to destruction by modern agricultural equipment, erosion, or remain buried under unrecognizable areas of Neolithic occupation. Given the importance of human burials and bioarchaeological investigations of the Po Valley and the challenges previously outlined, the present study will endeavor to examine previously unidentified burials and determine their origin with absolute chronological methods and determine the isotopic life histories of the assembled population. Only a small percentage of the assembled collection here is suspected to overlap with the Early Neolithic period, but those burials will be confirmed and chronologically identified with radiocarbon dating. Outlined below is the best approximation currently available of the Early, Middle, and Late Neolithic chronology based on previous summarized calibrated radiocarbon dates from sites within the region – representing various materials from plant remains to bones.

CULTURAL CHRONOLOGIES

Early Neolithic Cultures

Beyond the identification of ritual items, lithic and ceramic traditions have been typologically defined and geographically characterized by previous scholars and likely served to identify individual groups to traders and neighboring peoples, with major economic shifts marked by the transition to novel cultural materials across the landscape over time. Some of the earliest lithic traditions were contiguous from the Mesolithic into the early Neolithic period, with some improvement and distinction arising later with the development and arrival of the VBQ and the Chassey-Lagozza cultures discussed below (Pessina and Tiné, 2018). Regarding lithics, there is debate among scholars regarding the reliability of distinguishing groups, due to the wide similarities and distribution of the toolkits that were produced (Bietti, et al., 2004; Guidi and Piperno, 1992). Detailed analyses of local reuse, re-sharpening, or retouching is required to intricately describe the local *chaîne opératoire* of each group, with the goal of identifying any one cultural group from another (Barfield, 2016). Pervasive microburin techniques of notching blades and bladelets with bilateral semi-circular notches was carried over from the Mesolithic and practiced by early agricultural groups engaging in hunting and gathering activities, especially in the north, complicating further the attempt to classify any one lithic cultural group (Barfield, 1971; Barker, et al., 1990). The previously mentioned Gaban rock shelter, and the Vhò open-air plain village, as well as the Isolino di Varese pile dwelling site, all share similar lithic assemblages of mixed flint and chert burins and microburins, trapezes, rhomboids, scrapers, and blades that exemplify the continued reliance on Mesolithic styles, but also include later emerging retouched polished knives, leaf-shaped arrowheads, longer intricate blades, often found alongside polished axes and adzes as grave goods or within production areas (Pessina and Tiné, 2018). In the late

Neolithic, there is some evidence within burials of ceremonial, polished lithics potentially made specifically for ritual and burial purposes, and not for hunting or meat and game processing (Robb, 1994). These lithic technologies, as previously discussed, were influential in determining permanent settlement locations on the landscape, developing trade and material economies with southern, eastern, and to some extent northern groups, and facilitating the establishment of subsistence economies through early hunting and herding, and forest clearing for crops and village construction (D'Amico, 2005; Tykot, et al., 2005). These valuable items were likely also used to identify or distinguish specific individuals or groups, such as utilizing ornate polished tools or jewelry in burial and ritual contexts or as gifts, as prestige goods among emerging elites to accumulate wealth, and as economic currency within extensive trade networks (Micheli and Mazzieri, 2012).

Beginning with the earliest introduction of the Neolithic package in the Northern region, the subsequent summary of the early Neolithic ceramic cultures will introduce each as they occur geographically west to east. It is believed that the transmission of impressed ware ceramics in the Mediterranean occurred primarily via a maritime route. Impressed styles are found most often at coastal sites, which have been used to evidence the seafaring hypothesis for the spread of parts of the Neolithic package (Barnett, 2000; Capelli, et al., 2017). The Ligurian coast is the first to receive the Neolithic package in the North, where it is believed that agriculturalists rounding Sicily followed the western peninsular coast north, and reached the previously mentioned limestone cave systems, that characterize this period in the region, in the early sixth millennium BCE (Pessina and Tiné, 2018). The first Ligurian Impressed Ware forms were simple, mostly large, rounded jugs and jars with simple linear and stacked dot impressions made either with a rounded implement or linear shell impressions, indicative of the start of the Cardial Impressed Ware Phase (Pessina and

Tiné, 2018). The Cardial ceramic culture was defined by their distinctive zigzag or undulating impressions, created utilizing shells to form oblique and complex patterns of interlocking triangular chevrons, patterns of elongated perpendicular lines, and in some cases circular shapes into wet clay prior to firing (Barnett, 2000). The Cardial Impressed Ware style is believed to have mostly spread via a maritime route across the Mediterranean Sea, with coastal sites, such as those in Liguria, having the earliest record of the tradition. The peoples who practiced this tradition of ceramic manufacturing have been studied in detail, especially as part of the theoretical reconstruction of the wave-of-advance model previously discussed, due to the Cardial's rapid spread, as traded vessels and reproductions or copies can be seen at most coastal sites in southern France, Spain, and Portugal, and throughout the western Mediterranean islands (Bergin, 2016). These Ligurian sites become increasingly important in the Copper Age as the area nearby is rich in copper deposits, which were quickly sought and mined in the late Neolithic and early Copper Ages (De Pascale, et al., 2006).

Moving to the interior of the central Po Valley and the project area, one of the earliest, largest, and most temporally persistent and pervasive ceramic cultures in the region is known as Fiorano. This cultural group is the earliest-established ceramic producing population in the fertile lowland, beginning in the mid-sixth millennium BCE and continuing until the beginning of the fifth millennium and the arrival of the VBQ (Biagi and Cremaschi, 1981; Pessina and Tiné, 2018). Fiorano pots continue the early traditional use of simple linear impressions as dots in stacked, usually vertical, or horizontal bands, but also develop a long-incised line design that produces connected triangular and diamond shapes (Guidi and Piperno, 1992; Pessina and Tiné, 2018). A smaller number of decorative cords of clay were added to jars and jugs (Pessina and Tiné, 2018). Fiorano began a tradition of *tassa* (cup) making that becomes ubiquitous in the region, with many of the individual cultural groups adopting and producing their own form and style of the cup or bowl (Barfield, 1971; Guidi and Piperno, 1992; Pessina and Tiné, 2018). Fiorano groups are also noted for incorporating handles into their vessels, usually vertical and ribbon shaped, sometimes singular or in pairs in smaller utilitarian ware, or in groups of four on larger vessels (Pessina and Tiné, 2018). Fiorano ceramics can be found throughout the region and dominate the central Po Valley burial assemblages in Emilia-Romania, eastern Lombardy, and the Veneto during the early Neolithic period (Rosa, 2015).

Another central Po Valley group is the Vhò, who emerged in the western half of Emili-Romagna, southern Lombardy, and the eastern Piedmont in the latter half of the sixth millennium BCE. Vhò artifacts were initially typified by local Italian scholars as Fiorano based on similarities in style and decorations, which maintain the long-incised triangular lines and small concave dot impressions in undulating or linear bands (Biagi, et al., 2020; Pessina and Tiné, 2018). Despite the overlap in decoration, there remain unique departures from the Fiorano tradition (Bagolini and Biagi, 1975). The Vhò culture likely arose from a conclave of Fiorano migrants expanding westward and initially reproducing Fiorano vessels, but later modifying those shapes and expanding variety to form a new cultural group and likely identity (Guidi and Piperno, 1992). Vhò groups again produce their own cups and bowls, extremely similar to the Fiorano counterparts, but diverge in adding larger, vertical handles, that are thin, ovoid, and ribbon-like, with some having button extensions pulled out from the wet clay, likely for more secure handling (Pessina and Tiné, 2018). These button additions also frequently occur on the bodies of larger pots such as jars and jugs, described as corrugated forms (Pessina and Tiné, 2018). Many of the larger vessels include four handles like the Fiorano, but some occur horizontally (Pessina and Tiné, 2018). The major difference between the Fiorano and Vhò cultures is the base profile of vessels, with the Fiorano previously having rounded or flat bottoms, and the Vhò developing more elaborate pedestals, feet, or stands attached to the pots including, small void spaces in the center of the base (Pessina and Tiné, 2018). The Vhò also produce the first trapezoidal shaped vessels, known more as *fruttiera* or “fruit vases,” in later periods (Pessina and Tiné, 2018).

To the north in Trentino, northern Lombardy, and the Piedmont, two cultural groups have been described in the early Neolithic. Developing during the latter sixth millennium, these cultural groups include the Gaban group found in the eastern Alpine region in northern Lombardy and Trentino, especially in the Adige Valley (Cristiani, et al., 2009), home of a major prehistoric route into the Alps beginning near modern-day Verona (Artioli, et al., 2017; Müller, et al., 2003), and the Isolino, associated with western Lombardy and northern Piedmont occurring near the major western glacial lakes (Pessina and Tiné, 2018; Pétrequin, et al., 2006). The Gaban culture shares the most with the Fiorano in terms of style and shape of containers, while the Isolino have more in common with the Vhò (Pessina and Tiné, 2018). The Gaban ceramic producers essentially merged the earliest impressed ware and Fiorano traditions, creating pots that are decorated heavily with circular dot impressions and incised triangular, geometric, and linear bands (Pessina and Tiné, 2018). Most of the jars and jugs have a small, stunted foot at the base, that are similar to the Vhò, but not as robust or as large as the footed Isolino or Vhò vessels (Pessina and Tiné, 2018). Handles on both large and small vessels are similar in form and number compared with the Fiorano. The Isolino adopted the same incised linear designs but excavated much deeper tracks in the clay compared to the other groups and produced pots with pedestals more similar to the Vhò (Banchieri, 2017). The Isolino also attached corded clay like the Fiorano, utilized their fingers more for impressions and decorating the pots, and incorporated handles like both groups, but to less of an extent on smaller vessels (Pessina and Tiné, 2018). The Isolino and the Vhò both produced cups, with the Isolino having the most in common with the emerging middle Neolithic VBQ group in profile and shape. It is important to note that the Fiorano, Vhò, and Gaban vessels are all found frequently together, while the Isolino is usually only found alongside Vhò and Gaban containers and rarely with Fiorano material (Pessina and Tiné, 2018).

The last of the Early Neolithic groups on the Friuli plain and the eastern Veneto are the *Gruppi Friulani*, and the more eastern and Balkan *Vasi a Coppa*, first seen in the middle sixth millennium BCE (Pessina and Tiné, 2018). The *Gruppi Friulani*, also seen in the literature abbreviated as *Friulani*, share many characteristics with the Fiorano and the Vhò, but also have strong stylistic connections with the earlier Danilo and Balkan groups of Slovenia and Croatia (Bagolini and Biagi, 1985). Their pots are sometimes corrugated and include the same types of incised excavated lines creating chevrons and triangular patterns, while also incorporating more complex geometric patterns, similar to the Balkan groups, but not the extent of the *Vasi a Coppa* (Pessina and Tiné, 2018). The same types of shapes and forms occur as the Fiorano; usually large jugs and jars dominate assemblages with smaller cups and bowls also occurring frequently. All the larger storage jars have handles, usually smaller and less pronounced than the Fiorano pots (Pessina and Tiné, 2018). Towards the end of the sixth millennium the *Friulani* begin making footed or pedestaled vessels like the Vhò, possibly signaling a connection either in trade or migrants flowing from the central Po Valley (Pessina and Tiné, 2018). The *Vasi a Coppa* departs almost entirely from all the Early Neolithic traditions outlined above, with ceramics being produced that appear very similar to the Danilo, including rython vessels or animal like vessels, often used in dairying (Pessina and Tiné, 2018). Their pots often have small narrow bases with large, rounded bodies, appear plainer in terms of decorations than previous forms, and lack the more extensive handles seen in western groups ceramics (Pessina and Tiné, 2018). Some scholars have remarked that the *Vasi a Coppa* could represent the northern-most extent of the Danilo, but most believe they are likely migrants from the Danilo and combine the northern Italian groups and Danilo styles (Bernardini, et al., 2016; Spataro, 2001a; Spataro, 2001b).

Middle Neolithic Cultures

The middle Neolithic period in northern Italy is synonymous with the development and spread of the *Vasi Bocca Quadrata* or Square-Mouthed Pottery culture throughout the entire Po Valley and Ligurian coast at the beginning of the fifth millennium BCE (Figure 4.4) (Pessina and Tiné, 2018). VBQ sherds dominate the assemblages in the research area and the majority of the burials analyzed in the present study. A few summaries have been composed regarding the development and spread of the VBQ culture and provide the background used to construct this summary (Basoli, et al., 2015; Guidi and Piperno, 1992; Harris, 2013; Mottes, 2001; Mottes, et al., 2009; Pessina and Tiné, 2018; Rosa, 2015). The VBQ can be separated into three distinctive phases: the first occurring between 5000-4500 BCE, the second occurring between 4500-4300 BCE, and the third phase occurring between 4300-3900 BCE (Bernabò Brea, et al., 2010). During the first or geometric phase, there was a marked increase in shape and form diversity from the previous Fiorano or Vhò forms, with high necked cups, the introduction of fine clays for the manufacture of vessels including the first *figulina* or fine ceramics, and deeper, broader-bodied jars and jugs (Pessina and Tiné, 2018). There is a notable difference between the fine and coarse clays used between daily use wares, such as the cups, plates, and bowls seeing a higher use of fine clay, and storage vessels and large cooking pots manufactured from coarser clays (Barfield, 1971; Guidi and Piperno, 1992). Ultimately, both fine and coarse were sparingly used for both types of ceramics, with a greater disparity observed in the second phase (Pessina and Tiné, 2018). The decorations in the first phase included linear bands of incised triangular, diamond, and linear decorations primarily found on tableware, and bands of impressed dots and hollow spaces on larger storage and cooking pots, (Pessina and Tiné, 2018), with some occurrences of plain wear as burial goods (Rosa, 2015).

Figure 4.3: Example of a small VBQ phase one plain vessel

The second or meandro-spiral phase is increasingly complex and departs from the first phase primarily in decoration, incorporating intricate bands of incised spirals, typical of pottery found in the Balkans (Figure 4.5) (Bagolini and Biagi, 1985; Pessina and Tiné, 2018). In particular, the incorporation of this design may indicate the arrival or strengthening connections between the VBQ and the Balkan agriculturalists, who have access to a greater diversity of domesticated plants (Bagolini and Biagi, 1985; Rottoli and Castiglioni, 2009; Rottoli and Pessina, 2007). Indeed, as previously discussed, several sites have been identified to have significant increases in species diversity accompanying this change in the VBQ culture. It is possible that the present study can interrogate these potential differences between transitional phases of the VBQ via the construction of stable isotopic life histories. In terms of trade and expansion, VBQ II vessels were becoming more common across the north and even found in the south likely traded between northern enclaves of southern groups like the Serra d'Alto reportedly located in Emilia-Romagna (Pessina and Tiné, 2018; Rosa, 2015). These spiralized designs on pots have been associated with eastern groups who have been discovered with prestige materials such as amber, Egyptian blue, and gold (Barfield, 1971; Skeates, 1993). The influx of this design in the north may be an indication of the arrival of the land-based cultivars and signify the opening and novel access to extensive eastern trade networks.

Figure 4.4: VBQ phase two pot body sherd

Late Neolithic and Eneolithic Early (Copper Age) Cultures

During the late Neolithic, at the end of the fifth and beginning of the fourth millennium, the third or incised and impressed phase of the VBQ was primarily seen only in the east from the central Po Valley to the Friuli, with the arrival of the Chassey-Lagozza cultural group in the western half of the Po Valley (Figure 4.6) (Guidi and Piperno, 1992; Pessina and Tiné, 2018). The major demarcation of the late phase VBQ culture was the decrease of square-mouthed containers in favor of circular rims, with the same forms, shapes, and designs as the previous two phases, such as tall necked cups with incised spirals (Mottes, et al., 2009). Chassey-Lagozza becomes increasingly homogenous in ceramic forms, styles, and shapes, with more plain storage containers and table wears, with occasional decoration of plates and bowls being produced with a tight mix of incised and impressed designs (Pessina and Tiné, 2018). The Chassey-Lagozza culture spread very quickly in the north, and south of the Apennine Range, into sites dominated by late Ripoli and Diana ceramics (Borrello, 2015; Pessina and Tiné, 2018). The division in the north between these two final Neolithic cultures becomes more delineated east to west, rather than by individual areas or even ecozones like the earlier groups (Pessina and Tiné, 2018). The rapid and extensive spread of the Chassey-Lagozza could be due to access or knowledge of copper sources or smelting and could indicate a greater commitment by individuals to learning and manufacturing the first metal tools in the region, rather than producing uniquely identifiable pottery (Barfield, 1999). The Copper Age culture that emerged in the Po Valley after the manipulation and first copper tools were manufactured, was the Remedello culture, largely defined by copper artifacts found at the type site on the southern shores of Lake Garda (Marinis, 2013). The Remedello culture developed over several phases, that were largely defined by copper axe forms unique to the cultural group. They shared some similarities in ceramic styles with the Lagozza, but are seen as skilled copper craftspeople and mark the first declines in stone tool technologies, in favor of a mixture of flint and copper technologies (Marinis, 2013).

Figure 4.5: Example of a Chassey-Lagozza pot

CONCLUSION

The succession of technological and cultural changes throughout the Neolithic period surrounding the contemporary Italian city of Mantua are punctuated by influxes of new ideas and traded goods from disparate areas in the North and south. The natural abundance and temperate climate of the Po Valley provided the perfect locality for the first agricultural societies, with ample access to familiar resources and later abundant metal resources throughout the alpine range. Archaeologists focus on great transitions throughout human history and bookend these periods with rise and fall ceramic and lithic technologies in prehistory. It is extremely difficult to locate archaeologically those peoples that lived during these transitionary periods, as they often assume archaeological identities associated with the declining cultural sequence or with the newly developing technology. Transitions occur slowly but eventually result in a total replacement of previous traditions in favor of more advanced or useful technologies and often peak at a particular period before those that were once novel begin to decline as well. As was life throughout the Neolithic period in Northern Italy, with the first arrival of the Neolithic package with impressed ware groups and the development of the Vhò and the Fiorano cultures followed relatively rapidly by an influx of VBQ pots and traditions. Disparate materials such as greenstone, obsidian, and precious shells from the coasts made their way into the central Po Valley along with many new cultivars and other ideas, likely at periods of technological change. The current project seeks to explore the lives of those Neolithic peoples which overlapped periods of cultural development and change, often associated with the arrival of new ideas and lifeways. The assemblage studied here is dominated by VBQ peoples from both the earliest iteration of the technology to the subsequent first change in decoration and iconography in the second phase. The lives of these VBQ peoples will be compared and contrasted with those of the Early Copper Age when the development of the first metallic technologies.

CHAPTER FIVE:

BIOARCHAEOLOGIES OF THE NORTHERN ITALIAN NEOLITHIC

INTRODUCTION

Bioarchaeological research regarding the Neolithic and Copper Ages in Northern Italy has been extremely sparce and limited given the in part to the focus on lithics and ceramics and the low number of burial sites and skeletons available for study. Primarily much of the skeletal research that is available is focused on the Ligurian site of *Arene Candide* and other sites in the immediate vicinity. These projects have largely explored the health status of the inhumed population and explored questions surrounding diet, mobility, and transitions between cultural groups. Central Po Valley bioarchaeological studies of the Middle Neolithic, Late Neolithic, and Early Copper Age are rare, but of those available, again are heavily focused on paleopathological analyses. Larger summaries of mortuary treatments, gender, and status are positioned within a more theoretical range, where trends between high altitude, cave and open air, and peninsular sites can be explored, but are not limited to Northern Italy. This section will summarize the available bioarchaeological literature as it pertains to current bioarchaeologies being created or explored among Neolithic and Early Copper Age assemblages. Additionally, this section will explore the mortuary archaeology and contexts of the Neolithic and Copper Age periods, including fantastic bioarchaeological discoveries of the Alpine Iceman Ötzi and the Lovers of Valdaro.

NEOLITHIC MORTUARY PRACTICES IN NORTHERN ITALY

Burial Practices

As previously discussed, the Neolithic package that arrived in Northern Italy was exploited and supplemented by locally available products and resources, based on geographic location. The central Po Valley falls within this schema in terms of preparation and burial of their dead in key ways. Typically, in more rugged localities such as the coastal regions of Liguria or the elevated plains of the Friuli, cyst tombs are common, where local stone is used to line burials prior to internment (Sparacello, et al., 2019). Additionally, many of these tombs occur in caves dotting the local topography. Those people living on the Po Plain however did not have such ready access to caves or large locally available stones to create cyst tombs. For the Neolithic period, excavators often remark on the great number of plain earthen burials, many with little to no grave goods (Barfield, 1971; Biagi and Spataro, 2002; Guidi and Piperno, 1992; Rosa, 2015). No clear tomb excavation lines are typically noted, but do occur in rare circumstances; however, ovoid to rounded rectilinear earthen graves are characteristic of the entire Neolithic of the Central Po Plain (Rosa, 2015). Later Copper and Bronze Age tombs take on more cyst-like characteristics in the Central Po Plain, with more rectangular interments and more formalized necropolises and burial areas that include some wall linings with flat stones, or in some instances and even later in time, entire graves lined and capped with locally available stones (Tafuri, et al., 2018). Neolithic graves were typically excavated in two locations, either within the associated settlement areas or on the periphery of the habitation areas (Rosa, 2015). Small groups of graves are common and have been interpreted as possible familial groups or related individuals with plots closer to one another or within associated small settlements or hamlets (Rosa, 2015). Yet, some isolated burials are common as well, typically occurring on the periphery of associated settlements and especially those that do not parallel the typical skeletal burial position (Rosa, 2015).

The position of the body within the grave varies slightly, regarding mid-sagittal cardinal direction, level of limb flexing, or plane in which the body rests, regarding supine vs. prone, or right vs. left side (Rosa, 2015). It is overwhelming typical of Neolithic burials to present interred body positions largely on the left side as opposed to the right side, with fully flexed limbs at 90 degrees, and with the mid-sagittal alignment - head positioned to the east with the face towards the south and the feet positioned to the west (Rosa, 2015). This position can be described as a side resting kneeling position or a loose fetal position with the lower limbs usually not tightly tucked into the abdomen. Furthermore, it was common practice for the hands to be covering the individuals face or be placed very near the head (Rosa, 2015). As a result of the burial positioning, typically the side of the body closest to the surface, likely the right side, was at the greatest risk of damage or loss because of agricultural activity or infrastructure excavations. Variations in burial position such as those discovered in supine or prone positions associated with Neolithic time-periods could indicate either higher status or possibly deviant social status. These variations included those individuals diverging from the typical kneeling position with the hands in front of the face and extended to burials fully prone sometimes with extended limbs and sometimes with non-complimentary limb positions of both arms and legs. Some of these variations in burial position are observed with the current analyzed population. In later periods and typically in cyst tombs, individuals were mostly placed in a supine and fully extended, or a mixed upper limb flexed, lower limb extended position (Rosa, 2015).

These earthen burials themselves are often described as burial pits, which is likely heavily influenced by Neolithic multi-use and rubbish pit structures typical of Neolithic hut villages

(Starnini, et al., 2017). Pits of varying sizes are characteristic of many Po Plain Neolithic villages, which parallel those pitted hamlets and villages located in central peninsular Italy (Bagolini and Biagi, 1975; Biagi and Perini, 1979). No formal cemetery or necropolis areas were designated by Neolithic groups, rather only small groups of burials occurred on the periphery of villages, with isolated burials having the greatest probability for atypical burial position (Rosa, 2015). The limits of settlements were typical spaces for hearths and open-air cooking pits, likely to prevent combustion of structures within the village (Rosa, 2015). The use of many of these pits has been debated for many years in the academic literature but remains contested given the great amount of variation among pits structures and forms, only visible in negative space during excavation (Starnini, et al., 2017). In the current project, several cigar-shaped pits occur at many of the sites which appear to be relatively unique to the settlements in the north. These too often occur in the periphery of villages and are postulated to possible have been tanning pits, watering troths for animals, or simply specialized trash pits (Rovesta, 2010). A partitioning of activities was possibly occurring with more combustible and ritual taking place in peripheral common areas and more domestic activities taking place in the central village or within shared or individual huts or homes.

Grave Goods

To fully illuminate the life histories of Neolithic and Copper Age peoples, the presence, type, and position of grave goods needs to be incorporated into formal analyses of the individuals skeletal remains themselves. The incorporation and combination of included grave goods with the results of skeletal analyses is a vital part of the biocultural approach, as previously discussed. These material inclusions are critically important once demographic information is obtained from available skeletal remains to assess potential sex and age-related differences in ornamentation, occupation, or lifestyles. The present study seeks to explore these differences through the analyses of isotopic data as it relates to diet and mobility, but also as it related to chronological period. The production of a radiocarbon chronology for the assemblage can be supplementally useful to other archaeologists in determining the exact periods when certain unique pit structures were utilized, when specific trading of rare and disparate materials was taking place, and what types of social stratification if any was emerging among the sexes and among different age groups. The grave goods that are typical of the period included ceramics, flint projectile points, jewelry, polished stone axes, often greenstone, and sometimes animal burials or decorated bone objects. Some examples of these grave goods and their typical positions within burials are provided as current chapter figures from the current study.

Polished stone axes are commonly found throughout Neolithic and even Copper Age burials (Guidi and Piperno, 1992). Typically constructed of greenstone, these axes have been widely traded throughout Italy in the Neolithic and have been associated with large quarries in the western Piedmont region of Northern Italy (Capelli, et al., 2017; D'Amico, 2005). Axes are typically placed within the hands or just behind the hands when they are placed in front of the face with the sharpened edge almost always facing the individual (Rosa, 2015) (Figure 5.1). Beyond the position at the head, axes have also been found in isolation or in pairs, with one at the level of face, and another placed at the nape or upper spine with the sharpened end facing the individual (Rosa, 2015). Use wear analyses of these axes have revealed that they were not strictly ornamental, but were heavily utilized, often on "green" or fresh wood, sometimes associated with basket weaving or even felling fresh wood for construction, fuel, or potentially agricultural land (Giustetto, et al., 2017). As previously discussed, pollen and soil data from the Neolithic period have revealed many hardwood species were beginning to decline at a time when they had been expanding in the early Holocene in the region, which could be attributable to anthropogenic activity involving green stone axes (Zanon, et al., 2019). Other objects constructed of greenstone have also been recovered from Neolithic tombs to include chisels and upper arm bracelets (Rosa, 2015) (Figure 5.2). The chisels are extremely rare, with a few burials in the current assemblage having them included, with typical burial location at the crux in front of the abdomen, below the elbows but above the knees. The greenstone bracelets are typically found in situ around the humerus or at the elbow, with the elements passing through the bracelet, suggesting the individual was wearing the ornament when they were buried (Rosa, 2015).

Figure 5.1: Example of greenstone axe position within a VBQ burial at Roncoferraro

Figure 5.2: Neolithic greenstone material culture exemplars

Flint projectile points, knives or daggers, burins, and debitage are extremely common and occur in a variety of colors, with the most typical being a muted pink and gray, typical of Lessini flint deposit near contemporary Verona (Barfield, 1971; Pessina and Tiné, 2018). The points vary in their position within tombs, but they mostly are located between the hands or near the hands, with some found near the abdomen or at the back near the spine (Rosa, 2015). Typically, the projectile points parallel the body, but some are placed with the point towards the body (Rosa, 2015). In one remarkable circumstance in the current analyzed assemblage a tomb was uncovered with a spear point still hafted positioned parallel to the body (Castagna, 2009) (Figure 5.3), in addition to other remarkable grave goods. Use wear analyses show typical uses for these points are hunting small game in the case of hafted shafts, but for the smaller burins and some retouched flakes, they show possible use wear to cut green plants, potentially as part of plant harvesting activities or striping plant materials for basket and container crafting (Barfield, 1999; Bietti, et al., 2004; D'Amico and al., 2002). Flint projectiles have previously been with young adult men and potentially serve to illustrate a rite of passage into adulthood and the hunter or warrior role in society (Rosa, 2015).

Figure 5.3: Hafted flint projectile point from Roncoferraro

Ceramics are typically found either between the arms or places in the crux of the abdomen just below the elbows (Rosa, 2015). The ceramics found in these burials tend to be smaller square mouthed vessels that may have been created specifically for burial rituals or could have belonged to the individuals in life. It is unclear of these pots contained food offerings as part of the burial ritual, very little work has been done on the mortuary rituals specific to ceramic technologies.

Specific to the current project, a few burials did include freshwater fish remains discovered in processing remains for analyses, suggesting that potentially freshwater fish offerings or feasting activities were part of burial rituals. The presence of whole ceramics is the exception in most cases, where most burials are more likely to only contain ceramic sherds. These sherds in the period have mostly belonged to the VBQ cultural group. It is unclear at the present time if possibly during the Early Neolithic if burial practices were less common, potentially in favor of cremation or even surface decomposition methods of disposal, but burials dating to the Middle Neolithic dominate the mortuary landscape in Northern Italy with very few Early Neolithic burials ever recorded (Starnini, et al., 2017). The presence of ceramic materials allows for relative dates to be established for many burials containing only sherds and whole vessels, which can be used to enhance radiocarbon chronologies. It has been suggested that many ceramics are associated with female internment and represent women's roles in food storage and preparation (Rosa, 2015). Despite being found more frequently in female tombs, ceramics are also common among male tombs, especially those that appear to be higher status as indicated by prestigious ornaments (Rosa, 2015).

Figure 5.4: Example typical position of VBQ ceramic jars in situ

Lastly, Neolithic burials in the North have been discovered with various prestigious and anomalous objects and with other individuals and animals. Some Neolithic burials have rare or exotic materials that have been fashioned into jewelry or ornaments that could represent some connection to coastal or southern communities or assert some differential status within a group (Pessina and Tiné, 2018). A few examples from the current project mirror finds a nearby Middle Neolithic village sites like Vhó or Isorella (Bagolini and Biagi, 1975; Perini, et al., 2001), where steatite (soapstone), fossilized shells, and spondylus beaded bracelets and necklaces have been recovered in situ from around individual's wrists and necks (Figures 5.5 & 5.6). Some of these materials were sourced from coastal areas and suggest that inland plains villages had access or traded with coastal communities either in Liguria or the Venetian Lagoon. One individual, a middle-aged male, was recovered from the project site in Roncoferraro, with an amazing assortment of greenstone and flint objects and extensive shell and soapstone jewelry, indicating his potential higher status in the community (Castagna, 2009). It is likely that beaded jewelry was utilized in life to indicate status among and between groups, with the steatite beaded bracelets being a common ornament among many different sites. Additionally, small trinkets and figurines have also been recovered from Middle Neolithic burials, often crafted from local clays, these figurines are sometimes found in the hands or near the hands in situ (Rosa, 2015). One example from the current project is a rudimentary fired clay figurine with what appears to be roughly outlined legs and the beginning of a torso with a flattened surface on one side (Figure 5.7). Lastly, many materials crafted from bone, horns, and antlers have also been discovered such as bone awls and needles, carved musical horns and flutes, and spatulas and hoes, possibly for planting (Rosa, 2015).

Figure 5.5: Steatite beads recovered from San Giorgio Bretella Aut

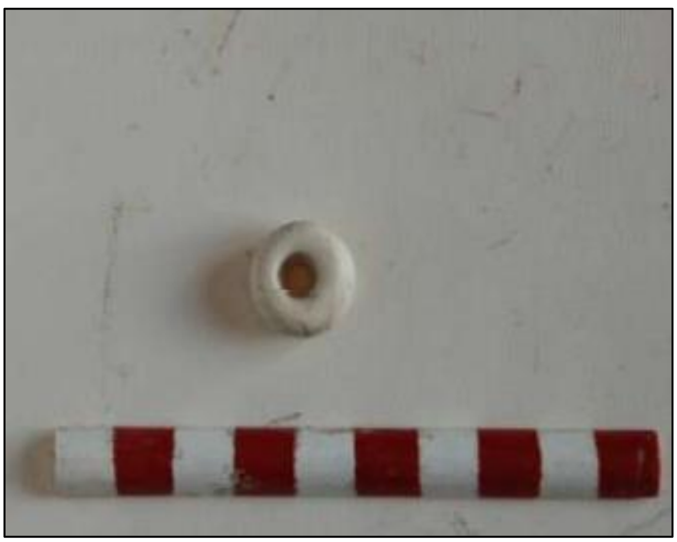

Figure 5.6: Spondylus bead from Olmo Lungo

Figure 5.7: Clay figurine from Olmo Lungo

A key feature of Middle Neolithic burials was the inclusion of animals in the tombs (Bernabò Brea, et al., 2010). On rare occasions, but found throughout the north, canids were sometimes placed at the feet of an individual (Rosa, 2015). It is unclear from reports if the canid was slain at the time of interment and placed with their potential owner, or if the depositions occurred separately at the time of natural death. No reporting of depositional history has been detailed enough, nor do osteological reports of the canid skeletons found in these contexts detail any traumatic injuries or taphonomy consistent with execution. Despite these unanswered mortuary questions, we do understand that dogs appear to have played an important role in Neolithic society in the north to warrant a place interred with their handlers (Pessina and Tiné, 2018). On such burial, which lifted in bulk and preserved from the current project site of Olmo Lungo, is on display at the *Museo Archeologico Nazionale di Mantova* (Figure 5.8) where previous studies have revealed that both the individual and the canid shared similar diets, suggesting that the animal was at a minimum commensal with village life. Their exact role is unclear, if they were utilized for defense of livestock herds or grain stores or if they were integral to hunting activities, canids can fulfil a variety of roles and responsibilities and are often rewarded with food, shelter, and protection from humans for their service.

Figure 5.8: Tomb of an older man and canid found at Olmo Lungo

The Lovers of Valdaro

In addition to the above-mentioned assortment of Neolithic grave goods, burials in the North have also been discovered with more than one individual. A particularly famous paired burial, known as the “Lovers of Valdaro,” so named because the burial is of two individuals, one male and one female, that appear to have been buried in a permanent embrace, facing one another with their lower limbs intertwined in crouching positions and their hands near each other’s faces (Figure 5.9). It was thought at the time of excavation that removing the individuals would be inappropriate, and thus the decision was made to excavate the tomb in bulk and preserve the integrity of their embrace, as appeared intended at the time of death (Geller, 2016). The images of this burial went viral online and has spurred speculations of a Neolithic Romeo and Juliette to songs and poems created detailing the possible romantic relationship between the two individuals (Urbanus, 2008). Other single burials were found in close association with the Lovers of Valdaro, some of which are included in the present study. One was located less than 3 meters away, which some have speculated to represent a possible love triangle between all three individuals in life. All the objects found in association with the tomb are flint blades, with the point placed at the man’s back the most intricate, with evidence of abrupt retouching for sharpening, and possibly evidence of a wooden handle, which is like the knife found with the Alpine Iceman (Geller, 2016), discussed later in this chapter. Very little research has been accomplished on the burials, with the archaeological superintendents and museums preferring to maintain the tombs integrity given its fame and potential to attract tourists to Mantua. The present dissertation will add some additional information regarding the diets and lifestyles of associated burials from Valdaro and the surrounding sites, allowing for some additional information to be used for interpretation of these two individuals.

Figure 5.9: The Lovers of Valdaro

ÖTZI THE ICEMAN

Much of the information regarding mortuary practices and burials themselves come from dry bone earthen burials, as describes above, but in 1991 a spectacular discovery was made by Alpine hikers passing by the Schnalastal Glacier (Kutschera, et al., 2014; Müller, et al., 2003). A Copper Age man, that had been frozen and perfectly preserved in the glacial ice, was found partially exposed at the bottom of a steep ravine. Initially the individuals that discovered the body, assumed it was a modern individual that met an unfortunate end after an accident, but it was later discovered that this individual was over 5000 years old and was later carefully excavated with a huge suite of organic materials such as clothing, containers, and wooden tools. The name Ötzi was given to the Alpine Iceman after the Ötztal Alps located in the northern most Italian Alps, where he was found. A specialized museum space within the South Tyrol Museum of Archaeology was created to house the body and the associated materials, located in Bolzano, Italy. The subsequent scientific analysis of the preserved body, including soft tissues, and of the material culture found with Ötzi would forever change our understanding of the late Neolithic and Early Copper Age in Italy.

Regarding the Chalcolithic or Copper Age, some of the best evidence of dietary trends has been extrapolated from the discovery of the Alpine Iceman, Ötzi, who likely originated from the area of study (Müller, et al., 2003). The revelations of detailed analyses conducted on physical materials recovered from the Iceman's stomach, such as pollen, seeds, and bones, the preservation of animal skins that were used to construct his clothing, and the stable isotopic information gleaned from his bones and teeth yield a rare glimpse into the Copper Age landscape. The pollen and seeds recovered were from more than 30 lichens and plants found much lower in the Adige Valley, southeast of the discovery site of the remains, while the seeds and bones originated from rye and einkorn wheat and domesticated goat (Dickson, et al., 2000; Oeggl, 2000). His clothing was made of hides from a variety of wild and domesticate animals including sheep, goat, cattle, red deer, and wolf, and yielded a few barley seeds trapped in the furs (Oeggl, 2000; Püntener and Moss, 2010). Some additional plant stones were also recovered which belong to wild strawberries, brambles, apples, and elder-berry taxa (Oeggl, 2000). Lastly, the stable isotopic analyses of his bones and teeth indicate a largely omnivorous diet, consisting primarily of C_3 plants and domesticate meat sources, as indicated by the pollen, bones, and seeds recovered from his stomach (Dickson, et al., 2000). The contents of the Ötzi's stomach and intestines corroborate the stable isotopic findings, heavily favoring C_3 plants such as wheat and rye. Copper Age alpine villages have also yielded similar palaeobotanical findings with C_3 plants dominating assemblages with an intensifying pastoral economy continuing to develop centering on sheep, goat, and cattle (Festi, et al., 2011).

These findings are important to the current study due to the Iceman's age of nearly ~5,300 years old, placing him well within the Copper Age, which began at the end of the 5th and beginning of the 4th millennium BCE in Northern Italy. The Iceman was dated to 3370 – 3100 cal BCE (Müller, et al., 2003). The dietary findings both isotopic and palaeobotanical provide some clues for the expected isotopic results in the current study. Ötzi clearly was not consuming or did not have access to C_4 plants such as millet at this time, and thus was completely reliant on C_3 plants and culled domesticate and hunted wild game meats. Additionally, some fruits, mushrooms, lichens, and bark were found in association with the Iceman with many believed to have been used medicinally (Oeggl, 2000). Beyond the diet, the previous research regarding the origin of Iceman have also involved stable isotopic provenancing and sourcing of the style and manufacture of the copper axe as part of the burial assemblage. Multiple stable isotopes such as oxygen and strontium were utilized to examine the origin of the Alpine Iceman and subsequently concluded that he was born and raised south of the discovery site, within the valleys surrounding Lake Garda (Kutschera, et al., 2014; Müller, et al., 2003). The isotopic findings are supported by the provenancing of the copper axe far to the south where many well-known copper deposits in northern Tuscany match the trace element and lead compositions of the axe match the copper deposit there (Artioli, et al., 2017). The cultural style of the axe, however, was clearly influenced by the Remedello Copper Age Cultural group that emerged in the southern Alpine region and Po Valley in the 4th millennium BCE. Specifically the axe belonged to an Alpine sub-group the Tamins-Carasso-Isera group, which was largely found in the Alpine valleys east of Lake Garda, but heavily influenced by the Remedello cultural group (Wierer, et al., 2018). It is clear that by the Late Neolithic and Copper Age that long-distance trade spanning the entire Po Valley, Apennine and Alpine ranges, and Adriatic and Ligurian coasts were becoming increasingly interconnected and established (Wierer, et al., 2018). These findings are critical in questioning the life histories of the Middle Neolithic VBQ cultures that were positioned at the crossroads near Mantua between East and West, but also of North and South. It is possible that during the development and popularity of the VBQ cultural group that these trade routes were established or utilized more intensely and likely resulted in the development of the Iceman's tool kit for long-distance trading or transhumance within the high Alpine valleys.

BIOARCHAEOLOGIES OF THE NEOLITHIC

Paleopathological Reconstructions

Regarding Northern Italy, the most heavily published Neolithic skeletal assemblages are those originating from tombs in Liguria. This uneven treatment of human remains in the scholarly literature is likely due to three factors: the preservation bias of the karst cave sites where the burials were located, the history of excavation of key sites along the coast, and the organization of the local museums and superintendents overseeing research programs utilizing the assemblage. As such, there have been no paleopathological studies conducted in the central Po Valley, with the exception of a briefly mentioned unpublished case of possible trepanation from the Casalmoro site in Mantua (Rosa, 2015). This case may reflect a connection in perimortem treatment knowledge between central Italian groups and central Po Valley groups, as a case of trepanation has been reported from Grotta Patrizi in Lazio (Zemour, 2020). Additionally, one case of adult tuberculosis from the Middle Neolithic site of Via Guidorossi in Parma tomb 24 was also discussed by Federica Rosa, but remains unpublished (Rosa, 2015). As previously mentioned, there have been nearly 200 individuals excavated to date from sites in the Central Po Valley region, including Mantua (Rosa, 2015), excluding the Neolithic burials of the current study, with often little subsequent anthropological analyses conducted, beyond what is known from the excavation reports by professional bioarchaeologists or academic scholars . It is therefore the position of the author that the western Ligurian research regime serves as an apt model for future studies of the tombs excavated in the Central Po Valley, to facilitate bioarchaeological comparisons of disease and ecological environments, as well as critical demographic and subsistence lifeways between these two regions.

As previously discussed, the natural habitats for infectious pathogens require increases in populations of host species, shifts in settlement and dietary regimes, as well as interactions with domesticate animals and hazardous environments. Following the proposed approach, research thus far among the Ligurian cemetery populations has revealed entheseal changes in human male lower limb and unilateral upper limb robusticity, and morphological changes in domesticate animal sizes, which reflect a possibly active breeding program that could produce a greater chance of targeted zoonoses (Marchi, et al., 2011; Sparacello and Marchi, 2008). Changes in male and female robusticity, namely increases for males and decreases for females, possibly reflect a commitment of women to settlement management, horticulture, and natural terrain challenges, and males to habitual vertical hiking, likely to manage domesticate herds, cut forested areas for wood and for future crops, and to hunt wild game (Marchi, et al., 2011). Regarding specific pathogens, a threat presented from domesticate cattle breeding is the *Mycobacterium bovis* transitioning to *Mycobacterium tuberculosis*, which when passed to humans can result in tuberculosis infection (Roberts and Manchester, 2005). To date, two cases of osteoarticular tuberculosis, with spondylitis being the most common form, have been reported among the studied individuals discovered in the Ligurian cave sites Arene Candide and Arma dell'Aquila, with a possible recent third case from Pollera Cave (Canci, et al., 1996; Sparacello, et al., 2016; Sparacello, et al., 2017). The individual from Arene Candide was an adolescent, approximately 15 years old, dated to 4786-4616 cal BCE (Sparacello, et al., 2019), and was found within a stone cyst in a crouched position on their left side. The first diagnosis was made in 1987 (Formicola, 1987), with subsequent analyses confirming the presence of the disease (Sparacello, et al., 2016). Lesions were observed in the lumbar vertebrae, where the individual was likely to have suffered with kyphosis as a result of loss of trabecular bone of the vertebral bodies, a classic location affected by tuberculosis spondylitis infections. The second individual was an adult female, approximately 30 years of age, dating to 4979-4360 cal BCE (Sparacello, et al., 2016), found during the Zambelli excavations of Arma dell'Aquila in 1936. No contextual information has been preserved for the burial. The individual had a similar presentation of classic skeletal lesions indicative of tuberculosis spondylitis (Canci, et al., 1996). The third case is a juvenile, approximately 5 years of age, from the Pollara cave site dating to 4685-4503 cal BCE. This case was of multifocal osteoarticular tuberculosis with trabecular bone erosion observed on the left humerus, cervical and thoracic vertebrae, the right scapula, ribs, and right ischium (Sparacello, et al., 2017). DNA testing was unable to conclusively detail the presence of the bacterium, but previous studies have also failed to yield results when presented with classic lesions indicative of the disease (Sparacello, et al., 2017). This infectious disease created a virulent environment possibly because of cattle breeding activities and resulted in the premature deaths of at least two individuals. Regarding the future studies of the assembled skeletal population, analyses such as these need to be carried out on remains originating from the central Po Valley, as cattle remains are common among Early and Middle Neolithic VBQ zooarchaeological assemblages and thus may also yield cases of tuberculosis.

Stress Indicators

Beyond specific disease processes, non-specific indicators of stress are also common in Liguria, with one publication detailing Linear Enamel Hypoplasia (LEH) in Trentino in the Adige Valley north of modern-day Verona and Mantua, much closer to the area of interest of the current study. Again, the previous outline of the unique ecozones exploited by early Neolithic farmers results in divergent skeletal lesions that represent the lifeways and subsistence strategies employed in the fifth millennium. Linear enamel hypoplasia occurs during the formation of the tooth crown because of the disruption of ameloblasts that are forming the enamel matrix. This interruption is thought to be caused by dietary stress as the body compensates and diverts energy to vital life processes, and away from growing long bones or forming teeth (Kinaston, et al., 2019). This creates a furrow in the enamel, which can be measured from the apex of the crown or the cemento-enamel junction (CEJ) to elucidate the age an individual was likely under stress using known crown formation rates and established metric methods (Blakey, et al., 1994; Guatelli-Steinberg, 2015; King, et al., 2005). As previously discussed, the human diet shifted during the Neolithic from a broad range of nutrient-dense resources to higher calorie, primarily carbohydrate and high-protein domesticate sources. As a result, the frequency of nutrient stress periods increased due to decreased consumption of nutrient-dense foods, shorter weaning intervals and stress, and lean harvest events, thus increasing the frequency of LEH and other non-specific stress indicators such as Harris lines in the long bones (Cohen and Armelagos, 2013). LEH specifically has been observed across the region, and specifically in Liguria and the Adige Valley (Cucina, 2002; Orellana-González, et al., 2019). Incidence of non-infectious dental disorders, such as dental plaque and calculus, carries, and tooth loss, also increased because of the increased consumption of carbohydrates contributing to the presence of simple sugars in the diet and at the gum line increasing bacterial populations that can erode the dental tissue. Macroscopic non-specific stress indicators were observed on each of the burials by the author for the current project and are discussed in the results and discussion chapters.

As previously mentioned, much of the previous bioarchaeological work regarding the Neolithic in Northern Italy is extremely limited both in published work and geographic regions. Burials are often included and described only briefly in much of the ceramic and lithic research that has been published throughout Northern Italy, but only as a potential provenance source for the artifacts of interest. Bioarchaeology remains a relatively new discipline in Italy, with much of the current work focused on medieval and Roman periods where many more human remains are available both in national collections and from ongoing archaeological excavations, most with ample funding. Prehistoric human remains continue to be elusive in Northern Italy and those that are uncovered often are tightly protected by superintendents and excavators alike due to their rarity, which regularly results in a lack of scientific analyses with subsequent publishable results.

The current project seeks to enrich the scientific literature by providing novel chronological data and isotopic life histories of a large assemblage of Neolithic burials from the central Po Valley, with the hopes of improving our understanding of Neolithic lifeways and the ecological legacies of the earliest agriculturalists on a critical Italian landscape.

CHAPTER SIX:

MATERIAL AND METHODS

INTRODUCTION

This chapter will present the skeletal materials (by site), *in situ* skeletal descriptions, and sampling protocols and procedures for obtaining and processing bone and tooth root samples for isotopic analyses and radiocarbon dating. Burial goods or "kits" associated with each of the individuals are described and discussed as they pertain to relative dates or previously discussed cultural patterns. Some reports were not available or unobtainable at the time of this research and therefore are only cursorily covered in this chapter. All descriptions and *in situ* burial photos are adapted from all provided archaeological reports, with permissions and accesses granted by the *Soprintendenza Archeologia del Mantua* (Superintendency for Archaeology in Mantua).

OVERVIEW OF SKELETAL MATERIALS AND PROVIENANCE

A total of 109 individuals and two animal burials were excavated as part of required archaeological investigations for various infrastructure projects around Mantua, akin to Italian Cultural Resources Management (CRM) projects. Most excavations of the analyzed assemblage occurred between 2003 and 2017, with one outlying Copper Aged burial excavated in 1936. A total of 24 separate excavations at 17 sites, some occurring over multiple seasons at the same site, yielded the skeletal remains coalesced into the analyzed assemblage. The individual unique excavations, burial totals, and report availability is summarized in Table 6.1. The site locations are reported in Figure 6.2.1. The following *in situ* summaries and illustrations of the analyzed assemblage materials for the project were translated from all provided Italian reports into English by the author in order to capture specifically skeletal preservation, position, orientation, and included burial goods, previously discussed in brief, for the purposes of subsequent analyses.

Table 6.1: Summary of Excavations, Burial Provenience, and Report Availability

Excavation ID	**Excavation Year(s)**	**Total Project Human Burials**	**Report Availability**
Valdaro Paganella	2016 & 2017	27	No
Valdaro Corte Tridolo	2010	3	Yes
Valdaro Interscambio	2012	2	Yes
Olmo Lungo	2009	7	Yes
Roncoferraro (SAP)	2009	3	Yes
Roncoferraro (GEA)	2009	13	Yes
Roncoferraro Allargamento (GEA)	2009	6	Yes
Bagnolo San Vito Alfa (Città della Moda)	2003	2	Yes
Bagnolo San Vito Tei	2003	2	No
Bagnolo San Vito Dalmaschio	2006, 2007, & 2008	7	Yes
San Giorgio Leale	N/A	1	No
San Giorgio Alberotto	2006	1	No
San Giorgio via Raffaello (Saci)	2006	4	Yes
San Giorgio Bretella Aut.	2009	10	Yes
San Giorgio via Isozo	2011	2	Yes
San Giorgio via Europa	2013	4	Yes
San Giorgio Valdaro Rossetto	2017	2	Yes
San Giorgio via Veneto	2017	4	Yes
San Giorgio via Sardegna	2018	2	Yes
San Benedetto Ca' dell'Aria	1936	1	No
Castelletto Borgo - Foroni	2012	8	Yes

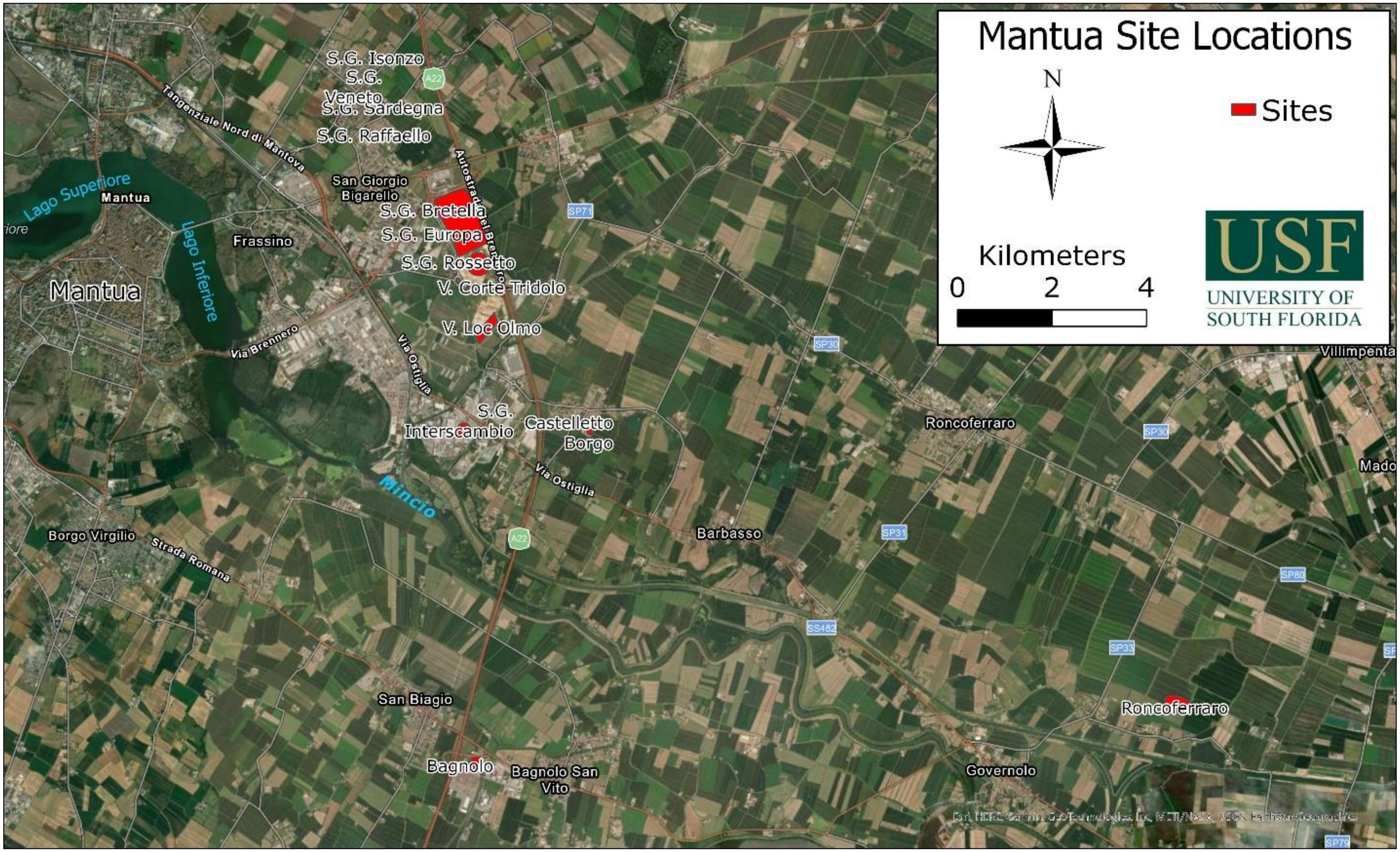

Figure 6.1: Map of approximate site locations

TOMBS

Valdaro Paganella

The formal archaeological reports outlining the findings from the 2016-2017 Valdaro Paganella excavations remain incomplete and unpublished. The total number of individuals within the analyzed collection from Valdaro Paganella missing contextual information is 27. However, despite lacking the individual excavation reports two of the three excavations, Valdaro Interscambio and Corte Tridolo, which were conducted in 2012 and 2010 respectively, do have excavation reports, representing five individuals within the analyzed assemblage that can be used to generally address any broad or general contextual questions regarding the specific larger area of Valdaro, now an industrial area to the north-east of the city center of Mantua. It is important to note that the Valdaro area shares a border with San Giorgio with many of the analyzed individuals coming from this general area just north-east of the industrial zone.

Valdaro Corte Tridolo

Tomb 3 is an ovoid-shaped bare-earth burial with a flat bottom. The remains are of an adult with poor preservation and highly fragmented with only small portions of the upper limbs, torso, and skull remaining. The individual was in a fully flexed position, resting on the left side with the hands placed in front of the face. The burial orientation is Southwest/Northeast with the skull positioned to the Southwest. A few grave goods are present, a “rough-type” ceramic jar sherd and one flint projectile point (Rodighiero, 2010). See Figure 6.2.

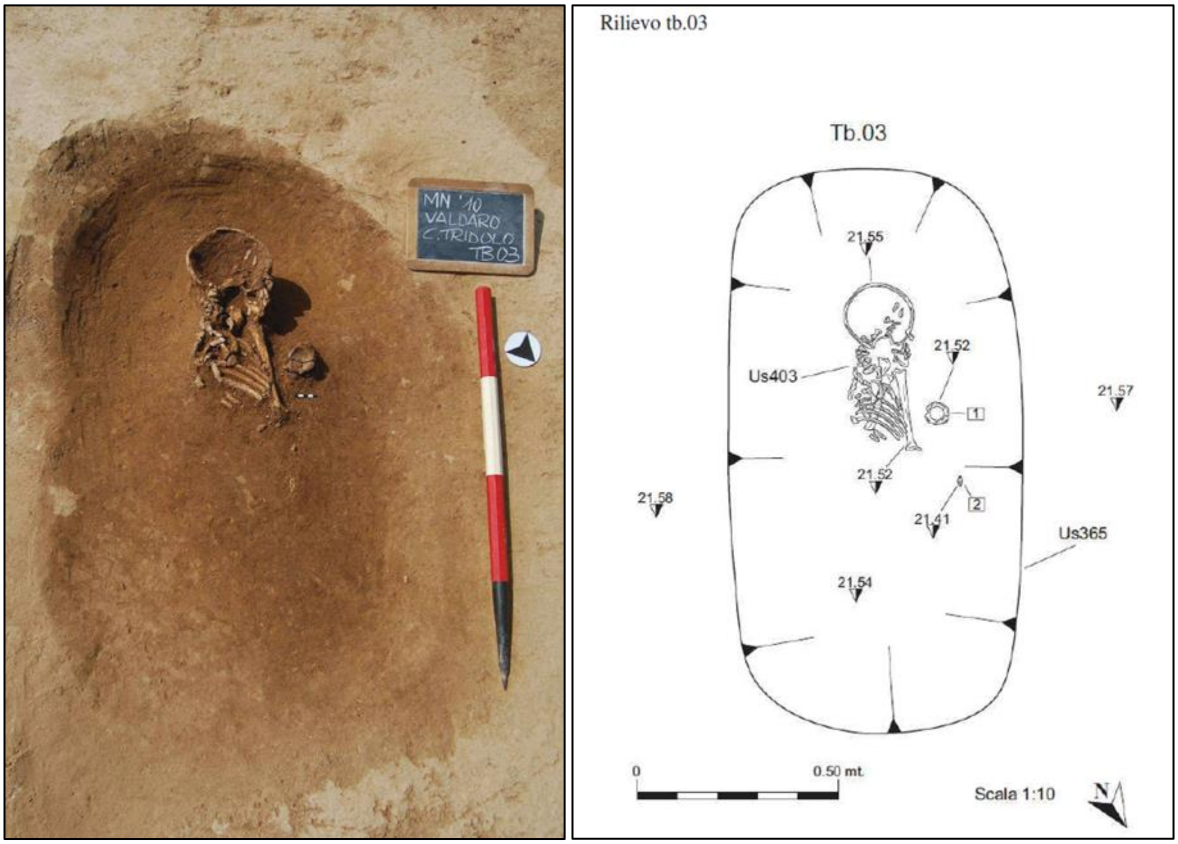

Figure 6.2: Valdaro Corte Tridolo tomb 3 *in situ* burial profile, sketch, and dimensions

Tomb 6 is an ovoid-shaped bare-earth burial with a flat bottom. The remains represent an adult individual with very poor skeletal preservation with only portions of skeletal elements from the right side of the lower body present, but highly fragmented, in addition to some portions of the skull. The individual was in an extended position with the upper limbs parallel to the body, resting on the right side. The burial orientation is North/South with the skull positioned to the South. No grave goods were recovered or observed in this burial. Excavators suggest bioturbation and modern agricultural activities significantly accelerated decomposition and fragmentation (Rodighiero, 2010). See Figure 6.3.

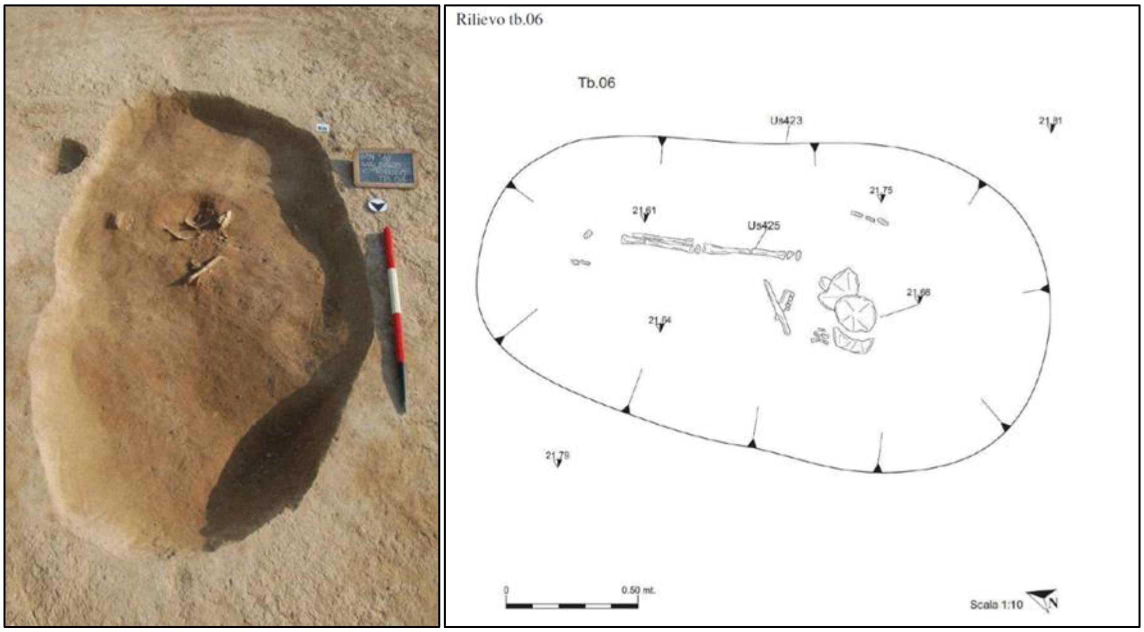

Figure 6.3: Valdaro Corte Tridolo tomb 6 *in situ* burial profile, sketch, and dimensions

Tomb 14 is an ovoid-shaped bare-earth burial with a flat bottom. The remains are of an adult with good preservation with only some of the appendicular skeleton present, largely from the lower body. The individual was in a fully flexed position, resting on the left side, with the upper limbs flexed, likely with hands placed in front of the face, and the lower limbs full extended and crossed at the knees. The burial orientation is North/South with the skull positioned to the South (Rodighiero, 2010). See Figure 6.4.

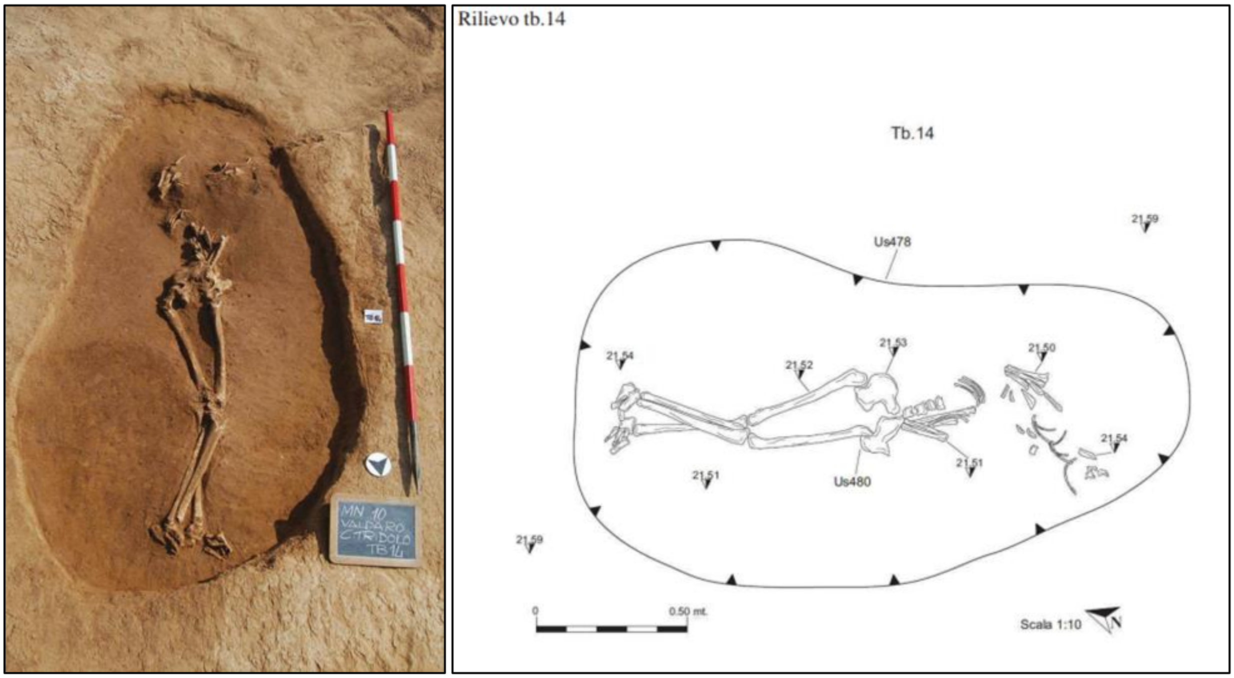

Figure 6.4: Valdaro Corte Tridolo tomb 14 *in situ* burial profile, sketch, and dimensions

Valdaro Interscambio

Tomb 2 is a bare-earth burial of an unidentifiable cut shape. The remains are of an adult in a state of generally poor and fragmentary preservation. The individual was in a semi-flexed position, resting on the left side, with the upper limbs fully flexed, possibly with hands in front of face and the lower limbs flexed at the knee, but half flexed at the hips (kneeling on-the-side). The burial orientation is Northeast/Southwest with the skull positioned to the Northeast. No grave goods were recovered or observed (Pajello and Castagna, 2012). See Figure 6.5.

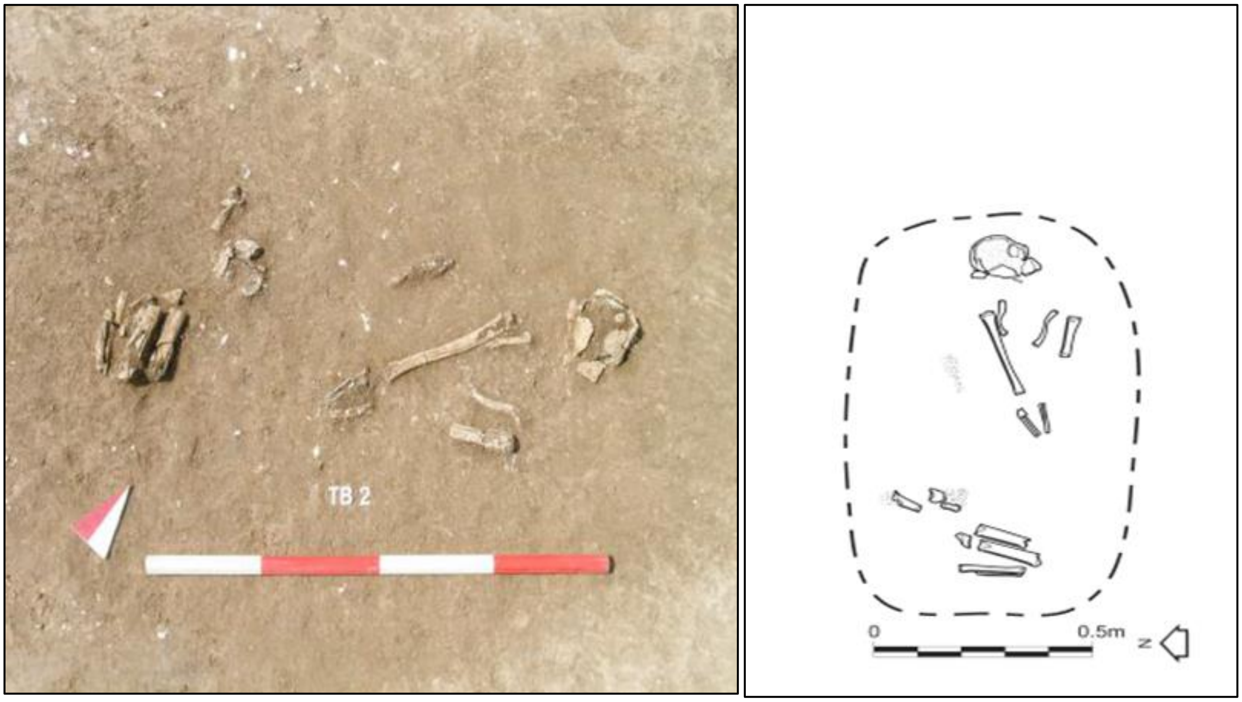

Figure 6.5: Valdaro Interscambio tomb 2 *in situ* burial profile, sketch, and dimensions

Tomb 6 is a circular bare-earth grave with a flat bottom. The remains are of an adult with good preservation, many elements preserved *in situ*, likely due to the deeper burial than the other Neolithic grave. The individual was resting on the left side in a semi-flexed position, with the upper limbs fully flexed and in front of the face, and the lower limbs half flexed at knees and hip (kneeling on-the-side). The burial orientation is East/West with the skull positioned to the East. Some flint flakes were recovered from the burial as well as a polished limestone block placed behind the skull (Pajello and Castagna, 2012). See Figure 6.6.

Figure 6.6: Valdaro Interscambio tomb 6 *in situ* burial profile, sketch, and dimensions

Olmo Lungo

Tomb 1 is a bare-earth burial with an unidentifiable cut shape. The remains are of an adult with generally poor skeletal preservation. The individual was resting on the left side, with the arms paralleling the torso, with forearms fully flexed at the pelvis. The lower limbs were semi-flex again in a kneeling position. The burial orientation is East/West with the skull positioned to the East. Some flint fragments, and a possible projectile point were recovered in the burial fill. The grave was isolated with respect to the other Neolithic burials (Fornari, 2009). See Figure 6.7.

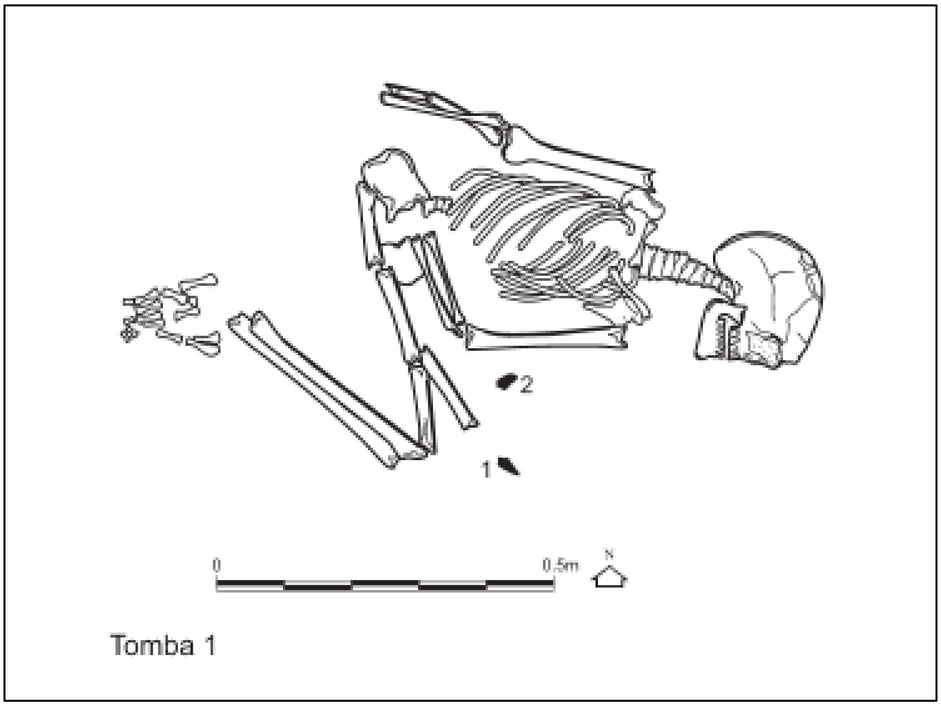

Figure 6.7: Olmo Lungo tomb 1 *in situ* burial profile sketch and dimensions

Tomb 2 is a circular bare-earth burial with a concave bottom. The remains are of an adult with poor preservation. The individual was resting in a supine position with the skull resting on the right side. The upper limbs are in different positions with the right side fully extended and parallel to the torso and the left fully flexed across the chest. The lower limbs are in an anomalous position, where the legs are both flexed at the hip, and resting perpendicular to the spine, and the feet are touching, due to near full flexion at the knees. The burial orientation is East/West, with the skull positioned to the East, but with the face North. One base of a miniature jar was recovered from the burial fill and five small shells were recovered arranged around the arm (distal right humerus), hypothesized to be parts of a bracelet (Fornari, 2009). See Figure 6.8.

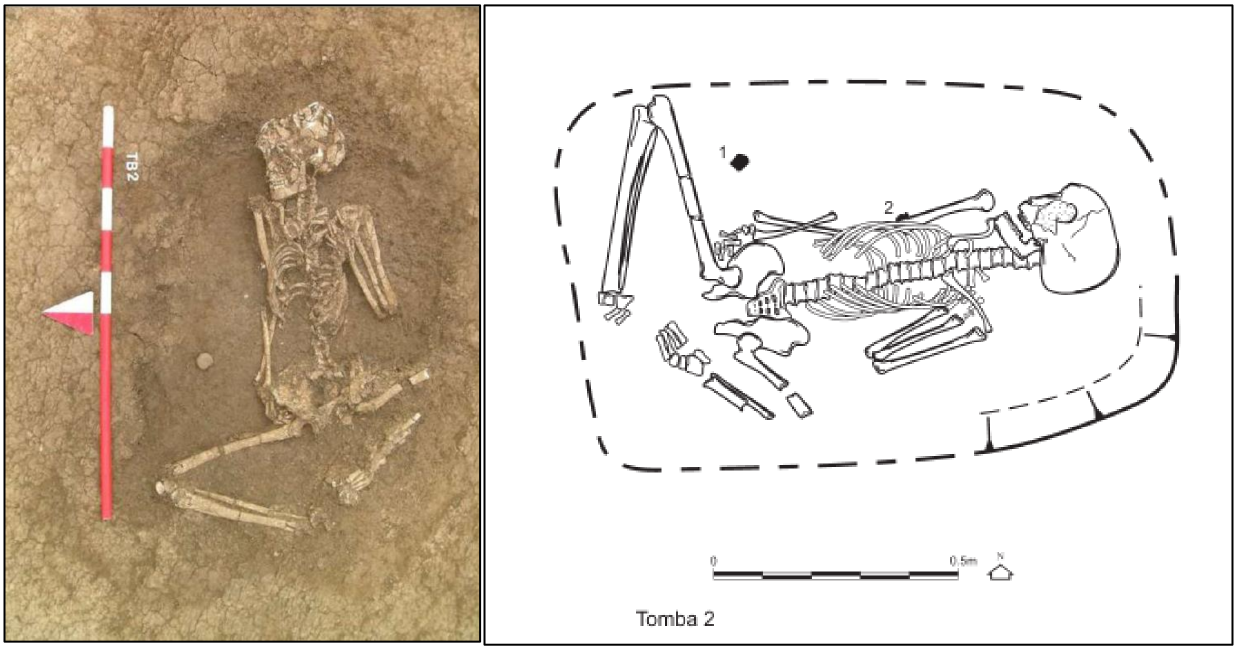

Figure 6.8: Olmo Lungo tomb 2 *in situ* burial profile, sketch, and dimensions

Tomb 3 is an ovoid bare-earth burial with a concave bottom. The remains are of an adult with poor preservation. The individual was resting on the left side, in a full-flexed position, with the upper limbs flexed with the hands in front of the face and the lower limbs appearing fully flexed resting against the abdomen. The burial orientation is East/West, with the skull positioned to the East. Some rare ceramic sherds and a small jar base sherd were recovered with some flint fragments. The jar was likely placed very close to the wrists, at the level of the face (Fornari, 2009). See Figure 6.9.

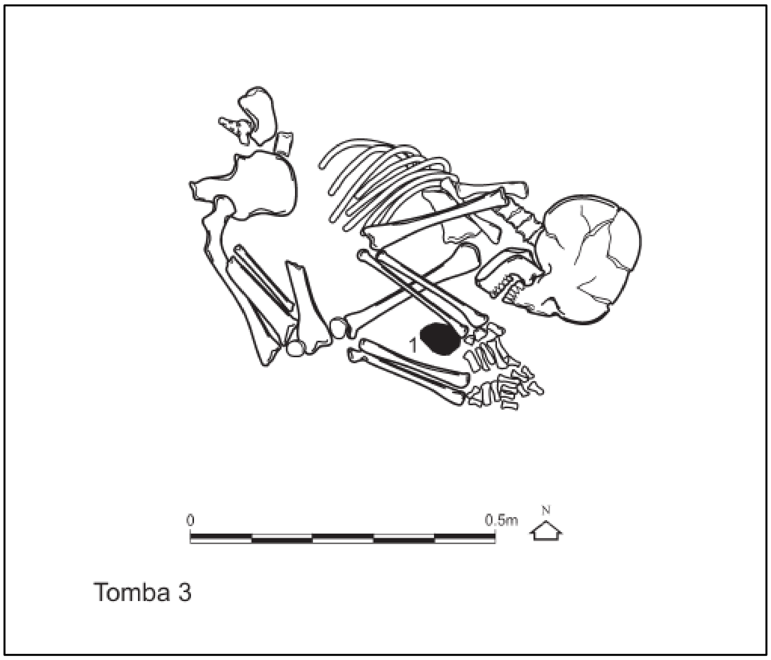

Figure 6.9: Olmo Lungo tomb 3 *in situ* burial profile sketch and dimensions

Tomb 4 is bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side with the lower limbs appearing to be fully flexed into the abdomen. The burial orientation is East/West, with the skull possibly positioned to the East, but not preserved. No grave goods were recovered or observed. No map is available of the excavated tombs; however, the archaeological report mentions that tombs 2, 3, and 4 were in a small group at the western most portion of the excavation area (Fornari, 2009). See Figure 6.10.

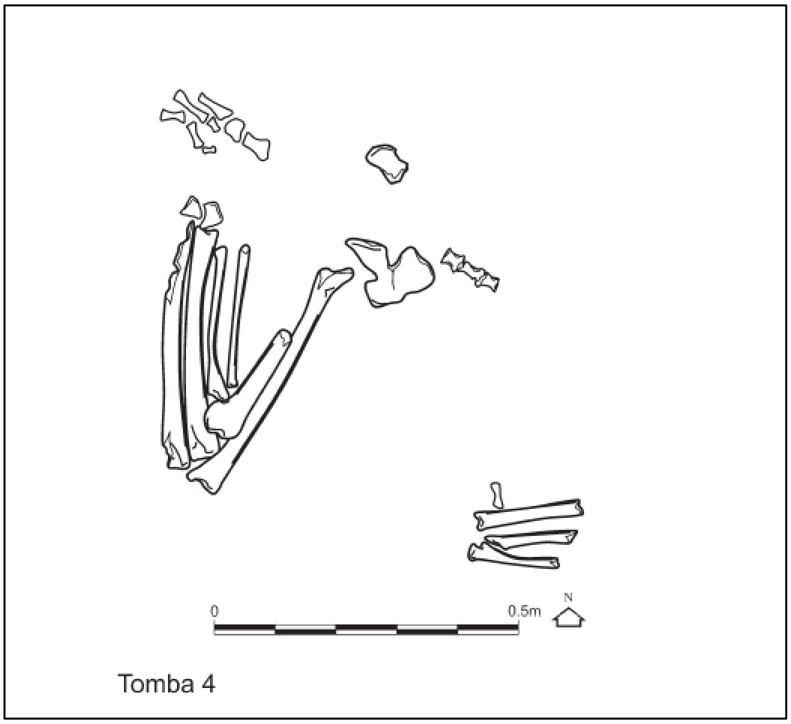

Figure 6.10: Olmo Lungo tomb 4 *in situ* burial profile sketch and dimensions

Tomb 5 is a bare-earth burial with a flat bottom. The remains are of an adult with extremely poor preservation and elements. The individual was resting on the left side, in a semi-flexed position, with the upper limbs fully flexed within the hands in front of the face and lower limbs semi-flexed in a kneeling position. The feet are just deep of the canid burial at the feet. The burial orientation is East/West, with the skull positioned to the East. The individual was buried with a canid placed at the feet, that was oriented North/South, with the head positioned to the Northeast. It appears as if the canid was placed on top of the individual's feet on the left side or in a semi-supine position at the time of burial. Additionally, two flint projectile points were recovered from the area surrounding the hands with a third flint object placed at the level of the forearms (Fornari, 2009). See Figure 6.11.

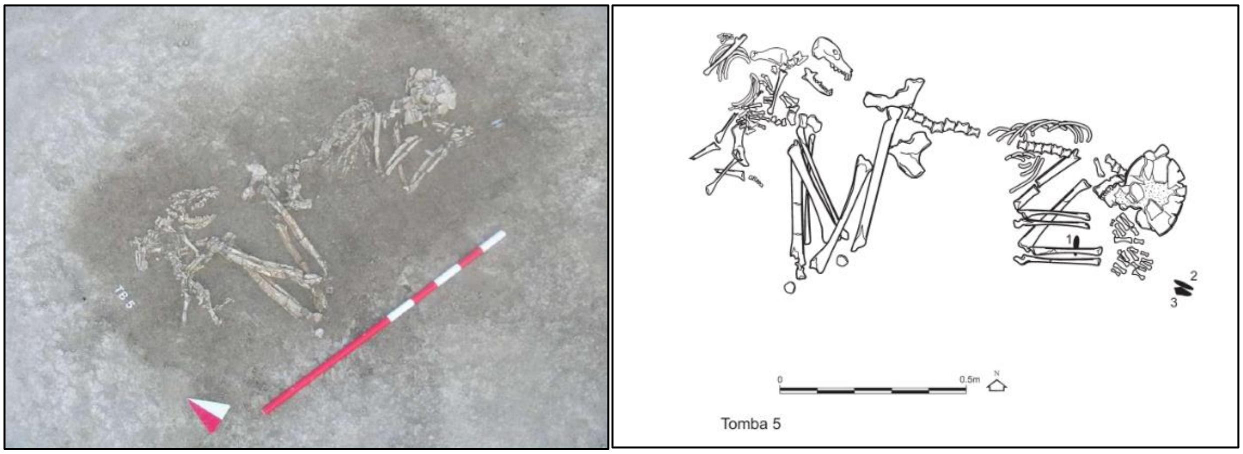

Figure 6.11: Olmo Lungo tomb 5 *in situ* burial profile, sketch, and dimensions

Tomb 6 is an ovoid bare-earth burial with a flat bottom. The remains are of a sub-adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position with the upper limbs fully flexed with the hands in front of the face, and the lower limbs in a kneeing, semi-flexed position. The burial orientation is East/West, with the skull positioned to the East. In front of the skull was a ceramic jar base sherd. The archaeological report mentions some possible ocher-colored staining near the mandible of the individual. Tombs 5 and 6 are possibly grouped according to the excavation report (Fornari, 2009). See Figure 6.12.

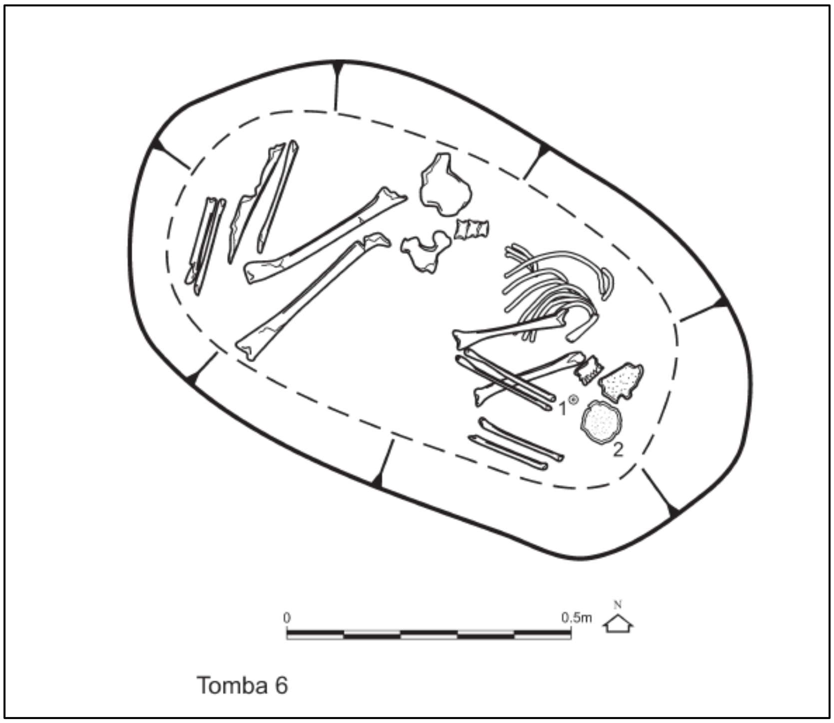

Figure 6.12: Olmo Lungo tomb 6 *in situ* burial profile sketch and dimensions

Tomb 7 is a bare-earth burial. The remains are of an adult with fair preservation and many skeletal elements intact, but not whole. The individual was placed in an anomalous prone position with the skull placed with the face toward the earth. The upper limbs are placed in a flexed position beneath the body and along the sides with some hand elements above the shoulders, near the face. The lower limbs were in a strange position with the right leg perpendicular to the spine at the hip, with the knee partially flexed with the foot turned inward and the left leg extended at the hip but flexed at the knee with the foot turned outward away from the body. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed. The excavation report notes, first, that the burial was isolated from all the others discovered and second, that an incisor and one phalanx were recovered from below the individual's pelvis, but in association with the level of the burial (Fornari, 2009). See Figure 6.13.

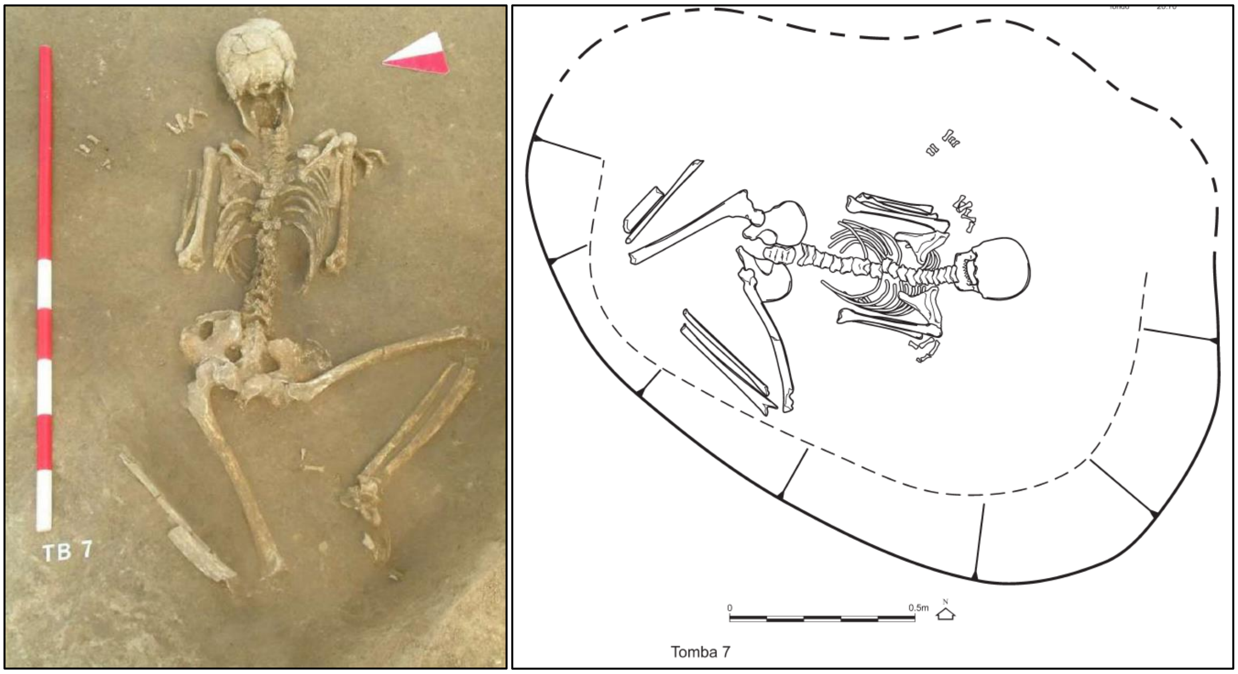

Figure 6.13: Olmo Lungo tomb 7 *in situ* burial profile, sketch, and dimensions

Roncoferraro (SAP)

Tomb 1 is a ovoid bare-earth tomb with a flat bottom. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, with the upper limbs flexed with the hands placed in front of the face and lower limbs semi-flexed to a kneeling position. The burial orientation is East/West, with the skull positioned to the East. One polished greenstone axe was placed with the cutting edge towards the face, but behind the hands. Additionally, a flint blade was place on the hands in front of the face(Castagna, 2009). See Figure 6.14.

Figure 6.14: Roncoferraro (SAP) tomb 1 *in situ* burial profile and dimensions

Tomb 2 is a rectangular bare-earth burial with a concave bottom. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, with the upper limbs fully flexed with the hands in front of the face and the lower limbs in a kneeling position, with the knees fully flexed. The burial orientation is East/West, with the skull positioned to the East. The burial goods associated with the tomb are the most elaborate and numerous of all of the burials within the analyzed assemblage. In the order they are listed in the report the burial goods include, 8 steatite cylindrical ornaments, placed at the back of the skull, a polished stone axe, placed just below the wrist with the sharpened end positioned towards the face, a series of rows of black and white steatite and microdentalium ornaments found near the neck, a flint blade located on the ribs, a second axe of polished stone placed with the sharpened end towards the mid-spine, a hafted flint spear with intact organic remnants of the shaft and hafting materials, a bone horn placed near the feet, a miniature square-mouthed bowl with double rows of vertical linear motifs placed between the arms and the body, and finally, a second flint spear with organic hafting and shaft material remnants placed behind the spinal column. The burial was lifted in bulk utilizing a wooden framework for more precise laboratory-based excavation of the materials, given the rare nature of the preserved grave goods (Castagna, 2009). See Figure 6.15.

Figure 6.15: Roncoferraro (SAP) tomb 2 *in situ* burial profile and dimensions

Tomb 3 is an ovoid bare-earth burial with a concave bottom. The remains are of an adult with extremely poor preservation. The field archaeologists were unable to determine the exact position of the individual or orientation due to the integrity of the skeleton and the lack of direct articulation *in situ*, suggesting that the burial may represent a secondary internment. A small ceramic sherd and a few flint fragments were collected from the burial fill (Castagna, 2009). See Figure 6.16.

Figure 6.16: Roncoferraro (SAP) tomb 3 *in situ* burial profile and dimensions

Roncoferraro (GEA)

Tomb 1 is an irregular ovoid bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, with the upper limbs fully flexed with the hands in front of the face and the lower limbs in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. One polished greenstone axe was placed behind the forearms, in front of the face, one flint blade was recovered near the skull, and some additional flint flakes were also observed (Rovesta, 2010). See Figure 6.17.

Figure 6.17: Roncoferraro (GEA) tomb 1 *in situ* burial profile and dimensions

Tomb 2 is bare-earth burial with a flat bottom. The remains are of a sub-adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs are flexed in front of the face and the lower limbs are in a kneeling position. The burial orientation is Southeast/Northwest, with the skull positioned to the Southeast. Only one artifact was recovered from the burial that is described as a sub-spherical shaped "token" related to other similar finds in the region (Rovesta, 2010). See Figure 6.18.

Figure 6.18: Roncoferraro (GEA) tomb 2 *in situ* burial profile and dimensions

Tomb 3 is an ovoid bare-earth burial with a flat bottom. The remains are of a sub-adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is Southeast/Northwest, with the skull positioned to the Southeast. Only small flint fragments in burial fill were recovered (Rovesta, 2010). See Figure 6.19.

Figure 6.19: Roncoferraro (GEA) tomb 3 *in situ* burial profile and dimensions

Tomb 4 is a sub-rectangular bare-earth burial with rounded corners. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is Southeast/Northwest, with the skull positioned to the Southeast. Only small flint fragments in burial fill were recovered (Rovesta, 2010). See Figure 6.20.

Figure 6.20: Roncoferraro (GEA) tomb 4 *in situ* burial profile and dimensions

Tomb 5 is a distinctive ovoid bare-earth burial with a slightly concave floor. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed (Rovesta, 2010). See Figure 6.21.

Figure 6.21: Roncoferraro (GEA) tomb 5 *in situ* burial profile and dimensions

Tomb 6 is an ovoid bare-earth burial. The remains are of a sub-adult with poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were flexed with the lower limbs above the pelvis. The burial orientation is East/West, with the skull positioned to the East. Only materials were recovered from the grave fill, which included ceramic sherds, fauna bone fragments, and flint fragments (Rovesta, 2010). No *in situ* photos of sketches provided.

Tomb 7 is a distinctive oval-shaped bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Several grave goods were recovered, including a green stone axe placed at the back of the neck with the cutting edge characteristically towards the body, a second smaller green stone axe possible placed in the hands, but now between the distal forearms, a green stone chisel, and a flint projectile placed in the burial but away from the body (10-15 cm, North) (Rovesta, 2010). Figure 6.22 is assumed to be tomb 7 due to the description in the report of the skeletal material, but more importantly of the burial goods and their relative positions. The report photo log for (US 640), what this photo is labeled, is after the tomb 7 set of photos, but both the prior tomb, six, and the subsequent tomb, eight, descriptions do not match the skeletal preservation and positions described in the report or the burial goods. This is especially apparent as in the description of tomb 9, the individual is described not having grave goods, whereas in Figure 6.22 three of the four grave artifacts described are present.

Figure 6.22: Possibly Roncoferraro (GEA) tomb 7 *in situ* burial profile and dimensions

Tomb 9 is a distinctive oval-shaped bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed (Rovesta, 2010). No *in situ* photos or sketches provided.

Tomb 10 is a distinctive oval-shaped bare-earth burial with a flat floor. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Only two flint fragments were recovered (Rovesta, 2010). No *in situ* photos or sketches provided.

Tomb 11 is a circular bare-earth well burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position, the left arm was flexed with the hand in-front of the face and the right arm was extended, parallel to the body, and the lower limbs were flexed with knees above the pelvis. The burial orientation is East/West, with the skull positioned to the East. Grave goods included a VBQ rim, spout, and body sherd, a polished bone tool, and a flint projectile places in the hands (Rovesta, 2010). See Figure 6.23.

Figure 6.23: Roncoferraro (GEA) tomb 11 *in situ* burial profile and dimensions

Tomb 12 is an irregularly shaped bare-earth burial. The remains are of an adult with poor preservation. Burial orientation was not discernable due to heavy disturbance from agricultural activity. Grave goods included a dentalium that was likely part of ornamental jewelry and a ceramic sherd (Rovesta, 2010). No *in situ* photos or sketches provided.

Tomb 13 is an ovoid-shaped bare-earth burial with a flat floor. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is Southeast/Northwest, with the skull positioned to the Southeast. No grave goods were recovered or observed (Rovesta, 2010). See Figure 6.24.

Figure 6.24: Roncoferraro (GEA) tomb 13 *in situ* burial profile and dimensions

Tomb 14 is a circular-shaped bare-earth, possibly secondary well burial. The remains are of an adult with fair preservation. The individual's original position and degree of flexion was not discernible due to the disarticulation of the remains, characteristic of secondary burials. The secondary burial orientation, however, was approximately East. Various ceramic sherds, fauna fragments, flint fragments, and a green stone axe was recovered from the burial fill (Rovesta, 2010). No *in situ* photos or sketches provided.

Roncoferraro Allargamento (GEA)

Tomb 1 is an ovoid bare-earth burial with a flat bottom. The remains are of an adult with poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed with the knees above the pelvis. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed (Molesini, 2010). See Figure 6.25.

Figure 6.25: Roncoferraro Allargamento (GEA) tomb 1 *in situ* burial profile and dimensions

Tomb 2 is an ovoid bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the right side, in a flexed position, the upper limbs were fully flexed, and the hands are placed under the head and the lower limbs were semi-flexed in a kneeling position, but also crossed. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed, but there were burnt bone fragments recovered from near the skull (Molesini, 2010). See Figure 6.26.

Figure 6.26: Roncoferraro Allargamento (GEA) tomb 2 *in situ* burial profile and dimensions

Tomb 3 is an ovoid bare-earth burial with a flat bottom. The remains are of an adult with poor preservation. The skeletal position was not reported as the burial has been heavily disturbed, and a burial placement could not be determined. The burial orientation is East/West, with the skull positioned to the East. A flint projectile point was found within the hand bones (Molesini, 2010). No *in situ* photos or sketches provided.

Tomb 4 is an ovoid bare-earth burial with a flat bottom. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and with hands placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. A small collection of stones near the base of the skull suggested a possible ornament like a necklace (Molesini, 2010). See Figure 6.27.

Figure 6.27: Roncoferraro Allargamento (GEA) tomb 4 *in situ* burial profile and dimensions

Tomb 5 is an ovoid bare-earth burial with a flat bottom. The remains are of an adult with extremely poor preservation. The individual was said to have been in a "fetal position" or typically referring to full flexion of upper and lower limbs. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed (Molesini, 2010). No *in situ* photos or sketches provided.

Tomb 6 is an ovoid bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side and is in a "crouching position" which could be interpreted as the kneeing position, similar to the other burials, but it is not possible to determine the position of the upper limbs from the report. The burial orientation is East/West, with the skull positioned to the East. Three flint fragments under the arm bones and one flint projectile point at the back of the skull were recovered (Molesini, 2010). No *in situ* photos or sketches provided.

Bagnolo San Vito Alfa

Tomb 7 is a bare-earth burial that was deep to a Roman aged cremation burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side and is in a "crouching position" which could be interpreted as the kneeing position, but the illustration in Figure 6.29 depicts the lower limbs fully flexed into the abdomen. The upper limbs were fully flexed with the hands placed in front of the face. The burial orientation is Southeast/Northwest, with the skull positioned to the Northwest. One ceramic sherd was recovered, one near the skull with linear engravings, and a coarse ceramic pot vessel located near the right humerus (Cerchi, 2003). See Figure 6.28.

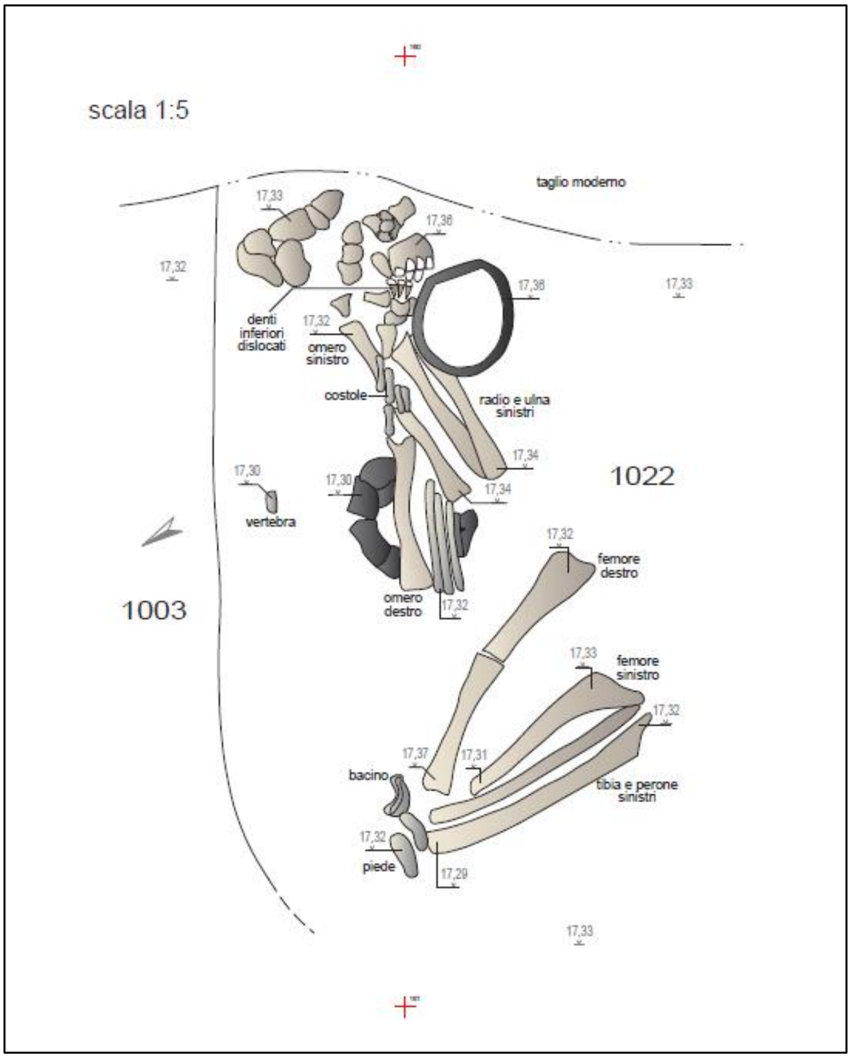

Figure 6.28: Bagnolo San Vito Alfa tomb 7 *in situ* burial sketch

Tomb 14 is an ovoid bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side and is in a "crouching position" with the upper limbs fully flexed with the hands in front of the face, and the lower limbs described as "broken" at the hip and full flexed and tucked under the right elbow. It was postulated to achieve this position the individual was possibly tightly wrapped in an organic material. The burial orientation is East/West, with the skull positioned to the West. No grave goods were recovered or observed (Cerchi, 2003). See Figure 6.29.

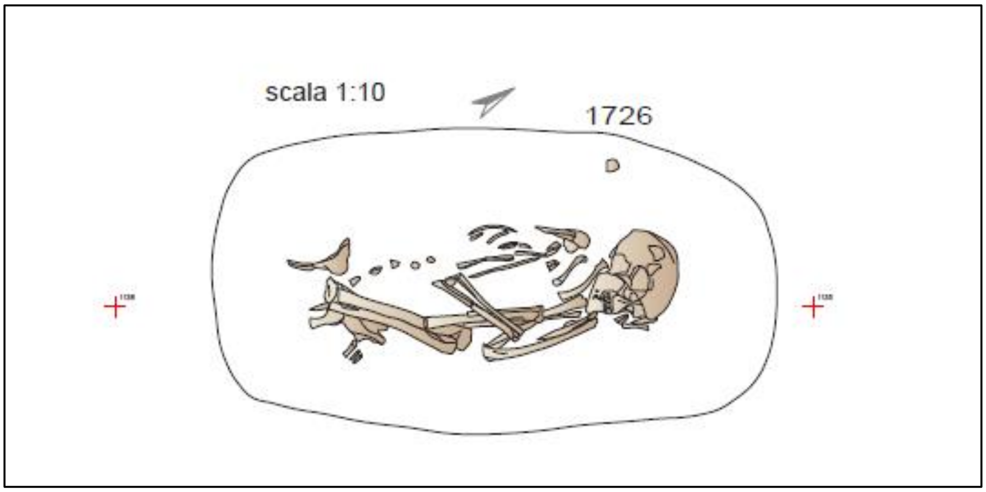

Figure 6.29: Bagnolo San Vito Alfa tomb 14 *in situ* burial sketch

Bagnolo San Vito Tei

Unfortunately, no excavation report was provided to outline the skeletal material provided from Bagnolo San Vito Tei site. In personal communications with the superintendent for archaeology in Mantua, the two tombs from this site (tombs 5 and 6, both adults with poor preservation) date to possibly the third phase of the Middle Neolithic and are rare in comparison with other burials in the region and should be targeted for radiocarbon dating to establish a regional chronological baseline for the period and phase.

Bagnolo San Vito Dal Maschio

Tomb 1 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Burial goods included two polished greenstone axes, one placed in the hands with the sharpened end towards the face and the other between the level of the elbows and knees with the sharpened end towards the body, and a polished stone chisel with two cutting ends placed near the elbows (Castagna, 2006). See Figure 6.30.

Figure 6.30: Bagnolo San Vito Dal Maschio tomb 1 *in situ* burial profile and dimensions

Tomb 2 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. A ceramic sherd was recovered from between the elbows and knees (Castagna, 2006). See Figure 6.31.

Figure 6.31: Bagnolo San Vito Dal Maschio tomb 2 *in situ* burial profile and dimensions

Tomb 3 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No grave goods were recovered or observed (Castagna, 2006). See Figure 6.32.

Figure 6.32: Bagnolo San Vito Dal Maschio tomb 3 *in situ* burial profile and dimensions

Tomb 4 is a quadrangular bare-earth burial. The remains are of an adult with good preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Burial goods included one square-mouthed pot placed between the elbows and knees, which included two ribbon handles and some engraved oblique lines (Castagna, 2006). See Figure 6.33.

Figure 6.33: Bagnolo San Vito Dal Maschio tomb 4 *in situ* burial profile and dimensions

Tomb 5 is an ovoid bare-earth animal burial. The remains have extremely poor preservation. The burial occurs in association with tombs 4 and 8 and is presumed to be domestic canid. No burial goods were observed or recovered (Castagna, 2006). No *in situ* photos or sketches provided.

Tomb 6 is an ovoid bare-earth animal burial. The remains exhibit extremely poor preservation. This burial is completely isolated from the others. Burial is presumed to be a possible canid. No burial goods observed or recovered (Castagna, 2006). See Figure 6.34.

Figure 6.34: Bagnolo San Vito Dal Maschio tomb 6 *in situ* burial profile and dimensions

Tomb 8 is a quadrangular bare-earth burial with rounded corners. The remains are of an adult with good preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a crouching position, at almost 90-degree angles. The burial orientation is East/West, with the skull positioned to the East. Burial goods included a flint blade places at the level of the hands and a flint projectile point in the right hand (Castagna, 2006). See Figure 6.35.

Figure 6.35: Bagnolo San Vito Dal Maschio tomb 8 *in situ* burial profile and dimensions

San Giorgio Leale

No formal excavation report is available for the San Giorgio Leale site. However, one individual from this site was analyzed. Tomb one is a sub-adult with generally poor preservation. An ovicaprine tooth was discovered in association with the collected material during analysis, but permission was not provided to utilize this animal tooth as an archaeological proxy for diet via isotopic analysis. No *in situ* photos or sketches provided.

San Giorgio Alberotto

No formal excavation report is available for the San Giorgio Alberotto site. Only one tomb was analyzed from the site, tomb 1, which was an adult with generally poor preservation.

San Giorgio via Raffaello

Tomb 1 is a bare-earth burial. The remains are of an adult with poor preservation. The provided archaeological report does not detail the *in situ* position and orientation of the skeleton and only one non-specific photo of included grave goods, which appear remains of a shell bracelet (Mazzeo, 2006). See Figure 6.36.

Figure 6.36: San Giorgio via Raffaello tomb 1 *in situ* burial goods

Tomb 2 is an ovoid bare-earth burial. The remains are of an adult with good preservation. The individual is resting on the left side, in a semi-flexed position, the upper limbs are missing but, the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Grave goods included a few ceramic sherds of square-mouthed pots and two flint projectile points (Mazzeo, 2006). See Figure 6.37.

Figure 6.37: San Giorgio via Raffaello tomb 2 *in situ* burial profile and dimensions

Tomb 3 is an ovoid bare-earth burial. The remains are of a sub-adult with poor preservation. The individual was resting on the right side, but the limbs are largely missing so overall position is difficult to interpret. The burial orientation is East/West, with the skull positioned to the West. No burial goods were observed or recovered (Mazzeo, 2006). See Figure 6.38.

Figure 6.38: San Giorgio via Raffaello tomb 3 *in situ* burial profile and dimensions

Tomb 6 is an ovoid bare-earth burial. The remains are of a sub-adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position The burial orientation is East/West, with the skull positioned to the East. No burial goods observed or reported (Mazzeo, 2006). See Figure 6.39.

Figure 6.39: San Giorgio via Raffaello tomb 6 *in situ* burial profile and dimensions

San Giorgio Bretella Aut.

Tomb 14 is a bare-earth burial. The remains are of an adult with good preservation. The individual was resting on the left side, in a flexed position with upper and lower limbs fully flexed. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 15 is a bare-earth burial. The remains are of an adult with extremely poor preservation. *In situ* skeletal position was not identifiable due to the lack of preserved upper and lower limbs. The burial orientation is East/West, with the skull positioned to the East. Burial goods included one polished green stone axe with the sharpened end towards the skull (Pajello, 2009). No *in situ* photos or sketches were provided.

Tomb 27 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual resting on the left side, in a semi-flexed position, the upper limbs were fully flexed, and the lower limbs were semi-flexed in a crouching position with knees bent at approximately 90 degrees. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 30 is a bare-earth burial. The remains are of an adult with poor preservation. The individual is resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or reported (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 31 is a quadrangular bare-earth burial. The remains are of an adult with fair preservation. The individual is resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Burial goods included five biconical steatite elements found near the skull, likely parts of a necklace and a broken flint tool placed in the hands (Pajello, 2009). See Figure 6.40.

Figure 6.40: San Giorgio Bretella Aut. tomb 31 *in situ* burial profile

Tomb 32 is a bare-earth burial. The remains are of an adult with fair preservation. The individual is resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a crouching position, with the knees bent at approximately 90 degrees. The burial orientation is East/West, with the skull positioned to the East. Burial goods included two flint projectile points, one with ocher, the flint point placed in the middle of the spine and the point with ocher placed in the hands. Additionally, there was a green stone axe placed behind the neck with the sharpened end towards the body and one additional broken flint stone tool placed on the skull. No *in situ* photos or sketched provided (Pajello, 2009).

Tomb 39 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 77 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Burial goods observed were extensive which included a horn instrument that was placed under the forearms, two projectile points, one placed at the level of the right scapula, and the other placed at the midshaft of the humerus, and one flint scraper placed at the edge of the burial (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 115 is a bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a crouching position, with knees bent at 90 degrees. The burial orientation is Northeast/Southwest, with the skull positioned to the Northeast. No burial goods were observed or reported (Pajello, 2009). No *in situ* photos or sketches provided.

Tomb 116 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a crouching position, with the knees bent at 90 degrees. The burial orientation is East/West, with the skull positioned to the

East. Burial goods included a retouched flint stone tool placed in the hands and a second retouched flint stone tool placed in between the elbows and knees. No *in situ* photos or sketches provided.

San Giorgio via Isonzo

Tomb 1 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the right side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed with the knees above the pelvis. The burial orientation is Northwest/Southeast, with the skull positioned to the Northwest. No burial goods were observed or recovered (Castagna, 2011). See Figure 6.41.

Figure 6.41: San Giorgio via Isonzo tomb 1 *in situ* burial profile and dimensions

Tomb 2 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed with the knees above the pelvis. The burial orientation is Northeast/Southwest, with the skull positioned to the Northeast (Castagna, 2011). No burial goods were observed or recovered. See Figure 6.42.

Figure 6.42: San Giorgio via Isonzo tomb 2 *in situ* burial profile and dimensions

San Giorgio via Europa

Tomb 1 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, possibly in a flexed position, but only foot elements are preserved so overall skeletal position is unknown. The burial orientation is possibly East/West, with the skull positioned to the East. No burial goods were observed or recovered (Pajello et al., 2013). See Figure 6.43.

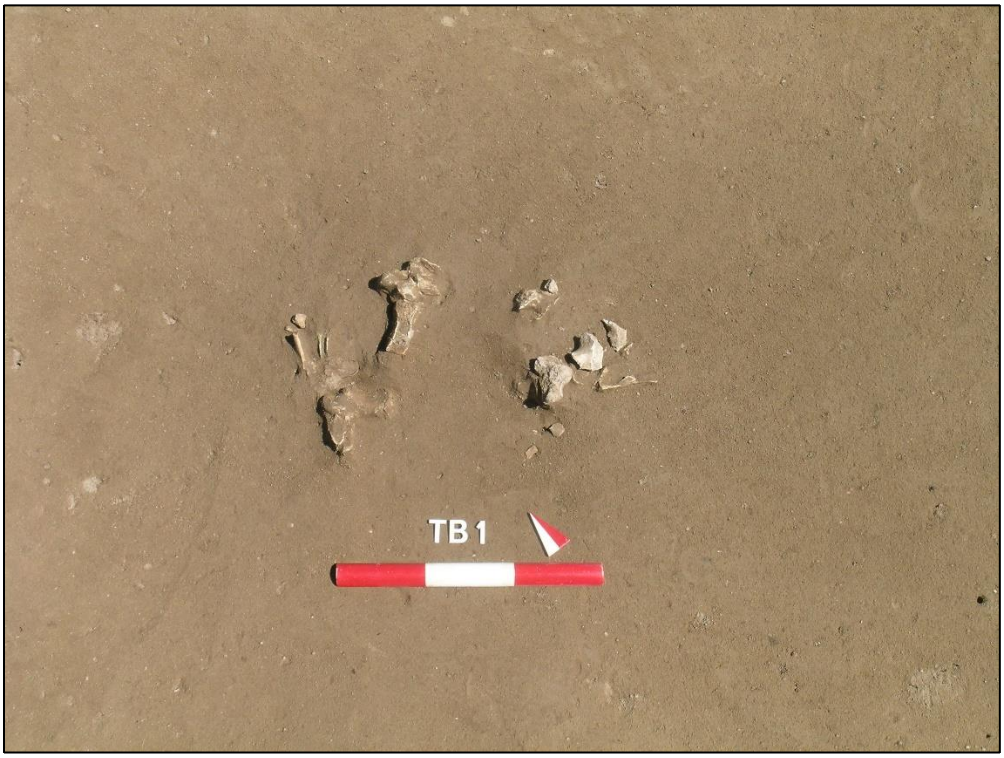

Figure 6.43: San Giorgio via Europa tomb 1 *in situ* photo and dimensions

Tomb 2 is an ovoid bare-earth burial with rounded bottom. The remains are of an adult with good preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were semi-flexed and placed in different positions with the left are flexed and in front of the face and the right are parallel to the side with the forearm semi-flexed in front of the chest. The lower limbs were semi-flexed in a crouching position. The burial orientation is East/West, with the skull positioned to the East (Pajello et al., 2013). No burial goods were observed or recovered.

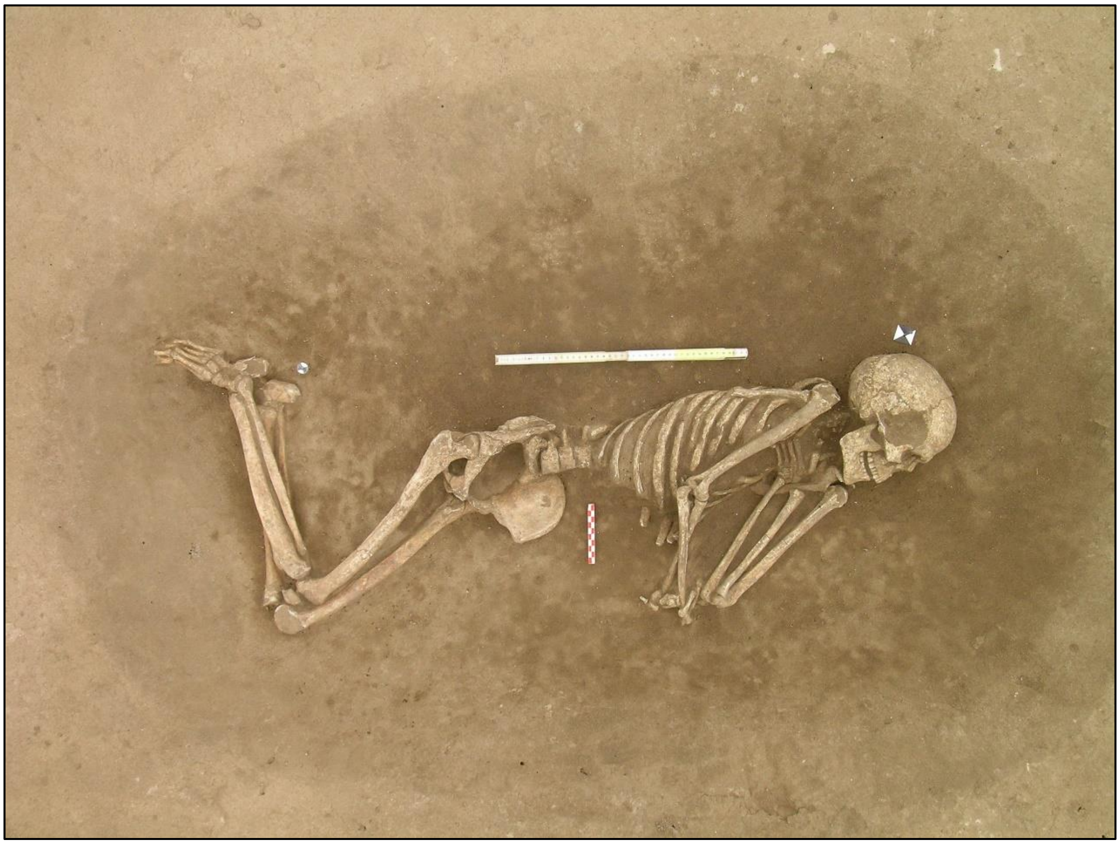

Figure 6.44: San Giorgio via Europa tomb 2 *in situ* photo and dimensions

Tomb 3 is an ovoid bare-earth burial with a curved bottom. The remains are of a sub-adult with good preservation. The individual was partially resting on the left side and partially supine, in a semi-flexed position, the upper limbs were mostly parallel with the left arm not flexed and the right semi-flexed with the forearm in-front of the abdomen. The lower limbs were semi-flexed with full flexion at the knees, but greater than 90 degrees of extension at the hips. The burial orientation is East/West, with the skull positioned to the East. Burial goods included a small square-mouthed pot with a deer bone or horn at the bottom placed at the level of the pelvis in front of the body to the south and one perforated shell possible part of an ornament. The excavators also commented on absent space near the skull possibly for organic tools or elements that were not preserved (Pajello et al., 2013). See Figure 6.44.

Figure 6.45: San Giorgio via Europa tomb 3 *in situ* photo and dimensions

Tomb 4b is not mentioned in the report but is an isolated juvenile humerus in poor preservation. It is unclear if this individual was buried with one of the other individuals or was from trench excavation. No burial goods were observed or recovered (Pajello et al., 2013). No *in situ* photos or sketches provided.

San Giorgio Valdaro Rossetto

Tomb 146 is a bare-earth burial. The remains are of a sub-adult with extremely poor preservation. The individual is resting on the left side, in a flexed position, with only the lower limbs present and appearing fully flexed. The burial orientation is North/South, with the skull positioned possibly to the North. No burial goods were observed or reported. All burial information was provided by personal communication with the Superintendent for Archaeology in Mantua. See Figure 6.45.

Figure 6.46: San Giorgio Valdaro Rossetto tomb 146 *in situ* photo and dimensions

Tomb 151 is a bare-earth burial. The remains are of an adult with poor preservation. The individual is resting on the left side, in a semi-flexed position, the upper limbs were mostly parallel along the torso with the right forearm partially resting on the abdomen. The lower limbs were fully flexed in a kneeling position, with knees at an acute angle of less than 90-degrees. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or reported. All burial information was provided by personal communication with the Superintendent for Archaeology in Mantua. No burial goods were observed or reported No *in situ* photos or sketches provided. See Figure 6.46.

Figure 6.47: San Giorgio Valdaro Rossetto tomb 151 *in situ* photo and dimensions

San Giorgio via Veneto

Tomb 1 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Verdi, 2017). See Figure 6.47.

Figure 6.48: San Giorgio via Veneto tomb 1 *in situ* photo and dimensions

Tomb 2 is a bare-earth burial. The remains are of a sub-adult with poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed with knees likely slightly above the pelvis. The burial orientation is East/West, with the skull positioned to the East. Burial goods included perforated shell elements that were likely part of a necklace from around the upper spine and near the skull (Verdi, 2017). See Figure 6.48.

Figure 6.49: San Giorgio via Veneto tomb 2 *in situ* photo and dimensions

Tomb 3 is a bare-earth burial. The remains are of a human of unknown approximate life stage with extremely poor preservation. The overall skeletal position and orientation is unknown due to preservation, but orientation is suggested to have been possibly East/West. No burial goods were observed or recovered (Verdi, 2017). See Figure 6.49.

Figure 6.50: San Giorgio via Veneto tomb 3 *in situ* photo and dimensions

Tomb 4 is a bare-earth burial. The remains are of a sub-adult with poor preservation. The individual was resting on the left side, in a flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were fully flexed with knees likely slightly above the pelvis. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Verdi, 2017). See Figure 6.50.

Figure 6.51: San Giorgio via Veneto tomb 4 *in situ* photo and dimensions

San Giorgio via Sardegna

Tomb 1 is a bare-earth burial. The remains are of an adult with extremely poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. No burial goods were observed or recovered (Verdi, 2018). See Figure 6.51.

Figure 6.52: San Giorgio via Sardegna tomb 1 *in situ* photo and dimensions

Tomb 2 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were fully flexed and placed in front of the face and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the East. Burial goods included two greenstone axes, one larger placed at the base of the neck with the sharpened end facing away from the body and the other placed perpendicular to the larger one with the sharpened end facing the larger axe. With the axes at the back of the individual was also a flint projectile point below the larger axe, with the point facing the larger axe. In addition, to those burial goods at the back, three additional flint tools were places among the arms, forearms, and hands, these were all bladelets. Lastly, two additional flint bladelets were placed behind the pelvis as well (Verdi, 2018). See Figure 6.52.

Figure 6.53: San Giorgio via Sardegna tomb 2 *in situ* photo and dimensions

San Benedetto Ca' dell'Aria

No formal excavation report is available for the San Benedetto Ca' dell'Aria site. One tomb, tomb 1, was excavated at the site in 1936, with the remains belonging to an adult with fair preservation. Copper staining on the bones from corroding copper objects placed in the burial environment was observed.

Castelletto Borgo – Foroni

Tomb 1 is a bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were semi-flexed with the left arm partially parallel to the torso with the wrist flexed towards the body and the right arm flexed with hands in front of the face. The lower limbs were semi-flexed in a kneeling position. The burial orientation is Northeast/Southwest, with the skull positioned to the Southwest. Burial goods included one black ceramic pot placed behind the skull (Gradella, 2012). See Figure 6.53.

Figure 6.54: Castelletto Borgo Foroni tomb 1 *in situ* photo and dimensions

Tomb 2 is a bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were crossed at the wrists and placed on the chest and the lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the West. Burial goods were like tomb 1, a black ceramic jar placed behind the skull (Gradella, 2012). See Figure 6.54.

Figure 6.55: Castelletto Borgo Foroni tomb 2 *in situ* photo and dimensions

Tomb 3 is a bare-earth burial. The remains are of a human of unknown approximate life stage with extremely poor preservation. The individual was resting on the left side. The exact skeletal position is not detailed but was said to be like the other tombs with semi flexed arms across the chest or abdomen and the lower limbs semi-flexed in a kneeing position. The burial orientation is East/West, with the skull positioned to the West. Burial goods included ceramic base sherds of a red vessel (Gradella, 2012). No *in situ* photos or sketches provided.

Tomb 4 is a bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side. The exact skeletal position is not detailed but was said to be like the other tombs with semi flexed arms across the chest or abdomen and the lower limbs semi-flexed in a kneeing position. The burial orientation is Northeast/Southwest, with the skull (not preserved) positioned to the Southwest. No burial goods were observed or recovered (Gradella, 2012). No *in situ* photos or sketches provided.

Tomb 5 is a bare-earth burial. The remains are of a possible adult with extremely poor preservation. The individual was possibly resting on the left side like tomb 3. The exact skeletal position is not detailed but was said to be like the other tombs with semi flexed arms across the chest or abdomen and the lower limbs semi-flexed in a kneeing position. The burial orientation is East/West, with the skull positioned to the West. No burial goods were observed or recovered (Gradella, 2012). No *in situ* photos or sketches provided.

Tomb 6 is a bare-earth burial. The remains are of an adult with fair preservation. The individual was resting in a supine position with the in a flexed position, the upper limbs were divergent the left arm was mostly parallel to the body and the right semi-flexed at the elbow and placed on the chest. The lower limbs were not preserved. The burial orientation is Northwest/Southeast, with the skull positioned to the Northwest. Burial goods included a polished black ceramic bowl with a flared rim placed behind the skull, a flint dagger placed next to the left humerus, and two flint projectile points, one placed on the chest and the other at the level of the pelvis (Gradella, 2012). See Figure 6.55.

Figure 6.56: Castelletto Borgo Foroni tomb 6 *in situ* photo and dimensions

Tomb 7 is a bare-earth burial. The remains are of an adult with poor preservation. The individual was resting on the left side, in a semi-flexed position, the upper limbs were mostly parallel to the torso with the forearms and hands semi-flexed and placed on the abdomen. The lower limbs were semi-flexed in a kneeling position. The burial orientation is East/West, with the skull positioned to the West. No burial goods were observed or recovered (Gradella, 2012). See Figure 6.56.

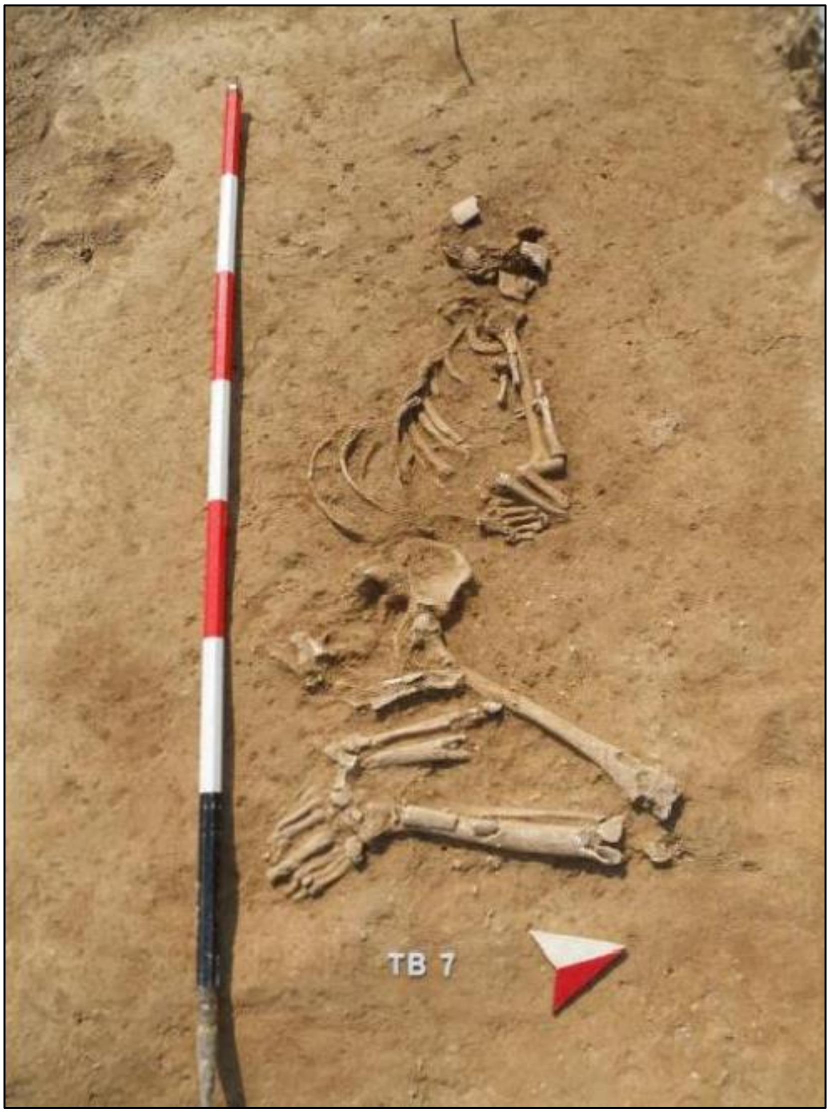

Figure 6.57: Castelletto Borgo Foroni tomb 7 *in situ* photo and dimensions

Tomb 8 is an ovoid bare-earth burial. The remains are of a sub-adult with extremely poor preservation. The individual was possibly resting on the left side like tombs 3 and 5. The exact skeletal position is not detailed but was said to be like the other tombs with semi flexed arms across the chest or abdomen and the lower limbs semi-flexed in a kneeing position. The burial orientation is East/West, with the skull positioned to the West. No burial goods were observed or recovered (Gradella, 2012). No *in situ* photos or sketches provided.

BIOLOGICAL PROFILE

As discussed above, many of the burials presented a challenge with highly fragmentary remains, as indicated by the assessment of preservation integrity (good, fair, poor, and extremely poor). These categories generally describe the relative level of fragmentation or proportion of the skeleton with complete elements vs. broken or partially decomposed elements. A large percentage of the burials were categorized as having poor levels of preservation, which hindered or in some cases prevented sex or age estimation entirely due to the wholesale absence of boney landmarks or whole elements which are required for skeletal assessments. Under these circumstances, standard methods of primarily sex and age estimation were undertaken with some macroscopic assessment of non-specific paleopathological stress indicators on primarily fragmentary remains. A gestalt of estimations based on standard methods, but also on the hierarchy of non-metric sexually dimorphic areas and elements of the skeleton where the elements of the pelvis are the most sexually dimorphic, followed by elements of the skull skeleton, and finally elements of the post-cranial skeleton. For example, when elements of the pelvis were present, any sex estimations that were determined based on pelvic morphology were assigned, despite potentially converse or indeterminate morphological traits on the skull. As a note, in an overwhelming number of instances the level of fragmentation within the analyzed assemblage limited the use of any metric sex or age estimation techniques and thus only non-metric methods were utilized.

Sex Estimation

Sex was estimated utilizing current non-metric bioarchaeological methods for binary (male vs. female) sex alone, but the author acknowledges that these methods are not comprehensive, and that sex is not a binary category, and the legacies of western binary systems can affect current and future interpretations of the assembled collection (Zuckerman, 2021). For the purposes of this dissertation, sex estimation was conducted with remains placed into one of three categories, male, female, or indeterminate. The indeterminate category is reserved for those individuals with mixed binary sex traits and therefore can capture both robust females and gracile males, as well as those tombs that lacked any sexually dimorphic landmarks that prevented any estimation. Sex estimations were facilitated using the manual, *Standards for Data Collection from Human Skeletal Remains* (*Standards*) (Buikstra and Ubelaker, 1994). Additional sources were also used that are not fully explored within the 1994 edition of Standards but have some merit in bioarchaeological contexts as outlined below. All statistical analyses grouped the probable females with females and probable males with males, while the indeterminates were narrowed to only those without elements present to produce a sex estimation or those with neutral or non-categorical sex traits.

Beginning with the pelvis, when pelvic elements were present, sex estimations followed Phenice's 1969 techniques for pubic bone, including the presence/absence of a ventral arc, sub-pubic concavity, and the medial aspect of the ischio-pubic ramus (Phenice, 1969). Together these three traits of the ventral human pelvis create an extension or stunting of the left and right pubis bones in articulation, altering the subpubic angle to a "U" shape for females and a more "V" shape for males respectively. Some of these traits based on the level of fragmentation of the pubis were scored in isolation. In addition to the ventral pelvic region, the dorsal aspect of the pelvis, particularly the greater sciatic notch, was also scored when present, following Walker 2005 techniques outlined in Standards (Walker, 2005). The greater sciatic notch is another highly sexually dimorphic structure of the pelvis and its profile has been classified by Walker into five distinctive categories, where 1 and 2 trend more female with a wider angle nearing 90 degrees, and 4 and 5 trend more male with a narrower acute angle. The middle score of 3 is more indeterminate.

Cranial sex estimation strictly followed Walker 2008. A total of five cranial landmarks were identified as sexually dimorphic and separated and scored on scales of one to five, the nuchal crest, mastoid processes, supra-orbital margins, supra-orbital ridge or glabella, and the mental eminence, where 1 and 2 represent more gracile or feminine traits and 4 and 5 more robust or male traits (Walker, 2008). Many of these traits were scored in isolation, and when portions of the skull were disarticulated and fragmented, only a few crania remained fully intact to examine all the traits in articulation.

Lastly, a few individuals only retained some post-cranial elements, or had a combination of os coxa, cranial, and post-cranial elements that are useful in the determination of skeletal sex. Two distinctive landmarks that have reliable survivability in the burial environment are the distal humerus and the clavicle. First, the distal humerus has been shown by Vance and colleagues and others have demonstrated the efficacy of the distal humerus as a sexually dimorphic area of the post-cranial skeleton (Stock, 2020; Vance et al., 2011). A set of three specific non-metric traits of the distal humerus are assessed on morphological presentation alone, the olecranon fossa shape (ovoid more feminine, triangular more masculine), the angle of the medial epicondyle (upward angle more feminine, flatter profile more masculine), and the presence (female)/absence (male) of a trochlear extension over the margin of the capitulum. Combined these traits all related to the carrying angle differences between males and females. Second, the presence (male)/absence(females) of a rhomboid fossa on the clavicle is associated with the stabilizing muscle of the pectoral girdle of the same name (Rogers et al., 2000). Both post-cranial locations have relatively high classifications for binary sex categories in modern and historic skeletal collections (Stock, 2020).

Age Estimation

All age estimations were similarly challenging to sex estimations, given the poor preservation and low survivability of diagnostic elements. When present the dentition was the preferred location for sub-adult age estimation, followed by epiphyseal union of long bones in any preserved post-cranial elements. Adult age estimations also targeted dentition when present, especially complete second and third molars, but also incorporated dental attrition or wear scoring as well as well-known localities of age estimation in the post cranial skeleton, such as the auricular surface of the ilium or the pubic symphysis when present. Again, a gestalt of the scores derived from these element scoring systems was utilized to produce an age estimation which was derived from the average lowest ages to the average highest ages.

Beginning with techniques used to age any dentition when present, the amelogenesis of the tooth crown was primarily scored utilizing a combination of Ubelaker 1989 and AlQahtani et al. 2009 (AlQahtani et al., 2010; Ubelaker, 1989). The Ubelaker (1989) aging system based on dental development was developed on a Native American sample but is broadly applied to general human development and is utilized within the Standards manual, while the AlQahtani *et al*. 2010 system was based on a modern European sample of x-rays of sub-adults. In addition to both systems, tooth root development was also evaluated utilizing the Moorrees *et al*. 1963 system for estimating age from tooth root development from crown formation to apical closure of the tooth roots (Moorrees et al., 1963). All teeth were evaluated when present, many were not in occlusion which facilitated rapid evaluation of the tooth roots, and ages were primarily estimated based on the latest forming tooth developmental stage. Dental aging is extremely effective for sub-adults and young adults, where the third molar crown or root has not completely formed. Individuals with distal root completion of any third molars were assigned one minimal age of 20 years of age or greater.

In the analytical circumstances when the adult dentition was complete, tooth wear of the occlusal crown surface was applied following Brothwell (1989) to estimate age-at-death. This system for aging only provides the broadest possible estimations as age-at-death estimations of adults, mature and elderly adults, as degenerative markers of age are much more variable than developmental changes because of growth and maturity (Clark et al., 2020). Only wear present on molars was evaluated utilizing Brothwell's system, which relies on wear facets and profiles of the cusps, pinprick to larger circular areas of dentin exposure on the chewing surfaces, and the overall combined amount of dentin exposed corresponds to one of four age categories. This system was developed on a medieval British bioarchaeological collection in the 1960s, where softer and less gritty foods were more likely consumed than in earlier prehistoric periods, which could result in more conservative estimates in the present study. The greatest limitation of the system is the large age ranges, typically about 10 years, with the greatest at 45 and above as the most disparate.

Lastly, the post-cranial skeleton was the last locality yielding age-at-death information possibly contributing to age ranges, based on preservation of useful landmarks. First, epiphyseal union of long bones following Schaefer *et al*. (2009) were utilized for sub-adult and young adult remains based on individual limits of post-cranial preservation. Second, classic landmarks within the os coxa, the auricular surface of the ilium and the pubic symphysis of the pubis were scored in individuals with appropriate preservation (Brooks and Suchey, 1990; Lovejoy et al., 1985). Third, the last system when the cranium or part of the caninum was preserved in articulation was cranial suture closure (Meindl and Lovejoy, 1985). Less than a handful of individuals retained appropriate preservation for scoring the auricular surface, the pubic symphysis, and cranial suture closure, but many more individuals retained long bone ends to apply epiphyseal union criteria.

STABLE ISOTOPE SAMPLE PREPARATION AND ANALYSIS

A total of 109 individual human bone fragments (Figure 6.22), 3 animals, and a total of 79 individual human tooth roots (Figure 6.23) were sampled for carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), and oxygen ($\delta^{18}O$) stable isotopic analysis. Bone samples were preferentially taken from long bones of the arms or legs. This was due to the greater level of preservation of these skeletal elements, which often translates to better preservation of bone collagen, given the age of the analyzed assemblage. These samples were taken often by selecting disarticulated and non-diagnostic fragments or using a handsaw. Second and third molars were targeted to decrease the effects of weaning on the analyzed isotopic values, typically associated with earlier forming teeth of the anterior dentition. However, some early forming teeth, incisors, were sampled (*n*=7), where the initial tooth root formation is estimated to be at or around 2 years of age for both males and females. Since the chosen tissue for dietary reconstruction was tooth roots and not enamel, all other tooth roots from canines to the latest forming third molars, all initiate growth after three years of age, which is after the latest known average Neolithic age of weaning cessation in pre-historic Northern Italian populations at 2.5 to 3 years (Goude et al., 2020). Teeth were often not in occlusion, but when still in occlusion the teeth were manually pried sockets, with little resistance. Tooth roots were removed by using two sets of needle-nosed pliers. Tape was places on the gripping ends for the pliers applied to hold the tooth crown while the other set used to mechanically separate the root from the crown at the cementum-enamel junction. Stable $\delta^{13}C_{co}$ and $\delta^{15}N$ were derived from both bone and tooth root collagen and $\delta^{13}C_{ap}$ and $\delta^{18}O_{ap}$ from tooth root and bone apatite for the current study. Tooth enamel was not allowed to be sampled in the current study; a restriction imposed by the Superintendent for Archaeology in Mantua.

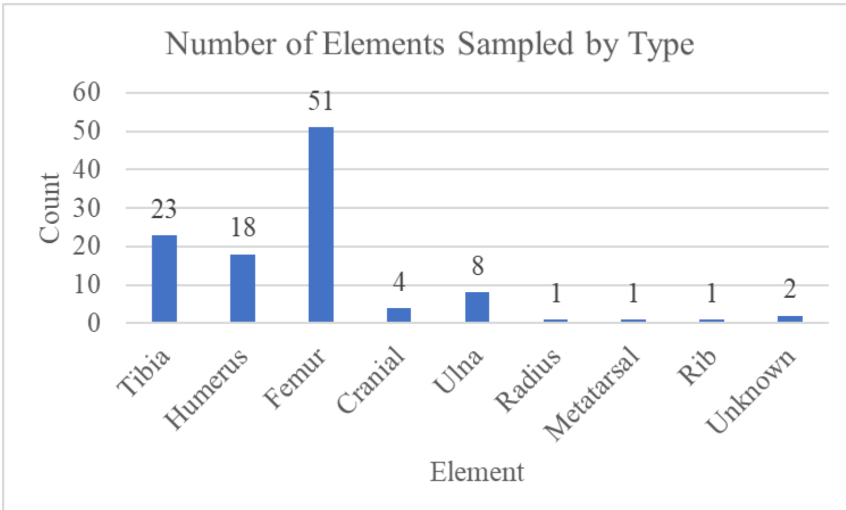

Figure 6.58: Bar chart of elements sampled for bone apatite and collagen extraction (*n*=109)

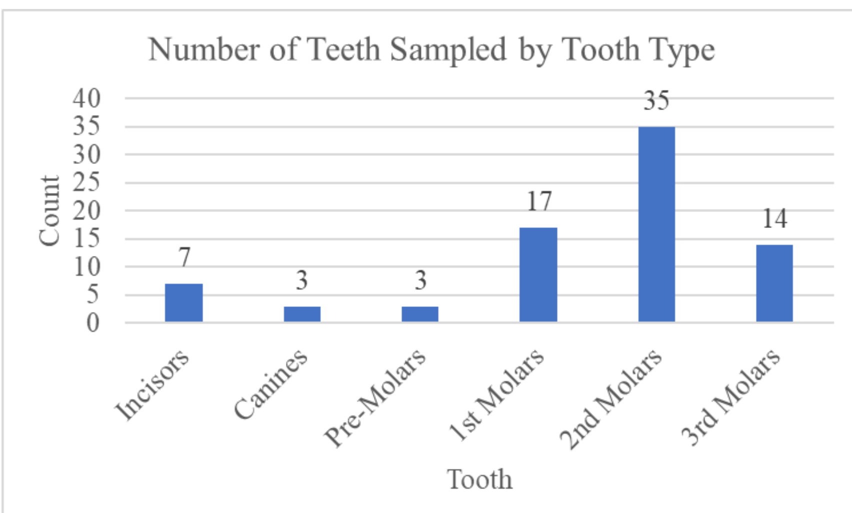

Figure 6.59: Bar chart of teeth sampled for tooth root apatite and collagen extraction (*n*=79)

Sample Preparation Protocol

Bone and tooth root samples were pre-treated at the USF Laboratory for Archaeological Sciences (L.A.S.), supervised by Dr. Robert Tykot following established and adapted protocols by Sealy and colleagues (Tykot, 2004).

Collagen Processing (Bone and Tooth Roots)

All bone and tooth root samples were first washed in water and mechanically cleaned with toothbrushes to remove any adhering soils or plant roots, sonicated in a warm water bath for 10 minutes in 100 ml glass vials and rinsed. Samples were left to air dry overnight and were then chemically processed following the below procedure:

1. A small area was cleaned on the surface of the bone using a diamond bit fitted to a high-speed precision microdrill and then drilled at high speed to collect ~10 mg bone powder, which would later be chemically treated to isolate apatite, described below. The remaining bone sample was broken into pieces, weighed, and placed into a 100 ml glass vial.
2. A 0.1 M NaOH solution was placed into each vial until the bone samples were just covered (~20–40 mls). Samples were left at room temperature in the solution for 24 hours to remove any humic acids from the sample.
3. The NaOH solution was decanted, samples were rinsed in the 100 ml glass vials with deionized water, and further mechanically cut into smaller pieces as needed with cleaned scalpels (rinsed with DI water and scrubbed dry between samples). A 2% HCl solution was added to each sample vial, until the sample was covered (20–40 mls), to demineralize carbonates, phosphates, and humic acids for 24 hours at room temperature.

4. The HCl solution was decanted, and samples were again rinsed with DI water in the 100 ml glass vials briefly and returned to a fresh solution of 2% HCl for another 24 hours at room temperature. This procedure was repeated until no more visible reaction was taking place (the HCl solution was clear after 24 hours and no bubbles were forming).
5. After the samples were demineralized and pseudomorphic collagen remained, the samples were again briefly rinsed with DI water, and soaked in a second round of 0.1 M NaOH, until the samples were covered (~20–40 mls) or floating, to remove any remaining humic acids released during demineralization for 24 hours at room temperature.
6. The NaOH solution was decanted and the pseudomorphs were rinsed with DI water one last time before being placed in 2-dram vials and dried overnight at 60^{o} C in an oven. [Optionally, samples are also treated with a 2:1:0.8 mixture of methanol, chloroform, and DI water, prior to drying, to remove any fatty acids in the sample; however, this mixture can introduce modern carbon to the sample, which can affect AMS dating. This "defatting" process was not conducted or needed on any of the samples.]
7. The dried samples were then weighed to determine total collagen yield. Part of the samples were then broken until 1 mg samples were obtained. This sample was then placed into tin capsules for combustion via mass spectrometry. Two total 1 mg samples were collected from the purified collagen and analyzed on the mass spectrometer to ensure reliability. Note the same procedure was used for collagen samples sent for AMS dating.

Apatite Processing (Bone and Tooth Roots)

As mentioned above, prior to the chemical processing of bone and tooth root collagen samples, approximately 10 mg of powdered bone was collected from each sample for apatite chemical processing as outlined below:

1. The 10 mg of bone powder was placed and processed in 1.5 ml microcentrifuge vials and samples were weighed. A solution of 2% bleach was added to each sample vial to remove collagen, bacterial proteins, and humates. Each sample was capped and vortexed and left to react for 72 hours at room temperature.
2. The 2% bleach solution was decanted after 72 hours and samples were then rinsed with DI water a total of 4 times, vortexting and centrifuging between each wash. After the fourth wash was decanted, an individual sterilized pipet for each unique sample was used to extract the last remaining liquid from each vial. The vials were them left uncapped and placed into a drying oven at 60° C overnight, lightly tented with foil to prevent any potential debris from entering the open vials.
3. After drying, samples were weighed again and then reacted with a 1 M acetic acid/sodium acetate buffer solution, vortexed, and capped for 24 hours at room temperature to remove any non-biogenic carbonates.
4. The 1 M acetic acid/sodium acetate buffer solution was decanted after 24 hours and samples were then rinsed with DI water a total of 4 times, vortexting and centrifuging between each wash. After the fourth wash was decanted, an individual sterilized pipet for each unique sample was used to extract the last remaining liquid from each vial. The vials were them left uncapped and placed into a drying oven at 60° C overnight, lightly tented with foil to prevent any potential debris from entering the open vials.

5. After drying, the samples were capped and weighed. A sub-sample of approximately 1 mg was then taken from the purified apatite and places into 2-dram glass vials.

Analytical Standards and Methods

The ways in which scientists ensure accuracy of the data provided by the mass spectrometer begins within the sample preparation protocols described above. Weighing each sample prior to a chemical treatment describes the waste products formed from chemical reactions occurring within the sample, thus removed from the sample, and decanted away. This is critically important with collagen samples when comparing dry bone sample weight and final dehydrated pseudomorph weight. This measurement imparts total sample whole collagen yield and describes the overall preservation status of the remains, as it relates to diagenesis in the burial environment of organic components, and it is representative of the reliability of the sample to accurately represent stable isotopic ratios during life. Collagen yield is an indicator of sample quality and has been examined by multiple researchers, that all have different cut-off standards, (between 1% and 3.5% collagen yields) for when a sample potentially becomes problematic (Ambrose, 1990; DeNiro and Weiner, 1988; van Klinken, 1999). The present study utilized the latest figure of 1%, proposed by Van Klinken, who suggested that any samples at or below 1% whole collagen extraction yield, could become potentially problematic (van Klinken, 1999).

A second crucial quality control for collagen is the atomic C:N ratio. Collagen concentration is non-linear, meaning that the ratio of concentrated carbon and nitrogen, due to sample preparation methods, is directly reflected in the ratio of the two isotopic values after analysis via mass spectrometry (Ambrose, 1990). Thus, the atomic C:N ratio is a better measurement of the overall reliability and quality of the sample and preparation methods. Poor sample preparation methods can introduce erroneous fractionation between the sample reactants and the desired measurable products, which can result in isotopic ratios that do not reflect the preserved ratios of the material being sampled. Typically, C:N ratios around 3.0 are the lowest accepted or considered reliable by the larger academic community currently (Sealy et al., 2014), although some have proposed a higher cut-off of 3.1 to 3.5 (van Klinken, 1999). Lastly, as described above, analyzing duplicate samples also further enhances the reliability of the produced stable isotopic values, especially when comparing the C:N ratios of pairs of samples. This can be especially helpful in instances where initial collagen yield is low and sample integrity is potentially problematic.

The $\delta^{13}C_{co}$ and $\delta^{15}N$ values from bone and tooth root collagen were obtained utilizing a Carlo-Erba NA2500-II EA with a Costech Zero-Bank autosampler coupled with a continuous flow ThermoFinnigan Delta + XL IRMS where the samples in tin cups are placed into the autosampler and enter a combustion/reduction furnace one at a time, producing CO_2 and N_2 gases, that are then transferred to the IRMS. The $\delta^{13}C_{ap}$ and $\delta^{18}O$ values from bone and tooth root apatite were obtained utilizing a ThermoFisher MAT253 IRMS coupled to a GasBench-II + continuous-flow interface with samples reacting with 600 μl 104% H_3PO_4 @ 25° C for 24 hrs, where CO_2 is entrained in a 99% helium carrier stream that passes through two membrane-diffusion water traps and is chromatographed to separate isobaric interferences and finally then transferred into the IRMS ionization source via an open-split interface. The University of South Florida St. Petersburg Marine Sciences Stable Isotopic Laboratory houses and operates both mass spectrometers referenced above. A combination of National Institute of Technology (NIST) and internal standards were run in concert with the sample load after every sixth sample. The precision of the analyzed carbon, nitrogen, and oxygen isotopic values are reported relative to standard. Carbon is typically reported with a precision of ± 0.1‰ relative to Pee Dee Belemnite (PDB), nitrogen is reported with a precision of ≤ 0.2‰ relative to AIR or the atmospheric nitrogen reservoir, and oxygen with a precision of ± 0.3‰ relative to PDB. Additional standards for oxygen included, TSF-1 (calcite), BORBA (marble), and LECO (calcium carbonate).

All isotopic ratios are reported in standard delta notation (δ) as previously discussed with carbon-13 values reported as $\delta^{13}C_{co}$ for bone and tooth root collagen and $\delta^{13}C_{ap}$ for bone and tooth root apatite, nitrogen values reported as $\delta^{15}N$ from both bone and tooth root collagen, and oxygen values reported as $\delta^{18}O$ from bone and tooth root apatite. Each isotopic value will be accompanied by sub-scripted or additional descriptions as needed for the exact standard value that is being used, carbon and nitrogen will be assumed to be standard VPDB and AIR related values respectively, while oxygen values will vary based on conversion standards. Oxygen values are more complex due to metabolic fractionation, as previously discussed, thus $\delta^{18}O_{VPDB}$ values must be converted to Vienna Standard Means Ocean Water (VSMOW) (Coplen, 1988), followed by subsequent conversion to phosphate values relative to VSMOW (Iacumin et al., 1996), and finally to drinking water values relative to VSMOW standards (Daux et al., 2008) using the below equations:

VPDB to VSMOW

$$\delta^{18}O_{VSMOW} = 1.03092 * \delta^{18}O_{VPDV} + 30.92$$

Carbonate VSMOW to Phosphate VSMOW

$$\delta^{18}O_{Phosphate} = 0.98 * \delta^{18}O_{Carbonate} - 8.5$$

Phosphate VSMOW to Drinking Water VSMOW

$$\delta^{18}O_{dw} = 1.54 * \delta^{18}O_{Phosphate} - 33.72$$

Converted drinking water values can then be compared more reliably with known oxygen isoscapes produced from precipitation and meteoric water samples in northern Italy (Cavazzuti et al., 2019). For the purposes of this dissertation, it is assumed that Neolithic and Early Copper Aged peoples were primarily sourcing water from major sources, such as the major rivers and lakes in the region, with primacy given to the Minco and Po rivers dur to their geographic relationship to the project sites.

RADIOCARBON SAMPLE PREPARATION AND ANALYSIS

Previously prepared samples utilized for dietary analyses from primarily tooth roots, was also analyzed utilizing AMS. See "collagen processing" section above for a review of collagen preparation methods and excluded optional steps due to subsequent radiocarbon dating as part of the project framework. Radiocarbon samples were analyzed utilizing AMS at the Center for Applied Isotopic Studies at the University of Georgia. The facility primarily utilizes a 500 kV NEC.1.5SDH-1 pelletron (CAMS) tandem accelerator equipped with a 134-cathode MC-SNICS negative ion source. Negative ions of ^{12}C, ^{13}C, and ^{14}C are sequentially injected and accelerated toward a positive high voltage terminal where the negative ions undergo charge exchange collisions with argon gas and become positive ions. The repulsion of the now positive carbon ions at the terminal causes them to accelerate further to a total energy of 1 MeV. After acceleration, each individual isotope is mass separated by a magnetic field where ^{12}C and ^{13}C beams are measured by Faraday cups and ^{14}C is measured utilizing a particle detector (Center for Applied Isotope Studies University of Georgia, 2022).

The selection of burials for radiocarbon dating was based on several criteria and discussed among the author, advisor, committee members, and the Superintendent for Archaeology in Mantua. These selections were critical due to the large expense of radiocarbon dating conducted by contemporary laboratories. Firstly, burials which included rich or rare burial goods were targeted to pinpoint the time periods when trade of exotic materials began, especially those materials originating from known geographic regions, such as the coast or lower piedmont in Northern Italy. These materials included greenstone and flint axes and chisels, shell or polished stone jewelry, diagnostic ceramics and lithic points, and ornamental carved bone tools and instruments. The second and third criteria was centered on the mortuary context, with the second focusing on individuals that were associated with structural components, such as the previously mentioned cigar-shaped pits and other unique architectural features. The third criteria utilized the mortuary analysis to target individuals from the same sites that were associated with one another, to date the other burials and site via archaeological association. To a lesser extent, a fourth criteria was attempted which was based on cultural modifications to bone discovered during the skeletal analysis such as those associated with habitual activities like holding or stripping plant materials to produce cultural materials using the central incisors. The most important criteria were the archaeological association among the burials and across sites. This allows the radiocarbon protocol to be expansive and potentially date as many of the sites as possible as well as group other burials by cultural group for the purposes of fine-grained statistical analysis, see results below. Following this criteria, unique or diagnostic burial goods was a nearly equally important selection criterion, with archaeological feature associations being the least important criteria because the present research is primarily concerned with the bioarchaeology of the sites and ordering and grouping burials for meaningful reconstructions of small cultural group life histories. However, attempts were made to date critical features associated with specific burials, examined in more detail in later chapters.

STATISTICAL ANALYSIS

All sample values and processing weights were recorded utilizing Microsoft Excel. Additional graphical analyses were carried out, as needed utilizing the Excel, but most figures and plots were produced utilizing Intel's SPSS v2.4 statistical software package. A mixed method approach is necessary given the variation in samples sizes that permit either parametric or only non-parametric comparative statistics.

CHAPTER SEVEN:

RESULTS

DEMOGRAPHICS

As previously discussed, all reported demographic information of the analyzed assemblage was obtained utilizing strict non-metric methods, do to time constraints imposed by the superintendent for archaeology in Mantua equaling 4 weeks to complete all sampling and analyses with the skeletal materials. Appendices A and B provide a summary of the entire analyzed assemblage with sex and age estimations by tomb and site in Appendix A. In total 111 individual sets of remains were analyzed with a total of 4 removed from the data set due to 1 extremely poor burial belonging to a canid and 3 burials dating to the Bronze Age. The total number of burials thus included in Appendix A are all Neolithic and Copper Age human burials (n =107). Appendix B includes all Neolithic and Copper Age human tooth root isotopic values (n =77). Lastly, Appendix C is a summary of all oxygen isotopic data and conversion values from bone and tooth roots utilized for the analysis of mobility in this chapter (n =67).

About 40% of the remains lacked any macroscopic landmarks that could be used to determine sex of the individual. The inability to estimate the sex of individuals, identified as indeterminate, was entirely due to skeletal preservation, as previously discussed in materials and methods. Similarly, only about 14% of the individuals lacked any macroscopic landmarks useful for estimating age at death, also due to poor or extremely poor skeletal preservation. There is significant overlap between those individuals that were labeled indeterminate for sex and age at death with 14 of the 16 individuals, where age could not be determined (88%), also lacking a binary sex estimation 14/45 or 31%. These results indicate that preservation status prevented sex and age determination in 13% of the entire analyzed assemblage. The assessed demographic results from Table 7.1 will be utilized throughout this chapter to examine sex and age-based differences during the Middle Neolithic, VBQ phases 1 and 2, and the Early Copper Age, and regarding diet, mobility, and non-specific stress markers and cultural modifications. The initial demographic information below explores trends within the entire analyzed population regardless of chronological age or cultural affiliation.

As briefly discussed above the distribution of sex within the analyzed assemblage is dominated by indeterminate estimations (40%). For those individuals with preserved skeletal landmarks useful for sex estimation, only 19% were estimated to be female and 23% were estimated to be male (Figure 7.1). The remaining 18% of the individuals were sub-adults. Currently, contemporary macroscopic scoring methods used to estimate skeletal sex in adults cannot be applied to sub-adult remains that have not fully matured. It can be estimated that based on the present difference between known males and females that the adult sized remains making up the indeterminate group could also follow the same pattern. Regardless the number of males and female burials is nearly equal resulting in men being buried at almost the same frequency as women. Finally, significantly more mature adults were buried than sub-adults with 41% of known mature individuals buried than only 18% of known sub-adults.

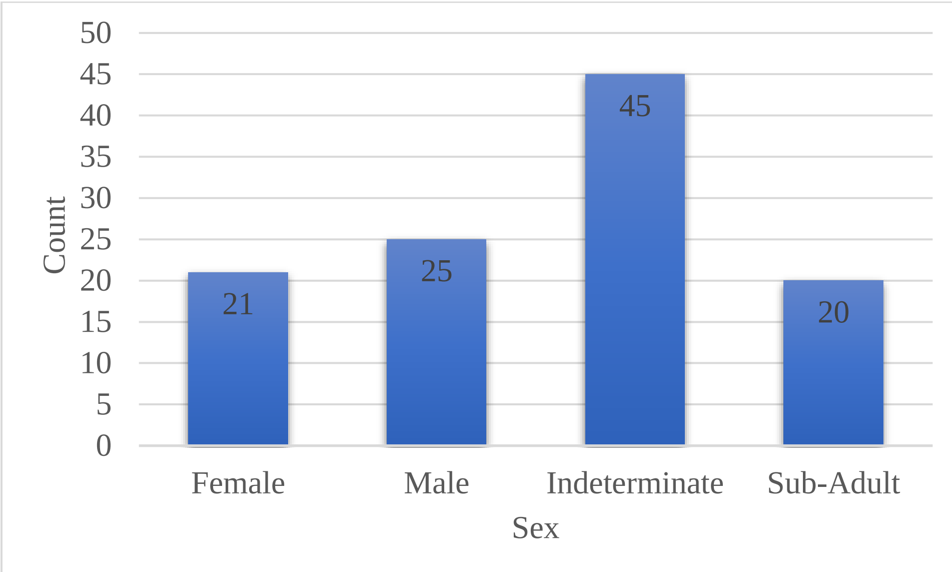

Figure 7.1: Distribution of sex within the analyzed population (*n* =111)

Age-at-death estimations indicate that individuals were three times more likely to have reached adult age (*n* =75/111, 68%) than to have perished as a sub-adult (*n* =20/111, 18%) (Figure 7.2). For these results 16-18 years of age is used as the break point for adult age with those individuals aged less than 15 years being considered sub-adults. Only a small percentage of individuals (*n* =16/111, 14%) lacked any preserved elements that could yield information the age-at death. A much smaller percentage of individuals survived to become older adults (*n* =14/111, 13%) when compared to the prime age adult population (n =61/111, 55%). Considering the analyzed assemblage is almost entirely made up of Middle Neolithic individuals, the break point for older adult age is 30 years, when contemporary skeletal maturation is complete and skeletal degeneration begins. Overall, the mortality profile of the entire analyzed assemblage resembles suggests that infant mortality was low (*n* =5/111, 5%), favoring survival into early adulthood and prime adult age ranges with death occurring near the same time.

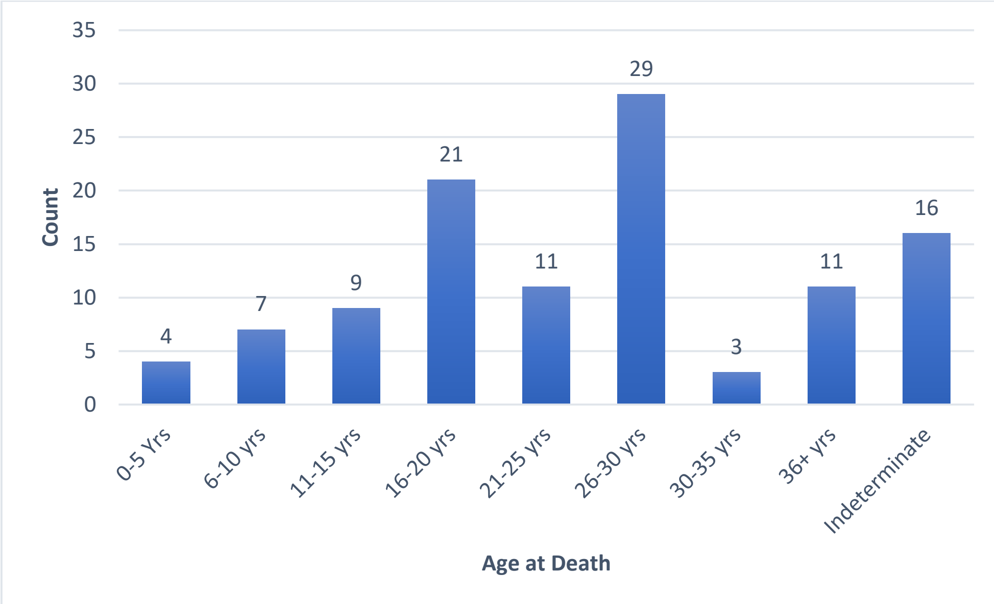

Figure 7.2: Distribution of age-at-death within the analyzed population (*n* =111)

RADIOCARBON RESULTS

Radiocarbon dating was completed on 23 of the 111 (21%) skeletons in the analyzed assemblage with individuals selected based on several criteria outlined in materials and methods. The radiocarbon selections were carried out following the criteria outlined in materials and methods previously. The resulting calibrated sequence shows an extremely tight period of occupation within the Middle Neolithic across all 23 individual sites (Table 7.2).

Table 7.1: Uncalibrated and Calibrated Radiocarbon Dates

Tomb	Site	USF Sample Number	Uncalibrated 14C Ages, years BP	Calibrated 14C Age Ranges, years BCE (95.4 CI)
14	Valdaro Paganella	38765	5590 ± 25	4490 - 4350
24	Valdaro Paganella	38771	5700 ± 25	4610 - 4450
3	Valdaro Corte Tridolo	38773	3470 ± 25	1890 - 1690
14	Valdaro Corte Tridolo	38775	3530 ± 25	1950 - 1760
1	Olmo Lungo	38778	5700 ± 25	4610 - 4450
2	Olmo Lungo	38779	5470 ± 25	4360 - 4250
7	Olmo Lungo	38783	5690 ± 25	4610 – 4450
5	Bagnolo San Vito Tei	38756	4410 ± 25	3290 - 2910
1	Bagnolo San Vito Dalmaschio	38791	5890 ± 25	4840 - 4700
5	Bagnolo San Vito Dalmaschio	38348	5560 ± 30	4460 - 4340
31	San Giorgio Bretella Aut.	38799	5640 ± 25	4540 - 4360
77	San Giorgio Bretella Aut.	38802	5760 ± 25	4700 - 4530
116	San Giorgio Bretella Aut.	38804	5750 ± 25	4690 – 4500
3	San Giorgio via Europa	38371	5700 ± 30	4660 – 4450
4B	San Giorgio via Europa	38372	3460 ± 25	1890 – 1690
151	San Giorgio Valdaro Rossetto	38808	5810 ± 25	4780 – 4550
2	San Giorgio via Sardegna	38811	5730 ± 40	4690 – 4450
1	Roncoferraro (SAP)	38817	5790 ± 25	4720 – 4550
2	Roncoferraro (SAP)	38818	5640 ± 25	4540 – 4360
7	Roncoferraro	38823	5720 ± 25	4680 – 4460
14	Roncoferraro	38338	5690 ± 30	4610 – 4450
1	San Benedetto Ca’ dell’Aria	38834	4680 ± 25	3530 – 3370
6	Castelletto Borgo Foroni	38832	4470 ± 25	3340 – 3020

Utilizing previously completed radiocarbon sequences, the SMP culture emerged around Mantua likely sometime around 4700 cal BCE and as late as 4600 cal BCE based on the radiocarbon chronological model produced in Figure 7.3. None of the burials at this site yielded any particularly diagnostic ceramic sherds, but the radiocarbon date suggests that at least Tombs 1 and 2, placed side by side, are potentially Late Early Neolithic or Early Middle Neolithic, possibly coinciding with the arrival of the SMP culture. For the purposes of the current research this site will be defined as Early Middle Neolithic and mark the arrival of the first phase of the SMP cultural group. As previously discussed, the lack of ceramic materials included in Tombs 1 and 2 at Bagnolo San Vito Dalmaschio and Tombs 146 and 151 at San Giorgio Valdaro Rossetto is potentially problematic at dating the exact arrival of the SMP culture to Mantua. The first impressed phase one VBQ ceramic sherds were first recovered in the chronological sequence in two archaeological features (US 547 and US 503) associated with Tomb 1 at Roncoferraro (SAP) 4720-4550 cal BCE. An additional limited chronological model, Figure 7.4, for the Copper Age tombs has also been produced, which allows for a more succinct start date for the Copper Age around Mantua to have begun between 3500–3400 cal BCE. As previously discussed, tomb 1 at San Benedetto Ca' dell'Aria is particularly useful in this sequence because a few elements recovered from the tomb were stained by copper alloys which suggest that this individual was potentially utilizing copper objects in life and was buried with them as well.

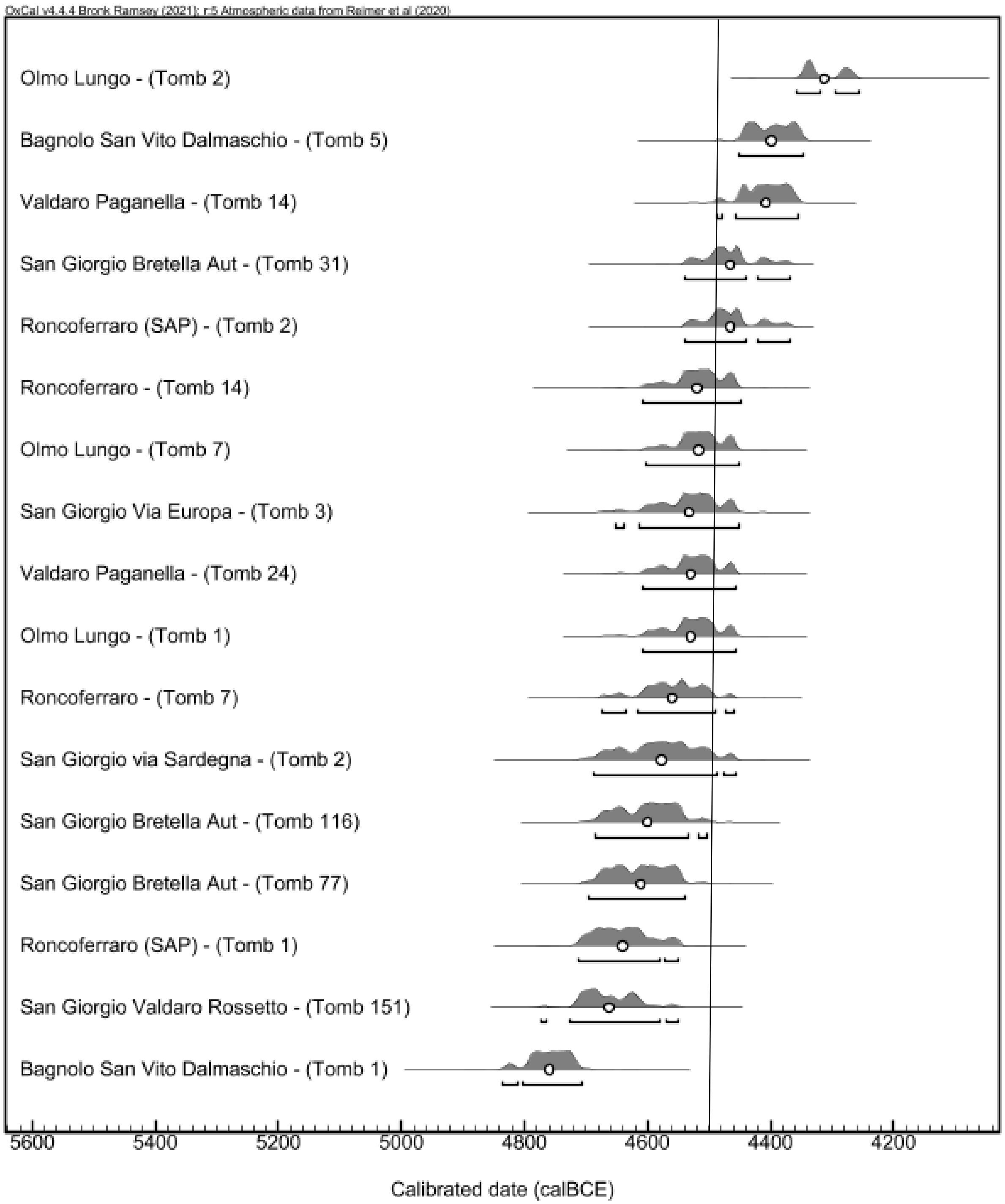

Figure 7.3: Chronological model of Middle Neolithic sites

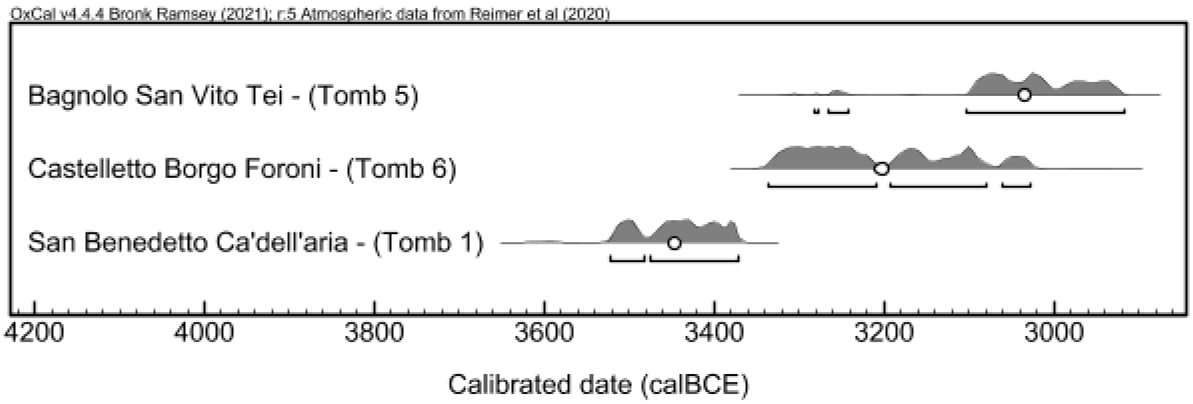

Figure 7.4: Chronological model of Early Copper Age sites

ISOTOPIC RESULTS

The results for $\delta^{13}C_{ap}$, $\delta^{13}C_{co,}$ $\delta^{15}N_{,}$ and $\delta^{18}O_{ap}$ from human bone and tooth roots are presented in this section. The carbon and nitrogen values are plotted by tomb, first to examine general diets among Middle Neolithic and Copper Age groups and in later sections general diets among males and females and adolescents and adults and more specifically by time period. Reliability indicators for carbon and nitrogen data include C:N ratios and $\delta^{13}C_{ap\text{-}co}$ for bone, $\delta^{13}C_{ap\text{-}co}$ for tooth root, and $\delta^{13}C_{ap}$ for bone and tooth root samples. The oxygen values are plotted by tomb to explore mobility trends, first through environmental and metabolic values of bone and tooth roots, but also through general bone and dentin spacing by individual. The section is outlined via the research questions previously discussed in the introduction chapter. Recalling the primary goal of the research is to examine differences in the human diet between the Middle Neolithic VBQ phase one and two and the Early Copper Age to specifically explore any differences between these major periods regarding diet and mobility. This section will apply the radiocarbon chronological sequences described above to facilitate the grouping of tombs by their potential cultural affiliation. The treatment of tombs as aggregates of known cultural groups was implemented due to the small sample sizes of individual remains across all sampled sites. If cohorts of tombs from each of the individual sites were compared among all 17sites, only non-parametric tests would be appropriate. However, in examining overall tomb membership to specific cultural groups more rigorous parametric testing could be accomplished.

Exploratory Data Analysis

To complete parametric testing via aggregate cultural group, it is necessary to first examine the distributions of each aggregate group, which include Middle Neolithic, Early Copper Age, VBQ phase one & two, VBQ phase one, and VBQ phase two independently. Descriptive statistics for the unaltered combined isotopic data set include measures of central tendency (mean and median), minimum and maximum values, and standard deviation and are reported in Table 7.2. Further, exploratory data analysis was conducted on the isotopic data to investigate normality and skewness via histograms, box and whisker plots, and Kolmogorov-Smirnov tests of normality (Figure 7.3), which will indicate if parametric statistical testing is appropriate and if the mean is reliable. The following results outline the descriptive statistics and normality of the isotopic data by tissue, first in the broadest extent, only the isotopic data, then by relative chronological period (Middle Neolithic (n = 107) and Early Copper Age (n = 11)), and finally aggregate cultural groups by absolute chronological period (VBQ phase one and two, VBQ phase one, VBQ phase two, and Lagozza or Early Copper Age).

The results of the Kolmogorov-Smirnov test of normality revealed that the bone $^{13}C_{ap}$ values are non-normally distributed (KS = 0.126, df = 107, $p < 0.001$). The resulting curve is thus skewed to the left (Figure 7.5) with one extreme value (more than 3 times the mean) of tomb 3 from San Giorgio Via Raffaello (Figure 7.6) having a maximum bone $^{13}C_{ap}$ value of -7.6, compared to the bone $^{13}C_{ap}$ mean of -12.8. Further, Kolmogorov-Smirnov test of normality also revealed that the bone $^{13}C_{co}$ values are non-normally distributed (KS = 0.172, *df* = 93, $p < 0.001$). The resulting curve is skewed to the left (Figure 7.7) with two extreme values identified as tomb 3 from San Giorgio Via Raffaello and tomb 8 from Castelletto Borgo Foroni. Tomb 3 from San Giorgio Via Raffaello was trimmed from the data set to establish normality among the bone $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ values for the purposes of conducting parametric statistical test comparing mean values. This tomb will not be removed in any non-parametric testing or plots to display an accurate and holistic plot of the isotopic data by tomb. Lastly, the Kolmogorov-Smirnov test of normality revealed that the bone $\delta^{18}O$ values are non-normally distributed (KS = 0.230, *df* = 107, $p < 0.001$). However, the bone and tooth root $\delta^{18}O$ was not subjected to parametric testing given the lack of utility of comparing group means, rather the importance of $\delta^{18}O$ data is to graphically depict outlying values (Figure 7.6) and compare them with environmental values for $\delta^{18}O$ from drinking water sources to identify locals and non-locals.

Table 7.2: Descriptive Statistics of the Raw Isotopic Data

		Bone				Tooth Root			
		$\delta^{13}C_{ap}$	$\delta^{13}C_{co}$	$\delta^{15}N$	$\delta^{18}O$	$\delta^{13}C_{ap}$	$\delta^{13}C_{co}$	$\delta^{15}N$	$\delta^{18}O$
n	Valid	107	93	93	107	77	75	75	77
	Missing	0	14	14	0	30	32	32	30
Mean		-12.8	-20.7	9.9	-5.1	-12.6	-20.5	10.2	-4.6
Median		-12.8	-20.8	9.9	-5.5	-12.5	-20.4	10.1	-4.7
Std. Dev.		0.8	0.5	0.6	1.8	0.8	0.4	0.7	0.9
Variance		0.7	0.3	0.4	3.1	0.7	0.2	0.5	0.7
Skewness		1.9	3.8	0.3	4.6	-0.1	0.2	0.5	1.7
Kurtosis		15.5	21.6	0.5	26.5	0.0	-0.1	0.8	5.3
Minimum		-15.1	-21.6	8.2	-7.1	-14.5	-21.4	8.3	-6.1
Maximum		-7.6	-17.2	11.5	7.1	-10.5	-19.5	12.3	-0.7

Table 7.3: Kolmogorov-Smirnov Test of Normality of the Raw Isotopic Data

Tissue	Isotope (δ)	Statistic	*df*	Sig.
Bone	$^{13}C_{ap}$	0.126	107	**<.001**
	$^{13}C_{co}$	0.172	93	**<.001**
	^{15}N	0.063	93	0.200
	^{18}O	0.230	107	**<.001**
Tooth Root	$^{13}C_{ap}$	0.084	77	0.200
	$^{13}C_{co}$	0.106	75	0.036
	^{15}N	0.128	75	0.004
	^{18}O	0.120	77	0.008

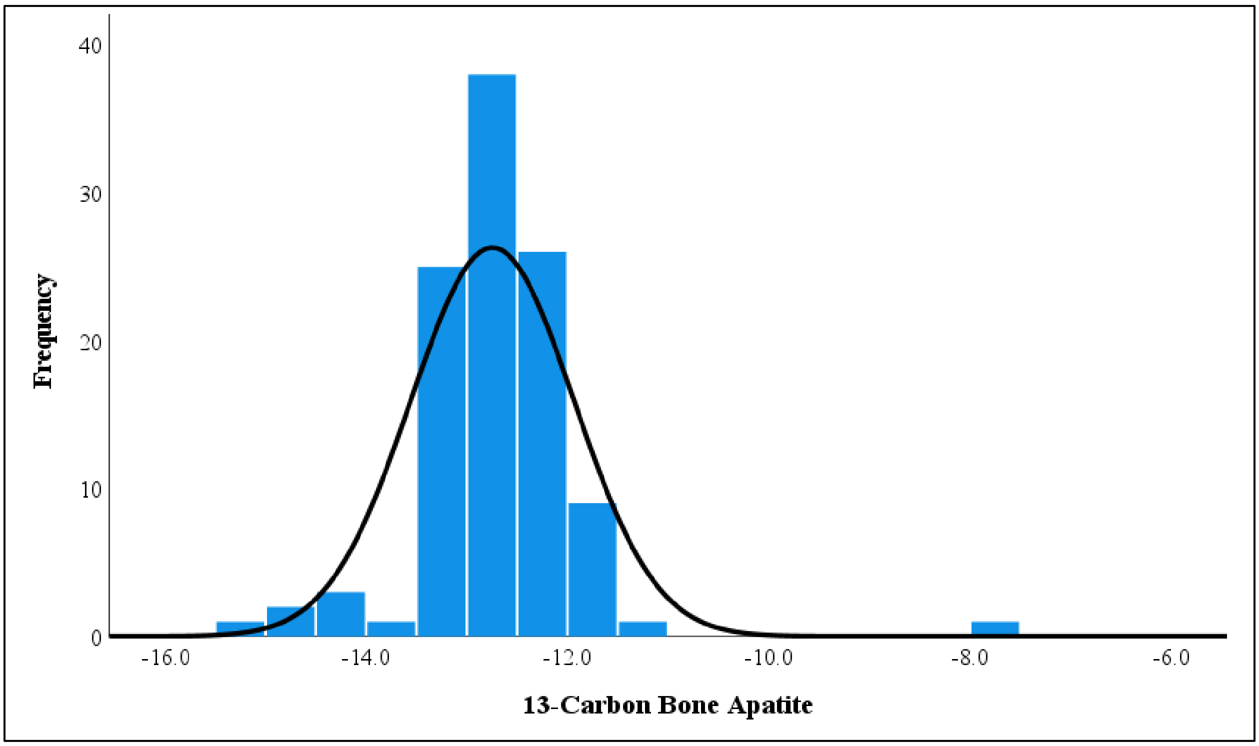

Figure 7.5: Histogram of $\delta^{13}C_{ap}$ data with outlying values

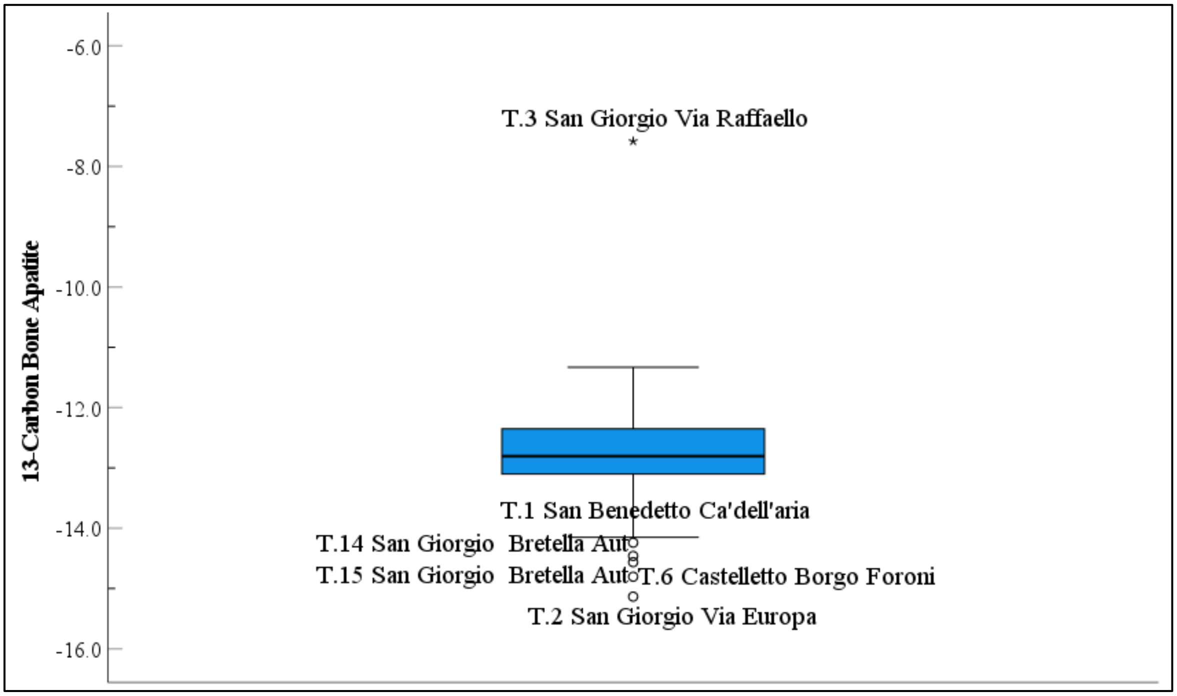

Figure 7.6: Stem-and-Leaf plot of $\delta^{13}C_{ap}$ data with outlying values

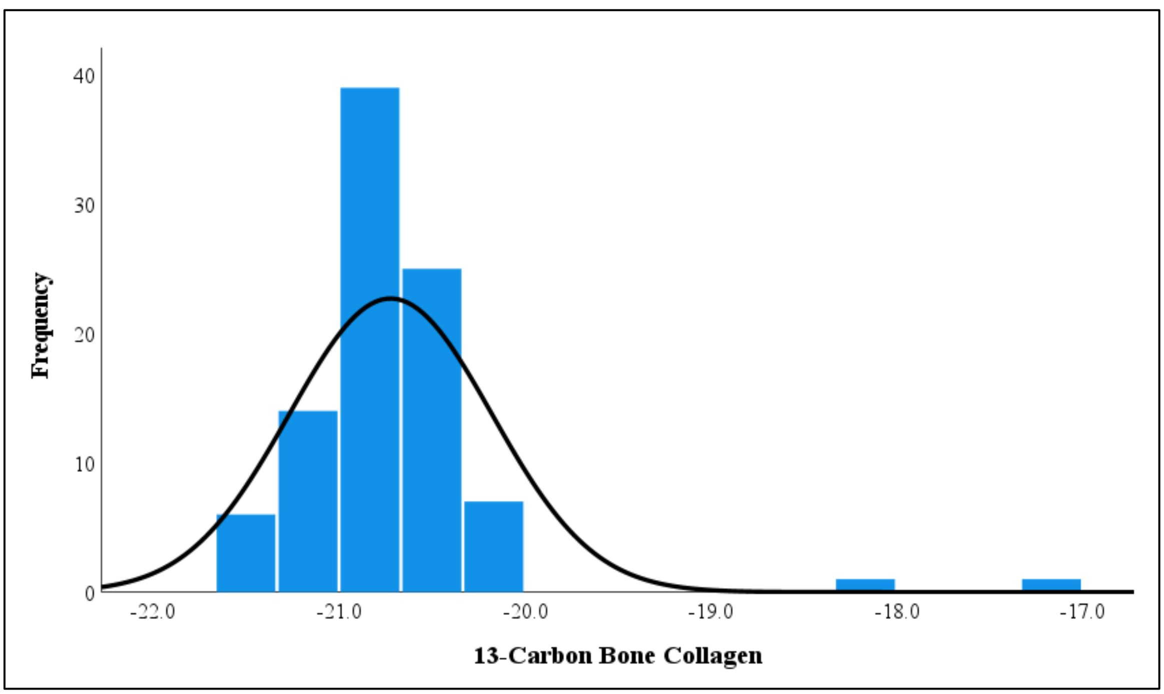

Figure 7.7: Histogram of $\delta^{13}C_{co}$ data with outlying values

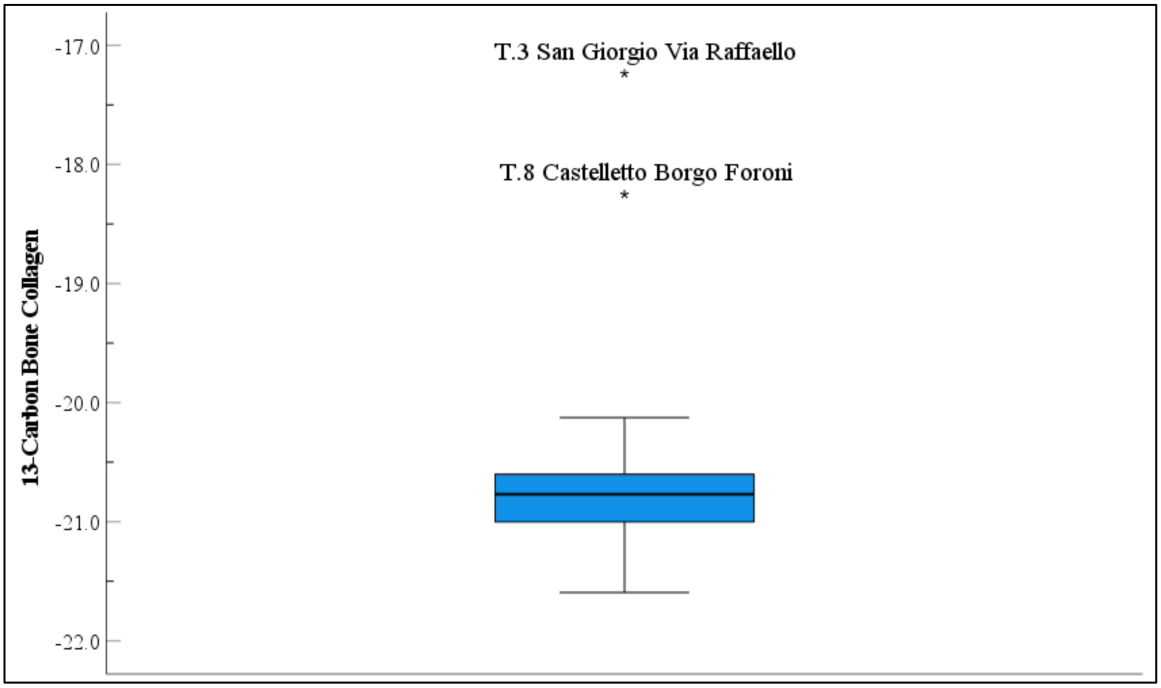

Figure 7.8: Stem-and-Leaf plot of $\delta^{13}C_{co}$ data with outlying values

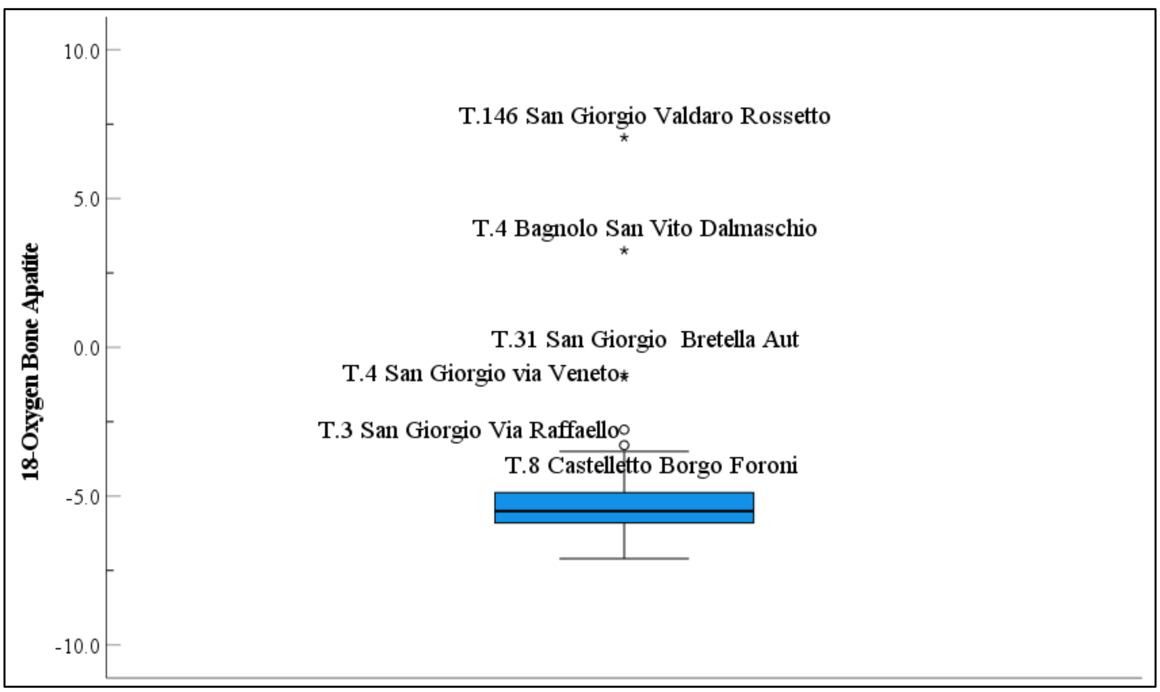

Figure 7.9: Stem-and-Leaf plot of δ18O data with outlying values

After tomb 3 from San Giorgio Via Raffaello was removed the bone $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ values were tested again utilizing the Kolmogorov-Smirnov test of normality (Table 7.4). The bone $\delta^{13}C_{ap}$ values are now normally distributed (KS = 0.092, *df* = 106, *p* = 0.027) and can be compared holistically as a combined isotopic data set. The bone $\delta^{13}C_{co}$ values are also now normally distributed with the removal of only tomb 3 from San Giorgio Via Raffaello (KS = 0.110, *df* = 92, *p* = 0.008) and can be compared holistically as a combined isotopic data set. As previously discussed in order to illuminate life histories of individual groups, parametric comparisons are also required of the general isotopic values of individual periods and cultural phase, from which sex and age differences will also be compared. Tests of normality are thus also required for the isotopic values when divided by period and cultural phase (Tables 7.5 and 7.6). The Kolmogorov-Smirnov test of normality by period shows only the Middle Neolithic bone $\delta^{18}O$ values are non-normally distributed (KS = 0.279, *df* = 95, $p < 0.001$). As mentioned above the $\delta^{18}O$ values were not parametrically tested so no additional trimming is required of the data set. These results allow for means comparisons of carbon and nitrogen values from bone and tooth roots by period and additionally for comparisons of possible differences resulting from sex or age. Lastly, the Kolmogorov-Smirnov test of normality by cultural phase shows only the VBQ Phase 1 & 2 (KS = 0.167, *df* = 55, $p < 0.001$), the VBQ Phase 1 (KS = 0.351, *df* = 27, $p < 0.001$), and the VBQ Phase 2 (KS = 0.378, *df* = 13, $p < 0.001$) for bone $\delta^{18}O$ values are all non-normally distributed, with all other isotopic values being normally distributed. These results will allow for means comparisons of carbon and nitrogen values from bone and tooth roots by cultural phase and additionally for comparisons of possible differences resulting from sex or age.

Table 7.4: Kolmogorov-Smirnov Test of Normality of the Trimmed Isotopic Data

Tissue	Isotope (δ)	Statistic	*df*	Sig.
Bone	$^{13}C_{ap}$	0.092	106	0.027
	$^{13}C_{co}$	0.110	92	0.008
	^{15}N	0.064	92	0.200
	^{18}O	0.233	106	**<.001**
Tooth Root	$^{13}C_{ap}$	0.084	77	0.200
	$^{13}C_{co}$	0.106	75	0.036
	^{15}N	0.128	75	0.004
	^{18}O	0.120	77	0.008

Table 7.5: Kolmogorov-Smirnov Test of Normality of the Trimmed Isotopic Data by Period

Tissue	Isotope (δ)	Period	Statistic	*df*	Sig.
Bone	$^{13}C_{ap}$	Middle Neolithic	0.077	95	0.200
		Copper Age	0.141	11	0.200
	$^{13}C_{co}$	Middle Neolithic	0.083	82	0.200
		Copper Age	0.272	10	0.035
	^{15}N	Middle Neolithic	0.067	82	0.200
		Copper Age	0.229	10	0.147
	^{18}O	Middle Neolithic	0.279	95	**<.001**
		Copper Age	0.124	11	0.200
Tooth Root	$^{13}C_{ap}$	Middle Neolithic	0.084	69	0.200
		Copper Age	0.151	8	0.200
	$^{13}C_{co}$	Middle Neolithic	0.113	67	0.034
		Copper Age	0.178	8	0.200
	^{15}N	Middle Neolithic	0.133	67	0.005
		Copper Age	0.179	8	0.200
	^{18}O	Middle Neolithic	0.128	69	0.007
		Copper Age	0.227	8	0.200

Table 7.6: Kolmogorov-Smirnov Test of Normality of the Trimmed Isotopic Data by Phase

Tissue	Isotope (δ)	Cultural Phase	Statistic	df	Sig.
Bone	$^{13}C_{ap}$	VBQ Phase 1 & 2	0.110	55	0.096
		VBQ Phase 1	0.161	27	0.072
		VBQ Phase 2	0.153	13	0.200
		Lagozza	0.141	11	0.200
	$^{13}C_{co}$	VBQ Phase 1 & 2	0.115	48	0.128
		VBQ Phase 1	0.107	22	0.200
		VBQ Phase 2	0.142	12	0.200
		Lagozza	0.272	10	0.035
	^{15}N	VBQ Phase 1 & 2	0.085	48	0.200
		VBQ Phase 1	0.138	22	0.200
		VBQ Phase 2	0.141	12	0.200
		Lagozza	0.229	10	0.147
	^{18}O	VBQ Phase 1 & 2	0.167	55	**<.001**
		VBQ Phase 1	0.351	27	**<.001**
		VBQ Phase 2	0.378	13	**<.001**
		Lagozza	0.124	11	0.200
Tooth Root	$^{13}C_{ap}$	VBQ Phase 1 & 2	0.142	39	0.046
		VBQ Phase 1	0.197	21	0.033
		VBQ Phase 2	0.238	9	0.152
		Lagozza	0.151	8	0.200
	$^{13}C_{co}$	VBQ Phase 1 & 2	0.115	37	0.200
		VBQ Phase 1	0.158	21	0.184
		VBQ Phase 2	0.210	9	0.200
		Lagozza	0.178	8	0.200
	^{15}N	VBQ Phase 1 & 2	0.150	37	0.035
		VBQ Phase 1	0.152	21	0.200
		VBQ Phase 2	0.199	9	0.200
		Lagozza	0.179	8	0.200
	^{18}O	VBQ Phase 1 & 2	0.170	39	0.006
		VBQ Phase 1	0.141	21	0.200
		VBQ Phase 2	0.161	9	0.200
		Lagozza	0.227	8	0.200

Neolithic vs. Early Copper Age Diets

This section will present the results of stable carbon and nitrogen values from bone and teeth by time period (Neolithic and Copper Age). These values are wholly confined to the Middle Neolithic and Copper Ages based on relative and absolute time scales as previously described. Descriptive statistics, separated by tissue and period, are reported in Table 7.7, for bone, and Table 7.8, for tooth roots. A total of 82 bone samples from the Middle Neolithic period and a total of 10 bone samples from the Copper Age period yielded carbon and nitrogen isotopic values for comparison and analysis. A total of 66 tooth root samples from the Middle Neolithic period and a total of 8 tooth root samples from the Copper Age period yielded carbon and nitrogen isotopic values for comparison and analysis. The carbon and nitrogen results for bone and tooth roots by period are presented below.

Bone

The descriptive statistics for bone carbon and nitrogen values from bone are summarized in Table 7.7. The range of Middle Neolithic bone carbon and nitrogen values were as follows: $\delta^{13}C_{ap}$ was -15.1‰ to -11.6‰ with an average of -12.8‰ ± 0.6 (Figure 7.10); $\delta^{13}C_{co}$ was -21.4‰ to -20.1‰ with an average of -20.8‰ ± 0.3 (Figure 7.11); and $\delta^{15}N$ was 8.2‰ to 11.5‰ with an average of 9.9‰ ± 0.6 (Figure 7.12). The range of Copper Age bone carbon and nitrogen values were as follows: $\delta^{13}C_{ap}$ was -14.1‰ to -11.3‰ with an average of -13.0‰ ± 1.1 (Figure 7.10); $\delta^{13}C_{co}$ was -21.6‰ to -18.3‰ with an average of -20.6‰ ± 0.9 (Figure 7.11); and $\delta^{15}N$ was 9.1‰ to 11.3‰ with an average of 9.8‰ ± 0.6 (Figure 7.12). An Analysis of Variance (ANOVA) was conducted on the bone isotopic values to explore the potential significance between Middle Neolithic and Copper Age mean values for carbon and nitrogen. The results of the ANOVA between groups were as follows: there are no significant differences in $\delta^{13}C_{ap}$ values between the Middle Neolithic and Copper Age (F = 1.492, *df* = 1, *p* = 0.225); there are no significant differences in $\delta^{13}C_{co}$ values between the Middle Neolithic and Copper Age (F = 1.896, *df* = 1, *p* = 0.172); and there are no significant differences in $\delta^{15}N$ values between the Middle Neolithic and Copper Age (F = 0.169, *df* = 1, *p* = 0.682). These results suggest that there were no major differences in carbon and nitrogen sources in the diet between the analyzed Middle Neolithic and Copper Age individuals, suggesting potential stability and continuity of subsistence practices between the two periods with respect to adult diet.

Table 7.7: Descriptive Statistics of $\delta^{13}C_{ap,}$ $\delta^{13}C_{co,}$ and $\delta^{15}N$ Bone Values

	Bone					
	$\delta^{13}C_{ap}$		$\delta^{13}C_{co}$		$\delta^{15}N$	
	Middle Neolithic	Copper Age	Middle Neolithic	Copper Age	Middle Neolithic	Copper Age
n	82	10	82	10	82	10
Mean	-12.8	-13.0	-20.8	-20.6	9.9	9.8
Median	-12.8	-12.8	-20.8	-20.7	9.9	9.7
Std. Deviation	0.6	1.1	0.3	0.9	0.6	0.6
Skewness	-0.9	-0.2	-0.0	2.0	0.3	1.5
Minimum	-15.1	-14.8	-21.4	-21.6	8.2	9.1
Maximum	-11.6	-11.3	-20.1	-18.3	11.5	11.3

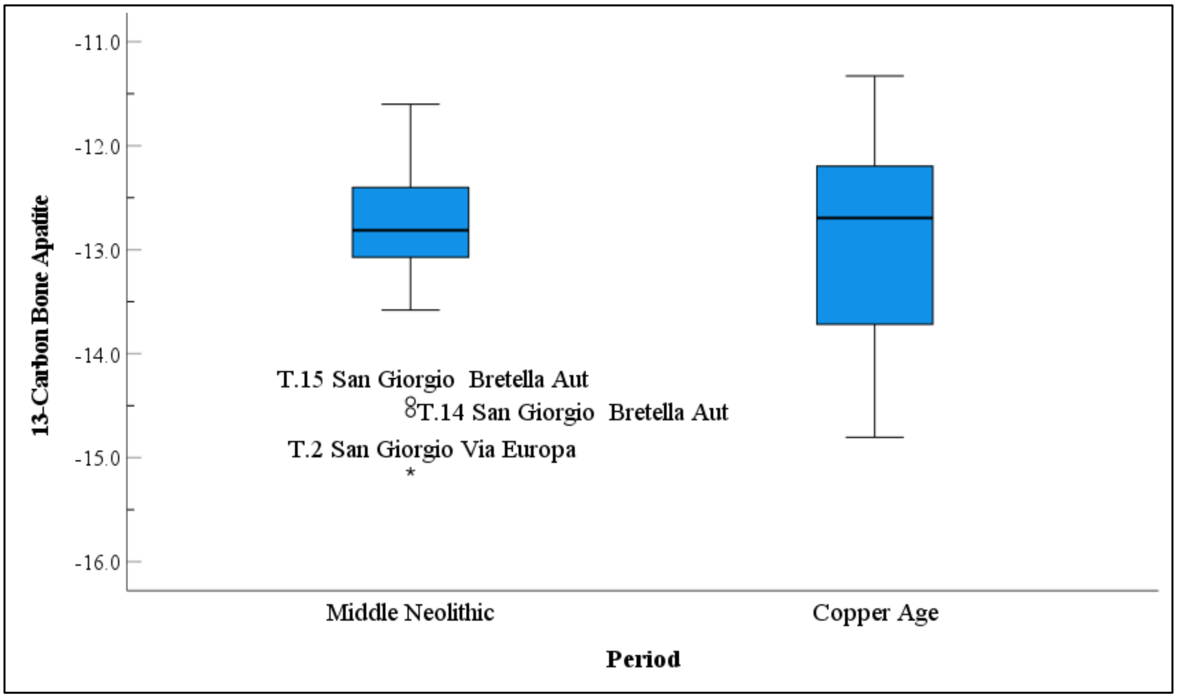

Figure 7.10: Stem-and-Leaf plot of $\delta^{13}C_{ap}$ bone values

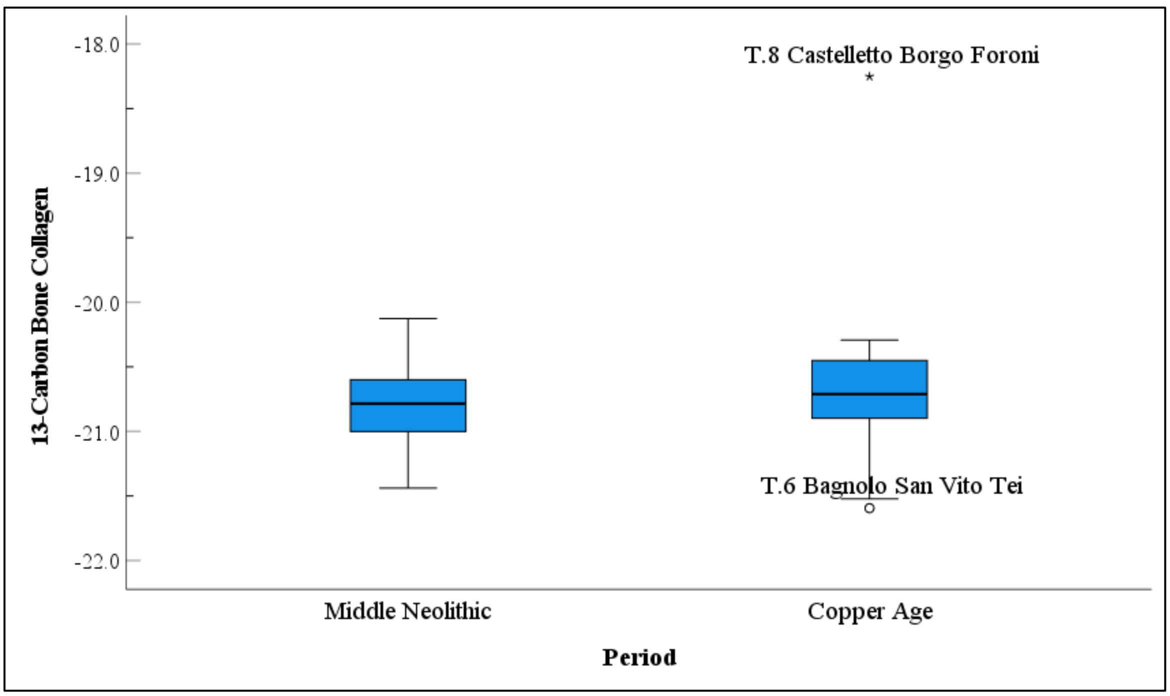

Figure 7.11: Stem-and-Leaf plot of $\delta^{13}C_{co}$ bone values

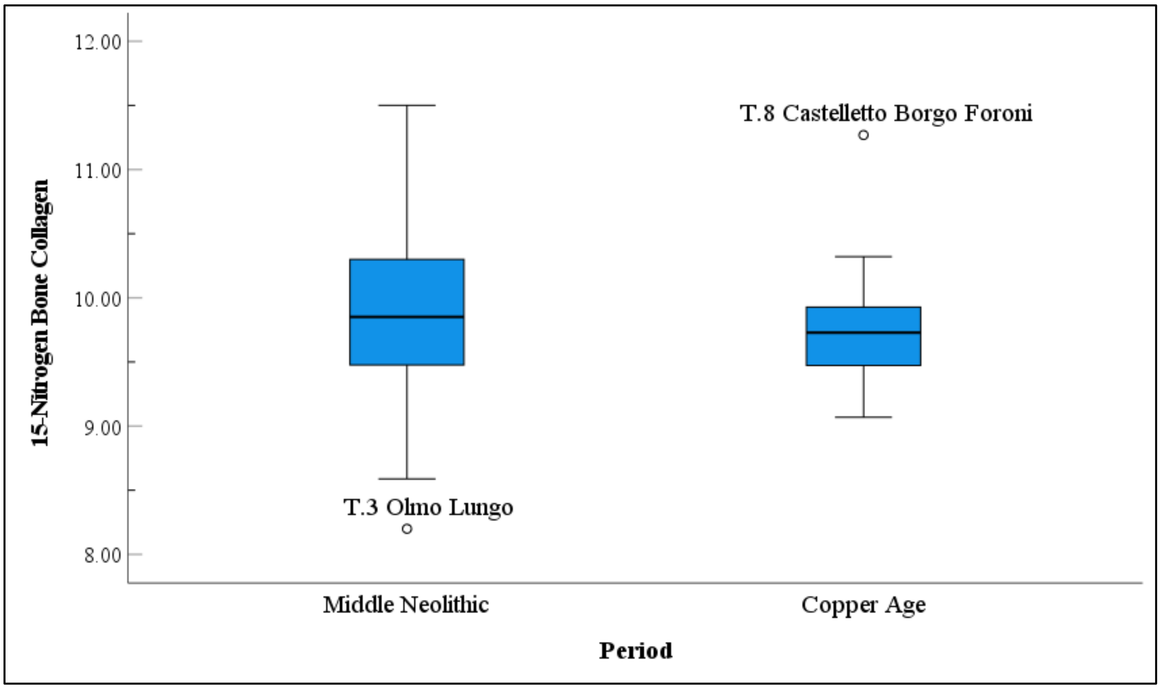

Figure 7.12: Stem-and-Leaf plot of $\delta^{15}N$ bone collagen values

The carbon and nitrogen isotopic values obtained from bone were analyzed graphically utilizing scatter plots. Plots were created to assess potential differences in protein sources by comparing $\delta^{13}C_{co}$ and $\delta^{15}N$ values and to potentially identify the influence of freshwater, marine, or terrestrial carbon sources on analyzed $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ carbon values between the Middle Neolithic and Copper Age periods. Scatter plots were also created to illustrate sex and age-based differences respectively of protein and carbon sources between the two periods of interest. Beginning with the analysis of adult dietary protein sources, Figure 7.13 displays the relationship between dietary protein between the Middle Neolithic and Copper Ages. Two outlying burials, tomb 8 from Castelletto Borgo Foroni and tomb 3 from San Giorgio Via Raffaello both have enriched $\delta^{13}C_{co}$ values -18.3 and -17.2, respectively. The enrichment of these values indicate that these two individuals may have slightly different protein sources than the rest of the populations, in favor of carbon potentially originating from marine proteins. One glaring similarity in the adult dietary protein analysis for the populations is the association with a similar carbon source, most closely resembling terrestrial C_3 collagen values of -21.5‰. The carbon spacing between bone apatite and collagen may yield additional evidence of terrestrial, marine, or freshwater carbohydrate sources. The major difference in the dispersion in adult dietary protein is within the nitrogen values, which suggests a relatively mixed diet of terrestrial protein sources and C_3 plants with very little freshwater or marine protein signatures observable in the human values.

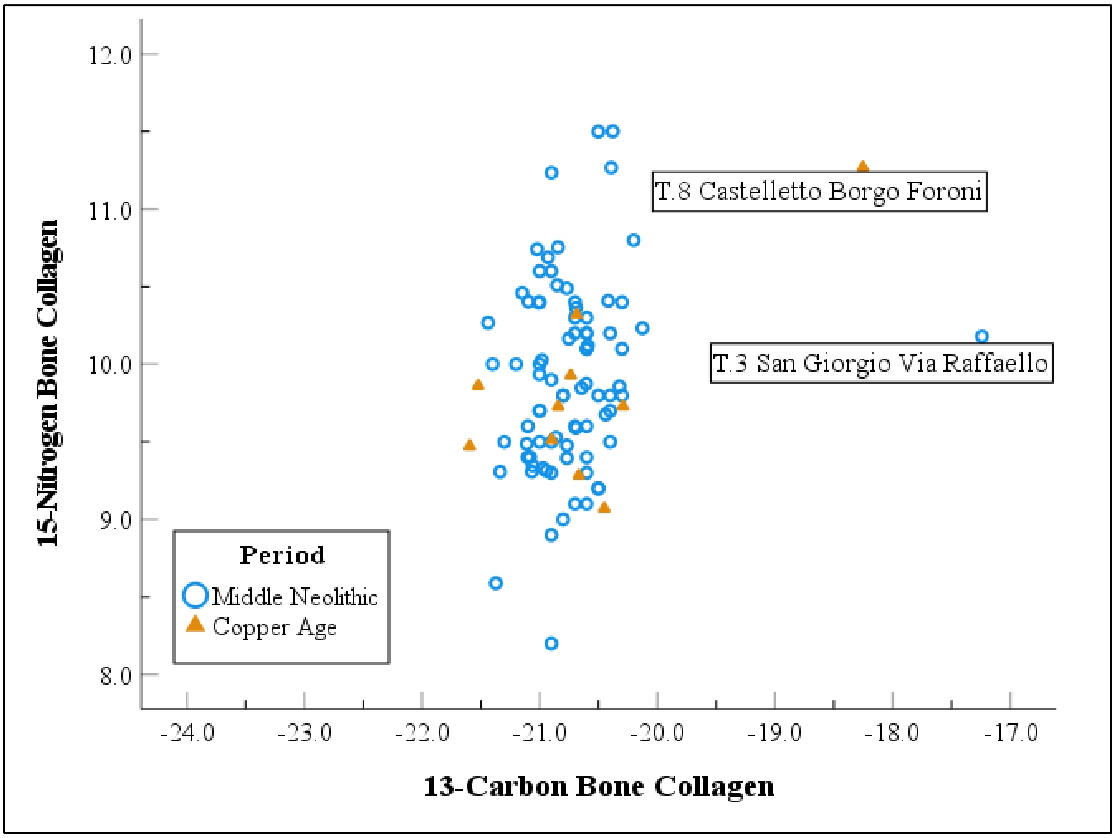

Figure 7.13: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values by period

In addition to the scatter plots of the aggregate time period isotopic data, scatter plots were also produced to analyze differences in adult dietary protein sources by sex and age. Individuals were distinguished first by time period and then by sex and age within those time periods. Age categories were developed based on adolescent growth periods, excluding infancy as no infants were included in the sample, and include sub-adults and adolescents together, given the very low presence of individuals in this range, (0-15 years), young adult ages (16-25 years), prime age adults (26-35 years), and older adults (36+ years). The goal of these analyses is to examine general differences between males and females and adult diets. Bone sample age ranges represent dietary data from a larger age range of individuals than tooth roots, discussed below, but to conduct meaningful comparisons based on age, categories must remain the same for bone and tooth root analyses. The scatter plot shows that no notable differences in adult protein sources between males and females of both the Middle Neolithic and Copper Ages (Figure 7.14). An ANOVA was conducted between the Middle Neolithic and Copper Age males and females respective of period and bone isotopic value. There were no significant differences between the Middle Neolithic and Copper Age male protein sources in the adult diet. The results of the ANOVA were as follows: there are no significant differences in male $\delta^{13}C_{ap}$ values (F = 4.855, *df* = 1, *p* = 0.040); there are no significant differences in male $\delta^{13}C_{co}$ values (F = 0.631, *df* = 1, *p* = 0.437); and there are no significant differences in male $\delta^{15}N$ values (F = 0.521, *df* = 1, *p* = 0.479). There were no significant differences between Middle Neolithic and Copper Age female protein sources in the adult diet. The results from the ANOVA were as follows: there are no significant differences in female $\delta^{13}C_{ap}$ values (F = 1.252, *df* = 1, *p* = 0.281); there are no significant differences in female $\delta^{13}C_{co}$ values (F = 0.552, *df* = 1, *p* = 0.469); and there are no significant differences in female $\delta^{15}N$ values (F = 1.251, *df* = 1, *p* = 0.281). These results indicate that male and female protein sources were similar between the Middle Neolithic and Copper Ages.

Sex-based differences in protein sources were also explored within each of the periods of interest utilizing ANOVA tests. First, there were no significant differences in adult dietary protein sources between males and females in the Middle Neolithic population. The results for the Middle Neolithic are as follows: there are no significant differences in $\delta^{13}C_{ap}$ values (F = 0.022, *df* = 1, *p* = 0.883); there are no significant differences in $\delta^{13}C_{co}$ values (F = 1.722, *df* = 1, *p* = 0.199); and there are no significant differences in female $\delta^{15}N$ (F = 2.507, *df* = 1, *p* = 0.123). Only four individuals were of known sex for the Copper Age (*n* = 3 males; *n* = 1 female) within the analyzed assemblage so parametric comparison of sex-based differences in diet were not possible. These results illustrate that protein sources within and between the Middle Neolithic and Copper Age remained consistent, further suggesting relatively stable adult dietary protein sources throughout time.

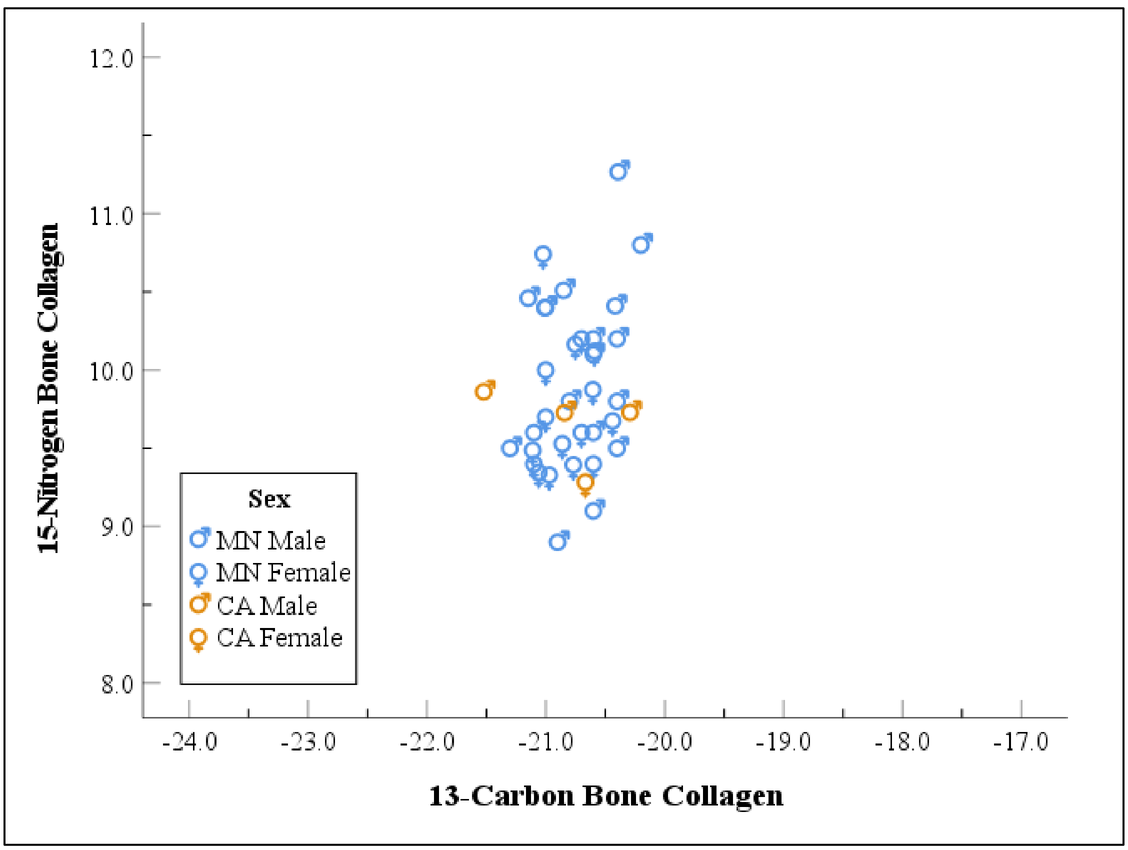

Figure 7.14: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

A scatter plot was also produced to explore potential difference in adult protein sources by age. Based on the previous holistic analysis of the two periods it is expected that no major differences exist between assigned age groups. The scatter plot shows each of the four age groups separated by time period and reveals no major differences based on age in protein sources in the diet (Figure 7.15). Tomb 3 from Castelletto Borgo again is an outlying burial where the driver for the variation in the plot is due to enrichment in carbon originating from bone collagen. This individual is also an adolescent from the Copper Age which could have affected access to different dietary protein sources of carbon than the larger population. The total amount of variation in dietary protein for the Middle Neolithic population based on sex is only 1.0‰, with slightly more variation among the Copper Age individuals with a total variation of 2.0‰. These results should be interpreted with caution as the known sex sample size is very low compared to the Middle Neolithic sample set.

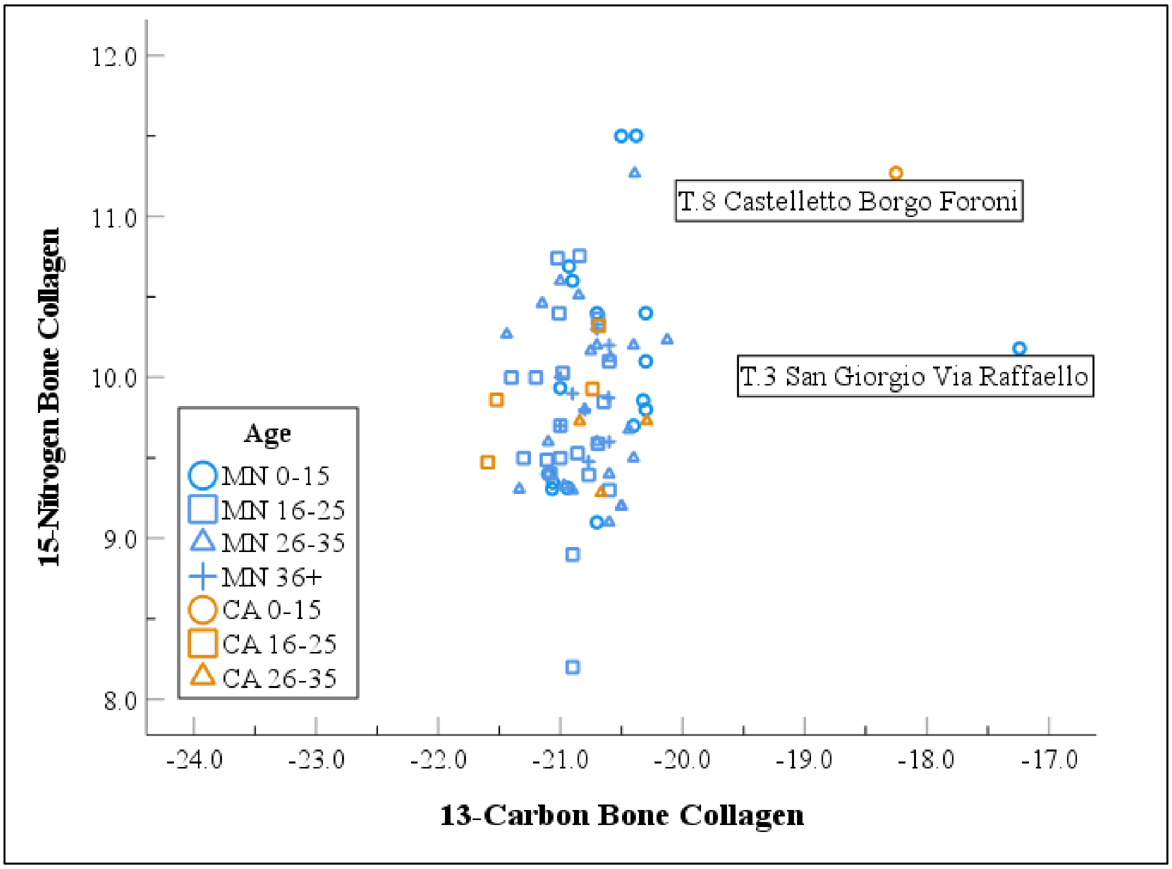

Figure 7.15: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

The scatter plot of total carbon contribution from the diet, with the protein portion represented by $\delta^{13}C_{co}$ and the carbohydrate portion represented by $\delta^{13}C_{ap}$ values depicts a very tight cluster of both Middle Neolithic and Copper Age tombs and thus total adult dietary carbon values (Figure 7.16). This suggests that little to no variation in proteins or carbohydrates existed between the Middle Neolithic and Copper Age adult diets. The average $\delta^{13}C_{ap}$ values are extremely close at -12.8‰ ± 0.6 for the Middle Neolithic and -13.0‰ ± 1.1, which is graphically visible in the scatter plot of the carbon values as a tight cluster. Tomb 3 from San Giorgio Via Raffaello continues to plot away from the analyzed assemblage and has a more enriched adult carbohydrate source in the diet compared with the other Middle Neolithic individuals. This individual is a sub-adult and could possibly have been consuming a more mixed diet of richer and softer protein and carbohydrate sources, such as secondary dairy products or fishes. It is expected that in a pure C_3 diet human $\delta^{13}C_{ap}$ values should cluster around -14.5‰, where enrichment in apatite values +3‰ or more could indicate a more mixed adult diet specific to carbohydrate sources and inclusion of some C_4 plants. Most of the analyzed population is clearly clustering very tightly around the expected pure C_3 dietary carbohydrate values and dietary protein values regarding carbon. Thus, the primary source of adult dietary carbohydrates and proteins within Middle Neolithic and Copper Age Mantua, was provided by C_3 plants.

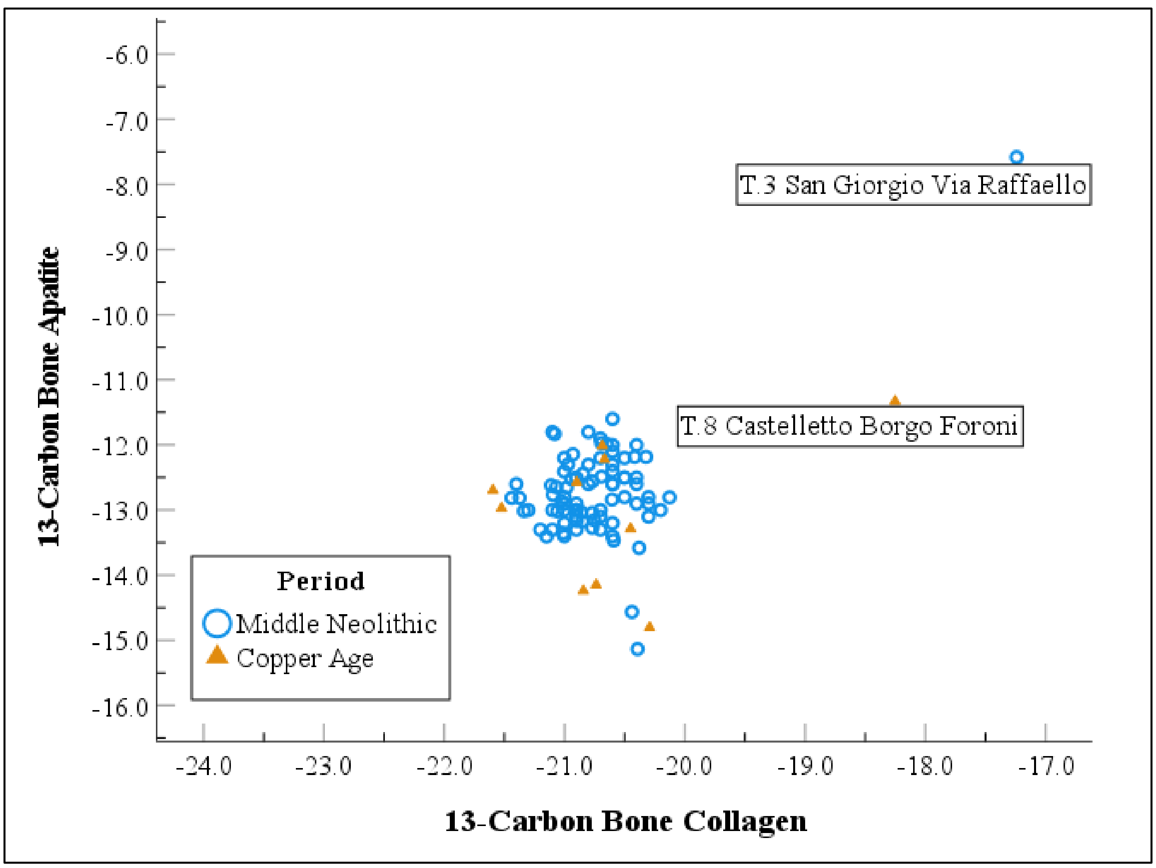

Figure 7.16: Human bone apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values (n = 93)

As previously discussed, there were no significant sex-based differences between males and females within the Middle Neolithic population. Additionally, there were no significant sex-based differences between Middle Neolithic and Copper Age males and females. Two scatter plots were also produced to examine any potential differences in carbohydrate or total dietary carbon sources between Middle Neolithic and Copper Age males and females (Figure 7.17), as well as age related differences (Figure 7.18). There appear to be no significant differences in total dietary carbon between males and females within and between the two periods of interest. Lastly, there is no apparent age-based differences within and between the two periods of interest. Both scatter plots suggest that dietary carbon as a whole was originating from a common food source. Likely a heavy reliance on C_3 plants with the addition of terrestrial meat sources either from wild or domesticated species. It is possible as previously mentioned that some slight enrichment observed in the outlying burials that these individuals were mixed feeders either with some small incorporation of marine foods or even C_4 plants.

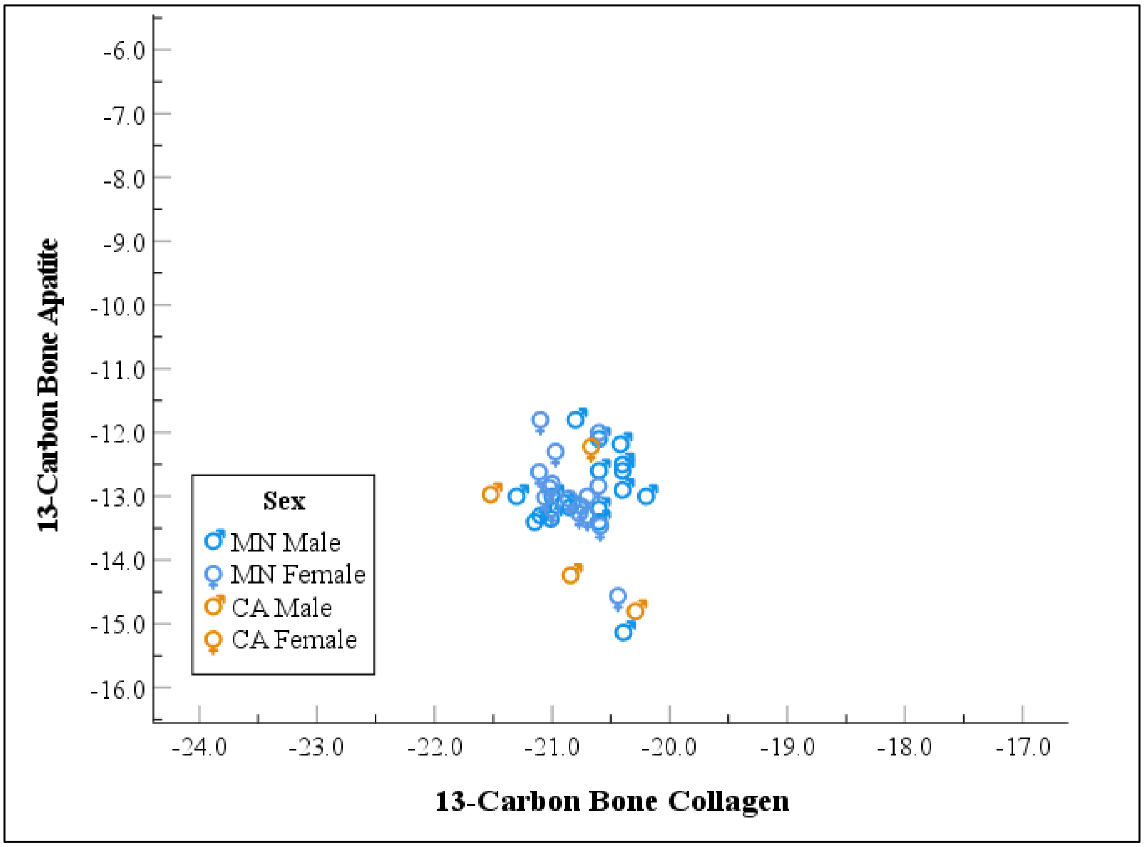

Figure 7.17: Human bone apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

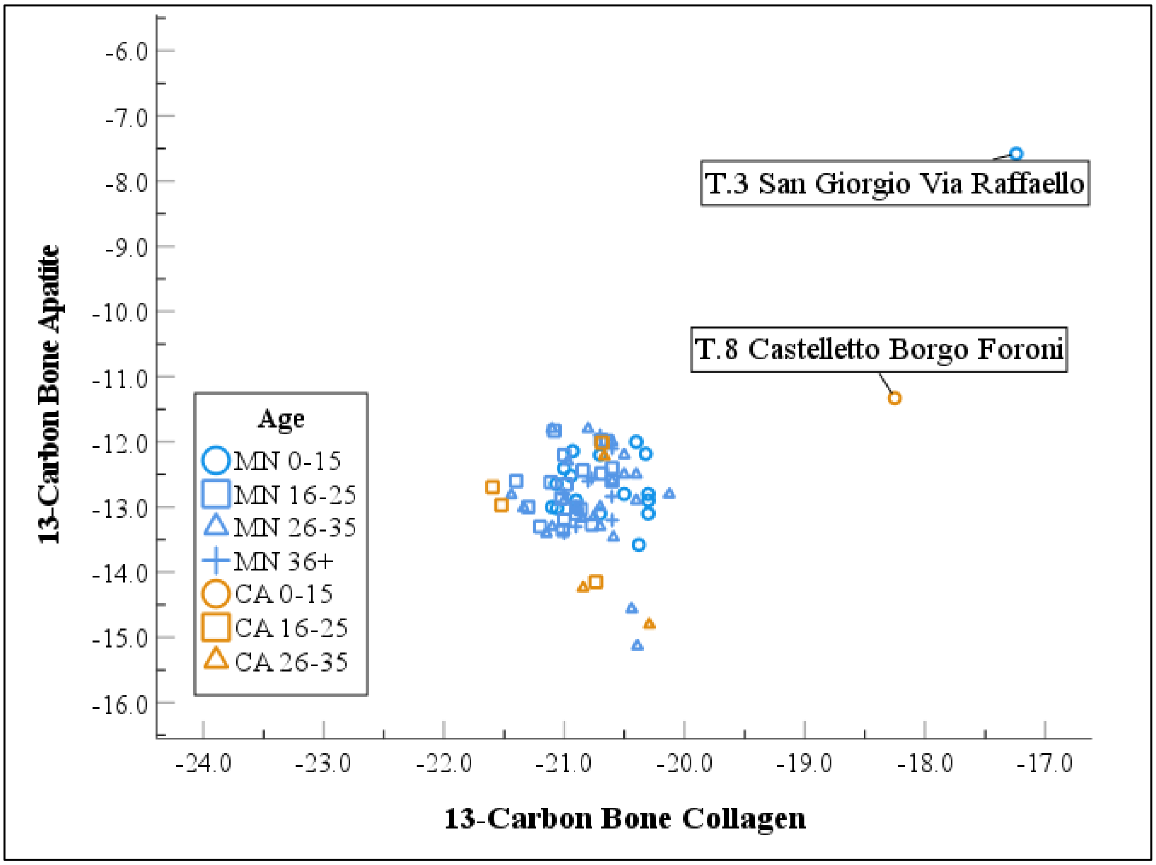

Figure 7.18: Human bone apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

Tooth Root

The descriptive statistics for bone carbon and nitrogen values from tooth roots are summarized in Table 7.8. The range of Middle Neolithic tooth root carbon and nitrogen values were as follows: δ13C_{ap} was -14.5‰ to -10.5‰ with an average of -12.6‰ ± 0.9 (Figure 7.19); $\delta^{13}C_{co}$ was -21.2‰ to -19.5‰ with an average of -20.2‰ ± 0.4 (Figure 7.20); and $\delta^{15}N$ was 8.3‰ to 11.7‰ with an average of 10.2‰ ± 0.7 (Figure 7.21). The range of Copper Age tooth root carbon and nitrogen values were as follows: $\delta^{13}C_{ap}$ was -13.8‰ to -11.7‰ with an average of -12.9‰ ± 0.8 (Figure 7.19); $\delta^{13}C_{co}$ was -21.4‰ to -21.1‰ with an average of -20.7‰ ± 0.4 (Figure 7.20); and $\delta^{15}N$ was 9.2‰ to 10.5‰ with an average of 9.8‰ ± 0.5 (Figure 7.21). An

Analysis of Variance (ANOVA) was conducted on the tooth root isotopic values to explore the potential significance between Middle Neolithic and Copper Age mean values for carbon and nitrogen. The results of the ANOVA between groups were as follows: there are no significant differences in $\delta^{13}C_{ap}$ values between the Middle Neolithic and Copper Age ($F = 1.107$, *df* = 1, $p = 0.296$); there are no significant differences in $\delta^{13}C_{co}$ values between the Middle Neolithic and Copper Age ($F = 4.517$, *df* = 1, $p = 0.037$); and there are no significant differences in $\delta^{15}N$ values between the Middle Neolithic and Copper Age ($F = 2.331$, *df* = 1, $p = 0.131$). These results suggest that there were no major differences in carbon and nitrogen sources in the adolescent diets between the analyzed middle neolithic and copper age Individuals, suggesting some continuity of subsistence practices between the two periods with respect to adolescent diet.

Table 7.8: Descriptive Statistics of $\delta^{13}C_{ap,}$ $\delta^{13}C_{co,}$ and $\delta^{15}N$ Tooth Root Values

	Tooth Root					
	$\delta^{13}C_{ap}$		$\delta^{13}C_{co}$		$\delta^{15}N$	
	Middle Neolithic	Copper Age	Middle Neolithic	Copper Age	Middle Neolithic	Copper Age
n	66	8	66	8	66	8
Mean	-12.6	-12.9	-20.4	-20.7	10.2	9.8
Median	-12.5	-12.8	-20.4	-20.7	10.1	9.8
Std. Dev.	0.9	0.8	0.4	0.4	0.7	0.5
Skewness	-0.2	0.1	0.3	-0.4	0.2	0.1
Minimum	-14.5	-13.8	-21.2	-21.4	8.3	9.2
Maximum	-10.5	-11.7	-19.5	-20.1	11.7	10.5

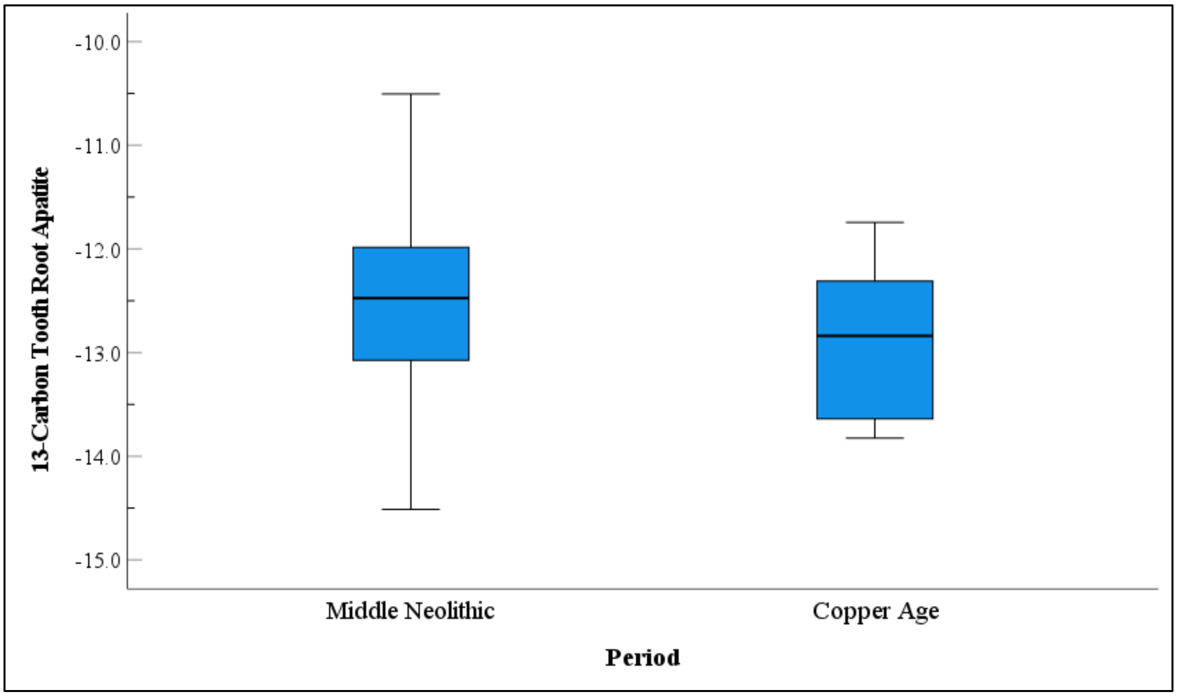

Figure 7.19: Stem-and-Leaf plot of $\delta^{13}C_{ap}$ tooth root values

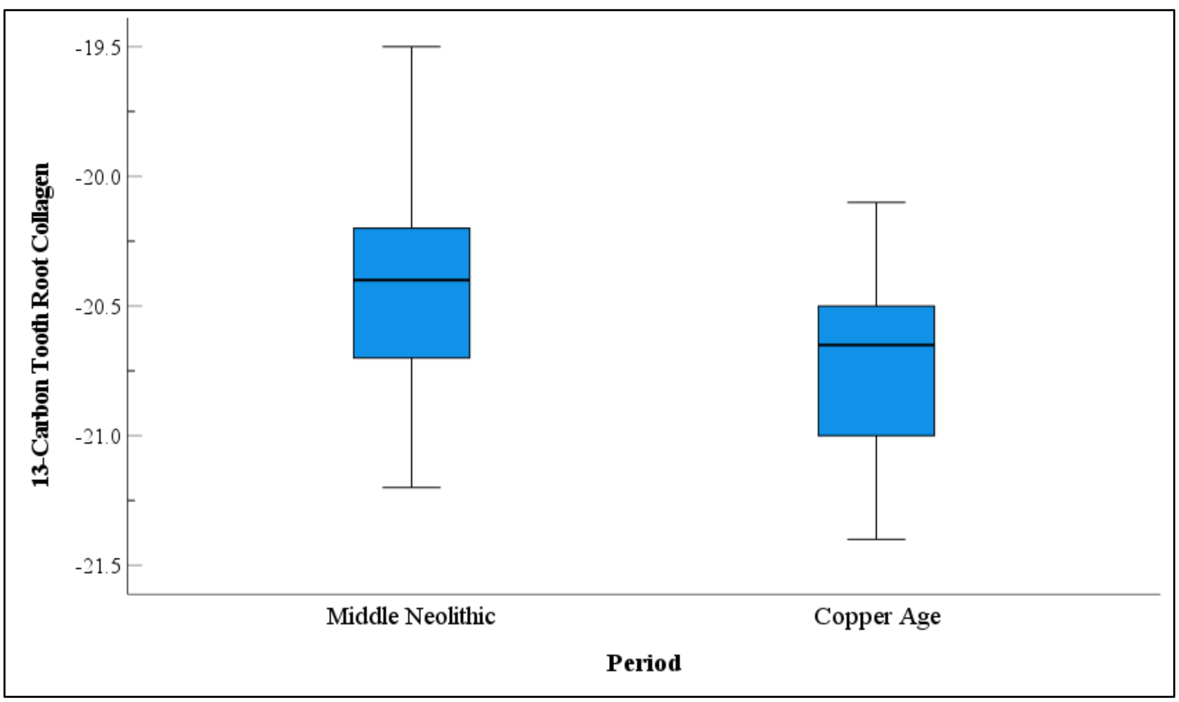

Figure 7.20: Stem-and-Leaf plot of $\delta^{13}C_{co}$ tooth root values

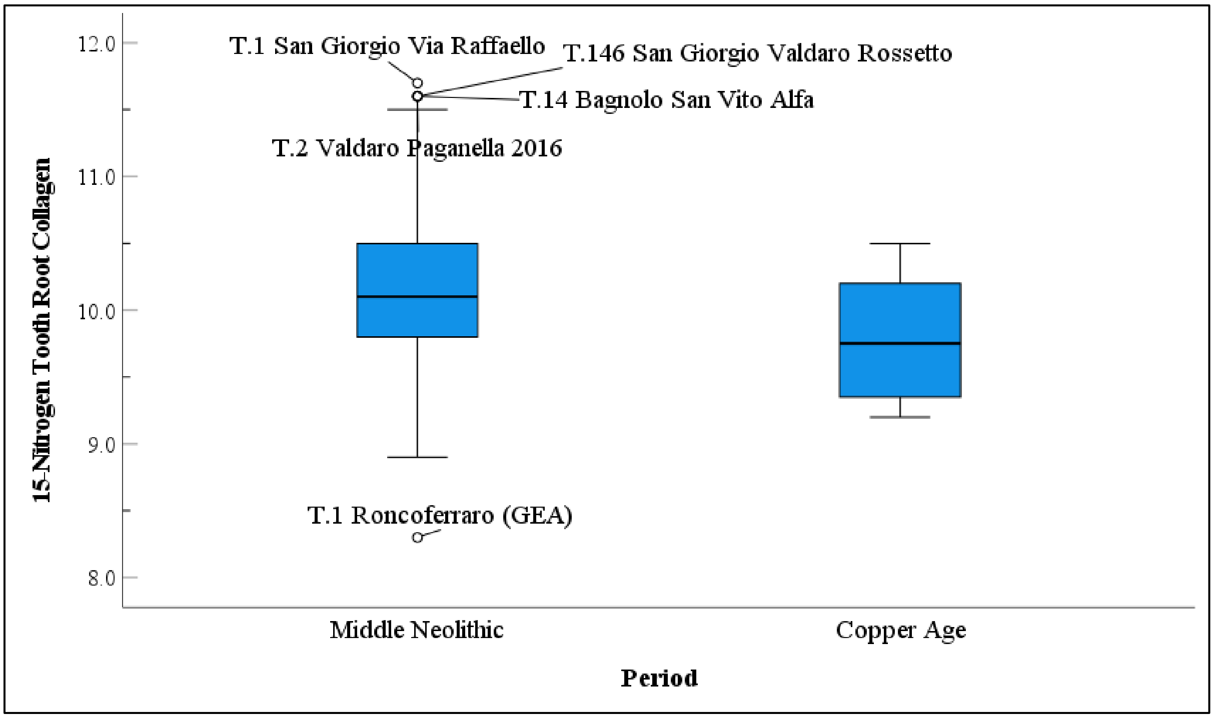

Figure 7.21: Stem-and-Leaf plot of $\delta^{15}N$ tooth root values

The carbon and nitrogen isotopic values obtained from tooth roots were analyzed graphically utilizing scatter plots. Plots were created to assess potential differences in protein sources by comparing $\delta^{13}C_{co}$ and $\delta^{15}N$ values and to potentially identify the influence of freshwater, marine, or terrestrial carbon sources on analyzed $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ carbon values between the Middle Neolithic and Copper Age periods. Scatter plots were also created to illustrate sex and age-based differences respectively of protein and carbon sources between the two periods of interest. Beginning with the analysis of sub-adult dietary protein sources, Figure 7.22 displays the relationship between dietary protein between the Middle Neolithic and Copper Ages. The cluster of points, although appearing further apart than the adult diet plot, are similar in contribution of protein from C_3 source, with much more dispersion in trophic level, likely caused by first molars and pre-molars retaining some weaning signatures within the tooth root. The primary result here is that sub-adult diets mirror adult diets regarding protein and protein carbon sources resembling a commitment to terrestrial C_3 collagen values of -21.5‰, as previously discussed. The carbon spacing between bone apatite and collagen may yield additional evidence of terrestrial, marine, or freshwater carbohydrate sources in the sub-adult diet, but that plot will also include data from early forming teeth as previously discussed.

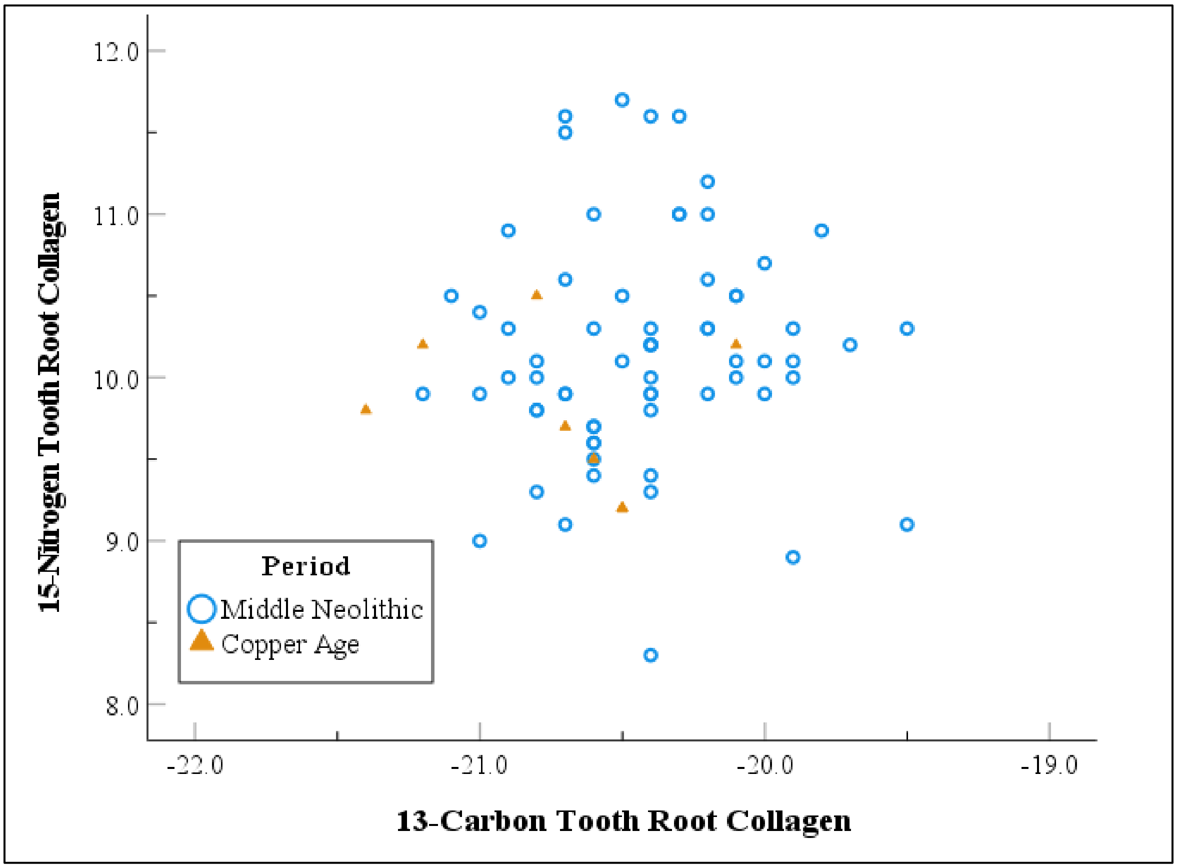

Figure 7.22: Human tooth root collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values (*n* = 74)

Scatter plots of the aggregate time period isotopic data were produced to analyze differences in sub-adult dietary protein sources by sex and age, similar to bone isotopic values. Individuals were distinguished first by time period and then by sex and age within those time periods. Age categories remain the same as previously discussed. The goal of these analyses is to examine general differences between males and females and adolescent diets. The tooth roots obtained largely come from late forming molar roots (second and third molars) that reflect late adolescence, with only three tooth roots sampled from individuals as old as 6 years but likely younger than 12 years of age. As previously mentioned, age categories must remain the same for meaningful comparisons to be made between age groups. The scatter plot shows that no notable differences in sub-adult protein sources between males and females of both the Middle Neolithic and Copper Ages (Figure 7.23). An ANOVA was conducted between the Middle Neolithic and Copper Age males and females respective of period and tooth root isotopic value. There were no significant differences between the Middle Neolithic and Copper Age male protein sources in the sub-adult diet. The results of the ANOVA were as follows: there are no significant differences in male $\delta^{13}C_{ap}$ values ($F = 0.895$, $df = 1$, $p = 0.358$); there are no significant differences in male $\delta^{13}C_{co}$ values ($F = 6.852$, $df = 1$, $p = 0.019$); and there are no significant differences in male $\delta^{15}N$ values ($F = 0.082$, $df = 1$, $p = 0.779$). There were no significant differences between Middle Neolithic and Copper Age female protein sources in the sub-adult diet. The results from the ANOVA were as follows: there are no significant differences in female $\delta^{13}C_{ap}$ values ($F = 0.214$, $df = 1$, $p = 0.649$); there are no significant differences in female $\delta^{13}C_{co}$ values ($F = 0.046$, $df = 1$, $p = 0.833$); and there are no significant differences in female $\delta^{15}N$ values ($F = 0.475$, $df = 1$, $p = 0.500$). These results indicate that male and female protein sources were similar between the Middle Neolithic and Copper Ages.

Sex-based differences in protein sources were also explored within each of the periods of interest utilizing ANOVA tests. First, there were no significant differences in sub-adult dietary protein sources between males and females in the Middle Neolithic population. The results for the

Middle Neolithic are as follows: there are no significant differences in $\delta^{13}C_{ap}$ values (F = 0.158, *df* = 1, *p* = 0.694); there are no significant differences in $\delta^{13}C_{co}$ values (F = 3.095, *df* = 1, *p* = 0.089); and there are no significant differences in female $\delta^{15}N$ (F = 0.381, *df* = 1, *p* = 0.542). Only five individuals were of known sex for the Copper Age (*n* = 3 males; *n* = 2 female) within the analyzed assemblage so parametric comparison of sex-based differences in diet were not possible based on sex within the Copper Age group. These results illustrate that protein sources within and between the Middle Neolithic and Copper Age remained consistent, further suggesting relatively stable sub-adult dietary protein sources throughout time.

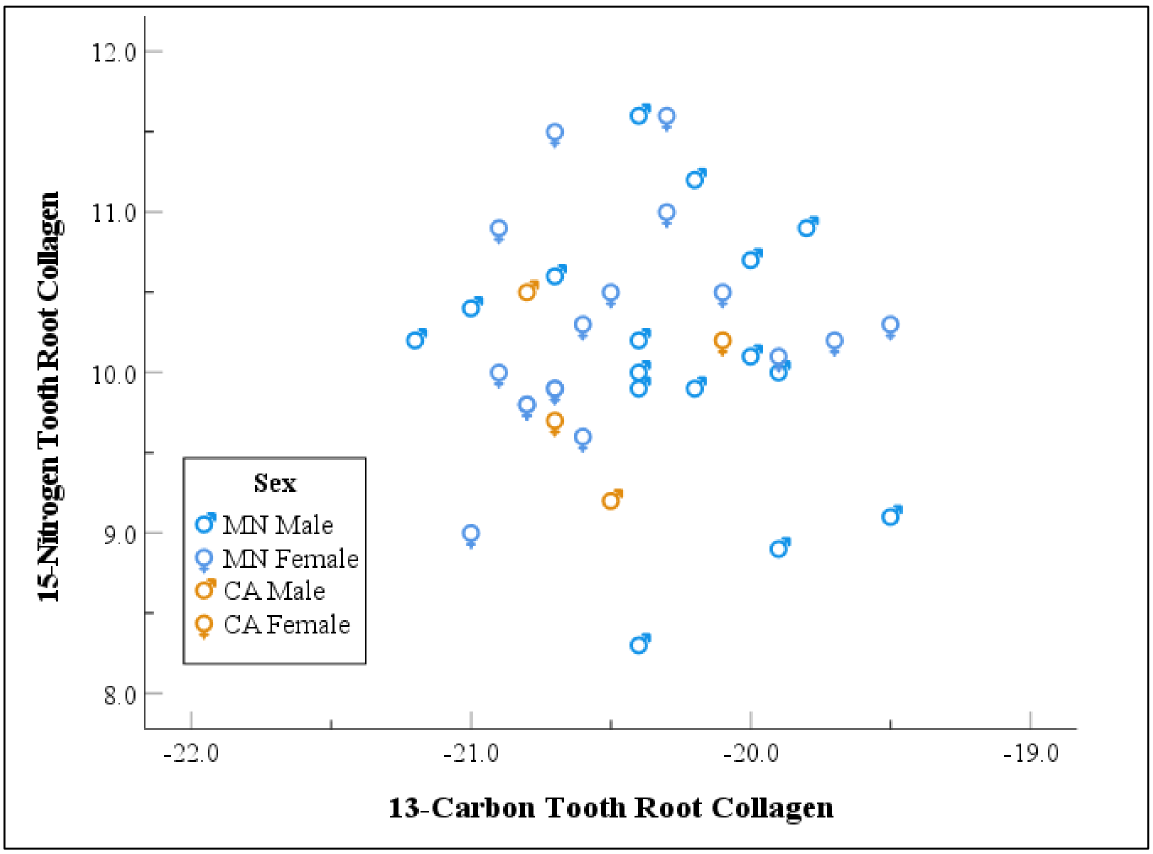

Figure 7.23: Human tooth roots collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

A scatter plot was also produced to explore potential difference in sub-adult protein sources by age. Based on the previous holistic analysis of the two periods it is expected that no major differences exist between assigned age groups. The scatter plot shows each of the four age groups separated by period and reveals no major differences based on age in protein sources in the sub-adult diet (Figure 7.24). The sub-adult diet appears again to tightly cluster around the expected C_3 protein carbon value of -21.5‰ with acceptable levels of deviation of no more than ± 2.0‰ in enrichment or depletion. Interestingly, trophic level is very similar between sub-adult and adult diets.

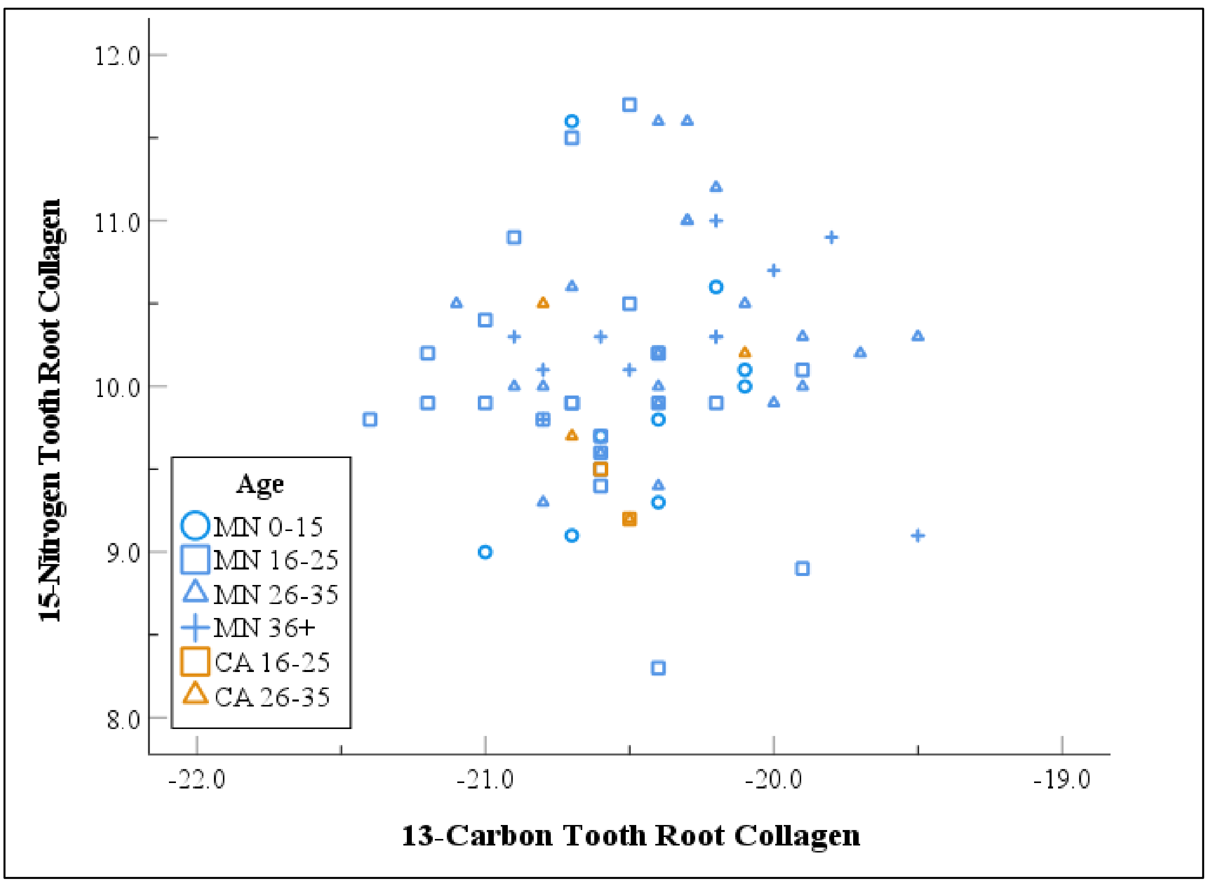

Figure 7.24: Human tooth root collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

The scatter plot of total carbon contribution from the diet, with the protein portion represented by $\delta^{13}C_{co}$ and the carbohydrate portion represented by $\delta^{13}C_{ap}$ values depicts a very tight cluster of both Middle Neolithic and Copper Age tombs and thus total sub-adult dietary carbon values (Figure 7.25). This suggests that little to no variation in proteins or carbohydrates existed between the Middle Neolithic and Copper Age sub-adult diets. The average $\delta^{13}C_{ap}$ values are extremely close at -12.6‰ ± 0.9 for the Middle Neolithic and -12.9‰ ± 0.8, which is graphically visible in the scatter plot of the carbon values as a tight cluster, with only slightly more dispersion than the adult dietary results reported above. It is expected that in a pure C_3 diet human $\delta^{13}C_{ap}$ values should cluster around -14.5‰, where enrichment in apatite values +3‰ or more could indicate a more mixed adult diet specific to carbohydrate sources and inclusion of some C_4 plants. Most of the analyzed population is clearly clustering very tightly around the expected pure C_3 dietary carbohydrate values and dietary protein values regarding carbon. Thus, the primary source of adult dietary carbohydrates and proteins within Middle Neolithic and Copper Age Mantua, was provided by C_3 plants. However, more dispersion in $\delta^{13}C_{ap}$ values exists in the Middle Neolithic population with four individuals having $\delta^{13}C_{ap}$ enriched values greater than +3‰ indicating a slightly more mixed sub-adult diet which possibly included some enriched carbohydrate sources. There appears be less dispersion in Copper Age values with more of the Copper Age individuals clustering more tightly to the expected C_3 mean when compared to the Middle Neolithic individuals.

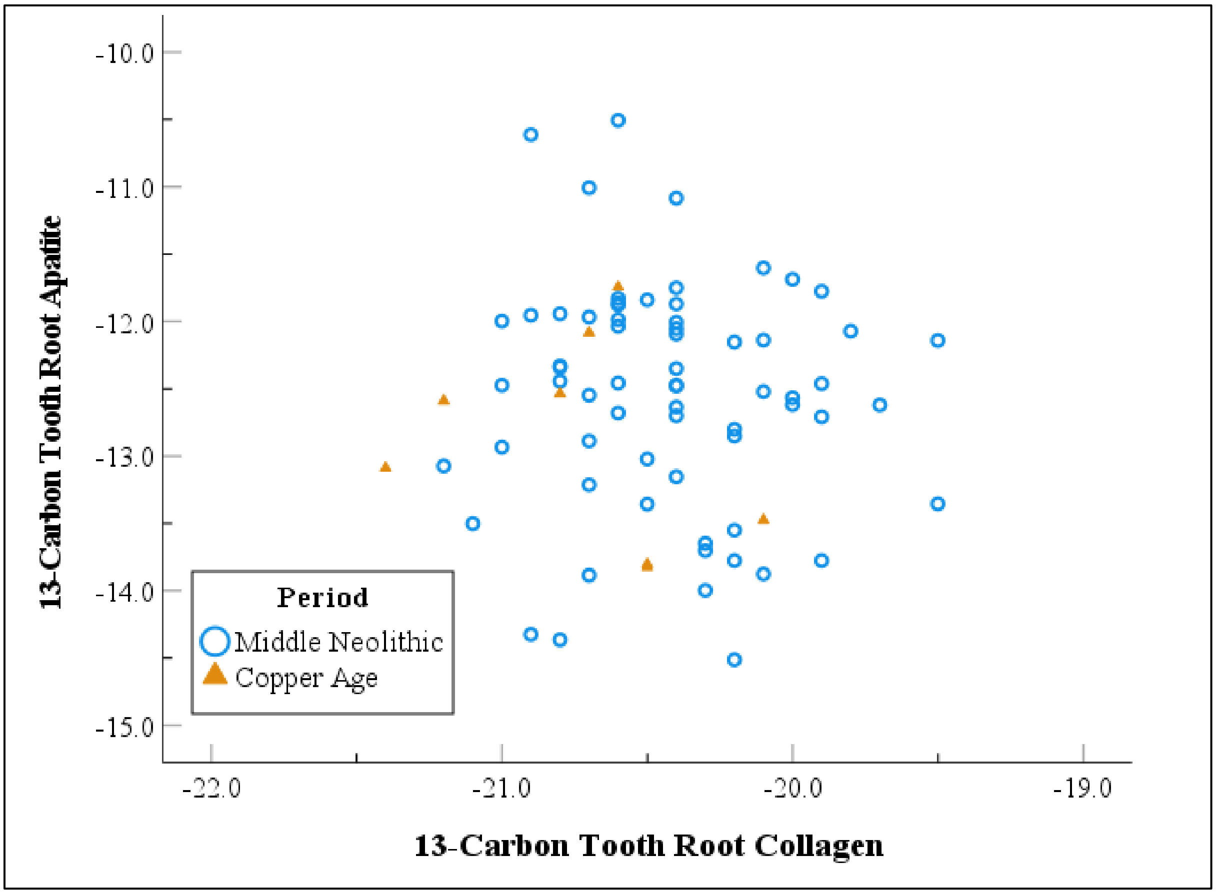

Figure 7.25: Human tooth root apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

As previously discussed, there were no significant sex-based differences between males and females within the Middle Neolithic population with respect to sub-adult protein sources. Additionally, there were no significant sex-based differences between Middle Neolithic and Copper Age males and females. Two scatter plots were also produced to examine any potential differences in carbohydrate or total sub-adult dietary carbon sources between Middle Neolithic and Copper Age males and females (Figure 7.26), as well as age related differences (Figure 7.27). There appear to be no significant differences in total sub-adult dietary carbon between males and females within and between the two periods of interest. Lastly, there is no apparent age-based differences within and between the two periods of interest. Both scatter plots suggest that dietary carbon was originating from a common food source. Likely a heavy reliance on C_3 plants with the addition of terrestrial meat sources either from wild or domesticated species. Two of the four individuals that were plotting outside of the expected range for C_3 carbohydrates are young adult and prime age females.

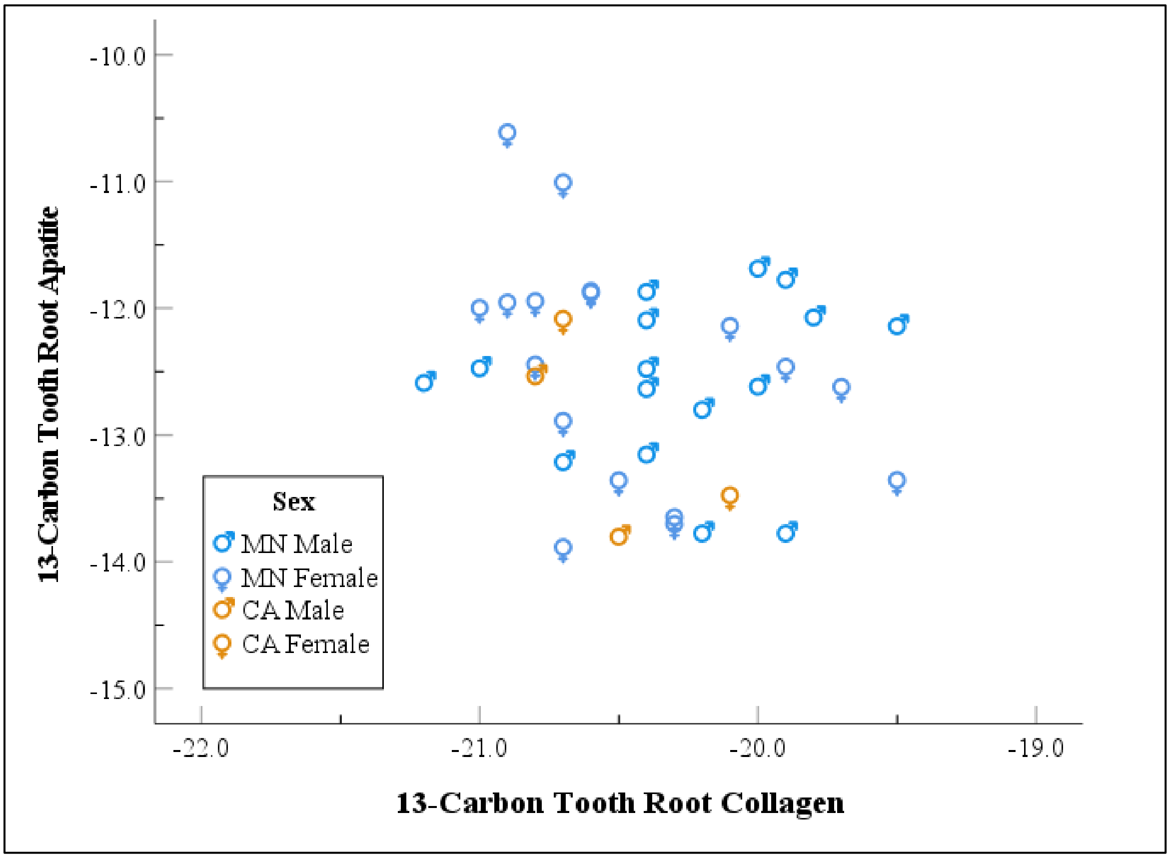

Figure 7.26: Human tooth roots collagen $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ (‰ VPDB) values by known sex

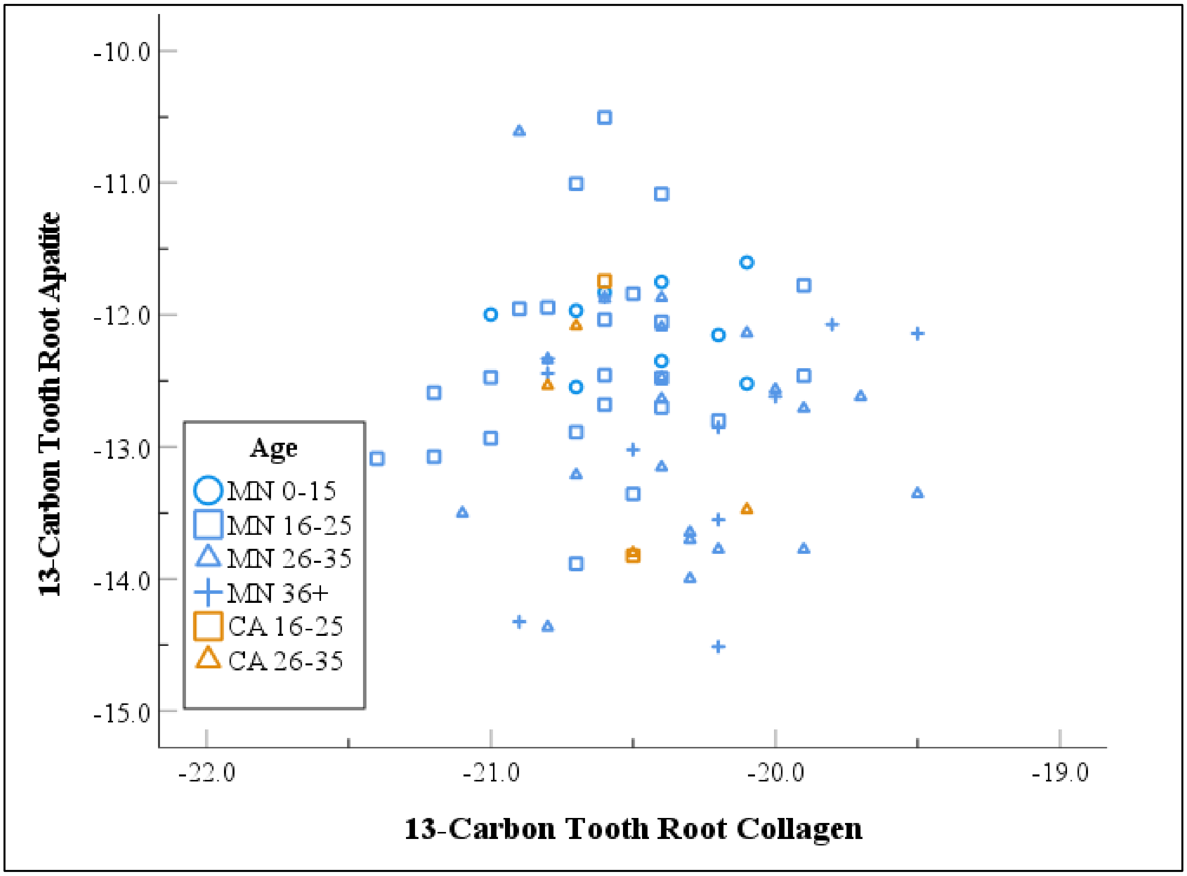

Figure 7.27: Human tooth root collagen $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ (‰ VPDB) values by known age

VBQ Phase 1 & 2 vs. Lagozza Diets

This section will present the results of stable carbon and nitrogen values from bone and tooth roots by cultural period (VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza). Cultural affiliation was determined based on the previously reported chronological model above. All burials that were radiocarbon dated were separated into groups by period and culture. Furthermore, burials that were associated with the dated burials were also separated into period and cultural groups. The radiocarbon dating regime was not extensive enough to associate all burials with a known cultural group, but all could be grouped by period because of material culture associations, some burials could be attributed to the VBQ group, but no phase distinction was possible from the material cultural remains alone. Those individuals that could not be assigned a cultural group due to either radiocarbon results, association, or material culture assemblages were placed in the VBQ 1 & 2 group. The term Lagozza is used for graphical simplicity to describe the Chassey-Lagozza cultural group of the Chalcolithic or Late Neolithic, as previously discussed. Descriptive statistics, separated by tissue and culture, are reported in Tables 7.9, 7.10, and 7.11 for bone and Tables 7.12, 7.13, and 7.14 for tooth roots. A total of 82 bone samples from the Middle Neolithic period and a total of 10 bone samples from the Copper Age period yielded carbon and nitrogen isotopic values for comparison and analysis. A total of 66 tooth root samples from the Middle Neolithic period and a total of 8 tooth root samples from the Copper Age period yielded carbon and nitrogen isotopic values for comparison and analysis. The carbon and nitrogen results for bone and tooth roots by period are presented below.

Bone

The descriptive statistics for bone carbon and nitrogen values from bone are summarized in Tables 7.9, 7.10, and 7.11. The range of the VBQ bone carbon and nitrogen values were as follows: VBQ 1 & 2 $\delta^{13}C_{ap}$ was -13.6‰ to -11.6‰ with an average of -12.8‰ ± 0.4, VBQ 1 was -15.1‰ to -11.8‰ with an average of -12.7‰ ± 0.9, and VBQ 2 was -13.4‰ to -12.1‰ with an average of -12.9‰ ± 0.4 (Figure 7.28); VBQ 1 & 2 $\delta^{13}C_{co}$ was -21.4‰ to -20.2‰ with an average of -20.8‰ ± 0.3, VBQ 1 was -21.4‰ to -20.1‰ with an average of -20.8‰ ± 0.3, and VBQ 2 was -21.2‰ to -20.5‰ with an average of -20.9‰ ± 0.19 (Figure 7.29); and VBQ 1 & 2 $\delta^{15}N$ was 8.6‰ to 11.5‰ with an average of 9.9‰ ± 0.6, VBQ 1 was 9.3‰ to 11.3‰ with an average of 10.0‰ ± 0.6, and VBQ 2 was 8.2‰ to 10.7‰ with an average of 9.8‰ ± 0.7 (Figure 7.30). The range of Copper Age or Lagozza bone carbon and nitrogen values were as follows: $\delta^{13}C_{ap}$

was -14.8‰ to -11.3‰ with an average of -13.0‰ ± 1.1 (Figure 7.28); $\delta^{13}C_{co}$ was -21.6‰ to -18.3‰ with an average of -20.6‰ ± 0.9 (Figure 7.29); and $\delta^{15}N$ was 9.1‰ to 11.3‰ with an average of 9.8‰ ± 0.6 (Figure 7.30). An Analysis of Variance (ANOVA) was conducted on the bone isotopic values to explore the potential significance between the VBQ 1& 2, VBQ 1, VBQ 2, and Lagozza cultural groups mean values for carbon and nitrogen. The results of the ANOVA between groups were as follows: there are no significant differences in $\delta^{13}C_{ap}$ values between the cultural groups ($F = 0.584$, $df = 3$, $p = 0.687$); there are no significant differences in $\delta^{13}C_{co}$ values between the cultural groups ($F = 0.868$, $df = 3$, $p = 0.461$); and there are no significant differences in $\delta^{15}N$ values between the cultural groups ($F = 0.799$, $df = 3$, $p = 0.799$). These results suggest that there were no major differences in carbon and nitrogen sources in the diet between the analyzed cultural groups, suggesting potential stability and continuity of subsistence practices among all of the cultural groups with respect to adult diet.

Table 7.9: Descriptive Statistics of $\delta^{13}C_{ap}$ Bone Values

	Bone			
	$\delta^{13}C_{ap}$			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	48	22	12	10
Mean	-12.8	-12.7	-12.9	-13.0
Median	-12.8	-12.6	-12.9	-12.8
Std. Deviation	0.4	0.9	0.4	1.1
Skewness	0.4	-1.4	0.6	-0.2
Minimum	-13.6	-15.1	-13.4	-14.8
Maximum	-11.6	-11.8	-12.1	-11.3

Table 7.10: Descriptive Statistics of $\delta^{13}C_{co}$ Bone Values

	Bone			
	$\delta^{13}C_{co}$			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	48	22	12	10
Mean	-20.8	-20.8	-20.9	-20.6
Median	-20.7	-20.8	-20.9	-20.7
Std. Deviation	0.3	0.3	0.2	0.9
Skewness	-0.3	0.1	0.6	2.0
Minimum	-21.4	-21.4	-21.2	-21.6
Maximum	-20.2	-20.1	-20.5	-18.3

Table 7.11: Descriptive Statistics of $\delta^{15}N$ Bone Values

	Bone			
	15-Nitrogen Collagen			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	48	22	12	10
Mean	9.9	10.0	9.8	9.8
Median	9.8	9.9	9.9	9.7
Std. Deviation	0.6	0.6	0.7	0.6
Skewness	0.5	0.9	-1.0	1.5
Minimum	8.6	9.3	8.2	9.1
Maximum	11.5	11.3	10.7	11.3

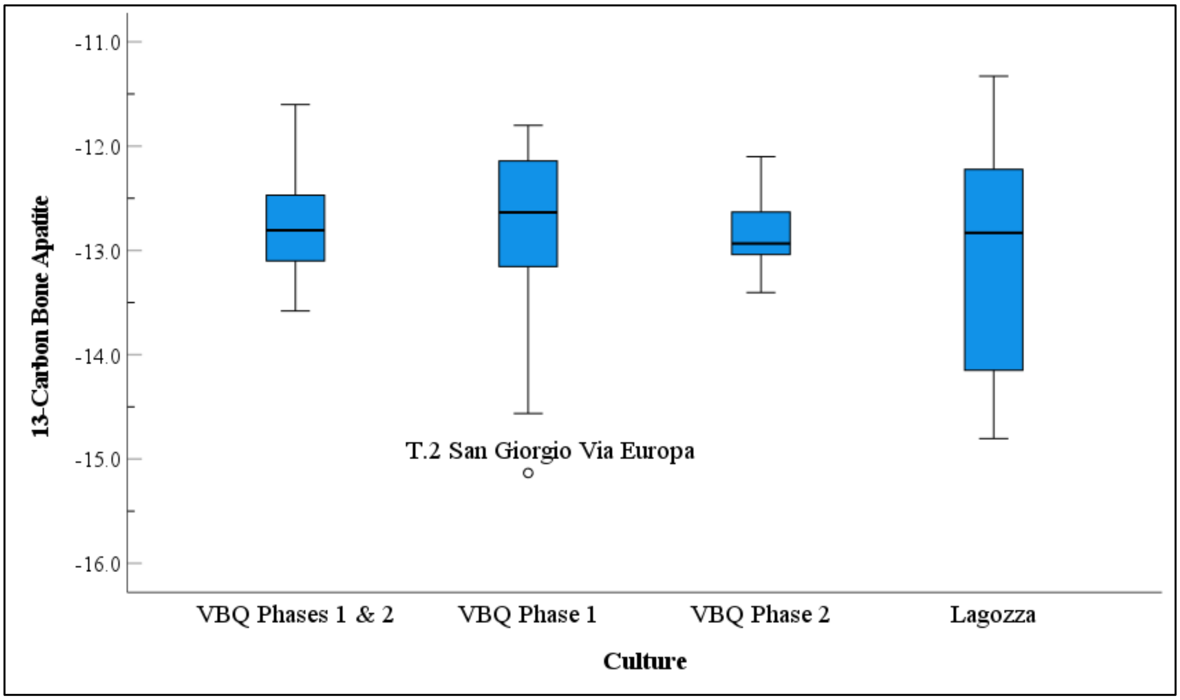

Figure 7.28: Stem-and-Leaf plot of $\delta^{13}C_{ap}$ bone values of the aggregate VBQ

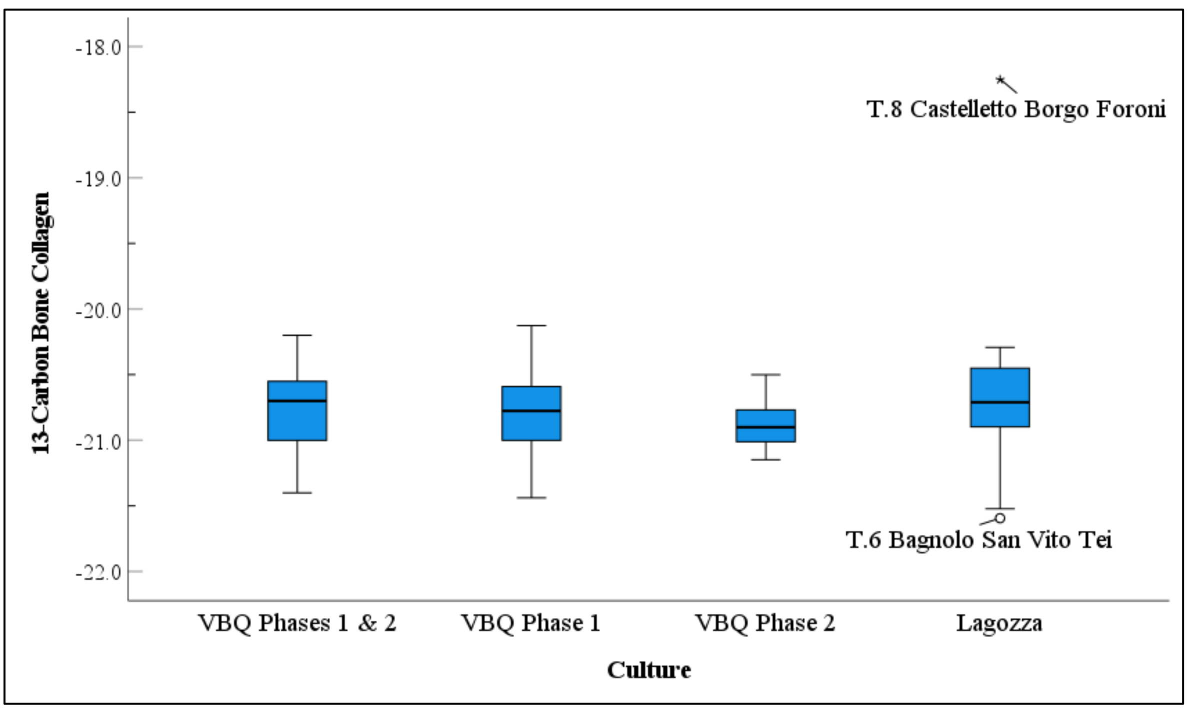

Figure 7.29: Stem-and-Leaf plot of $\delta^{13}C_{co}$ bone values of the aggregate VBQ

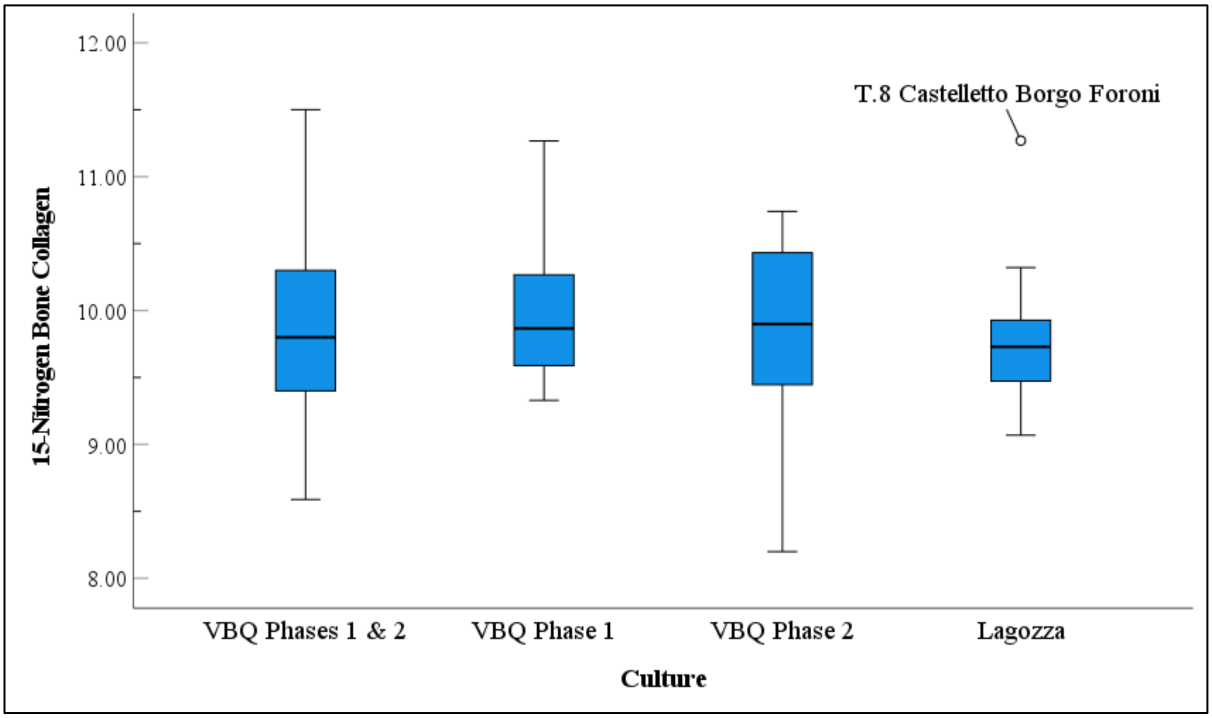

Figure 7.30: Stem-and-Leaf plot of $\delta^{15}N$ bone values of the aggregate VBQ

The carbon and nitrogen isotopic values obtained from bone were analyzed graphically utilizing scatter plots. Plots were created to assess potential differences in protein sources by comparing $\delta^{13}C_{co}$ and $\delta^{15}N$ values and to potentially identify the influence of freshwater, marine, or terrestrial carbon sources on analyzed $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ carbon values between the four cultural groups represented within the analyzed sample. Scatter plots were also created to illustrate sex and age-based differences respectively of protein and carbon sources between the represented cultural groups. Beginning with the analysis of adult dietary protein sources, Figure 7.31 displays the relationship between dietary protein between the cultural groups. One outlying burial, tomb 8 from Castelletto Borgo Foroni has an enriched $\delta^{13}C_{co}$ value of -18.3, as previously reported. The enrichment of this value indicates that this individual may have a slightly different protein source than the rest of the population, in favor of carbon potentially originating from marine proteins.

Like the period results, the cultural groups most closely plot with the expected terrestrial C_3 collagen values of -21.5‰, as previously discussed. There is slightly more trophic dispersion in the VBQ values than the Lagozza, which suggests a greater utilization of terrestrial meat resource by the VBQ than Lagozza peoples. The carbon spacing between bone apatite and collagen may yield additional evidence of terrestrial, marine, or freshwater carbohydrate sources. The major difference in the dispersion in adult dietary protein is within the nitrogen values, which suggests a relatively mixed diet of terrestrial protein sources and C_3 plants with very little freshwater or marine protein signatures observable in the human values, apart from tomb 8 from Castelletto Borgo Foroni.

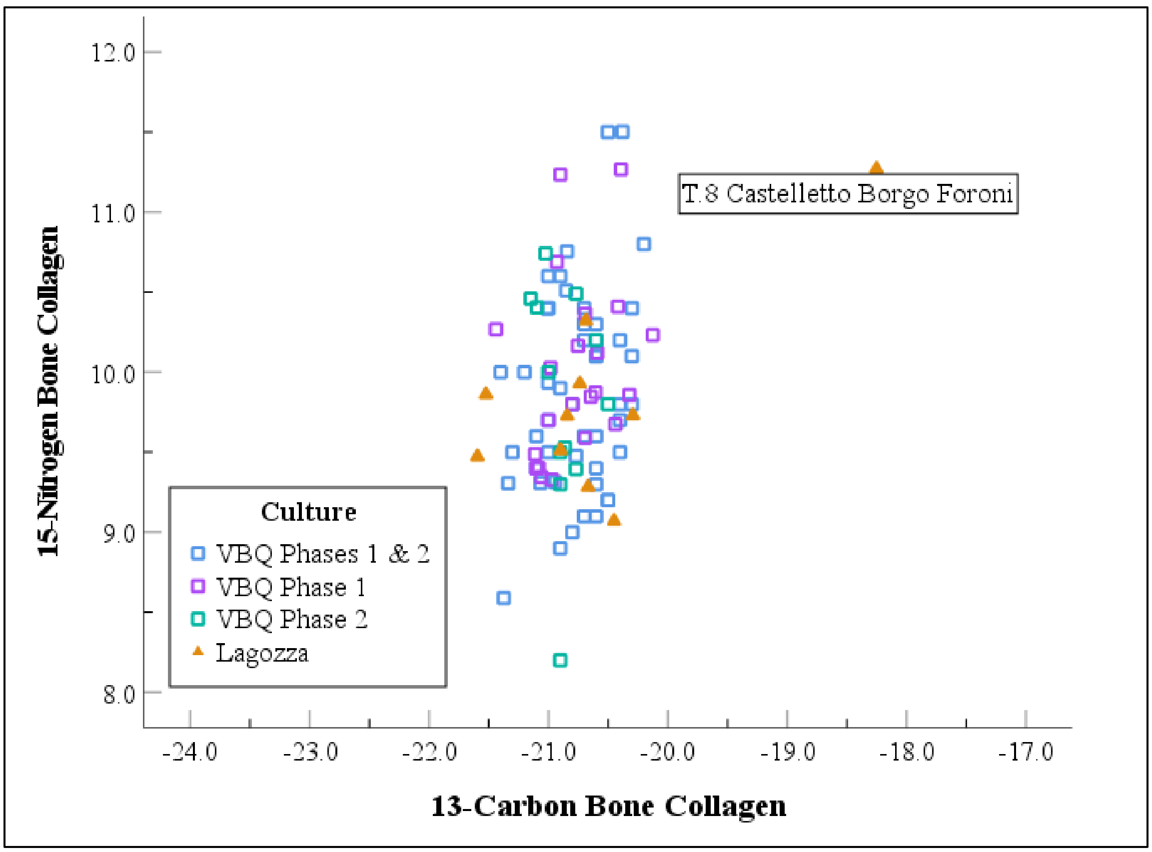

Figure 7.31: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

Scatter plots of cultural group isotopic data were also produced to analyze differences in adult dietary protein sources by sex and age. Individuals were distinguished first by cultural group and then by sex and age within those groups. Age categories remains consistent with the previous time period analyses. The scatter plots shows that no notable differences in adult protein sources between males and females of VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza groups (Figure 7.32). An ANOVA was conducted between the VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza males and females respective of period and bone isotopic value. There were no significant differences between the male protein sources in the adult diet between cultural groups. The results of the ANOVA were as follows: there are no significant differences in male $\delta^{13}C_{ap}$ values (F = 1.535, *df* = 3, *p* = 0.242); there are no significant differences in male $\delta^{13}C_{co}$ values (F = 0.555, *df* = 3, *p* = 0.652); and there are no significant differences in male $\delta^{15}N$ values (F = 1.441, *df* = 3, *p* = 0.266). There were no significant differences between VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza female protein sources in the adult diet. The results from the ANOVA were as follows: there are no significant differences in female $\delta^{13}C_{ap}$ values (F = 0.387, *df* = 3, *p* = 0.764); there are no significant differences in female $\delta^{13}C_{co}$ values (F = 0.540, *df* = 3, *p* = 0.663); and there are no significant differences in female $\delta^{15}N$ values (F = 0.687, *df* = 3, *p* = 0.576). These results indicate that male and female protein sources were similar between the VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza cultural groups. Based on the previous ANOVA results and scatter plots sex-based differences in protein sources were not parametrically explored due to the previous non-significant findings. There appear to be no significant difference between male and female adult diets within the VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza cultural groups respectively. These results illustrate that protein sources within and between represented cultural groups remained consistent, further suggesting relatively stable adult dietary protein sources throughout time regardless of sex.

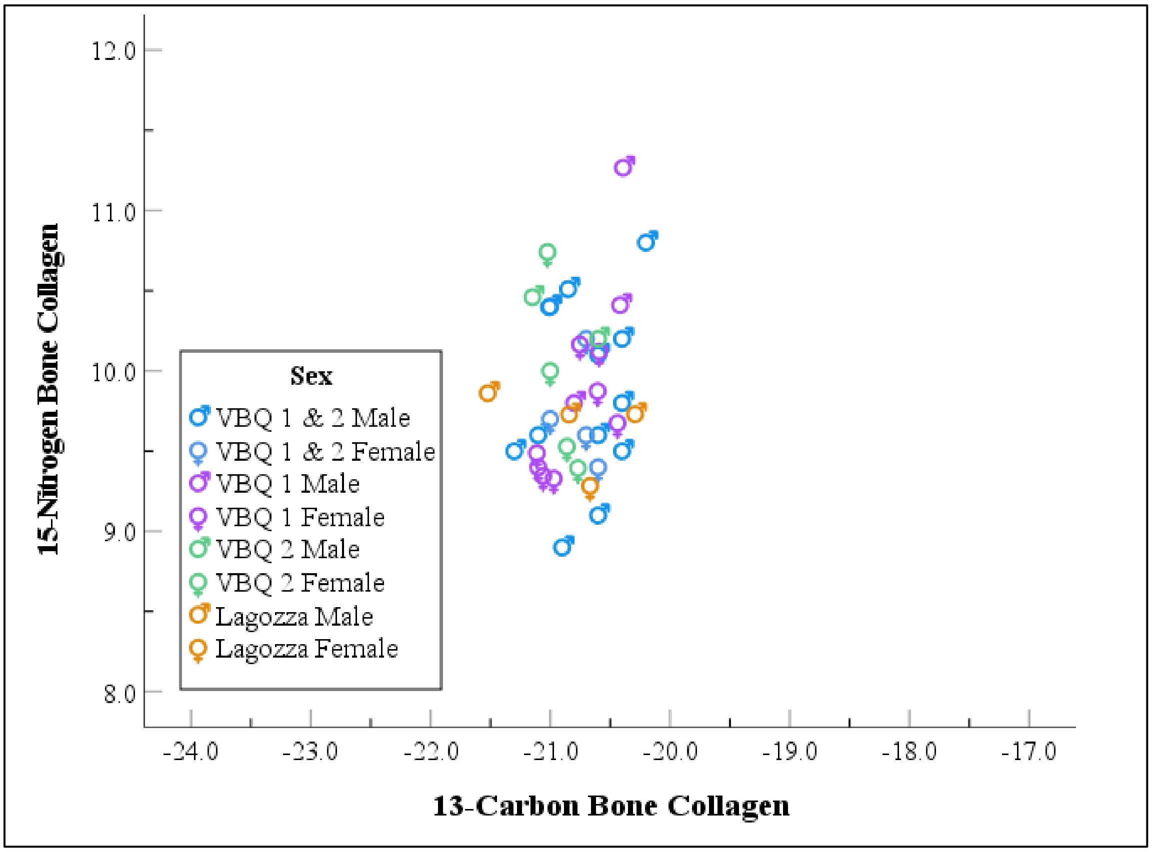

Figure 7.32: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

A scatter plot was also produced to explore potential difference in cultural group specific adult protein sources by age. Based on the previous holistic analysis of the cultural groups it is expected that no major differences exist between assigned age groups. The scatter plot shows each of the four age groups separated by cultural group affiliation and reveals no major differences based on age in protein sources in the diet (Figure 7.33). Tomb 3 from Castelletto Borgo again is an outlying burial where the driver for the variation in plot is due to enrichment in carbon originating from bone collagen. This individual is also an adolescent from the Lagozza cultural group which could have affected access to different dietary protein sources of carbon than the larger population.

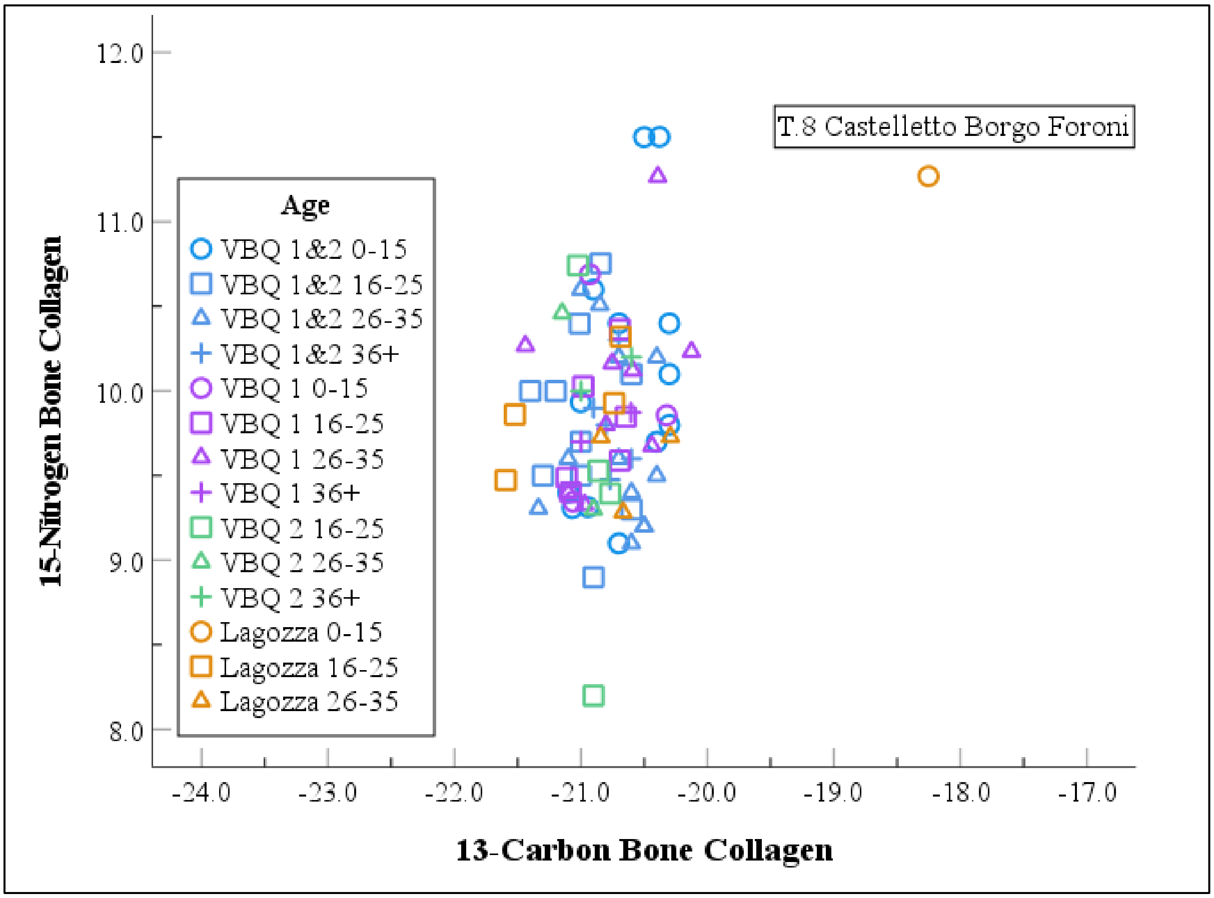

Figure 7.33: Human bone collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

The scatter plot of total carbon contribution from the diet, with the protein portion represented by $\delta^{13}C_{co}$ and the carbohydrate portion represented by $\delta^{13}C_{ap}$ values depicts a very tight cluster of all tombs regardless of cultural group and thus total adult dietary carbon values (Figure 7.34). This suggests that little to no variation in proteins or carbohydrates existed between cultural groups adult diets. The average $\delta^{13}C_{ap}$ values are extremely close at -12.8‰ ± 0.4 for the VBQ 1 & 2, -12.7‰ ± 0.9 for the VBQ 1, -12.9‰ ± 0.4 for the VBQ 2, and -13.0‰ ± 1.1 for the Lagozza. Tomb 8 from Castelletto Borgo Foroni continues to plot away from the analyzed assemblage and has a more enriched adult protein carbon source in the diet compared with the other individuals. This individual is a sub-adult and could possibly have been consuming a more mixed diet of richer and softer protein and carbohydrate sources, such as secondary dairy products or fishes. It is expected that in a pure C_3 diet human $\delta^{13}C_{ap}$ values should cluster around -14.5‰, where enrichment in apatite values +3‰ or more could indicate a more mixed adult diet specific to carbohydrate sources and inclusion of some C_4 plants. Most of the analyzed population is clearly clustering very tightly around the expected pure C_3 dietary carbohydrate values and dietary protein values regarding carbon, with most less than one standard deviation. Thus, the primary source of adult dietary carbohydrates and proteins among the VBQ phase 1 and 2, and Lagozza in Mantua, was provided by C_3 plants.

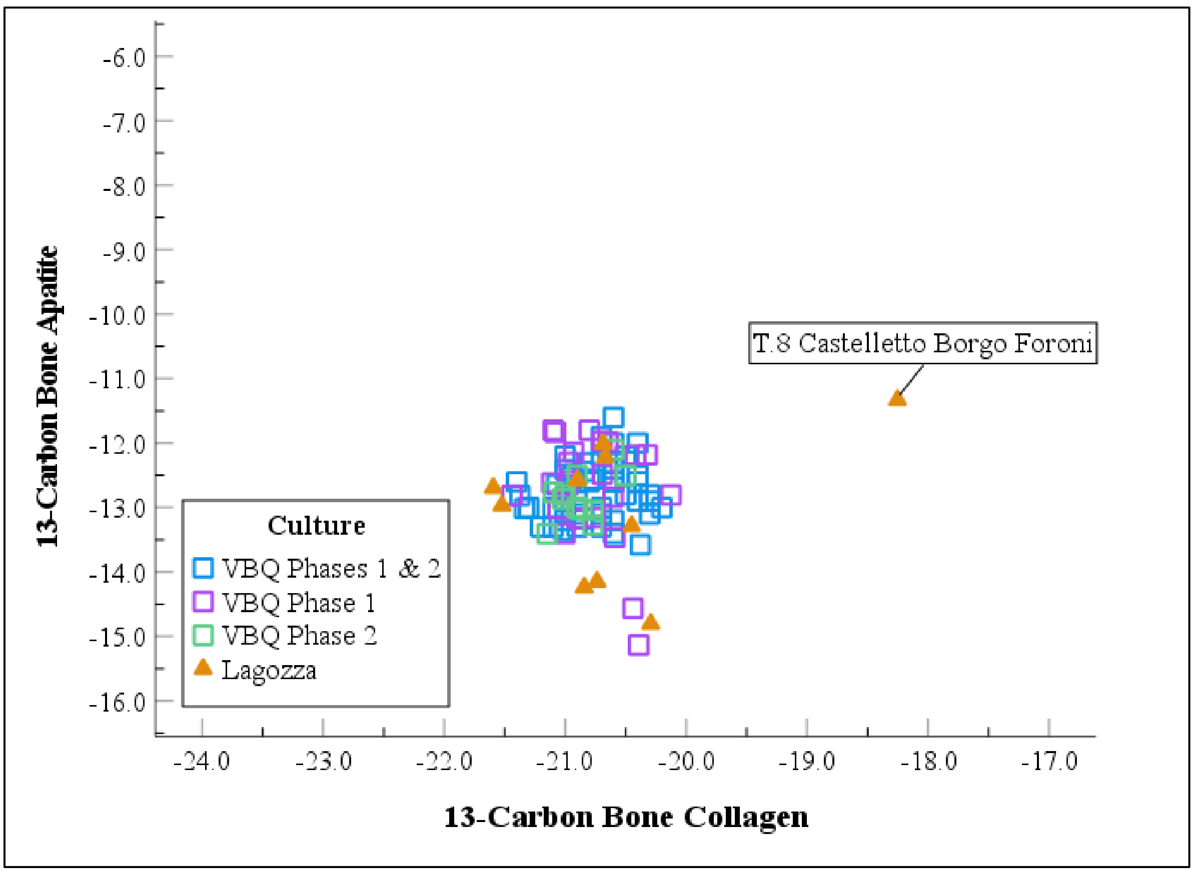

Figure 7.34: Human bone apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

As previously discussed, there were no significant sex-based differences between males and females between or within the represented cultural groups. Two scatter plots were also produced to examine any potential differences in carbohydrate or total dietary carbon sources between respective cultural group males and females (Figure 7.35), as well as age related differences (Figure 7.36). There appear to be no significant differences in total dietary carbon between males and females within and between the cultural groups of interest. Lastly, there is no apparent age-based differences within and between the cultural groups of interest. Both scatter plots suggest that among all three cultural phases dietary carbon was originating from a common food source. Likely a heavy reliance on C_3 plants with the addition of terrestrial meat sources either from wild or domesticated species. It is possible as previously mentioned that some slight enrichment observed in the outlying burials that these individuals were mixed feeders either with some small incorporation of most likely marine foods or less likely C_4 plants.

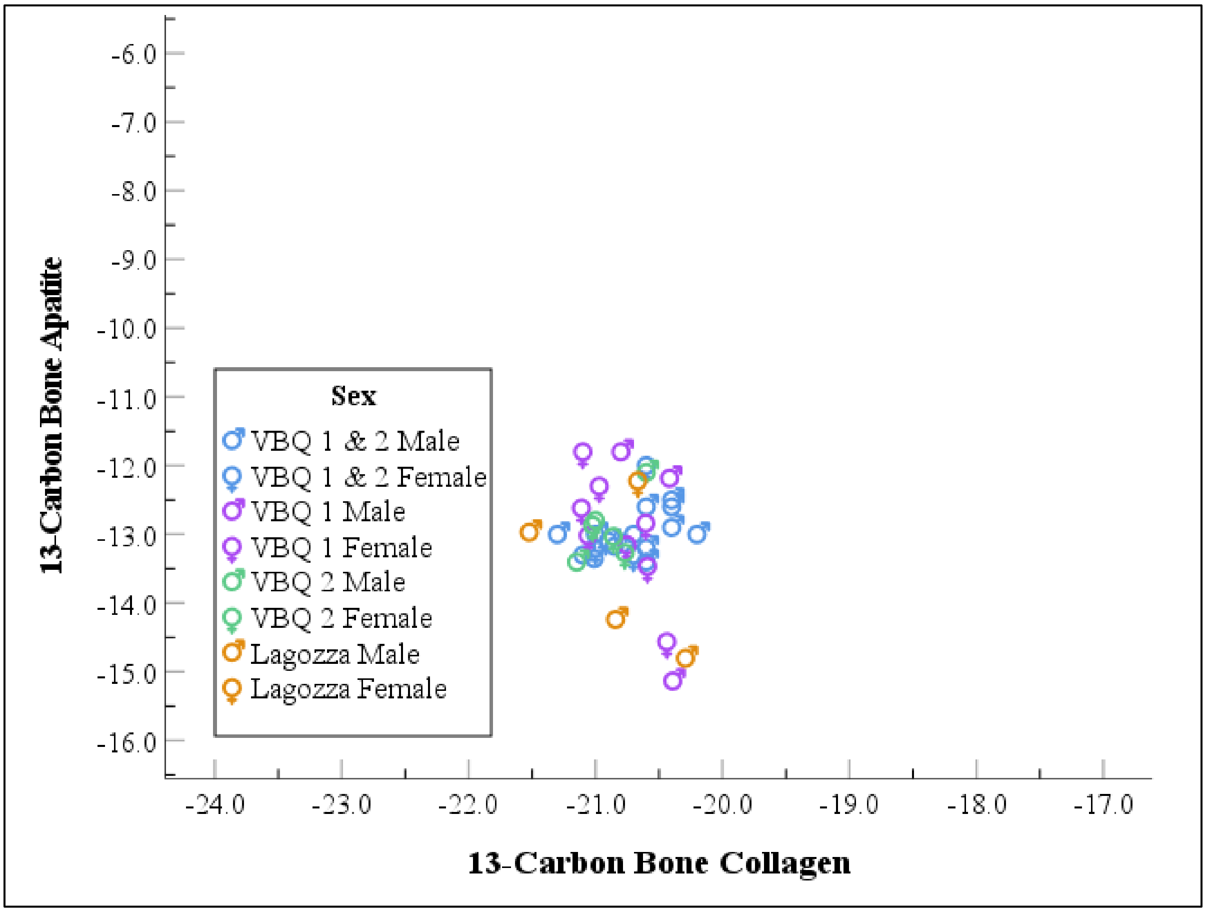

Figure 7.35: Human bone collagen $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ (‰ VPDB) values by known sex

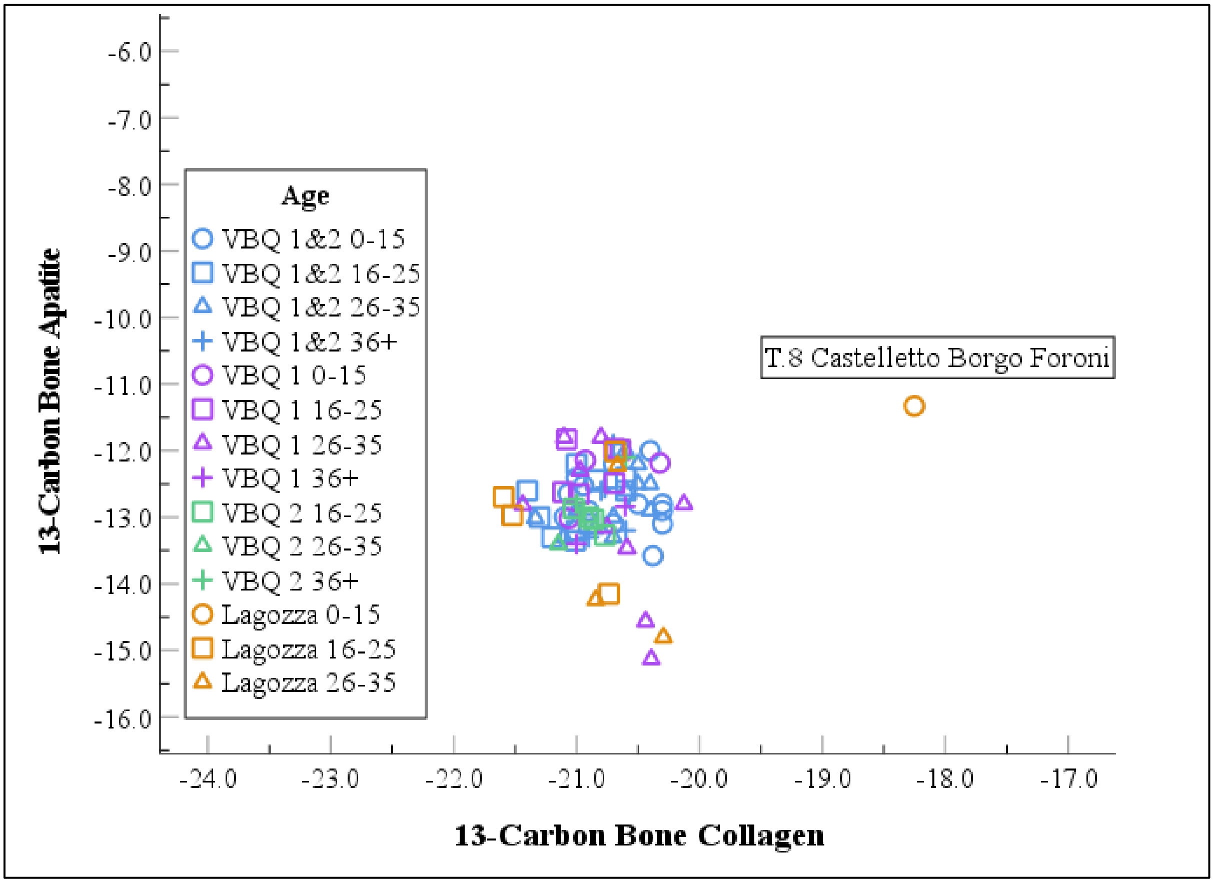

Figure 7.36: Human bone apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

Tooth Root

The descriptive statistics for carbon and nitrogen values from tooth roots are summarized in Tables 7.12, 7.13, and 7.14. The range of the VBQ tooth root carbon and nitrogen values were as follows: VBQ 1 & 2 $\delta^{13}C_{ap}$ was -14.5‰ to -11.6‰ with an average of -12.8‰ ± 0.7, VBQ 1 was -14.3‰ to -10.5‰ with an average of -12.3‰ ± 1.0, and VBQ 2 was -13.2‰ to -11.0‰ with an average of -12.2‰ ± 0.6 (Figure 7.37); VBQ 1 & 2 $\delta^{13}C_{co}$ was -21.2‰ to -19.5‰ with an average of -20.3‰ ± 0.4, VBQ 1 was -21.1‰ to -19.5‰ with an average of -20.5‰ ± 0.4, and VBQ 2 was -20.9‰ to -19.8‰ with an average of -20.6‰ ± 0.4 (Figure 7.38); and VBQ 1 & 2 $\delta^{15}N$ was 8.3‰ to 11.7‰ with an average of 10.2‰ ± 0.7, VBQ 1 was 8.9‰ to 11.6‰ with an average of 10.1‰ ± 0.6, and VBQ 2 was 9.4‰ to 11.5‰ with an average of 10.3‰ ± 0.7 (Figure 7.39). The range of Copper Age or Lagozza tooth root carbon and nitrogen values were as follows: $\delta^{13}C_{ap}$ was -13.8‰ to -11.7‰ with an average of -12.9‰ ± 0.8 (Figure 7.37); $\delta^{13}C_{co}$ was -21.4‰ to -20.1‰ with an average of -20.7‰ ± 0.4 (Figure 7.38); and $\delta^{15}N$ was 9.2‰ to 10.5‰ with an average of 9.8‰ ± 0.5 (Figure 7.39). An Analysis of Variance (ANOVA) was conducted on the tooth root isotopic values to explore the potential significance between the VBQ 1& 2, VBQ 1, VBQ 2, and Lagozza cultural groups mean values for carbon and nitrogen. The results of the ANOVA between groups were as follows: there are no significant differences in $\delta^{13}C_{ap}$ values between the cultural groups (F = 2.870, *df* = 3, *p* = 0.042); there are no significant differences in $\delta^{13}C_{co}$ values between the cultural groups (F = 3.119, *df* = 3, *p* = 0.031); and there are no significant differences in $\delta^{15}N$ values between the cultural groups (F = 1.023, *df* = 3, *p* = 0.388). These results suggest that there were no major differences in carbon and nitrogen sources in the diet between the analyzed cultural groups, suggesting potential stability and continuity of subsistence practices among all the cultural groups with respect to sub-adult diet.

Table 7.12: Descriptive Statistics of $\delta^{13}C_{ap}$ Tooth Root Values

	Tooth Root			
	$\delta^{13}C_{ap}$			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	36	21	9	8
Mean	-12.8	-12.3	-12.2	-12.9
Median	-12.7	-12.0	-12.1	-12.8
Std. Dev.	0.7	1.0	0.6	0.8
Skewness	-0.6	-0.3	0.3	0.1
Minimum	-14.5	-14.3	-13.2	-13.8
Maximum	-11.6	-10.5	-11.0	-11.7

Table 7.13: Descriptive Statistics of $\delta^{13}C_{co}$ Tooth Root Values

	Tooth Root			
	$\delta^{13}C_{co}$			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	36	21	9	8
Mean	-20.3	-20.5	-20.6	-20.7
Median	-20.4	-20.6	-20.7	-20.7
Std. Deviation	0.4	0.4	0.4	0.4
Skewness	-0.2	0.9	1.7	-0.4
Minimum	-21.2	-21.1	-20.9	-21.4
Maximum	-19.5	-19.5	-19.8	-20.1

Table 7.14: Descriptive Statistics of $\delta^{15}N$ Tooth Root Values

	Tooth Root			
	$\delta^{15}N$			
	VBQ 1&2	VBQ 1	VBQ 2	Lagozza
n	36	21	9	8
Mean	10.2	10.1	10.3	9.8
Median	10.1	10.1	10.3	9.8
Std. Dev.	0.7	0.6	0.7	0.5
Skewness	0.1	0.2	0.3	0.1
Minimum	8.3	8.9	9.4	9.2
Maximum	11.7	11.6	11.5	10.5

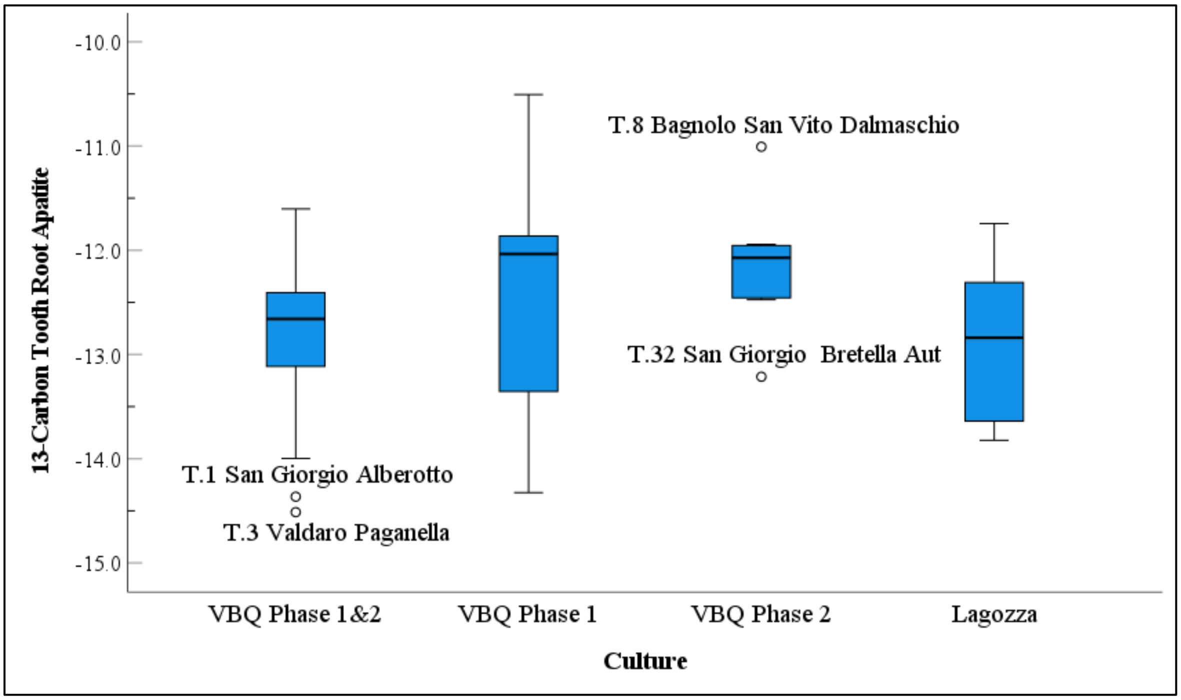

Figure 7.37: Stem-and-Leaf plot of $\delta^{13}C_{ap}$ tooth root values by cultural group

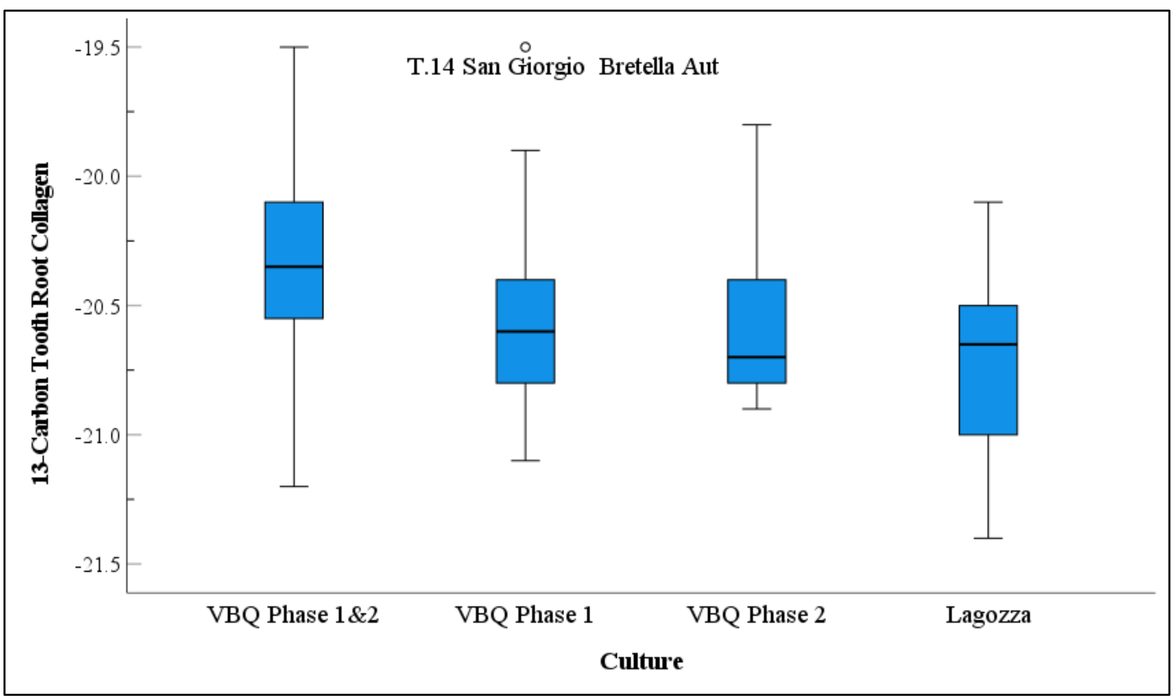

Figure 7.38: Stem-and-Leaf plot of $\delta^{13}C_{co}$ tooth root values by cultural group

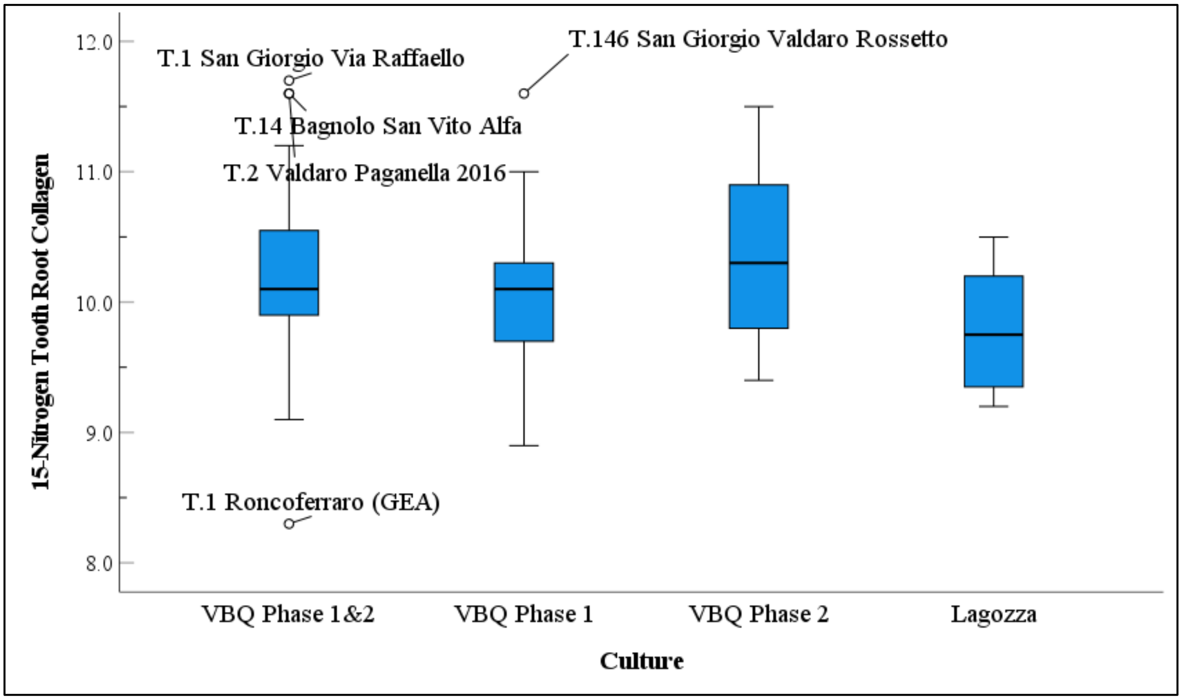

Figure 7.39: Stem-and-Leaf plot of $\delta^{15}N$ tooth root values by cultural group

The carbon and nitrogen isotopic values obtained from tooth roots were analyzed graphically utilizing scatter plots. Plots were created to assess potential differences in protein sources by comparing $\delta^{13}C_{co}$ and $\delta^{15}N$ values and to potentially identify the influence of freshwater, marine, or terrestrial carbon sources on analyzed $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ carbon values between the respective cultural groups. Scatter plots were also created to illustrate sex and age-based differences respectively of protein and carbon sources between the cultural groups of interest. Beginning with the analysis of sub-adult dietary protein sources, Figure 7.40 displays the relationship between dietary protein between VBQ 1 & 2, VBQ 1, VBQ 2, and the Lagozza cultural groups. The cluster of points, although appearing further apart than the adult diet plot, are similar in contribution of protein from C_3 source, with much more dispersion in trophic level, likely caused by first molars and pre-molars retaining some weaning signatures within the tooth root. The primary result here is that sub-adult diets mirror adult diets regarding protein and protein carbon sources resembling a commitment to terrestrial C_3 collagen values of -21.5‰, as previously discussed. The carbon spacing between bone apatite and collagen may yield additional evidence of terrestrial, marine, or freshwater carbohydrate sources in the sub-adult diet, but that plot will also include data from early forming teeth as previously discussed.

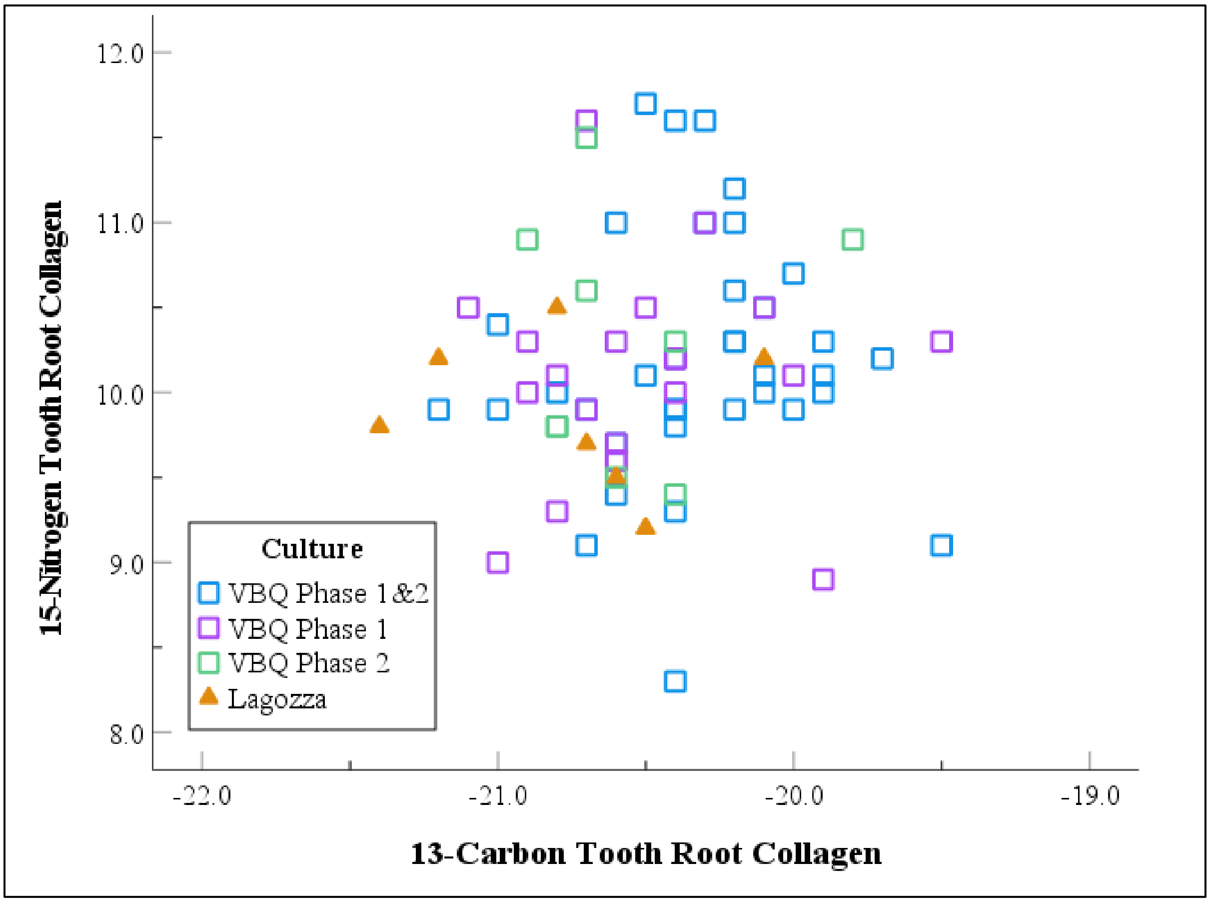

Figure 7.40: Human tooth root collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

Scatter plots were produced to analyze differences in sub-adult dietary protein sources by sex and age, like bone isotopic values. Individuals were distinguished first by cultural group and then by sex and age within those groups. Age categories remain the same as previously discussed.

The goal of these analyses is to examine general differences between males and females and adolescent diets as they relate to cultural group. The tooth roots obtained largely come from late forming molar roots (second and third molars) that reflect late adolescence, with only three tooth roots sampled from individuals as old as 6 years but likely younger than 12 years of age. As previously mentioned, age categories must remain the same for meaningful comparisons to be made between age groups. The scatter plot shows that no notable differences in sub-adult protein sources between males and females from all cultural groups (Figure 7.41). An ANOVA was conducted between males and females respective of cultural group and tooth root isotopic value. There were no significant differences between males respective of cultural group and protein sources relating to the sub-adult diet. The results of the ANOVA were as follows: there are no significant differences in male $\delta^{13}C_{ap}$ values (F = 2.660, *df* = 3, *p* = 0.089); there are no significant differences in male $\delta^{13}C_{co}$ values (F = 2.145, *df* = 3, *p* = 0.140); and there are no significant differences in male $\delta^{15}N$ values (F = 0.679, *df* = 3, *p* = 0.579). There were no significant differences between females respective of cultural group and protein sources relating to the sub-adult diet. The results from the ANOVA were as follows: there are no significant differences in female $\delta^{13}C_{ap}$ values (F = 1.056, *df* = 3, *p* = 0.397); there are no significant differences in female $\delta^{13}C_{co}$ values (F = 1.743, *df* = 3, *p* = 0.201); and there are no significant differences in female $\delta^{15}N$ values (F = 0.543, *df* = 3, *p* = 0.661). These results indicate that male and female protein sources were similar between all cultural groups. Based on the previous ANOVA results and scatter plots sex-based differences in protein sources were not parametrically explored due to the previous non-significant findings. There appear to be no significant difference between male and female sub-adult diets within the VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza cultural groups respectively. These results illustrate that protein sources within and between represented cultural groups remained consistent, further suggesting relatively stable sub-adult dietary protein sources throughout time regardless of sex.

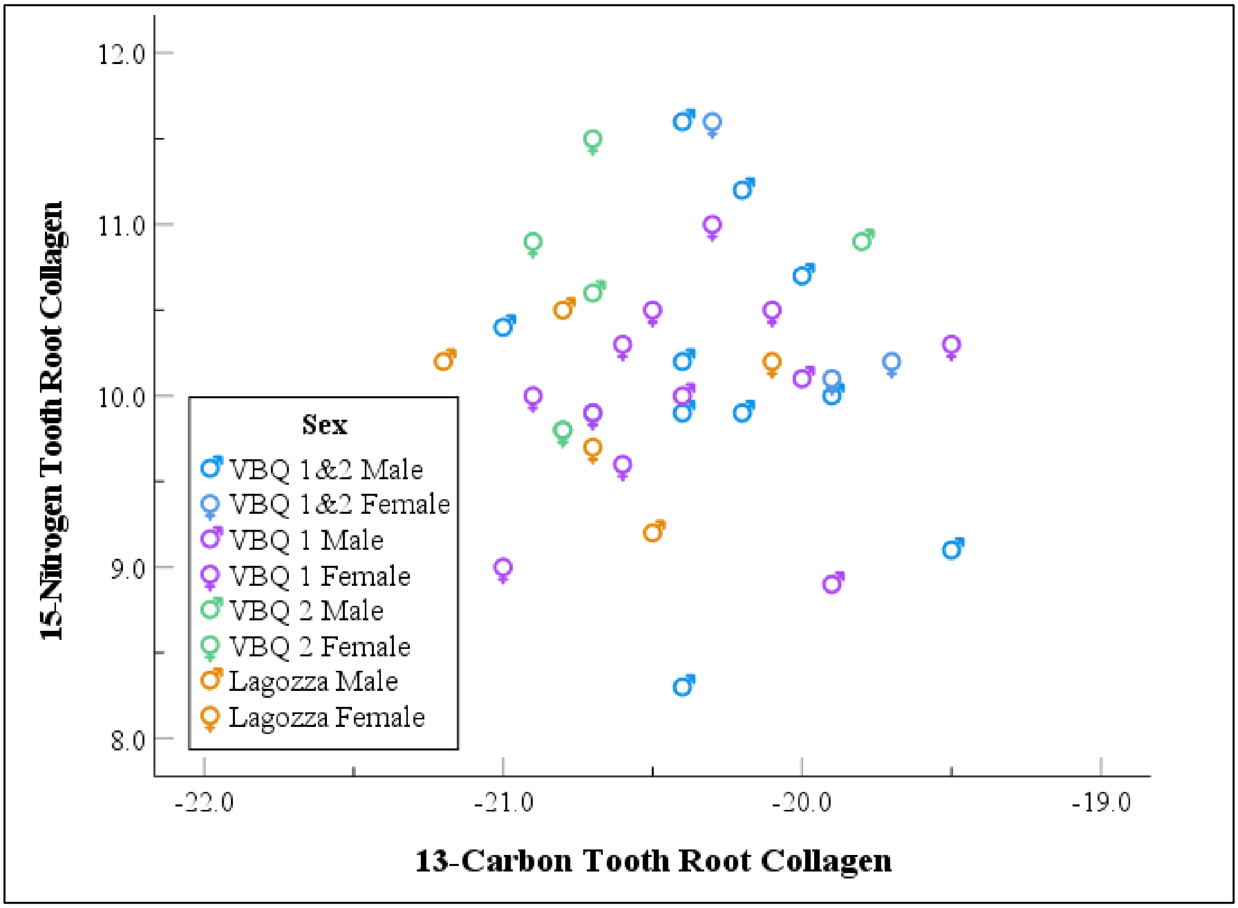

Figure 7.41: Human tooth roots collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

A scatter plot was also produced to explore potential difference in sub-adult protein sources by age. Based on the previous holistic analysis of the cultural groups respectively it is expected that no major differences exist between assigned age groups. The scatter plot shows each of the four age groups separated by cultural group and reveals no major differences based on age in protein sources in the sub-adult diet (Figure 7.42). The sub-adult diet appears again to tightly cluster around the expected C_3 protein carbon value of -21.50‰, but with notably more dispersion than in the adult diet. A few values are more than 2‰ enriched and appear to be two prime age adults and one older adult of the VBQ 1 & 2 and VBQ 1 groups. These three individuals are only slightly more enriched in protein carbon than most of the population and likely represent actual regional sub-adult variation.

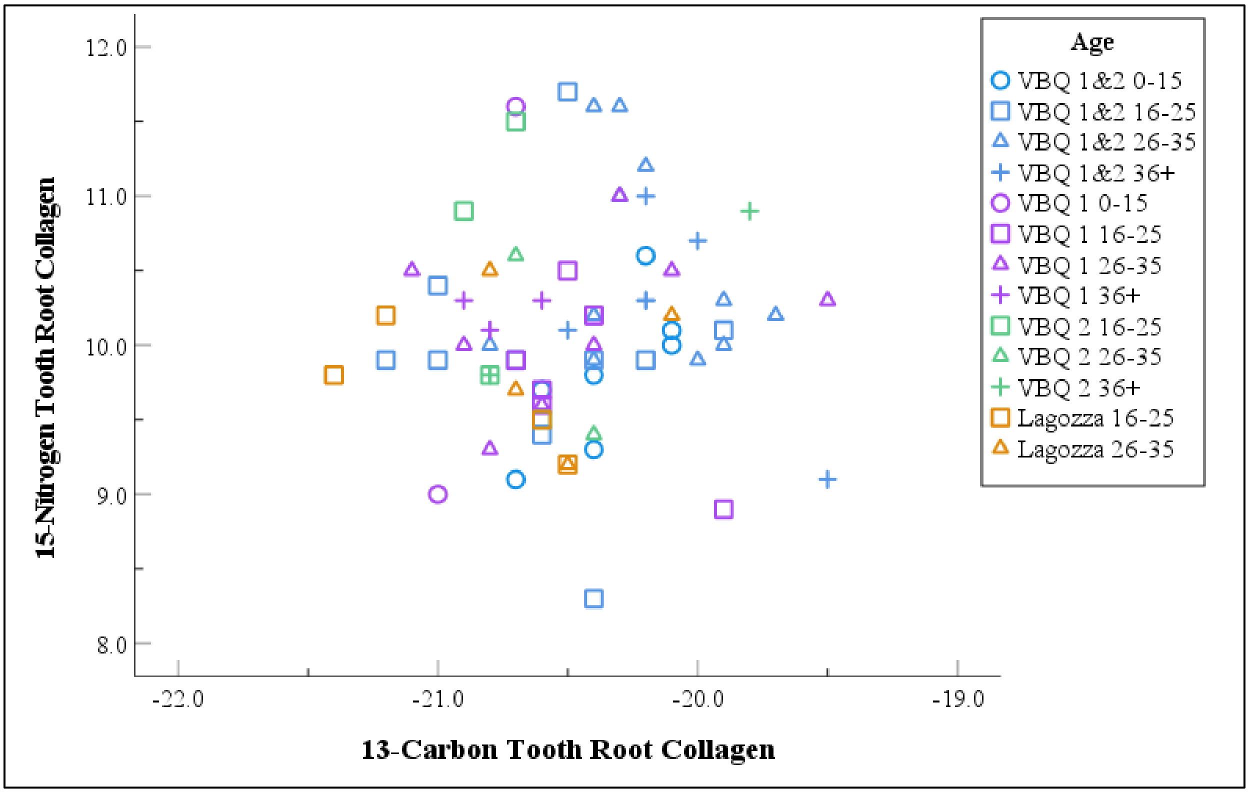

Figure 7.42: Human tooth root collagen $\delta^{13}C_{co}$ (‰ VPDB) and $\delta^{15}N$ (‰ AIR) values

The scatter plot of total carbon contribution from the diet, with the protein portion represented by $\delta^{13}C_{co}$ and the carbohydrate portion represented by $\delta^{13}C_{ap}$ values depicts a very tight cluster respective of culturally affiliated tomb and thus total sub-adult dietary carbon values (Figure 7.43). However, these values again show slightly more dispersion than the adult bone values and thus may reflect sub-adult and adult dietary differences, but they are not significant.

Little to no variation in proteins or carbohydrates existed between the represented cultural groups. The average $\delta^{13}C_{ap}$ values are extremely close at -12.8‰ ± 0.7 for the VBQ 1 & 2, -12.3‰ ± 1.0 for the VBQ 1, -12.2‰ ± 0.6 for the VBQ 2, and -12.9‰ ± 0.8 for the Lagozza. It is expected that in a pure C_3 diet human $\delta^{13}C_{ap}$ values should cluster around -14.5‰, where enrichment in apatite values +3‰ or more could indicate a more mixed adult diet specific to carbohydrate sources and inclusion of some C_4 plants. Most of the analyzed population is clearly clustering very tightly around the expected pure C_3 dietary carbohydrate values and dietary protein values regarding carbon. Thus, the primary source of sub-adult dietary carbohydrates and proteins within the VBQ and Lagozza in Mantua, was provided by C_3 plants. However, more dispersion in $\delta^{13}C_{ap}$ values exists in the VBQ with four individuals having $\delta^{13}C_{ap}$ enriched values greater than +3‰ indicating a slightly more mixed sub-adult diet which possibly included some enriched carbohydrate sources. There appears to be less dispersion in Lagozza values than the VBQ groups as a whole, indicating a wider range of food sources among the VBQ groups than the Lagozza.

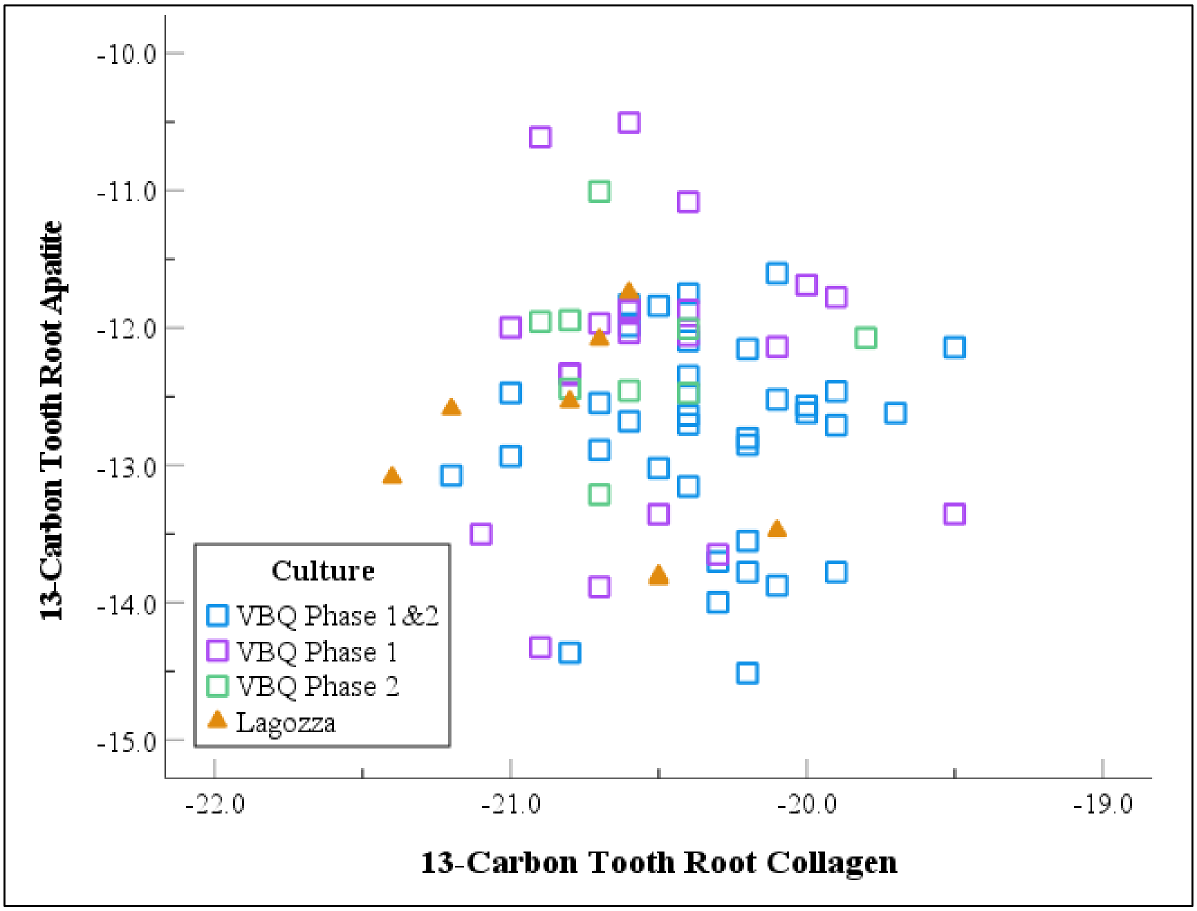

Figure 7.43: Human tooth root apatite and collagen $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ (‰ VPDB) values

As previously discussed, there were no significant sex-based differences between males and females within or between cultural groups with respect to sub-adult protein sources. Additionally, there were no significant sex-based differences between VBQ and Lagozza males and females. Two scatter plots were also produced to examine any potential differences in carbohydrate or total sub-adult dietary carbon sources between VBQ 1 & 2, VBQ 1, VBQ 2, and Lagozza males and females (Figure 7.44), as well as age related differences (Figure 7.45). There appear to be no significant differences in total sub-adult dietary carbon between males and females within and between the cultural groups of interest. Lastly, there is no apparent age-based differences within and between the cultural groups of interest. Both scatter plots suggest that dietary carbon was originating from a common food source regardless of cultural affiliation. Likely a heavy reliance on C_3 plants in the sub-adult diet is causing the large degree of agreement among the cultural groups regardless of sex or age. Two of the four individuals that were plotting outside of the expected range for C_3 carbohydrates are young adult females from the VBQ cultural group phase 1 and 2.

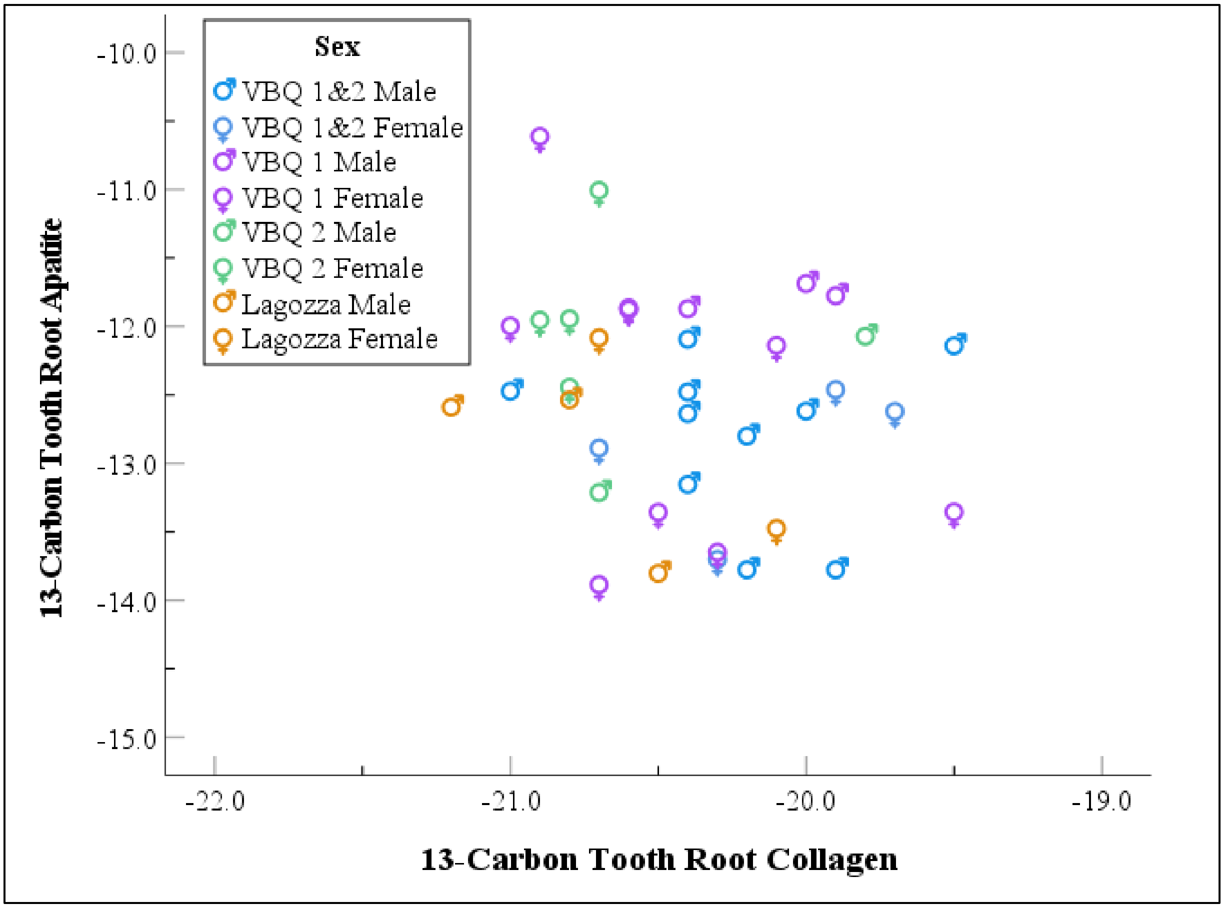

Figure 7.44: Human tooth roots collagen $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ (‰ VPDB) values by known sex

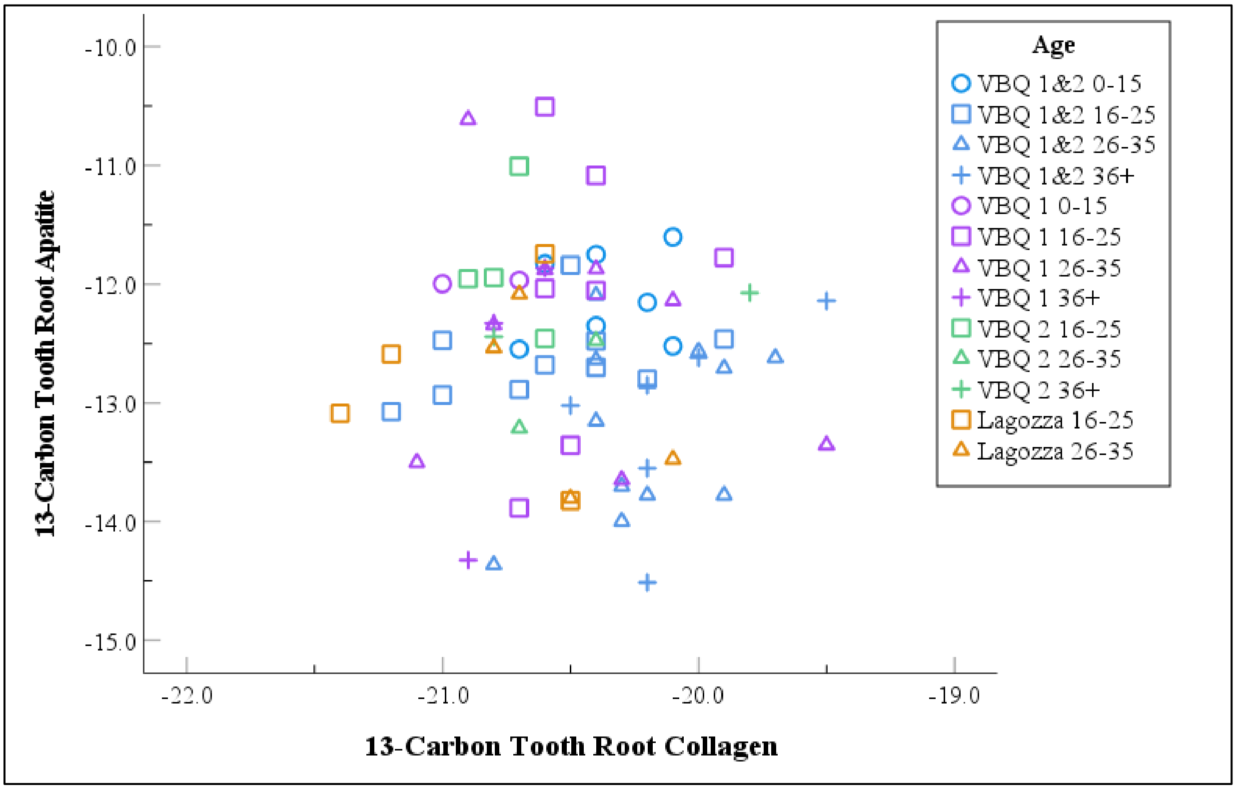

Figure 7.45: Human tooth root collagen $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ (‰ VPDB) values by known age

Domesticate vs. Wild Food Sources

As described above there are no significant differences in adult or sub-adult diets between the periods or cultural groups of interest. Additionally, there are no significant differences in adult or sub-adult diets between the periods or cultural groups of interest based on sex or age. The lack of variation within the sample as a whole and when controlling for temporal and demographic factors does not negate the utility of these findings, but rather can simplify the additional research questions. Thus, this section will explore the correlation between proxy animal and plant values from the project region utilizing discriminate function analysis (DFA) on the data set as a whole. As reported above, DFA is a viable parametric test because the dataset is normally distributed and has robust sample sizes for each set of isotopic values from both bone and tooth roots.

First, adult diet was analyzed utilizing discriminate functions produced from isotopic data from human and animal bone samples and plant carbon-13 values collectively from the current project and nearby related Neolithic and Early Bronze Age sites (Table 7.15) (Biagi, et al., 2020; Varalli, et al., 2016). The total sample size for the adult diet DFA was 103, with three missing nitrogen values from the plant samples utilized for this analysis. Two functions were produced utilizing the $\delta^{13}C_{co}$ and $\delta^{15}N$ values for both the humans, plants, and animals respectively. A test of the equality of covariance was conducted to examine the differences in the means of the isotopic values. The Wilks' Lambda values measure how well each variable will contribute to the model on a scale of 0 to 1, where a value of 1 would mean no discrimination was possible. Typically values less than or around 0.7 are considered good variables for DFA. The equality of measures test indicated that $\delta^{13}C_{co}$ (WL = 0.719; F = 9.567; *df* = 4, 98; *p* <0.001) and $\delta^{15}N$ ((WL = 0.327; F = 50.446; *df* = 4, 98; *p* <0.001) are good variables with enough variation between each to be utilized for DFA.

Table 7.15: Comparative Animal and Plant Isotopic Values

Species	Site	Feature & Site	$\delta^{13}C_{co}$	$\delta^{15}N$	C:N	Source
Bos	Roncoferraro Allargamento	T4 Roncoferraro	-18.0	9.8	3.4	Current Project
Bos	Vho Campo Ceresole	Pit 29 Vhó Campo Ceresole	-21.9	6.7	3.1	Biagi *et al.* 2020
Bos	Vho Campo Ceresole	Pit 32 Vhó Campo Ceresole	-22.2	7.8	3.2	Biagi *et al.* 2020
Bos	Vho Campo Ceresole	Pit 40 Vhó Campo Ceresole	-21.0	8.0	3.2	Biagi *et al.* 2020
Cervus	Arano	Area A Arano	-17.4	5.3	3.2	Varalli *et al.* 2016
Cervus	Arano	Area A Arano	-20.0	3.2	3.2	Varalli *et al.* 2016
Fish	Veneto	Modern Veneto Lagoon	-21.2	7.8	3.6	Current Project
Ovis/Capra	Isorella Cascina Bocche	Pit 1 Isorella Cascina Bocche	-21.7	4.8	3.3	Biagi *et al.* 2020
Ovis/Capra	Vho Campo Ceresole	Pit 22B Vhó Campo Ceresole	-23.0	8.9	3.4	Biagi *et al.* 2020
Ovis/Capra	Vho Campo Ceresole	Pit 22B Vhó Campo Ceresole	-22.4	6.6	3.2	Biagi *et al.* 2020
Hordeum sativum	Vho Campo Ceresole	Pit 18 Vhó Campo Ceresole	-26.3	0.0	0.0	Biagi *et al.* 2020
Triticum aestivum	Isorella Cascina Bocche	Pit 1 Isorella Cascina Bocche	-23.4	0.0	0.0	Biagi *et al.* 2020
Triticum monococcum	Isorella Cascina Bocche	Pit 1 Isorella Cascina Bocche	-25.3	0.0	0.0	Biagi *et al.* 2020

The resulting DFA produced two functions, the first had an eigenvalue of 2.470 and accounted for 87.5 percent of the variation in the model and the second had an eigenvalue of 0.353 and could only account for 12.5 percent of the variation within the model. The Wilks' Lambda test of the two functions found that the first function (WL = 0.213; Chi-Square = 152.325; $df = 8$; p <0.001) and the second function (WL = 0.739; Chi-Square = 29.768; $df = 3$; p <0.001), both significantly contributed to the variation within the model. A Box's M test was also conducted as part of the DFA to examine the assumption of equal covariance of the functions. The results of the Box's M test (M = 51.026; F = 5.754; $df = 6, 269$; p <0.001) reject the null hypothesis of equal covariance and indicate unequal covariance within the functions. These results suggest that there is a significant amount of variation within each of the two functions. Despite this significance DFA can still be robust even when this assumption is violated (Fields, 2018). To understand which isotopic value is driving each model, the produced functional coefficients were examined and revealed that the first function is largely comprised from $\delta^{15}N$ values and the second function is mostly comprised of $\delta^{13}C_{co}$ values. Thus, the first function is representative of the net protein contribution is the adult diet or the trophic level of the consumer. The first function is plotted in Figure 7.46 on the x-axis and thus variation in net protein source or trophic position can be interpreted left to right. The second function is representative of the protein carbon in the adult diet and is thus reflective of the protein carbon source. The second function is plotted in Figure 7.46 on the y-axis and thus variation in protein carbon source can be interpreted from top to bottom. The results depicted in Figure 7.46 indicate that the adult diet was primarily comprised of C_3 plants such as wheat and barley, as indicated by the associated related samples. Further, the humans plot the closest to fish and cattle, but further from the sheep, goats, and cervids, indicating that domesticated cattle and wild freshwater fish were likely a small part of the diet with domesticated sheep and goat and wild cervids being the least important overall. It appears that fishing may have been a more important source of wild protein than pursuit prey like red deer or ibex as previously discussed, but as reported above was not a major part of the diet. A few outlying values have been highlighted to explore potential differences in the burials that differ from the aggregate adult diet.

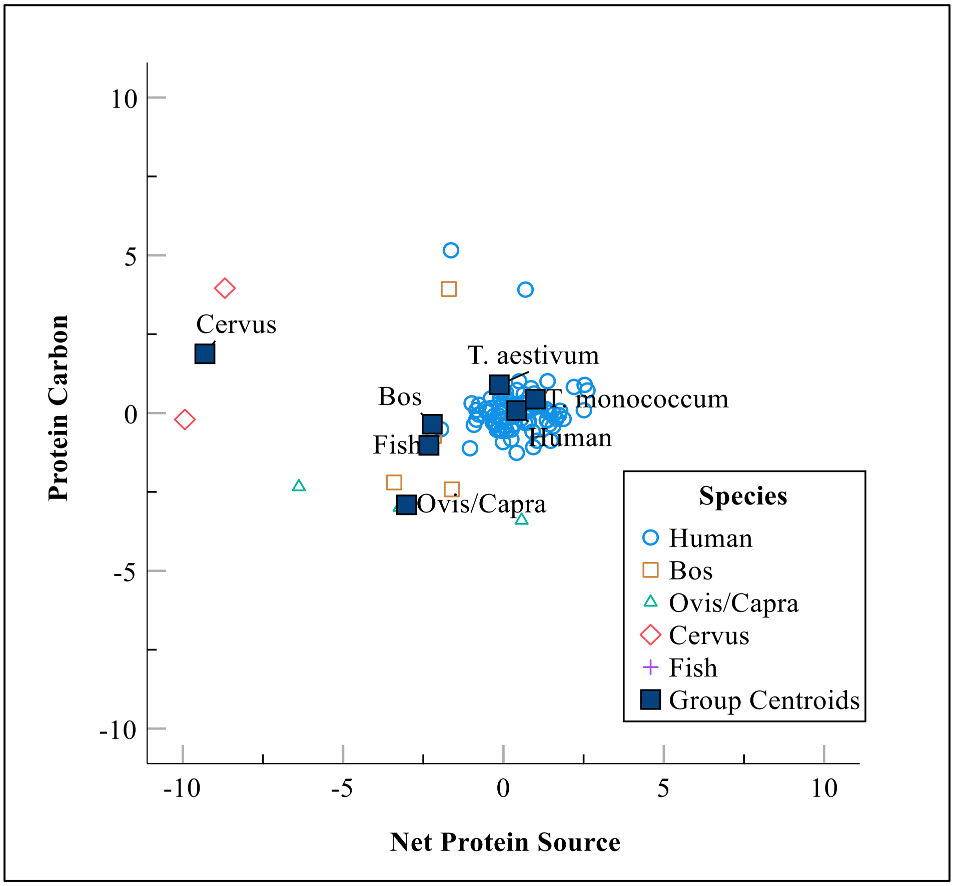

Figure 7.46: Discriminate functional distribution of $\delta^{13}C_{co}$ and $\delta^{15}N$ bone values

Second, sub-adult diet was analyzed utilizing discriminate functions produced from isotopic data from human tooth root, animal bone samples, and plant carbon-13 values collectively from both the current project and nearby related Neolithic and Early Bronze Age sites. The total sample size for the sub-adult diet DFA was 84, with three missing nitrogen values from the plant samples utilized for this analysis. Two functions were produced utilizing the $\delta^{13}C_{co}$ and $\delta^{15}N$ values for both the humans, plants, and animals respectively. Again, a test of the equality of covariance was conducted to examine the differences in the means of the isotopic values. The equality of measures test indicated that $\delta^{13}C_{co}$ (WL = 0.593; F = 13.565; *df* = 4, 79; *p* <0.001) and $\delta^{15}N$ ((WL = 0.301; F = 45.901; *df* = 4, 79; *p* <0.001) are good variables with enough variation between each to be utilized for DFA. Comparably the sub-adult functions produced utilizing tooth root $\delta^{13}C_{co}$ values outperformed the adult functions produced utilizing bone $\delta^{13}C_{co}$ values, which indicated greater covariance between the tooth root $\delta^{13}C_{co}$ values.

The resulting DFA produced two functions, the first had an eigenvalue of 2.470 and accounted for 78.4 percent of the variation in the model and the second had an eigenvalue of 0.679 and could only account for 21.6 percent of the variation within the model. The Wilks' Lambda test of the two functions found that the first function (WL = 0.172; Chi-Square = 140.116; *df* = 8; *p* <0.001) and the second function (WL = 0.596; Chi-Square = 41.201; *df* = 3; *p* <0.001), both significantly contributed to the variation within the model. A Box's M test was also conducted as part of the DFA to examine the assumption of equal covariance of the functions. The results of the Box's M test (M = 64.195; F = 7.238; *df* = 6, 269; *p* <0.001) reject the null hypothesis of equal covariance and indicate unequal covariance within the functions. These results suggest that there is a significant amount of variation within each of the two functions. To understand which isotopic value is driving each model, the produced functional coefficients were examined and revealed that the first function is largely comprised from $\delta^{15}N$ values and the second function is mostly comprised of $\delta^{13}C_{co}$ values. Thus, the first function is representative of the net protein contribution is the sub-adult diet or the trophic level of the consumer. The first function is plotted in Figure 7.47 on the x-axis and thus variation in net protein source or trophic position can be interpreted left to right. The second function is representative of the protein carbon in the sub-adult diet and is thus reflective of the protein carbon source. The second function is plotted in Figure 7.47 on the y-axis and thus variation in protein carbon source can be interpreted from top to bottom. It is important to note that all tooth root samples are represented as an aggregate human sample, but individually represent tooth roots that form at different ages during the adolescent growth period as previously discussed. No outlying values are present in the aggregate plot in Figure 7.47, which indicates a similar diet throughout childhood despite the temporal differences in tooth root formation. The results depicted in Figure 7.47 indicate that the sub-adult diet was primarily comprised of C_3 plants such as wheat and barley, as indicated by the associated related samples. However, compared to the previously reported adult results, there is slightly more dispersion in the grouping, possibly indicating a slightly more diverse source of food in the sub-adult diet. It should be noted that no major outliers occur in the sub-adult sample as opposed to the adult sample where those individual adults differed from the aggregate group in protein source, likely due to the inclusion of more wild meat sources. Like the adults the sub-adults all plot the closest to fish and cattle, but further from the sheep, goats, and cervids, indicating that wild meat sources being less important to sub-adult diet than domesticated plants or animal proteins, but possibly included more often than in the adult diet. As with the adults, it appears that fishing may have been a more important source of wild protein than pursuit prey to the sub-adult diet, like red deer or ibex as previously discussed, but as reported above was not a major part of the diet. These results should be interpreted with some caution due to the low sample sizes for the included animal proxies compared with the human population. This is especially salient in relating to the importance of domesticated cattle vs sheep and goats because there is overlap in these values, but with the centroids plotting slightly further apart from the human population, which may indicate some inclusion of sheep and goat within the diet.

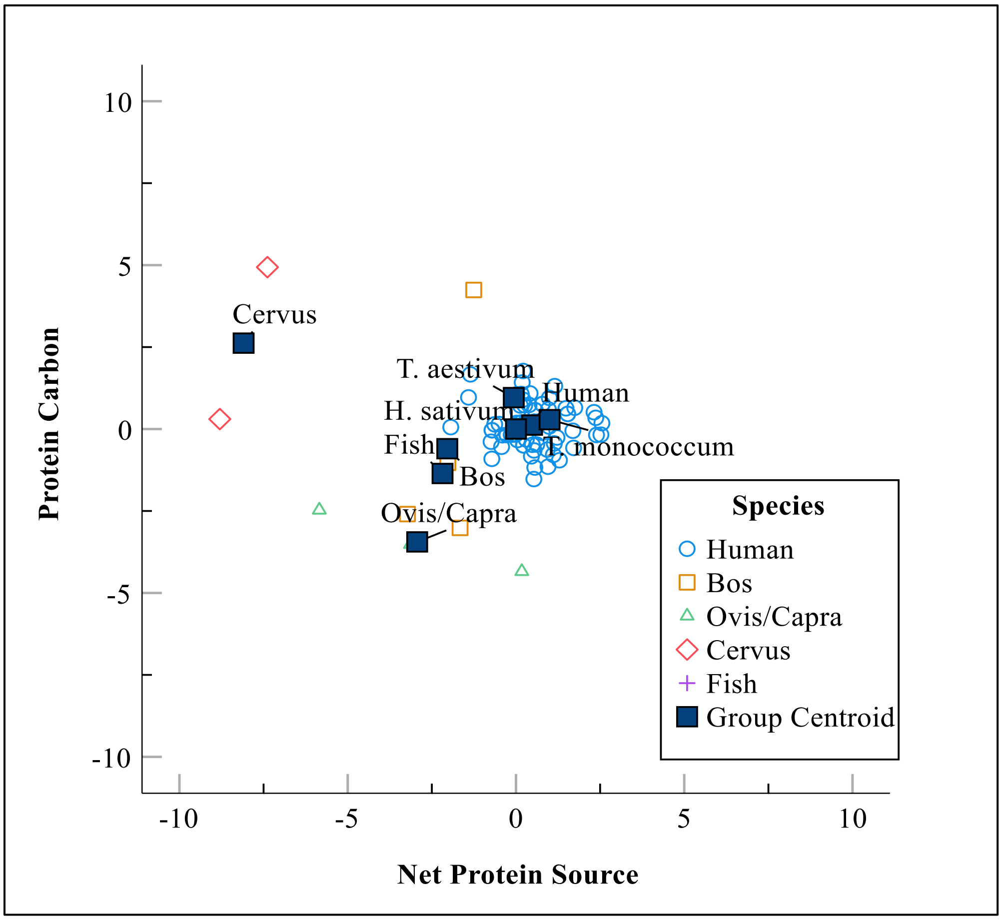

Figure 7.47: Discriminate functional distribution of $\delta^{13}C_{co}$ and $\delta^{15}N$ tooth root values

Mobility

This section will present results from individual burials with both bones and tooth roots that yielded $\delta^{18}O$ values. Oxygen values were reported originally utilizing VPDB but converted to reflect drinking water values using standard conversion equations as previously discussed. All $\delta^{18}O$ values reported in this section reflect drinking water values in parts per mil relative to VSMOW. No parametric statistical tests were performed utilizing any of the oxygen values as the utility of the $\delta^{18}O$ values is the direct comparison of individual adult and adolescent values to known environmental drinking water values. Only tooth roots of molars were utilized in these analyses, despite a few samples reported in Appendix B originating from adult canines and incisors, and deciduous molars. These teeth were intentionally omitted due to their early forming timing and the potential for breast feeding interference in the oxygen isotopic values. Additionally, the one available *Bos taurus* bone processed from Roncoferraro yielded an oxygen value of -4.5‰ VPDB but converted to the drinking water value was -7.2‰ VSMOW. The goals of these analyses are to examine the presence of locals and non-locals within the analyzed assemblage, to interrogate the amount of general mobility between the Middle Neolithic and Copper Age and between the cultural groups of interest, and finally to examine the level of mobility of males vs. females. These questions will allow for greater understanding of group life histories regarding mobility and supplement future kinship studies.

It is important to note that oxygen values, as previously discussed, are primarily affected by average annual rainfall, temperature, climate, and elevation. In Northern Italy, no previous Neolithic studies have been published which report $\delta^{18}O$ values for bone, tooth roots, or enamel. Thus, environmental baselines are produced here from precipitation values recorded and reported previously by Longinelli and Selmo (2003). They report VSMOW oxygen values from 77 different sampling sites across Northern Italy. Since the Po Plain is between two mountain ranges, the Alps to the north and the Apennines to the south and is home to extremely large glacial lakes in the Alpine foothills, Northern Italy has the potential to have extremely variable climatic conditions within very short distances. This was previously discussed as microclimatic zones or ecozones in a previous chapter. The study reports regional ranges based on an aggregate of oxygen values taken from similar localities with respect to elevation and annual rainfall. The central Po Valley has a typical range of -6.0‰ to -5.0‰ VSMOW. A more recent update to Longinelli and Selmo was provided by Giustini and colleagues in 2016, which further added additional sites from surrounding Austria, France, and Croatia. Giustini and colleagues also suggested that values in the north for stationary populations could deviate by as much as 2.0‰ VSMOW (Giustini, et al., 2016). The reported precipitation value for Mantua was -6.0‰ VSMOW (Longinelli and Selmo, 2003). It is thus expected that any obtained oxygen values within the analyzed assemblage that fall within this range or within an expected deviation of 2.00‰ VSMOW for sedentary populations making the central range -8.0‰ to -4.0‰ VSMOW. Any values more depleted than -8.0‰ VSMOW should thus be considered more associated with higher elevations either in the Alps or Apennine ranges, or values that are more depleted than -4.0‰ VSMOW could indicate a more coastal locality or depleted water source, such as a well. Giustini and colleagues observed a more marked effect by elevation in Northern Italy, than by temperature or climate, with an estimated -0.2‰ VSMOW depletion for every 100 meters of elevation. Further, shadowing from the Apennine range effected oxygen values more than the same expected effect from the Alps, which results in slightly more negative values for southern Po Valley localities and hilly sites near the Apennine range. High Alpine values would be closest to -10.0‰ VSMOW as reported from precipitation values (Longinelli and Selmo, 2003). The present study will primarily utilize the Mantua precipitation baseline to identify locals and non-locals and potentially more coastal (enriched) or high elevation (depleted) mobility when applicable.

Middle Neolithic vs. Copper Age Mobility

The descriptive statistics for bone and tooth root apatite $\delta^{18}O$ VSMOW values by period are summarized in Table 7.15. The range of Middle Neolithic and Copper Age bone values were as follows: $\delta^{18}O$ VSMOW was -11.2‰ to -1.7‰ with an average of -8.7‰ ± 1.3 (Figure 7.5); $\delta^{18}O$ VSMOW was -8.3‰ to -6.7‰ with an average of -7.3‰ ± 0.6 (Figure 7.48). These results indicate that there was more adult mobility within the Middle Neolithic than the Copper Age. Tomb 31 from San Giorgio Bretella Aut. in an extreme value, more than three times the mean, with an enriched oxygen value of -1.7. The range of Middle Neolithic and Copper Age tooth root values were as follows: $\delta^{18}O$ VSMOW was -9.6‰ to -1.3‰ with an average of -7.3 ± 1.4 (Figure 7.49); $\delta^{18}O$ VSMOW was -8.2‰ to -5.6‰ with an average of -6.8‰ ± 0.8 (Figure 7.49). Similarly, to bone, there appears to be a greater amount of mobility occurring among Middle Neolithic adolescents than Copper Age adolescents.

Only about 25% of the Middle Neolithic adult population have an oxygen value that is within the lower standard deviation of precipitation values for Mantua, with most of the population more depleted than the $\delta^{18}O$ VSMOW range for Mantua. This suggests that adult Middle Neolithic mobility in the villages around Mantua, in general, consists of activities within the lower Alpine range, or possibly sites along the Apennine range. Adult mobility in the Copper Age however is much less pronounced, with the entire analyzed population falling within the expected range for Mantua, with values falling along the more depleted end of the range. Juvenile mobility or region of origin is much more in line with the expected Mantua range for both the Middle Neolithic and Copper Age. About 25% of the Middle Neolithic juvenile population appear to be more depleted, suggesting a possible slightly more northerly or southern region of origin, but still within the Po Valley. Like the Copper Age adult values, the adolescent values all fall within the expected range for Mantua. These results suggest that analyzed individuals in the Middle Neolithic and Copper Ages were more likely to be born and raised around Mantua with the Middle Neolithic adults engaging in more local mobility either north or south to the foothills regions than compared to the Copper Age adults. A drop-bar plot of bone and tooth root values was produced to examine the differences holistically between the Middle Neolithic and the Copper Age, where burial IDs less than 62 are Middle Neolithic and greater than 62 are Copper Age. Much more mobility from adolescence into adulthood was occurring in the Middle Neolithic than the Copper Age (Figure 50). Further analyses will reveal if any major patterns emerge between cultural groups or among males and females.

Table 7.16: Descriptive Statistics of $\delta^{18}O$ VSMOW values

	Bone		Tooth Root	
	$\delta^{18}O$ VSMOW		$\delta^{18}O$ VSMOW	
	Middle Neolithic	Copper Age	Middle Neolithic	Copper Age
n	61	6	61	6
Mean	-8.7	-7.3	-7.3	-6.8
Median	-8.9	-7.2	-7.4	-6.7
Std. Dev.	1.3	0.6	1.4	0.8
Skewness	2.5	-1.1	1.8	-0.4
Minimum	-11.2	-8.3	-9.6	-8.2
Maximum	-1.7	-6.7	-1.3	-5.6

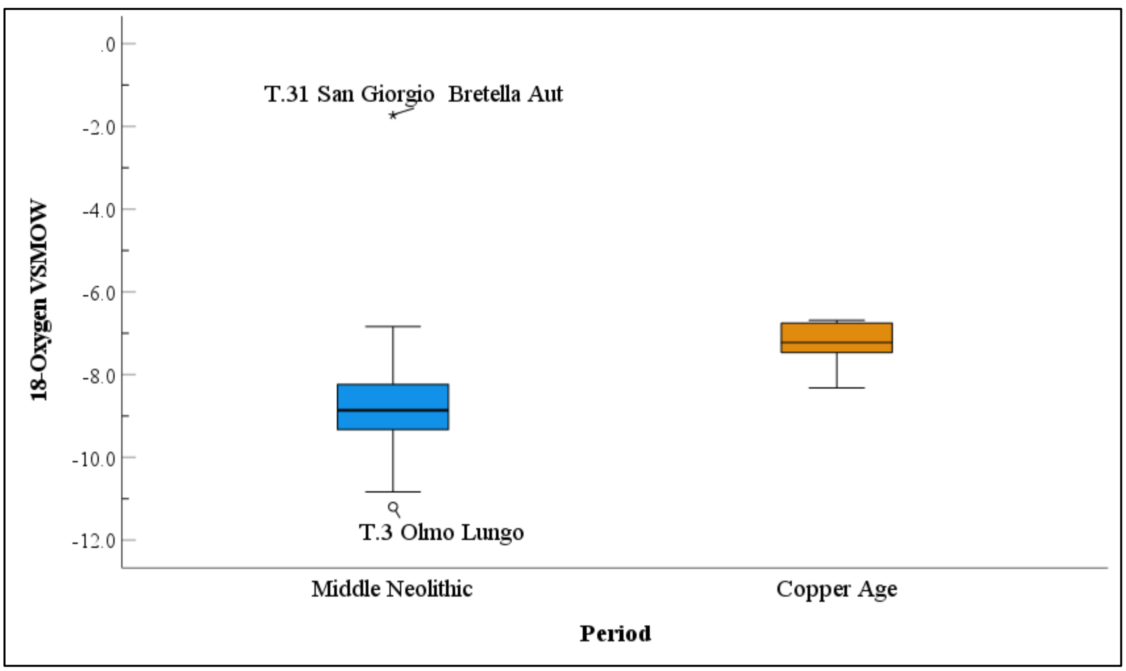

Figure 7.48: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW bone values by period

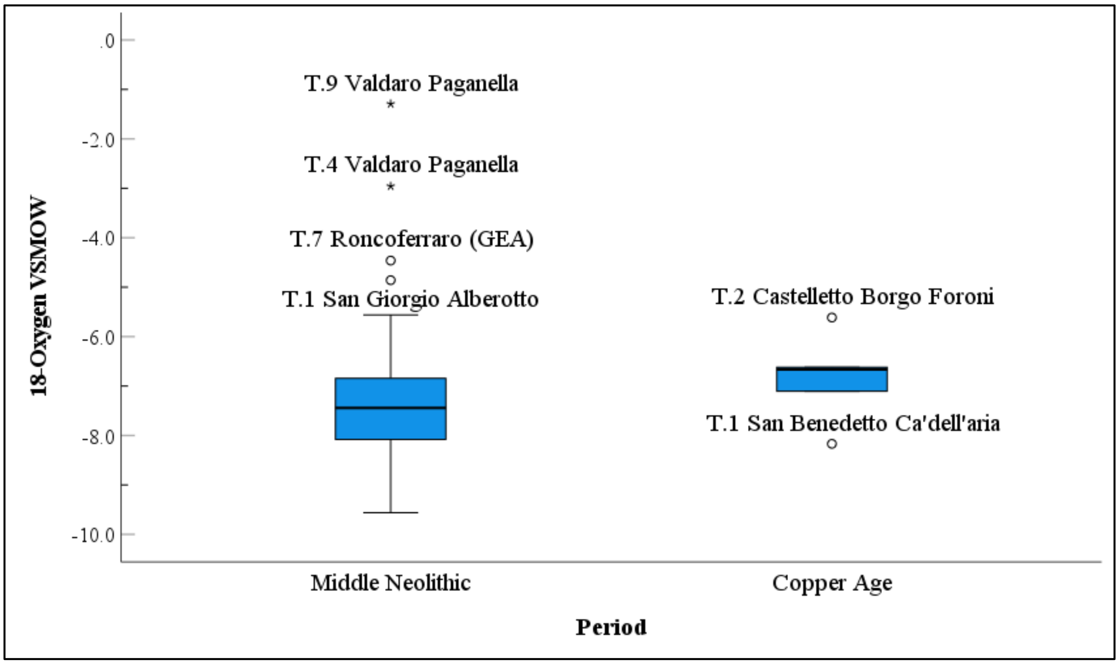

Figure 7.49: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW tooth root values by period

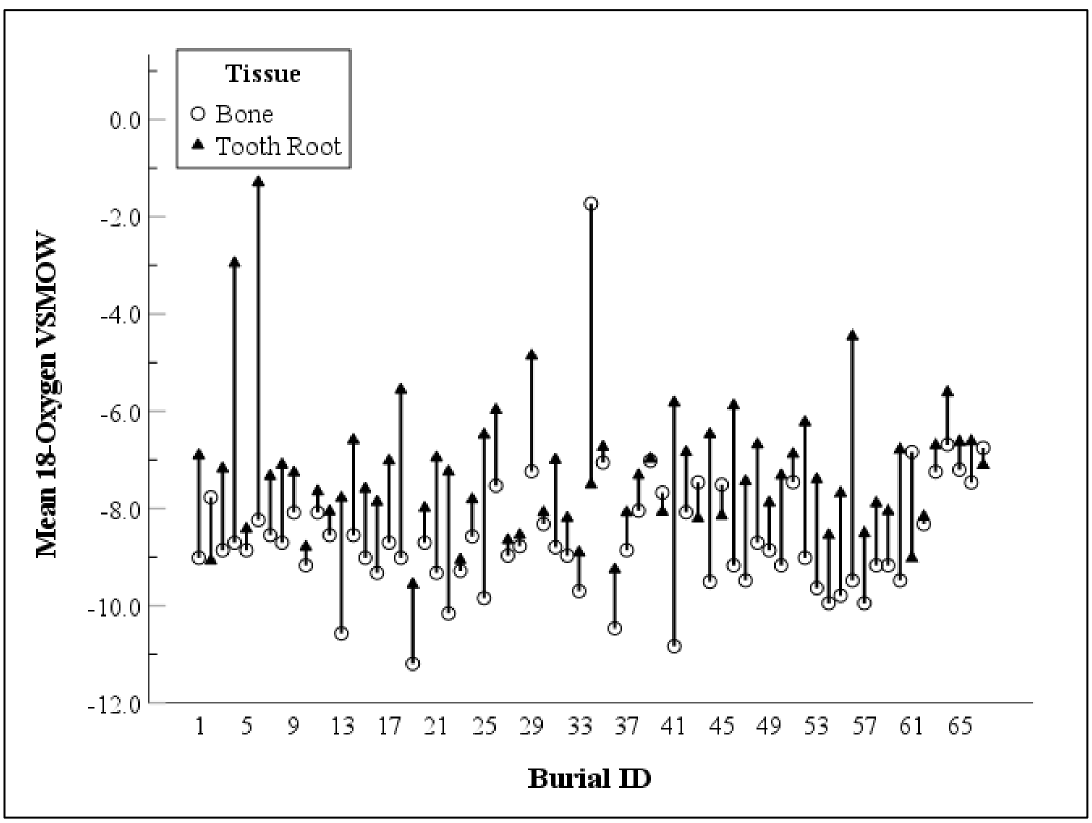

Figure 7.50: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots

VBQ vs. Lagozza Mobility

The descriptive statistics for bone and tooth root apatite $\delta^{18}O$ VSMOW values by cultural group are summarized in in Table 7.16. The range of the VBQ and Lagozza bone apatite $\delta^{18}O$ VSMOW were as follows: VBQ 1 & 2 $\delta^{18}O$ VSMOW was -10.6‰ to -6.8‰ with an average of -8.9‰ ± 0.8, VBQ 1 $\delta^{18}O$ VSMOW was -10.8‰ to -7.0‰ with an average of -8.7‰ ± 1.1, and VBQ 2 $\delta^{18}O$ VSMOW was -11.2‰ to -1.7‰ with an average of -8.0‰ ± 3.0; and Lagozza $\delta^{18}O$ VSMOW was -8.3‰ to -6.7‰ with an average of -7.3‰ ± 0.6 (Figure 7.51). The range of the VBQ and Lagozza tooth root apatite $\delta^{18}O$ VSMOW were as follows: VBQ 1 & 2 $\delta^{18}O$ VSMOW was -9.1‰ to -1.3‰ with an average of -7.7‰ ± 1.6, VBQ 1 $\delta^{18}O$ VSMOW was -9.3‰ to -4.5‰ with an average of -7.3‰ ± 1.1, and VBQ 2 $\delta^{18}O$ VSMOW was -9.6‰ to -5.6‰ with an average of -7.4‰ ± 1.4; and Lagozza $\delta^{18}O$ VSMOW was -8.2‰ to -5.6‰ with an average of -6.8‰ ± 0.8 (Figure 7.52).

These results suggest, as previously reported, that more adult mobility was occurring during all phases of the VBQ than during the Lagozza. When examining the known VBQ 1 and 2 analyzed individuals there appears to be a greater amount of regional mobility during the first phase of the VBQ 1, with more individuals traveling farther than what was observed during the VBQ 2. During the second phase of the VBQ, more individuals seem to favor more local mobility, likely into the foothill regions of the Alps or Apennine ranges, with some outliers traveling into higher elevations, but not as frequently at the VBQ 1 individuals. As previously mentioned, Tomb 31 from San Giorgio Bretella Aut., is a VBQ 2 burial with extremely enriched adult $\delta^{18}O$, suggesting possible costal travel or a different water source such as a well. Like the period analysis, the Lagozza population has very low amount of adult mobility with most of the time being spent in the region immediately surrounding Mantua. Adolescent mobility between the cultural groups is much different than adult mobility, with typically 75% of the population being born and raised in the immediate area around Mantua within the VBQ 1 and 2 phases. All the analyzed copper age individuals were born and raised around Mantua. These results suggest that there was possibly a greater amount of migration into the area around Mantua beginning in the first phase of the VBQ and peaking during the second phase of the VBQ and falling off substantially during the Lagozza phase. The greatest amount of dispersion involves more enriched $\delta^{18}O$ VSMOW values, suggesting a possible favorable migration from coastal sites to more inland sites during phase 1 and two of the VBQ. Drop-bar plots were produced for known VBQ 1, 2, and Lagozza burials individually to examine differences in mobility between the major cultural groups of interest. Both the VBQ 1 and 2 plots display similarities previously observed, where tooth root or adolescent $\delta^{18}O$ values are plotting within the Mantua range and associated bone values from the same individuals are more depleted suggesting more time being spent potentially in the Alpine and Apennine foothills (Figures 53 & 54). The Lagozza plot, however, clearly depicts tooth root and bone $\delta^{18}O$ values or adolescent vs adult values from the same individuals near one another, suggesting that these individuals were born, lived, and died mostly in and around Mantua (Figure 55).

Table 7.17: Descriptive Statistics of $\delta^{18}O$ VSMOW values

	Bone				Tooth Root			
	$\delta^{18}O$ VSMOW				$\delta^{18}O$ VSMOW			
	VBQ 1 & 2	VBQ 1	VBQ 2	Lagozza	VBQ 1 & 2	VBQ 1	VBQ 2	Lagozza
n	34	20	7	6	34	20	7	6
Mean	-8.9	-8.7	-8.0	-7.3	-7.7	-7.3	-7.4	-6.8
Median	-8.9	-8.8	-9.0	-7.5	-7.5	-7.2	-7.5	-6.7
Std. Dev.	0.8	1.1	3.0	0.6	1.6	1.1	1.4	0.8
Skewness	0.4	-0.3	1.8	-1.1	2.2	0.6	-0.2	-0.4
Minimum	-10.6	-10.8	-11.2	-8.3	-9.1	-9.3	-9.6	-8.2
Maximum	-6.8	-7.0	-1.7	-6.7	-1.3	-4.5	-5.6	-5.6

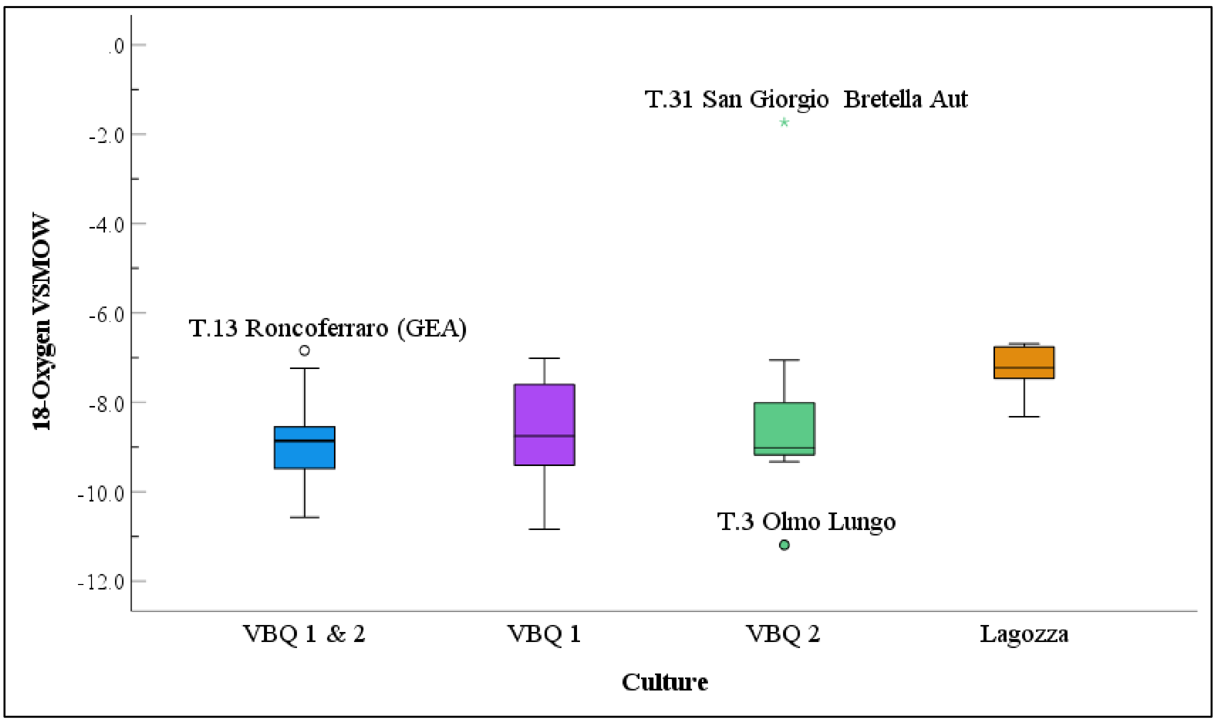

Figure 7.51: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW bone values by cultural period

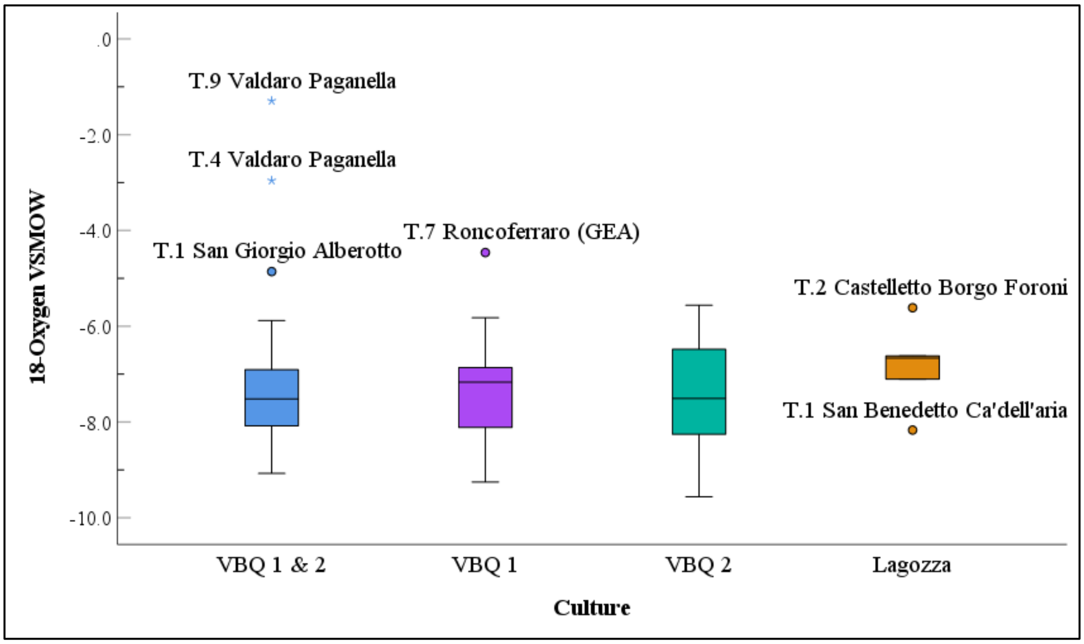

Figure 7.52: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW tooth root values by cultural period

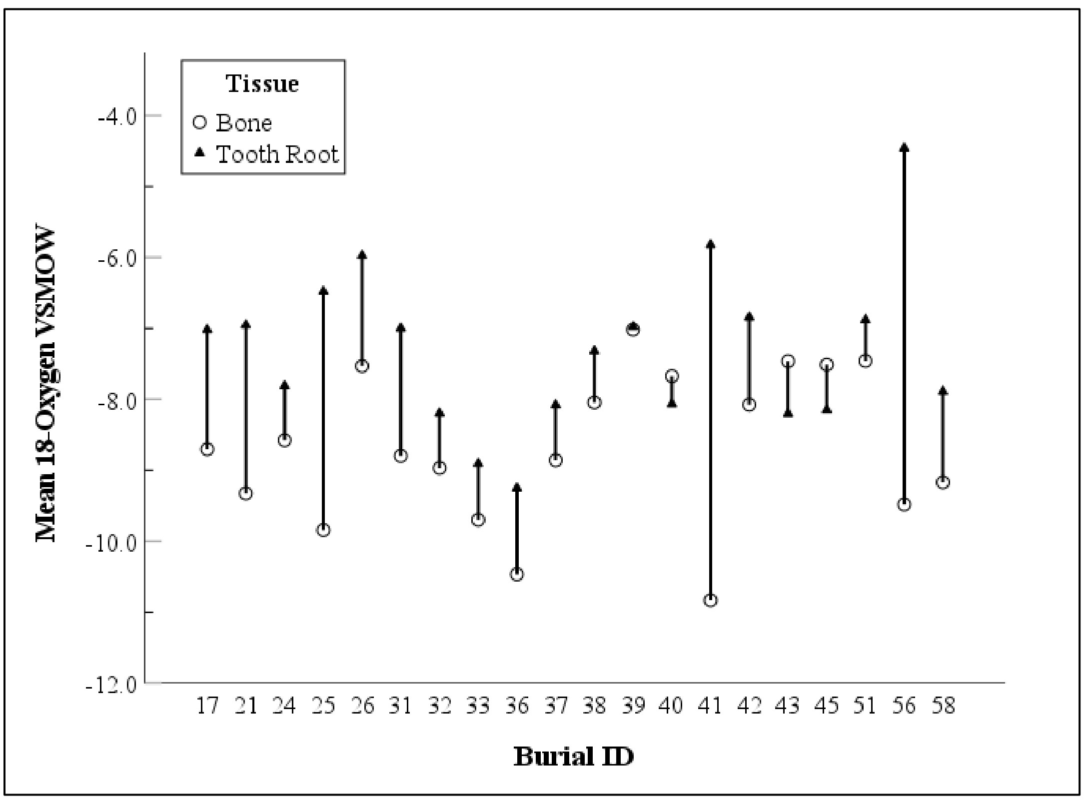

Figure 7.53: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots

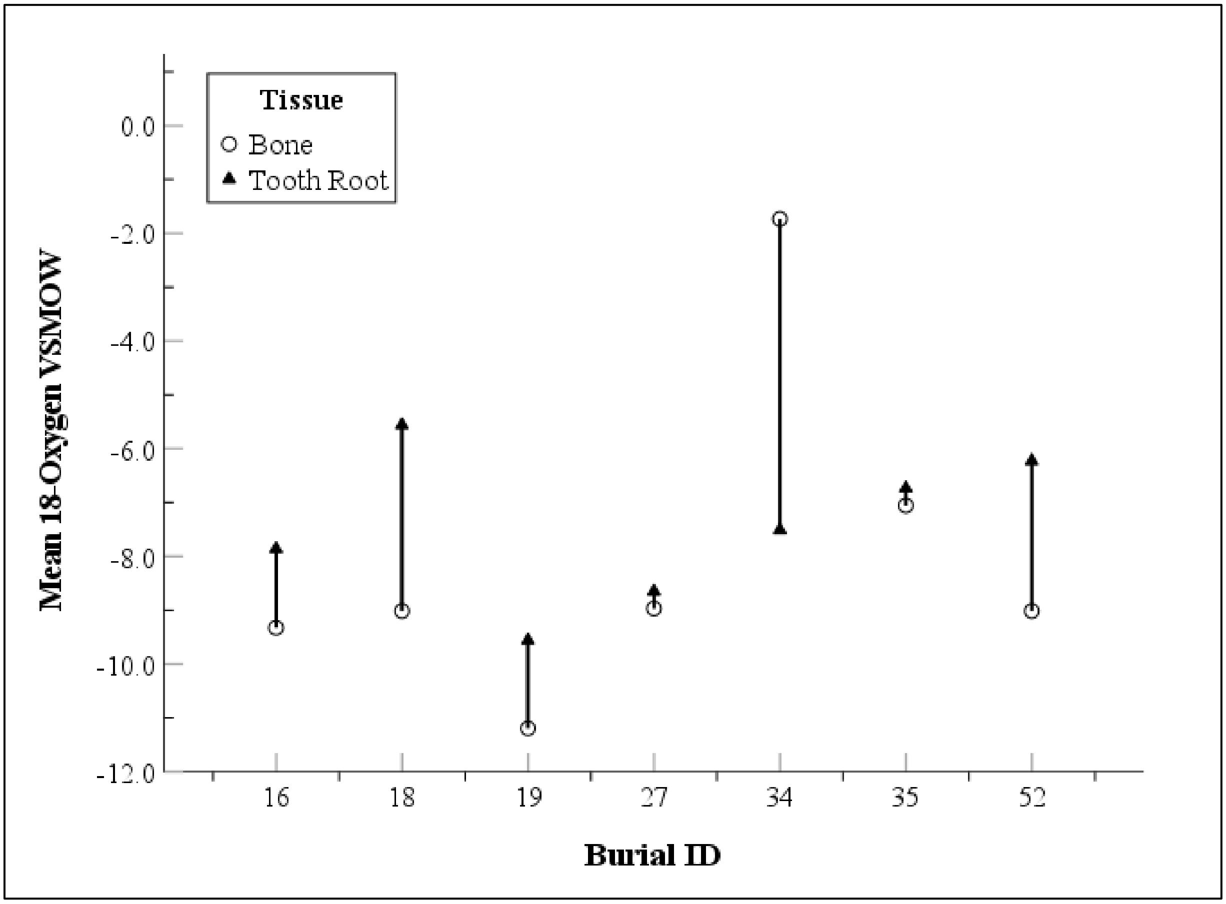

Figure 7.54: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots

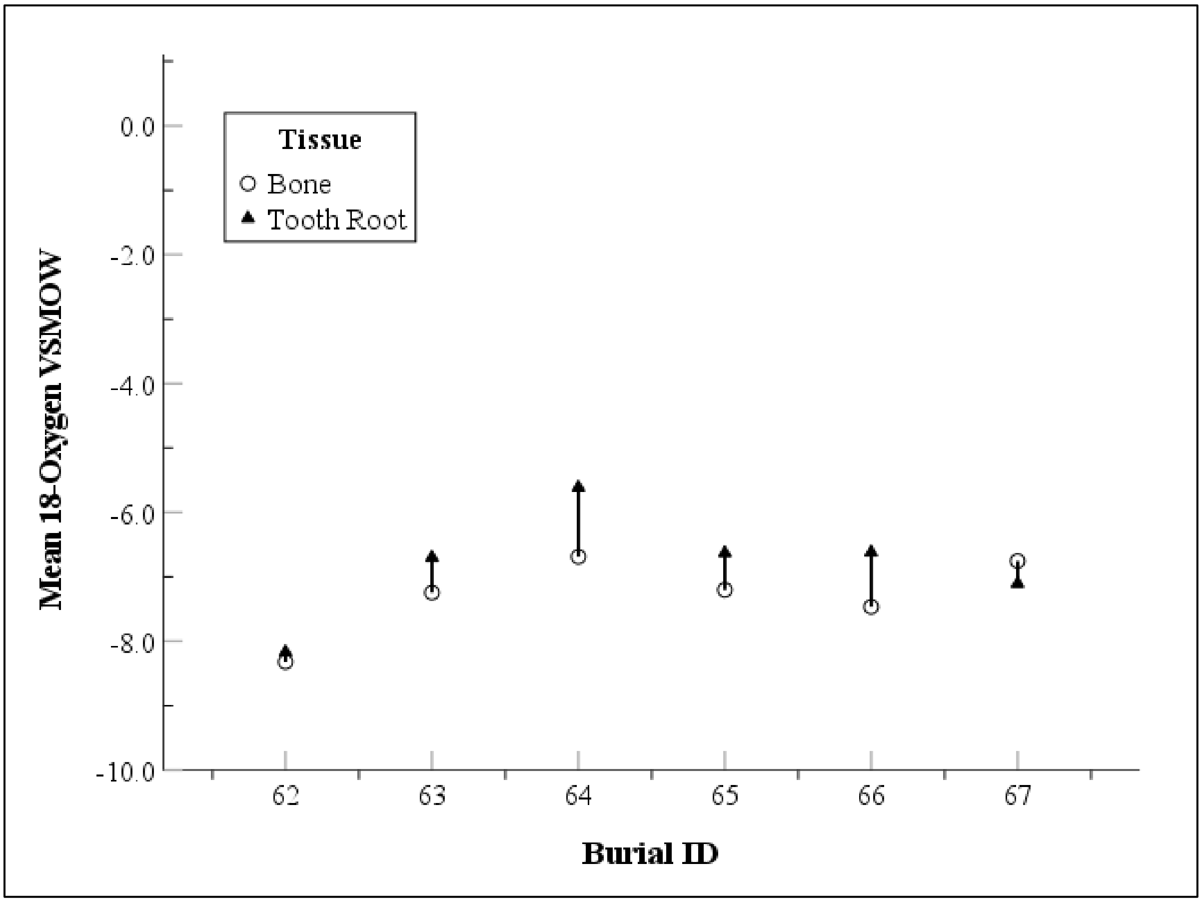

Figure 7.55: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots

Male vs. Female Mobility

The descriptive statistics for bone and tooth root apatite $\delta^{18}O$ VSMOW values by sex are summarized in Table 7.17. The range of Middle Neolithic and Copper Age bone values were as follows: $\delta^{18}O$ VSMOW was -9.6‰ to -7.1‰ with an average of -8.6 ± 0.8 (Figure 7.56); $\delta^{18}O$ VSMOW was -9.8‰ to -1.7‰ with an average of -8.1‰ ± 1.84(Figure 7.56). These results indicate that over 75% of males spent more time outside of Mantua as adults than females, but over 50% of females also spent more time outside of Mantua as adults. This suggests that nearly equal responsibilities for males and females warranted more time be spent away from Mantua, likely in the foothills of the Alps or Apennines. The range of male and female tooth root values were as follows: $\delta^{18}O$ VSMOW was -9.07‰ to -1.29‰ with an average of -6.97‰ ± 2.06 (Figure 7.57); $\delta^{18}O$ VSMOW was -9.02‰ to -5.56‰ with an average of -7.41‰ ± 0.97 (Figure 7.57). Unlike bone, here it appears that over 75% of both males and females were born and raised in or around Mantua. Curiously, two males plot with extreme values, tomb 9 and tomb 4 from Valdaro Paganella, suggesting a more coastal region of origin and subsequent adult migration to Mantua. In general, it appears as if males and females are moving an equal amount, again with most being born and raised near Mantua, with much of adult life being spent either further north or south in the foothills regions (Figures 58 and 59).

Table 7.18: Descriptive Statistics of $\delta^{18}O$ VSMOW values

	Bone		Tooth Root	
	18-OVSMOW		18-OVSMOW	
	Male	Female	Male	Female
n	16	18	16	18
Mean	-8.6	-8.1	-7.0	-7.4
Median	-8.7	-8.8	-7.4	-7.4
Std. Deviation	0.8	1.8	2.1	1.0
Skewness	0.6	2.7	2.0	0.1
Minimum	-9.6	-9.8	-9.1	-9.0
Maximum	-7.1	-1.7	-1.3	-5.6

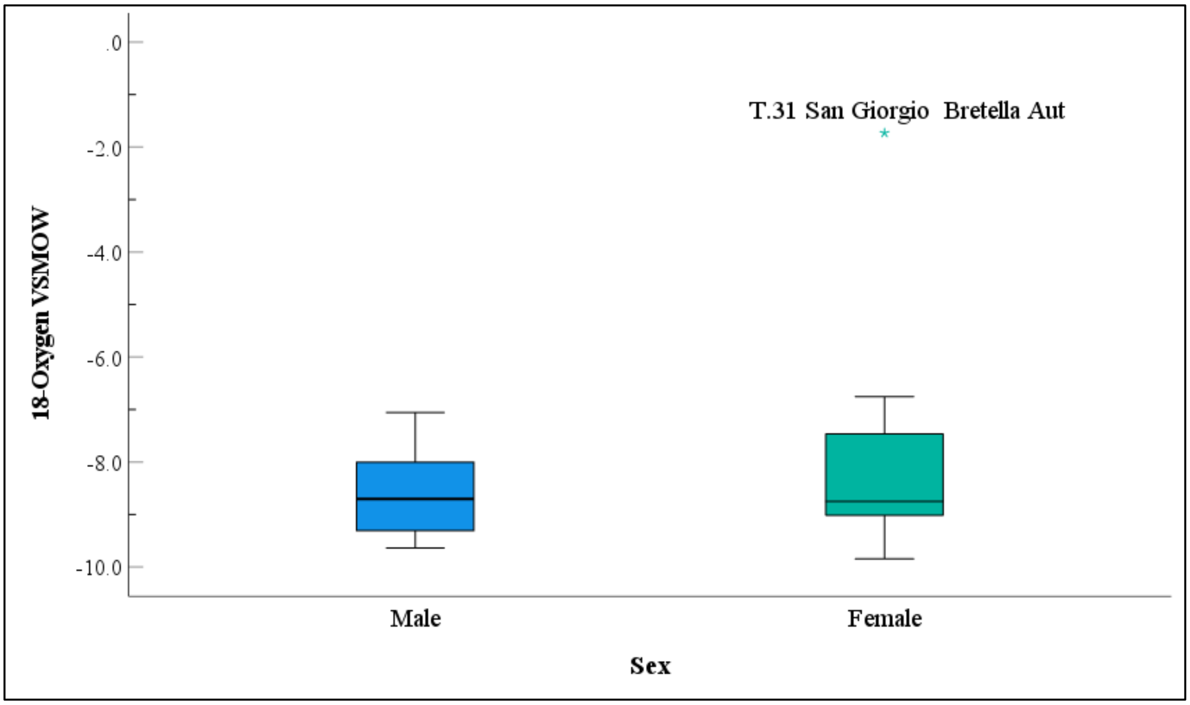

Figure 7.56: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW bone values of males and females

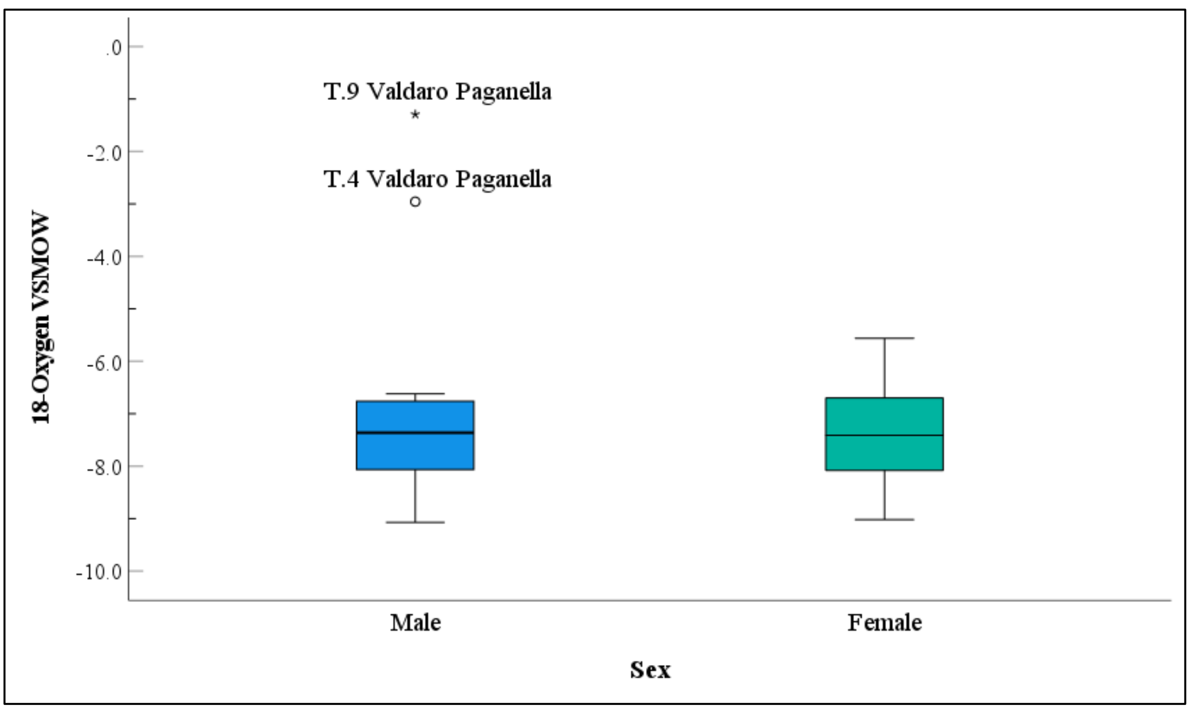

Figure 7.57: Stem-and-Leaf plot of $\delta^{18}O$ VSMOW tooth roots values of males and females

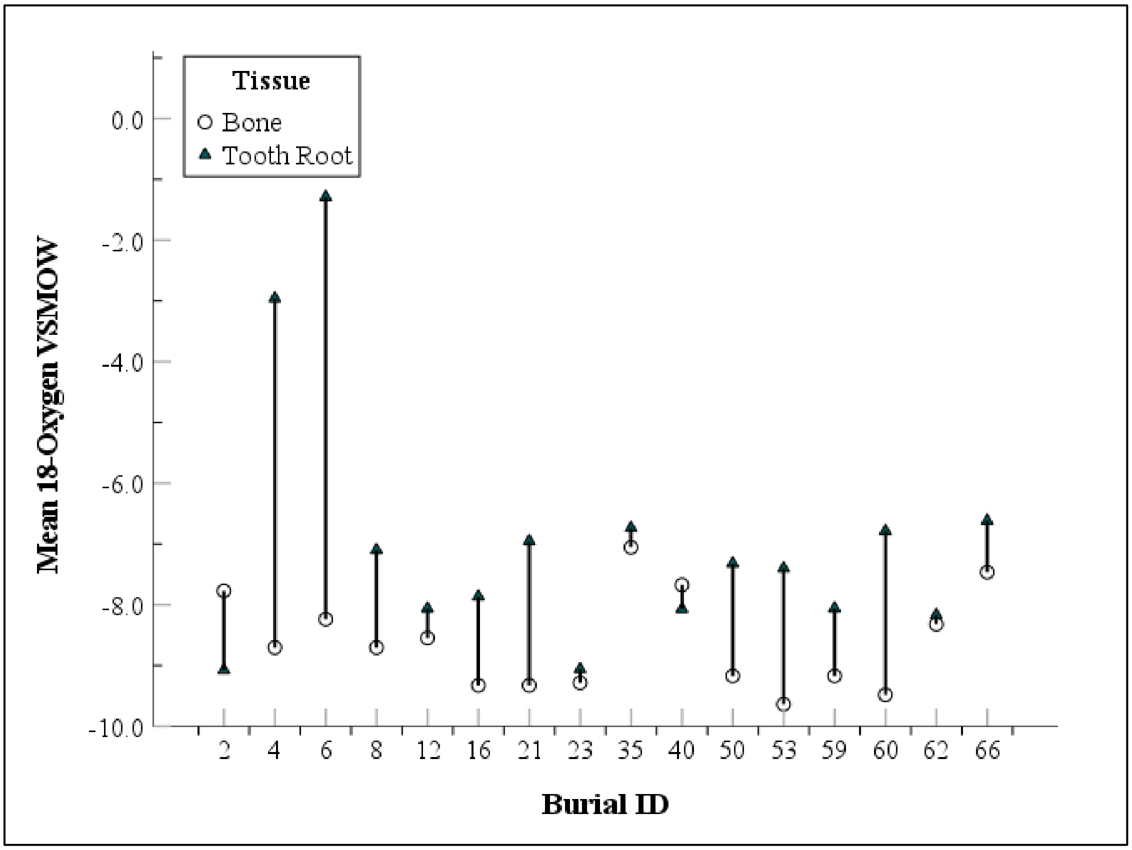

Figure 7.58: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots from males

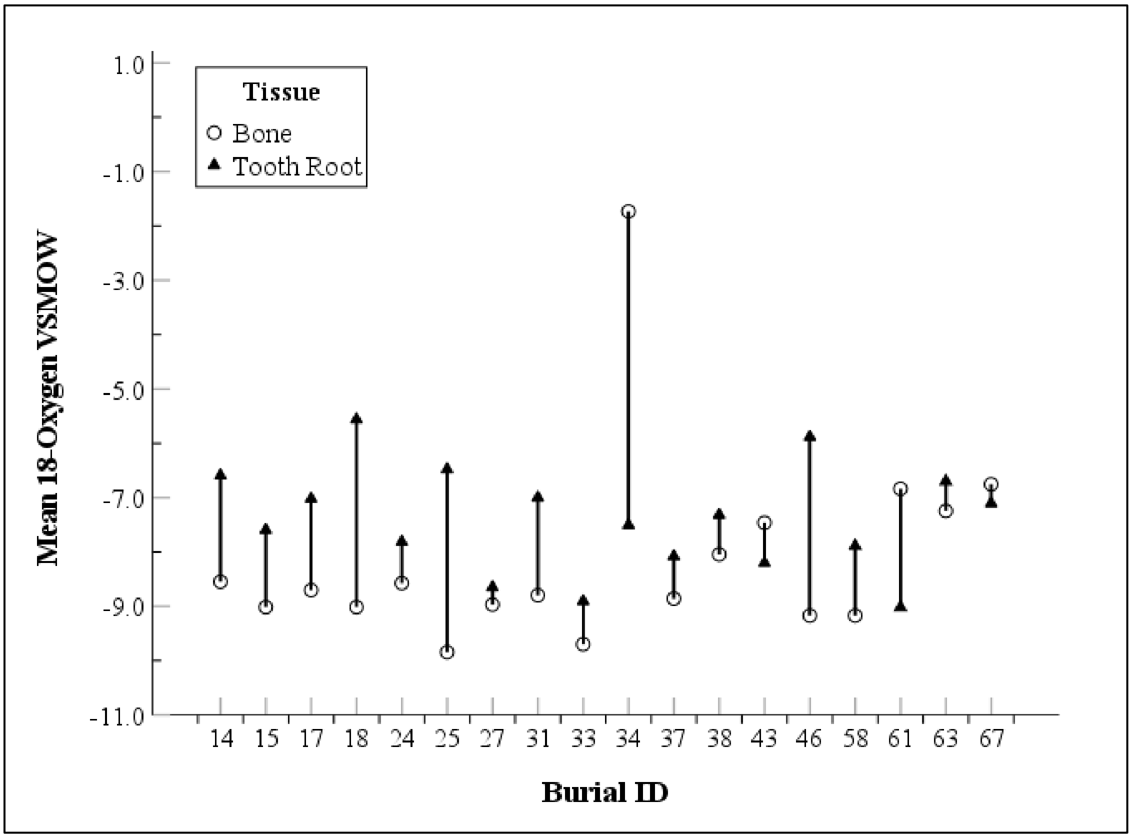

Figure 7.59: Drop-bar plot of $\delta^{18}O$ VSMOW values from bone and tooth roots from females

CHAPTER EIGHT:

DISCUSSION

INTRODUCTION

This chapter will summarize the results reported in chapter seven. The organization of this chapter follows the original outline of research questions are presented in the introduction. In this way the results and discussion chapter have a mirrored relationship in how the results are reported and subsequently interpreted here. The current research sought to interrogate Neolithic and Early Copper Age diets and mobility from an isotopic life history perspective. Though targeted questions regarding the roles of crop agriculture, foraging, animal husbandry, and hunting in the overall lives of Neolithic and Copper Age peoples. A biochemical approach combined with a life history perspective provided the architecture for a meaningful interpretation of these questions. The findings from the current study have applied ramifications for modern Italian farming communities, food cultural heritage, and identities. The agricultural legacies of the Po Valley are ones of transformation, taming, and exploitation of a once undulating, wooded, sub-tropical landscape into one of substantial agricultural production that has persisted well into the 21st century.

CHRONOLOGICAL INSIGHTS

At the offset of the current research project, there was anticipation by the author and the superintendent for archeology in Mantua that at least one site had the potential to yield an Early Neolithic radiocarbon date. As previously discussed, the rarity of Early Neolithic burials in

Northern Italy cannot be understated, with less than a handful ever being recovered, all of which occurred in the early 20th century (Biagi, et al., 2020). Those burials are only known to the scholarly community through local site reports and local publications. One site was highlighted by the Superintendent in personal communications, San Giorgio Bretella Aut., particularly tombs 77 and 116, which were found in close association with the earliest known simple rhomboid type stone tools and plain pottery sherds, potentially signaling an Early Neolithic burial. However, upon the return of the radiocarbon samples these burials dated between 4700–4500 BCE, which is just after or around the arrival of the first phase of the VBQ at Roncoferraro as early as 4720 BCE. Despite the persistence of the rhomboid stone tool usage and plain pottery sherds, these burials are more likely to be associated with the first phase of the VBQ and Middle Neolithic rather than Early Neolithic. This finding does not equate to a lack of Early Neolithic burials because as previously stated the earliest burial dated was tomb 1 from Bagnolo San Vito Dal Maschio at 4840 to 4700 BCE, which only slightly overlaps the first evidence of the arrival of the VBQ among the analyzed assemblage. It is possible that the associated burials at Bagnolo San Vito Dal Maschio, burials 1, 2, and 3 are all Early Neolithic, but for the purposes of this dissertation, there were treated as Middle Neolithic, specifically, phase one of the VBQ.

General Chronological Model

The insights gained from the chronological model have been interpreted through the general cultural chronology for the Neolithic in Northern Italy through typographic and other published radiocarbon chronological summaries (Pearce, 2013; Pessina and Tiné, 2018; Skeates, 1994; Starnini, et al., 2017). These sources generally attest, as previously discussed but summarized again here, to the beginning of the Neolithic around 5600 BCE with the arrival of

Impressed Ware groups, and the emergence of the Fiorano and Vhó peoples in the Central Po Valley. These Early Neolithic groups persisted until sometime between 5000 BCE and 4500 BCE, which were slowly transitioned to the first Phase of the VBQ, signaling the start of the Middle Neolithic between the same period. The VBQ itself was partitioned into three phases, based on functional and iconographic seriation, the first lasting until 4500 BCE, with the rise of the second phase around 4500 BCE to about 3500 BCE, and the third persisting to the Copper Age or Chalcolithic slowly replaced by the eastward expansion of the Chassey-Lagozza sometime after 4000 BCE and lasting until the Early Bronze Age around 2000 BCE. Important to the current project, the earliest aspects of the first phase of the VBQ overlap Early Neolithic traditions and often material culture. Archaeologists often utilize hard divisions between ceramic phases to assess differences among groups more effectively statistically, but also understand that these transitions were gradual and often involved much trial and error and introduction and reintroduction as particular phases or ceramic groups gain and lose popularity. It is extremely difficult in archaeology and especially in bioarchaeology, to discover and quantify transitions within the archaeological record due to the combination of individual lifespans in prehistory and the usually slow transitions from one phase to another that tend to meander rather than simply ebb and flow. However, for the purposes of analytical discourse, the current project utilized 4500 BCE as a dividing line for what is believed to be the transitory period for phase one and two of the VBQ.

As can be seen in the model, many of the dated tombs plot very closely to the 4500 BCE dividing line and could be considered transitionary burials typically straddling the 4600 to 4400 BCE transitionary period. What is important here; however, regarding the produced chronological model, are the fringes, particularly the earliest dates and the latest dates which signal the transition between the Early Neolithic and Copper Ages for sites around Mantua. These transitions are important because they relay critical information to researchers regarding local chronologies, which can later be evaluated from a regional perspective to examine rates of transition or spread of materials or ideas. As previously discussed, very little is known about the Early Neolithic and Copper Age transitions with respect to skeletal analyses and studies of the actual people living through these periods. What can be inferred from the chronological model is the regional start of the VBQ culture and the arrival of the Chassey-Lagozza, which likely connected East and West and provided trade potential for copper.

Dating the VBQ and Lagozza

Based on the findings in the chronological model and the inclusion of associated artifacts, it appears as if the first emergence of the first phase of the VBQ began around 4700 BCE, based on the earliest dated tombs with VBQ pot sherds at Roncoferraro. The burials dating earlier, appear to be transitionary, where rudimentary lithic tools and plain pottery overlap with those earliest Roncoferraro tombs, but appear Early Neolithic archaeologically. The site of Bagnolo San Vito Dalmaschio is less than five kilometers from the Roncoferraro site, a distance that could be easily traversed in less than a day by foot. It is possible for other Early Neolithic sites to be located around the site of Bagnolo San Vito Dalmaschio and future excavations could yield earlier settlements or burials. In utilizing the mean calibrated radiocarbon date 12 of the radiocarbon dated burials could be assigned to the first phase of the VBQ with five burials mean calibrated radiocarbon date falling after the 4500 BCE transition to VBQ phase two. Many of the burials within the analyzed population were thus most representative of phase one of the VBQ. Consequently, both Roncoferraro and Bagnolo San Vito Dalmaschio were observed to be the longest occupied sites in the region with over 200 or more years of continuous occupation. The total dispersion of the burials is very minimal as whole with most of the burials dating to between 4700 BCE to about 4300 BCE, a span of some 400 hundred years, almost evenly split between the first 200 years being VBQ phase one and the second 200 years being VBQ phase two. Many sites appear to have been continuously occupied between VBQ phase one and two, with some smaller sites like San Giorgio via Sardegna and San Giorgio via Europa being primarily occupied during the first VBQ phase. The largest of the sites, Valdaro Paganella in terms of overall village area and number of burials, appear to be established as the area is beginning the transition from VBQ phase one to VBQ phase two. This site could represent a larger coalescing of the smaller VBQ villages or represent the foci for the VBQ transition from phase one to two in the area around Mantua.

One of the more striking findings of the chronological model regarding group representation and transitions is the near 800-year gap of occupation between the VBQ phase two and the Chassey-Lagozza or Copper Age sites in the area. There are several apparent explanations for this gap, including the possible abandonment of settlement after VBQ phase two and into phase three, that the analyzed assemblage is simply missing any representative sites that were continually occupied between 4300 BCE and 3500 BCE, and that the gap was caused by a shift in burial practice that resulted in less human burials. An even greater likelihood is that many of the later VBQ sites, especially phase three of transitionary sites between VBQ and Chassey-Lagozza were simply destroyed via agricultural mechanisms. Regardless, the presence of copper staining within the burials recovered and dated from the earliest analyzed Copper Age site, San Benedetto Ca' dell'Aria, can accurately date the beginning of the Copper Age in the region to around 3500 BCE.

Archaeological Insights

One of the key findings of this research utilizes the chronological model and postulates questions surrounding mortuary practices and settlement patterns. In assembling these materials, a simple question was put to the superintendent for archaeology in Mantua and excavators with personal relationships to the dissertation committee, what Neolithic burials have been uncovered around Mantua and can we destructively analyze them? From this, 17 different sites excavated mostly between 2003 and 2018, two were distinctly Copper Age, 1 was dated to the Bronze Age, Valdaro Corte Tridolo, leaving 14 of the sites attributable to the Neolithic. However, of the 14 sites excavated over a period of about 15 years that were attributed to the Neolithic, all of the remains recovered were dated to only the Middle Neolithic and likely belonged to the VBQ cultural group. These excavations were entirely random, in the sense that the infrastructure projects requiring archaeological consultation over the 15-year period could be considered random regarding archaeological inquires across the city of Mantua. It should be noted that all of the sites generally occur either to the North or East of the city and other site are likely located to the South, West, and within the city proper. Yet, it is remarkable that all 14 Neolithic sites were attributable to the VBQ only and no uniquely Early Neolithic burials were recovered from these areas.

This finding is paradoxical within archaeology and is a recognized phenomenon among necropolis and cemetery sites. The sample size and number of sites is large enough to assert some logical reasoning to the absence of any Early Neolithic burials within the analyzed assemblage. First, as previously stated, there simply may not have been Early Neolithic settlements within the research areas to the North and East of Mantua city center. The absence of a particular phase of occupation does not essentially equate to an overall absence in the area but could simply be a function of location or settlement preference. However, the opposite could certainly be true, especially if only VBQ burial sites continue to be the only Neolithic sites discovered around Mantua. As previously stated, the Bagnolo San Vito sites were some of the earliest dated in the current study and the larger area could yield even earlier burials upon future excavations. It remains entirely possible there were little to no Early Neolithic settlements in and around Mantua specifically, which could be due to populations being extremely low, groups were still highly mobile, or the burials were being reused and destroyed during later occupations.

Second, the lack of Early Neolithic burials can be attributed to differences in burial practices between the Early Neolithic and the VBQ. It is clear of the limited literature on the Neolithic in the region that most burials generally referred to as Neolithic, are attributable to the VBQ or Chassey-Lagozza. The number of VBQ burials in the region far exceed the less than five Early Neolithic burials ever recovered from the region that remain disputed due to a lack of more comprehensive radiocarbon dating in the region. As previously stated, the current chronological timeline for the Neolithic in the Central Po Valley is constructed largely from radiocarbon dating regimes of plant remains and not human burials. Clearly, during the Early Neolithic populations were much lower than the Middle Neolithic, which leads to less individuals to be buried. However, the overall absence of Early Neolithic burials in an assemblage from a resource rich area over a 15-year period when combined with the almost complete lack of Early Neolithic remains in the region holistically is potentially evidence for differences in burial practices or mobility. All the VBQ burials follow a similar burial pattern of a body being placed in a shallow earthen burial pit that is either rounded or quadrangular, placed on the left side, and facing South. It is possible that in the Early Neolithic people were not buried, but rather left on the surface to decompose or cremated. Another possibility is that the VBQ and Middle Neolithic burials reused Early Neolithic graves, destroying the Early Neolithic remains in the process. Without absolute dates from Early

Neolithic tombs it is currently not possible to fully understand the mortuary practices of the period, but the overall absence of them across the region and in studies with large sample sizes such as this, provide further support for paradoxical archaeological evidence and inferences.

As a result of the chronological modeling conducted in the current study, it is possible to establish important trade connections in the region with the Middle Neolithic and Copper Age sites around Mantua. As previously discussed, Mantua is situated geographically at a natural crossroads, between North and South and East and West, and thus likely had access to many non-local materials as a result. The material most frequently recovered from the analyzed burials was polished flint points and greenstone axes. Objects crafted from both materials were recovered from the earliest burials at Bagnolo and the latest burials throughout the VBQ – both phase one and two. As previously discussed, the Lessini flint deposit near Verona was a common place near Mantua that many flint blades and points were likely sourced, which often yielded flints ranging from deep grey to light pink and red. Much of the greenstone material found throughout the Po Valley can be provenanced to large quarry sites in the western foothills of the Italian Alps in the modern Piemonte and Liguria regions. The presence of these artifacts alongside the individuals analyzed here suggest a strong connection of the Central Po Valley VBQ sites to those in the west. These tools were very rarely ceremonial, but rather functional axes, projectile points, knives, and rarer chisels for felling trees and working the wood to hunting and processing of meats and hides. These tools were so common that they were sometimes found in pairs or multiple types of greenstone or flint tools were found within one burial. Polished hard-stone tools were incredibly important to the lives and livelihoods of the VBQ in the Central Po Valley, especially when it comes to creating arable land for planting crops, which will be discussed later.

The second group of artifacts that represent an important trading connection are those soapstone or steatites and Spondylus beads utilized for jewelry during the Neolithic. Their appearance and inclusion in Neolithic VBQ burials can be assumed to signify some level of differential status of the individual in the group but based on the biochemical analyses conducted in the current study, those burials at San Giorgio Bretella Aut., San Giorgio via Veneto, and Olmo Lungo that yielded these artifacts did not differ significant from the other individuals regarding diet or mobility. More importantly that possibly different social roles for this dissertation is the connection to the sea and foothills surround the Po Valley where these materials were sourced. Some connection between the Central Po Valley and either the Adriatic or Ligurian Seas was established due to the presence of the Spondylus beads as they are sourced from saltwater shell fishes. These types of artifacts are much less common than polished stone and likely do illude to some unique social or societal role of the individuals interred with these ornamental artifacts. Among the individuals recovered with beaded jewelry, all were either females of varying ages or of indeterminate sex. The sites where these objects were recovered overlap in time and date to the early VBQ phase one (4700 BCE) throughout the VBQ phase two. The trade route between the seas and the Central Po Valley potentially were secondarily established as part of the entrenched routes where the raw or polished stone tools were already moving. These objects could also have traveled from an even greater distance, as other sites not included here, like Gaione to the southwest, have yielded obsidian artifacts from volcanic sources on the islands of Sardinia, Lipari, and Palmarola (Tykot, 2017; Tykot, 2021). Regardless of provenance, these beads display a clear connection between the Middle Neolithic people of the Central Po Valley and the surrounding seas.

The use and utility of canids in the Middle Neolithic has been a topic of interest for scholars of the region and because of the current research the burials which included a canid or were associated with a near-by canid burial an also be analyzed. Two burials were discovered with a canid placed at the feet of the interred individual, tomb 5 at Olmo Lungo and tomb 5 at Bagnolo San Vito Dalmaschio, with an additional canid likely found at the site as well but extremely poorly preserved and identified as tomb 6. These tombs date to just before and after the VBQ phase one and two transition. The earliest occurrence was at Olmo Lungo likely around 4600 BCE and the latest at Bagnolo San Vito Dalmaschio around 4460 BCE. It is unclear from the assemblage if canids were utilized earlier than these the two dated instances here, but it is possible given the two tombs occur in each observable phase of the VBQ.

Lastly, unique infrastructure can also be attributed to specific time periods because of the current research. The Middle Neolithic pitted village was the most common type of settlement that occurred throughout the Central Po Valley and even in parts of Central peninsular Italy as previously discussed. One unique structure previously touched on is a cigar-shaped pit of relatively unknown importance or utility to village life, previously discussed. The first occurrence of this structure is at Bagnolo San Vito Dal Maschio which reveals its extremely early use in the region likely as a transitionary structure of the Early Neolithic village into the Middle Neolithic. There are several possible uses for these pits, as either water troths for domesticated animals, tanning pits for soaking leathers prior to stretching, drinking water wells for humans, clay or material quarries, or uniquely shaped trash pits. The elongated form does create more available access points for multiple animals to drink at one time if they were utilized as watering pits and resemble similar modern elevated watering troth functionality. Importantly these uniquely shaped pit structures continue to be observed throughout the Middle Neolithic sites, but do not appear at the Copper Age sites.

NEOLITHIC AND COPPER AGE DIETARY LIFE HISTORIES

The biochemical results that describe the general dietary regimes of the VBQ and Lagozza peoples are largely unremarkable with respect to expected differences by period, cultural group, or demographics. For all instances of expected changes, the null hypothesis was accepted. Despite the degree of similarities when comparing the Middle Neolithic to the Copper Age, the VBQ phases and the Lagozza, or exploring differences in diet based on sex or age, there are some interesting trends worth summarizing. This section will translate and interpret the dietary results reported in the previous chapter and highlight key findings from the research. This section is divided into two parts, the Middle Neolithic and Copper Age cultural groups, in order to construct group isotopic life histories for each and to make inferences regarding how diet is reflected in landscape changes, wild resource acquisition, and the importance of domesticates and the consequences to identity and agricultural legacy of each potential taxa of interest.

VBQ Diets

At the outset of this research, it was expected that some differences would be apparent in the general subsistence regime of Middle Neolithic and Copper Age peoples. As previously discussed, Mantua geographically functions as a crossroads and thus during the rise of the second phase of the VBQ new domesticates and ideas were arriving at the region. These novel species were largely various free threshing forms of wheat, new glume, that were easier to harvest than the more ancient taxa likely originally utilized in the Early Neolithic and during the beginning of the VBQ (Rottoli and Castiglioni, 2009). While previous palaeobotanical research has found that during the Middle Neolithic various new taxa such as new glume wheats and spelt were becoming available in Northern Italy, but some millet varieties, such as foxtail and pearl, have also been discovered at lake side sites in the western Alps like *Pizzo di Bodio*, that date to the Early Neolithic (Castelletti and De Carlo, 2017), but not at any other sites. The research questions were thus poised to answer questions about potential shifts in C_3 and C_4 plant usage between the VBQ phases, potentially being traded with the new wheat taxa in the second phase, or if millet was potentially gaining popularity and spreading with the expansion of the Lagozza. Additionally, within a life history framework it is crucial to explore potential differences in diet between adolescence and adulthood, between males and females, and between different age groups.

The results presented in the previous chapter overwhelmingly found that all tombs that could be assigned to the Middle Neolithic or either the VBQ phase one or two contextually or chronologically, were consuming C_3 plants as their primary food source. The level of consumption is made even more striking by the general lack of dispersion from the expected pure C_3 feeders mean values for both apatite (-14.5‰) and collagen (-21.5‰). In general, all the Middle Neolithic burials were very tightly clustered around these mean values for both tissues respectively regarding explorations of period, culture, and demographic. The isotopic evidence thus supports a diet of primarily wheat, barley, and possibly rye grain-based foods. Furthermore, no significant differences were found between Middle Neolithic men and women and different age groups with respect to protein or carbohydrate sources. There was remarkable similarity between both phases of the VBQ regardless of sex or age.

The results from the Middle Neolithic dietary analysis can be utilized to construct life histories based on the isotopic data. From a biocultural perspective, the contextual evidence obtained from the careful excavation these remains reveal the importance of greenstone axes and flint points to the period. Previous research, discussed earlier, revealed the functional aspects of these artifacts rather than ceremonial ones as part of burial traditions marking the period (D'Amico, 2005). These axes were critically utilized to clear appropriate land that was free draining and likely slightly elevated near major water sources, such as the Minco and Po Rovers near Mantua. These areas would have been vital to the production of viable wheat, barley, and rye crops that were sustaining the Middle Neolithic groups of both the first and second phases of the VBQ. Felling trees and undergrowth would have become a usual and important task of all members of the Neolithic villages and hamlets. The micro burin flints were likely used in harvesting equipment and placed either on organic wooden or bone scythes to cut crops for further processing (Mazzucco, 2015). Interestingly here is that the greenstone axes occur slightly less often in female burials than males but remain almost equally present among both sexes. Additionally, the rarer greenstone chisels discovered among the current assemblage tombs were found more often in female tombs than males. Other instances of greenstone chisels are rare and almost absent from the literature and often are simply known from early 20th century excavations via word-of-mouth. The presence of greenstone axes in both male and female burials likely signifies an equal division of labor, apart from potential processing and refining responsibilities for rough-cut lots and timber being a female dominated task. Future research into the use of greenstone axes found in female burial alongside greenstone chisels should examine if the blunt end of the axe was potentially utilized for striking the flat chisel end, potentially relating to woodworking activities by females. The isotopic evidence provided by the current project attests that both male and female labor was likely critical and primarily driven towards preparing fields and for the harvest, planting seed, and processing grains and organic products from the acquired viable wood resources.

One of the key findings from this research departs slightly from the C_3 dominated diet and explored the potential importance of wild vs. domesticated resources as part of the VBQ subsistence economy. Several animal and plant isotopic values were obtained from nearby sites that previously reported animal collagen values and from one *Bos taurus* or domesticated cow bone found at Roncoferraro, outlined in the previous chapter, and compared to the human isotopic values utilizing discriminant function analysis of human bone and tooth root collagen isotopic values. In this way effects of extraneous variables or noise within the data set were reduced to functions that represented the net protein sources within the diet and dietary carbon originating from those protein sources. The plotted model was largely driven by the trophic level or net protein source within the diet and created a close cluster of human values with those of the included domesticated wheat and barley samples. Based on both models produced for bone and tooth root collagen isotopic values, C_3 protein again was revealed as the primary source of protein within the diet. However, an advantage of utilizing dimensional reductive statistical tests is that the distances between mean centroids on the plot is telling the relative level of importance of other non-plant protein sources in the diet. Despite the initial dietary scatter plots lacking slightly more negative collagen carbon values that would indicate the consumption of freshwater fishes, the DFA model revealed that for both the adult and adolescent diets, freshwater fish were the next closest source of protein. The inclusion of freshwater fishes within the analyzed tombs because of freshwater fish bones being found in close association with a few of the tombs in the study. Weather these fishes were simply burial offerings or part of burial ritual behavior is unclear, but their proximity to the plotted human values within the model suggest that freshwater fish were at least a secondary source of protein within the diet. Based on previous summative zooarchaeological research on other Neolithic sites in northern Italy, the relative importance of domesticate species to the human diet appears relatively high while the acquisition of wild resources such as red deer or ibex appears to be more opportunistic or rare (Tecchiati, et al., 2013). Cattle in particular plot very close to freshwater fishes and the tightly clustered human values. Previous research has shown that the Middle Neolithic appears to have witnessed an increase in cattle rearing. Yet, for northern Italian Neolithic sites it has yet to be shown if any amount of time was allocated to transhumance into the Apennine or Alpine ranges to take advantage of fertile summer pastures, that has been undertaken since the Bronze Age and remains an important part of contemporary Italian farming culture and identity. The close association with the human cluster and the cattle values in the model suggest that the Middle Neolithic villages around Mantua were also raising cattle. Which provides further potential evidence for the cigar shaped pits discovered at several sites to have been used to collect water for cattle while they were in the village. The other sources of protein included in the model, domesticated sheep and goats and red deer, appear to have less importance in the overall diet, with the sheep and goat plotting closer to the human group than the red deer. The red deer have the greatest distance from the human values and thus were likely not a common source of dietary protein during the VBQ periods. As discussed in chapter four, wild species, like red deer, ibex, and boar, are all found consistently throughout the previous Paleolithic, Mesolithic, and Early Neolithic periods, with abundances of at least 50% of many analyzed assemblages, but as seen in the current study, these wild species become rare during the Middle and Late Neolithic.

These results have bioarchaeological significance because if there were intensive cattle rearing around Mantua, with cattle sharing human spaces, it would be expected that some zoonoses would occur between the cattle and the humans. Cattle borne tuberculosis should have effect at least one or more individuals in the analyzed assemblage. As previously discussed, previous literature has documented several cases of tuberculosis in both the Early Neolithic at Arene

Candide (Sparacello, et al., 2017) and during the VBQ at Casalmoro in Emelia Romagna (Rosa, 2015). Yet during the analysis of the remains no major macroscopic indicators of tuberculosis were observed on any skeletons, with special attention directed to vertebral and os coxa elements. There are two possible reasons for the lack of skeletal tuberculosis, in that the general level of preservation and survivability of elements typically effected by the disease were often absent so the presence or absence of the disease could be affected by preservation, or the amount of cattle rearing occurring in this area was lower than other regions. The extremely tight cluster of human values surrounding primarily the wheat and barley values in the DFA plot alludes to a very intensive plant-based subsistence economy. One further supported by a more common paleopathological lesion within the analyzed assemblage, sub-lingual dental carries at the cemento-enamel junction (CEJ). Carries in this location are typical of early agricultural societies when the amount of carbohydrates in the diet is increased through the consumption of primarily plants. This type of reliance on domesticated plant species leads to increased bacterial activity particularly at the gum line of individuals, where these carries are found, due to excess sugars in the diet originating from the domesticated species. Other types of dental carries, including sub-lingual, drastically increase when millet or corn, C_4 plants, are primarily consumed, which directly lead to more widespread instances of occlusal carries due to their extremely high sugar content compared to wheats or barley, which results in enamel degradation. The question of cattle as a reservoir for human labor in the Middle Neolithic for the purposes of subsistence is complicated by the mobility results of the current study.

In sum, the VBQ life ways were unsurprisingly egalitarian. Equal divisions of labor were clear first from contextual evidence of greenstone axes and flint tools found almost equally among male and female tombs and later through the dietary analysis showing no significant differences in diet between males and females. In some instances, it could be expected that males would plot higher than females, in terms of trophic level due to their assumed roles as hunters and therefore higher likelihood for consuming meat. Yet that is not the case here. As previously addressed, the second phase of the VBQ witnessed a potential increase in domesticated plant varieties, but those varieties appear to be limited to new forms of C_3 plants that would be invisible in the current study due to their equal isotopic values to mor ancient C_3 varieties already grown. In all the Middle Neolithic villages around Mantua were remarkably stable with little to no indicators of dietary related stresses on the analyzed remains, a likely rising population compared to the Early Neolithic, and the possible increasing spectrum of domesticated food sources, such as the inclusion of cattle, gaining traction during the period. While the dietary evidence for the period overall falls within the expectations of previous palaeobotanical research, the current study does provide some evidence for first the importance of C_3 plants and the production of arable lands to cultivate them and the secondary importance of cattle, which can be explored further by future studies as discussed later.

Lagozza Diets

The two Copper Age sites included in the current study have provided dietary insight into a very poorly understood period and transitionary time in prehistory. The Lagozza cultural replacement of the VBQ occurred sometime after 3500 BCE and cannot fully be explored by the current project due to the near 800-year gap between the latest VBQ burials and the earliest Lagozza burials within the analyzed assemblage. However, the two periods, three cultural groups, and males and females could still be compared to explore potential changes in diet over the course of the chronological gap in the analyzed assemblage. The dietary results for the Copper Age parallel those for the Lagozza because all of the available Copper Age samples can be attributed to the Lagozza culture and much of the polished stone assemblage and copper tools resemble stylistically the first phase of the Remedello culture (Gradella, 2012; Marinis, 2013). The dietary results of the current project revealed no major differences based on period, cultural groups, or demographics between the Copper Age and the VBQ. The entire period could be similarly defined by a primarily C_3 dominated subsistence economy, likely relying on many of the novel varieties of wheats, spelt, and barley introduced during the second phase of the VBQ.

Bioculturally, the tombs within the analyzed assembled yielded no greenstone artifacts, but rather only more elaborate and complex flint projectile points and knifes. Greenstone may have started to decline during the period due to the introduction of copper and especially with the common production of copper axes in the Remedello form, although none were found with any of the burials, only evidence of a copper tool at San Benedetto Ca' dell'Aria as copper staining on bone. It is likely that forest clearcutting to produce more arable land likely increased as copper tools became more common. The isotopic dietary life history revealed by the current study indicate a potential increasing reliance on C_3 plants with Copper Age and Lagozza values clustered even more tightly around the expected collagen means than the VBQ. It is possible that by this period prior to the Bronze Age, when millet quickly becomes the prominent stable crop, that the elevated fields created during the Middle Neolithic for wheat and barley production have likely halved in size due to erosion and the soil instability created from the removal of tree and shrub root systems. Those undulating raised areas that were once good for wheat and barley production due to their protection of inundation and free draining soils, potentially were slowly disappearing and reaching the flood level and staying wetter for longer, retarding wheat and barley growth and maturity. Most C_3 plants do not cope well in these types of conditions, so new areas likely had to be sought and cleared by Copper Age peoples so as a productive and sustaining harvest could be achieved. We know that the modern Po Valley is extremely flat compared to the likely undulating landscape of the Neolithic, but Neolithic and Copper Age legacies of intensive wheat and barley farming in the Central Po Valley likely contributed to the swift transition to millet in the Early Bronze Age. Millet and other C_4 plants prefer wetter soils and growing conditions, and the Po Valley would have been provided perfect growing conditions as the landscape flattened out and became more susceptible to more extensive floods and wet soils. However, the Copper Age peoples in the current study were overwhelming reliant on C_3 plants like the VBQ.

The dietary life histories of the Lagozza peoples would have been remarkably like the VBQ in the Central Po Valley, apart from the sourcing, manipulation, and use of copper tools and materials. It is clear of the data that like the Middle Neolithic, the Chalcolithic was highly egalitarian with males and females consuming similar diets regardless of age. Even with respect to the inclusion or substitution of wild or domesticated meat resources. These dietary results reflect those revealed by the detailed analysis of Ötzi's remains, as previously discussed. Ötzi shared a similar diet of primarily C_3 plants, but also incorporated some meat resources, likely dried domestic and wild meats, possibly utilized to sustain individuals on long journeys.

The Copper Age peoples included in the analyzed assemblage were included in the DFA analyses described above and thus shared similar subsistence relationships with respect to freshwater fishes and cattle and a less important use of sheep and goat or wild meat sources like red deer. It should be noted that despite the distance of these species from the human clusters in the DFA plot it is likely these species were still consumed from time to time or during special occasions, just not as often or regularly as wheat and barley, freshwater fishes, or cattle. The overall importance of cattle and sheep and goat to Middle and Late Neolithic diets is still unclear and requires larger sample sizes to elucidate the utility of these domesticated species more fully in subsistence economies for both periods. Thus, labor would have again been primarily focused on the preparation of land for farming, planting, and tending crops, and harvesting and processing grain. These activities would have required the production and maintenance of axes, scythes, and storage containers. Secondarily, based on the results of the DFA, some level of occasional fishing and cattle rearing was also taking place, likely with the cattle grazing on wild C_3 plants rather than being foddered on wheat and barley as the cattle do not plot with the plant values. However, there may have been some supplemental foddering with wheat and barley grain as the cattle values plot close to the plant values, but not directly with them like the humans, and thus their primary diet was likely obtained from wild grazing. Life histories of both periods were dominated by farming C_3 plants and involved occasional local sourcing of freshwater fishes and rearing and grazing of cattle.

MOBILITY

The biochemical results presented in the previous chapter comprise the analysis of only one stable isotope, Oxygen, that is useful for interpreting relative levels and localities frequented in adulthood and adolescence. As previous discussed, Oxygen isotopes obtained in the current study from human bone and tooth root apatite, primarily reflect the meteoric water sources utilized during the last 10 years of life with respect to bone and those sources available during initial tissue production during adolescence, regarding tooth roots. Like diet, adult and adolescent mobility was explored by comparing Oxygen isotopic values by period, cultural group, and by sex. Differences in mobility by age would be reflected in any differences observed between tooth root and bone values from the same burial. As outlined in the introduction the purpose of interrogating individual mobility is two-fold, first to describe any potentially relevant findings pertaining to life history or mobility to near-by or disparate locations and second to estimate possible localities of origin and favorable adult locations that could indicate behavior related to subsistence or trade. Additionally, interest in locals and non-local, specifically regarding tooth roots, is useful to provide support for overall levels of migration, the stability of populations, and kinship. One limiting factor in the current summary is the use of only one isotope, when multiple isotopes can be more useful in narrowing down provenance or localities of frequent travel or creating robust kinship models.

The mobility results indicate that there was more adult and childhood mobility in the Middle Neolithic, during both phases of the VBQ than during the Copper Age. A significant decrease was observed between VBQ mobility and Lagozza groups. These results are in apparent contrast with what is currently known about Copper Age mobility because of the discovery of Ötzi, whom was provenanced to the area of the current study but found near the modern Austrian border, high on an Alpine glacier and due to the distances between copper sources and excavated copper artifacts. The mobility results were directly compared to drinking water values collected from sample sources across northern Italy by converting the obtained VPDB values first to VSMOW, then to phosphate, and finally to drinking water, to readily compare body water with the environmental values, as previously discussed. Several outlying values were also discovered via individual plots and indicate possible exceptional cases.

VBQ mobility

Generally, the VBQ was a period of high individual regional mobility. This is immediately apparent by examining the level of dispersion between bone and tooth root samples. Approximately 75% of the adult bone oxygen values fall outside of the expected environmental range for the Central Po Valley, which indicates that adults are spending much of their time outside of the immediate area. One outlying case with an extremely enriched oxygen value, tomb 31 from San Giorgio Bretella Aut., is possibly traveling to the sea much more than the rest of the population or simply has a different water source, such as a well or cistern, than the other analyzed individuals. The differences between the bone values and the tooth root values are significant, with approximately 75% of the individuals aligning with the more negative possible vales for the Central Po Valley. As previously discussed, prior environmental canvasing and Oxygen sampling has found values that were slightly more negative for the Po Valley than previously thought (Giustini, et al., 2016). Interestingly, the additional 25% of the population that falls just outside of the expected range for the Central Po Valley have only slightly more negative values between -9.6‰ to -8.16‰. These values indicate that at least 25% of the analyzed population originated from possibly North of the Central Po Valley, with relatively equal numbers of male and female non-locals. These findings are important because they suggest a critical connection to the northern sites, most likely for the exchange of raw lithic materials quarried at Lessini outcrop and other near-by flint quarries for wheat and barley grain from the Po Valley. These populations were likely also related with potential relatives living in either location with a quarter of the analyzed assemblage likely born further North than where they were buried and presumably lived. Two interesting outlying burials of two males both from Valdaro Paganella, tombs 4 and 9, seem to have originated from a more coastal location. Only two individuals compared with nearly a quarter of the population from more northerly latitudes, suggest a slightly more important role of the Alpine foothills and lakes, than the sea, but a connection to the sea remains.

An interesting trend emerged when the Oxygen values from tooth roots and bone were plotted for the same individual. Overall, the drop-bar plots show a general trend for both the first and second phases of the VBQ, which indicate a childhood spent in the Po Valley and an adult life spent largely outside of it within the larger region, likely to the North of Mantua. However, despite this some of the differences between the individuals possibly moving frequently between Mantua and Northern sites, and those with less disparate oxygen values between bone and tooth roots are patterned. It appears that of those individuals moving more frequently between the Po Valley and the North, are prime age and older females, with some of the individuals of indeterminate sex. But of those individuals that have much less mobility and appear to stay within the Po Valley, they consist mainly of older individuals of mixed sex and adolescents and young adults. This trend for both phases of the VBQ indicate that whatever activities are drawing adults North for long periods of time, there is a preference towards prime age adults and older adults likely with ample experience. This may leave the responsibilities for the care and tending of children and crops more in the hands of the young adults and the eldest adults than the prime aged adults. Although some prime age females are among these fewer mobile groups as well. In terms of life history, it is a complicated picture, as it seems that all activities are equally shared among the sexes with possibly more experienced travelers, shepherds, or traders ranging more frequently North, leaving older less able individuals behind with young adults and children. It is possible that both males and females are important in trading relationships with Northern settlements or that males and females share the burden of pasturing cattle equally. What can be concluded is that age and potentially knowledge, capability, or experience was potentially responsible for a division of labor, but sex-based divisions are almost entirely absent.

Phase one of the VBQ appears to have witnessed slightly more adult mobility than phase two. For whatever reason more known phase one individuals were ranging into higher latitudes more often than the known phase two individuals. However, the VBQ phase two individuals do appear to have some percentage of individuals moving more frequently within the immediate area around the Po Valley, likely back and forth from Mantua to areas around the Southern extent of Lake Garda. Yet some individuals are moving frequently to even higher elevations in the first phase of the VBQ, north of modern Trento or south into the elevated areas within the Apennine Range. The most depleted Oxygen values are around -9.5‰ which is 1.5‰ less than the most negative expected value for the Po Valley. Based on the previous calculation for the relationship between oxygen and elevation in Northern Italy at 0.2‰ depletion for every 100 meters traveled, the most depleted individuals are changing at least 700 meters in elevation from the area around Mantua which is at 18 meters above sea level. As previous stated, based on sex-based comparisons, males and females are equally mobility with likely both sexes making long distance treks into the Alps or Apennines.

Lagozza mobility

The Lagozza individuals included in the analyzed assemblage had significantly less mobility than what was observed among the VBQ peoples. Based on the plots presented in the previous chapter all the individuals analyzed were born, lived, and died in the central Po Valley. These findings do not rule out less frequent trips of shorter duration around the immediate area but can fundamentally assert that the Copper Age peoples around Mantua were largely stationary. From a life history perspective these findings when combined with the dietary results indicate a possible livelihood centered on farming, that was becoming increasingly intense compared to the Middle Neolithic. It is unclear if trading relationship were waning or if less and less individuals were required to conduct trading business. The position of Mantua as a crossroads also returns to the forefront of thought here, especially if previous Middle Neolithic routes were still in use, were becoming more entrenched with exotic materials moving more easily across the valley, with settlements filtering off needed supplies. From the Lagozza burials materials from regional locations were still available to the population, but the local population appear unlikely to be responsible for their acquisition or transport to the area.

The lack of evidence for a mobile Lagozza population is surprising given the rise and widespread use of copper in the period and the discovery of the Alpine Iceman, whom was provenanced to the project area. As previously mentioned, provenance work conducted on Ötzi's copper axe, concluded that the copper was sourced from Apennine copper deposits in Northern Tuscany. The material evidence combined with the bioarchaeological evidence indicates a likely more expansive trade network, but one that is traversed by fewer traders than in the Middle Neolithic. The slight apparent increase in C_3 crops in the diet as evidenced by the even tighter clustering of copper age individuals within the C_3 means, translates to a greater allocation of labor to farming. The focus on crop production above trading, shepherding, or ranging into high elevations, likely compounded the already deleterious effects on the landscape regarding suitable land for wheat and barley production. Additionally, a greater reliance on plant subsistence could eventually lead to crop failures in monoculture environments and during severe flood events due to the reducing size of elevated farming areas. For the people in particular these types of events can have adverse health outcomes when crops fail and potentially create nutritional stresses or create an environment with increasing likelihoods of dental disease or decay.

APPLIED INTERPRETATIONS OF RESEARCH

Isotopic and Mortuary Paradox

Applied applications of this research involve the key findings described above but expanded here to greater effect for the scholarly and Italian agricultural communities respectively. The current research project is one of importance to the literature due to the unique provenance of the skeletal assemblage to the Neolithic and Copper Age and the subsequent radiocarbon dating and biochemical methodologies utilized, that have rarely been implemented in the region. From a scholarly standpoint the current research is novel in utilizing a biocultural approach to reconstruct isotopic dietary and mobility life histories of Neolithic and Copper Age individuals from the Central Po Valley. The addition of the radiocarbon dating regime was implemented in part due to request for a few radiocarbon dates by the Superintendent for archaeology in Mantua, but also out of association with published literature by Italian scholars of the region asserting the need for rigorous and comprehensive dating of Neolithic sites (Starnini, et al., 2017). The utility of the produced radiocarbon chronology and the dietary and mobility isoscapes provides easily comparable data for future scholars undertaking bioculturally significant research in Northern Italy with respect to the Neolithic and Copper Age. More broadly the current research contributes to the overall understanding of dietary trends within Italy from the commencement of farming into the contemporary period.

One of the key findings from the chronological model, was the general absence of any uniquely Early Neolithic tombs in the assemblage. It was expected that at least a handful of tombs may possibly date to the Early Neolithic, but as previously discussed failed to identify any tombs as strictly Early Neolithic. However, a few tombs at the Bagnolo San Vito Dalmaschio site could be considered transitionary from the Early Neolithic into the first phase of the VBQ. This finding is important to future excavations planned in the area surrounding Bagnolo, as potentially undiscovered Early Neolithic sites or tombs maybe close to the surface. As previously discussed Early Neolithic tombs in Northern Italy are exceedingly rare with most found prior to World War 2 which were potentially unreliably dated utilizing very early radiocarbon dating methods (Starnini, et al., 2017). The utility of human burials for creating accurate chronological timelines is critical for comparative purposes to those produced from solely palaeobotanical or zooarchaeological remains. Burials often contain grave goods which can be associated with relative ceramic or lithic chronological sequences and when combined with radiocarbon dates from the human skeletal material can result in tighter and more refined chronologies. However, as previously discussed, the current project failed to identify any distinctive Early Neolithic burials from a random assortment of archaeological inquires pertaining to new infrastructure projects occurring around Mantua over a 15-year period. These findings indicate a troubling dilemma concerning the presence of Early Neolithic burials, mainly in their perceived absence that there may not have been a large Early Neolithic population around Mantua or that the mortuary traditions of burying the dead were not consistent between the Early and Middle Neolithic in Northern Italy. At a minimum, the current research project can hopefully provide some critical insight and potential direction for Italian archaeological firms and government entities as to where there is potential to locate Early Neolithic burials in the future around Mantua.

Early Neolithic life histories can be postulated further based on these results, where the implicitly embodied diets and mobility reported for Middle and Late Neolithic populations here, potentially suggest that life may have been less centralized around permanent settlements in the Early Neolithic. Experimentation with the Neolithic package was likely characteristic of the first farming groups which would have attempted to strike a balance between sedentism and farming vs mobility and hunting and gathering to survive. The osteological paradox can be of some use here in describing population non-stationarity, where it is understood that when populations are more mobile cultural practices and life ways are directly tied to migration and movement and individuals may not be wholly reflective of the landscape in which they are recovered archaeologically. This means that during the Early Neolithic burial practices may not have been centered around permanent villages, but rather followed a more sporadic pattern of burying individuals along migration routes or at temporary camps and open-air sites. The mortuary behavior of the period can be further explored through embodied life histories, where if Early Neolithic lifeways can be characterized as more mobile compared with the Middle and Late Neolithic then burial practices would not be centralized and more difficult to locate archaeologically. Overall, it is likely that previously discussed population mixing models in the Neolithic in general, were likely largely characteristic of more mobile Early Neolithic groups and not of the Middle and Late Neolithic periods, which is likely reflected in settlement patterns, mobility, and the life histories of the Early Neolithic and the results of the current study.

Anthropogenic Landscape

The second primary finding of the current research involves linking previous lithic research with the bioarchaeological analysis conducted here using a biocultural approach. As previously mentioned, the importance of polished stone tools manufactured from flint and greenstone cannot be understated in Neolithic communities, especially the Middle Neolithic and the VBQ represented within the current study. It is clear from previous use wear research that these tools were functional and ceremonial use was likely linked with burial, but with functional tools, likely used by the deceased, placed in burials. Combining these previous findings with the biochemical results here provides an avenue for inference into landscape changes begun in the Neolithic, continued into the Copper Age, and engrained on the contemporary landscape. The commitment to a subsistence economy heavily influenced by the cultivation of C_3 plants like wheat and barley, equate to a need by the farming communities for clear, arable lands, with free draining soils, near water sources. As previously discussed, Neolithic peoples in Northern Italy would have encountered a much hillier and undulating, forested landscape that was is visible today as a flat, deforested flood plain. Elevated areas near major water sources such as the Po River and its tributaries, would have proved attractive to Neolithic farmers seeking to grow wheat and barley that prefer these types of microenvironments. However, in clearing these areas of understory and trees, the soils would have become unstable without the support of organic root structures and left more susceptible to erosion overtime, especially with continual use. This activity was the start of the anthropogenic landscape transformation, which has resulted in a flat, flood plain that is susceptible to heavy, extensive flooding, which occurs regularly in Northern Italy (Dada, et al., 2021; Luino, 2005).

The Neolithic and Copper Age periods were responsible for destabilizing the natural elevated areas for the purposes of productive C_3 plant cultivation, which based on the results of the current research was heavily practiced for nearly 2500 years. Combined with increasing demand from growing Middle Neolithic and Copper Age populations, more and more land was likely cleared to make way for wheat and barley crops throughout the periods. This activity, supplemented further by the summarized dietary life histories, has contributed to contemporary instability of the landscape and the resiliency of modern communities to flood risks. In addition, the radically shifting climate across the globe have also contributed to heavier rainfalls in modern Northern Italy, which have increased the frequency of flood events, requiring extensive modern investments in flood mitigating infrastructure and protective barriers and levees for flood prone cities and towns (Luino, 2005). The legacies of intensive C_3 cultivation and subsistence economies in the Middle Neolithic helped contribute to the flood prone contemporary anthropogenic landscape along with the intensive C_4 agricultural systems constructed beginning the Bronze Age and continuing into the Iron Age (Tafuri, et al., 2018).

Italian Identities in Food

Despite the landscape destabilization occurring because of land clearing and C_3 cultivation, the last primary finding of the current research is the antiquity of cattle rearing and the increases in suitable damp soils and land for moisture heavy crops. Northern Italy is a major breadbasket or net food exporter of the world due to the fertile, but sometimes volatile flood plain of the Po River (Fortis, 2016). Yet, the popularity of Italian food products is not simply limited to the net production of food stuffs, but rather the types and quality of products that are uniquely Italian and beloved by consumers. Many products in Italy are strictly quality controlled by the PDO and PGI, as previously discussed, and are often specialty foods that can only be produced at high quality in Italy (Aprile, et al., 2012). Production of these products are often extremely time intensive and require specialty knowledge that is typically attributed to traditional methods passed down generationally among families and tradespeople. Secondary products produced from milk from cattle, sheep, and goats are particularly prized because they are utilized to produce some of the most widely used cheeses in the world such as parmesan and mozzarella that are made with cows' milk and Romano cheeses which are made from sheep's milk. The close association among the VBQ and Lagozza groups with cattle provide some evidence to their early importance to the Middle Neolithic and Copper Age communities in Northern Italy. It appears more likely that these early cattle were possibly utilized for meat rather than dairy, but the isotopic analyses conducted here would not identify any dairying economies if they were present. Future studies could chemically test VBQ and Lagozza pottery sherds and search for evidence of fatty acids and proteins associated with milk to explore the potential for dairying in these periods. However, it is important to emphasize the segmentation of local agricultural and dairy product production among contemporary Italian producers. These modern lifeways resemble in some part those that originated in the region during the Neolithic and involve many of the same domesticated plants and animals. The success of the Neolithic diet, as demonstrated in the current project, is reflected in modern northern Italian diets, which heavily feature wheat pastas, milk-derivatives of cheese, cream, and yogurts and a huge variety of cheeses and specialty meat products.

Lastly, the landscape change discussed above may have begun the cascade of landscape changes that have resulted and exacerbated flooding issues in the modern era, but those changes also provided space for more moisture loving cultivars in later periods such as millet and rice. As the landscape began to lose areas for growing large amounts of wheat and barley, millet become increasingly important beginning in the Bronze Age, with much of Northern Italy perfectly suited for growing crops such as millet and rice (Tafuri, et al., 2018). Parts of the developing social stratification observed in later periods, including the Bronze Age, that were made more identifiable due to the consumption of millet, were partly made possible to anthropogenic land changes begun in the Middle Neolithic and Copper Ages. Much later in time, likely in the Late Middle Ages, rice cultivation was begun in Northern Italy, specifically in Lombardy and the Piedmont regions due to swampy conditions, suitable to millet and rice cultivation (Davidson, et al., 2014). Italian rice cultivation has grown to the point of Italy becoming the largest rice producer in the European Union (EU) (Blengini and Busto, 2009). Northern Italy is well-known for their delicious rice cuisine, especially Risotto, made utilizing high quality risotto rice varieties that have been grown since the early 19th century (Wilson, 2006). Italian identities are often intricately linked with many of these specialty foods and delicacies that have become uniquely Italian and attract millions of tourists and consumers all over the world (Wilson, 2006). Just as the Northern Italian landscape has become more flood prone because of the intensive land clearing and C_3 cultivation in the Middle Neolithic and Copper Age, so the contemporary Italian culture has adapted and become partially defined by anthropogenic changes that have allowed to produce unique and valuable foods. The legacies of landscape change and life histories linked with intensive wheat and barley cultivation from the current project have many applied applications involving contemporary Italian’s still cultivating the Central Po Valley.

CHAPTER NINE:

CONCLUSIONS, LIMITATIONS, AND FUTURE DIRECTIONS

In the conclusion of this research, the emphasis on the egalitarian characterization of the Neolithic across the spectrum of the archaeological literature applies equally well to the Middle Neolithic and Copper Age groups of Northern Italy (Barker, 2006; Price, 2000a; Watson, 2003). The current project has shown that humans living in these periods, regardless of sex and cultural group, shared a remarkably stable way of life that is revealed through the biochemical and biocultural characterization and analyses of the analyzed assemblage of tombs. The stability witnessed during the Middle Neolithic and Copper Age respectively in Northern Italy is likely uniquely made possible by the environment in which these peoples lived and irreparably changed because of intensive crop agriculture. The VBQ and the Lagozza appear to have simply continued with the farming traditions begun first by the Fiorano and Vhó people of the Early Neolithic, while the second phase of the VBQ brought new ideas and C_3 cultivars to the region. This research is a critical contribution to the Neolithic and Copper Age specific bioarchaeological literature of Northern Italy due to the robust radiocarbon chronology and biochemical methodologies applied, but rarely if ever seen within the current literature of this size and scope. The isotopic life histories of the Middle Neolithic and Copper Age peoples surrounding Mantua, are simplistic, but informative regarding the contemporary landscape and modern northern Italian identities. However, the current project only serves as an initial contribution to a growing Italian bioarchaeological literature pertaining to the Neolithic and Copper Age in Northern Italy and concludes with limitations of the current research and future directions for research.

The implicitly embodied diets of Middle and Late Neolithic agriculturalists relay information on Middle and Late Neolithic social and cultural systems and environmental and ecological settings salient to the constructed life histories, which detail the stability and resilience of Neolithic social and cultural systems and landscapes. Additional work could combine these life histories into a more comprehensive narrative surrounding agricultural niche construction theory where Neolithic agricultural groups, mainly the VBQ and the Lagozza in Northern Italy, could be compared with other Neolithic cultural groups from Central and Northern Europe that occupied similarly agriculturally productive localities. The illustrated stability shown within the present study, is observable through the life histories of the VBQ and the Lagozza but can also aid in interpreting behavior not directly observable in earlier and later periods, as previously discussed, by comparing these life histories with other sites and periods. The intensive focus of the VBQ and Lagozza on crop agriculture, despite the diffusion of new ideas and people into the Central Po Valley as previous discussed, helps to further galvanize these conclusions but also raises additional questions regarding the VBQ and Lagozza on a region level, the inclusion of exclusion of certain domesticated taxa, and the localities visited most frequently by the VBQ and why.

Future use of this population and these constructed life histories could be combined with other bioarchaeological data sets from VBQ sites like Le Mose and Ponte Ghiara in Emilia-Romagna which could interrogate that if stability was a characteristic of the VBQ in Mantua then it should also be an observable characteristic of the VBQ across the Central Po Valley. Additionally, it is critically important that the Middle and Late Neolithic domesticated subsistence economies be further explored in-order to determine the overall importance of domesticated cattle vs sheep and goat. This can be accomplished through the addition of more archaeological proxy samples from other VBQ and Lagozza sites, which also contain testable human burials. If cattle were more important than sheep and goat in VBQ and Lagozza diets then future DFA analyses of dietary protein, which include additional animal proxies, should continue to plot human values closest to cattle values. Lastly, through the addition of other isotopic systems like strontium and sulfur, additional questions surrounding mobility could be answered. If VBQ mobility was confined largely to the Central Po Valley then novel isotopic values from strontium and sulfur should correspond with environmental values unique to the Alpine and Apennine foothills.

Limitations

The current study cannot be considered a holistic examination of the Middle Neolithic across the Po Valley or Northern Italy. Bioarchaeology and much of archaeological studies in general are first and foremost local. They analyze sample sizes of artifacts or skeletal remains that originate usually from discrete places and sometime multiple sites within a larger region. So the primary limitation of the current study is that it can be utilized alone to only characterize the community lives around Mantua during the Middle Neolithic and Copper Age. However, when combined with other previous or future research can be utilized to highlight differences in life histories among discreate regions and sites of related period or cultural groups. This research can also serve as a sample of Middle Neolithic and Copper Age burials with known diets and mobility information within a larger frame of regional research assessing broad changes over time from the Neolithic to the Iron Age, when utilized in concert with other studies.

This research was subject to limitations in sampling during the data collection phase imposed by the Museum and the Superintendent for Archaeology in Mantua. Access to the remains was at first denied upon the initial planned data collection trip to Italy, which required a second funded trip with guaranteed access to the assemblage. Yet, even after permissions and space was granted for the analysis, data collection was limited to only four weeks' time, in which acquiring bone and tooth root samples was prioritized followed by rudimentary sex and age estimations to facilitate the analysis. Some paleopathological information and observations were made, and major lesions were sought and documented when present. Only macroscopic analyses were conducted including sex, age, and paleopathological analyses, due to the constraints on time. No work was conducted on the weekends as the museum space allotted for the skeletal analysis was closed. Additionally, only tooth roots were allowed to be sampled and access to destructively sample tooth enamel was forbidden by the permissions. Also, animal remains that were associated with the included sites were also withheld from destructive analyses based on requests for zooarchaeological analysis prior to any planned destructive analyses. The only exception made was with the cattle bone from the Roncoferraro site. Other animal remains included, carp vertebrae and teeth, a cervid tooth and tooth root, and two pig teeth also with available tooth roots. Further limitations included the exclusion of strontium isotopic analysis from the dissertation due to issues securing facilities at USF to purify bone and tooth root apatite for analysis via multi-collector ICP mass spectrometry. Lastly, the availability of full excavation reports was a significant issue, especially the absence of a report for the largest site and sample of tombs, Valdaro Paganella. The reports provided by the Superintendent were limited also in scope to only discussion of the burials themselves and often did not include the excavator's interpretations of the associated material culture or the potential site chronology or associated features.

The most significant limitation on the current research was the COVID-19 pandemic and the subsequent closure of isotopic and radiocarbon laboratories for many months. The pandemic ceased work on the current project until all the isotopic values and radiocarbon dates could be returned. Once laboratories were reopened, they commenced operations with minimal staffs and often a large backlog of samples to process from many other research projects. Additionally, during the pandemic much of Italy was closed for over a year and a half, which significantly hindered access to inter-library loaning of additional Italian scholarly sources, which were already significantly difficult to acquire, as most Italian literature pertaining to the periods and cultures of interest are routinely published in local or Italian journals or reports. Despite these limitations many of the most relevant Italian sources were previously acquired before the pandemic and referenced within the current project.

Additional Isotopic Work

As with any project, limitations on time and financial resources often determine the scope of the work that can be accomplished. With the inclusion of additional time, permissions, and resources it would be prudent to further explore some of the inferences established here regarding the dietary relationship between humans and cattle and human and animal mobility. First, the inclusion of additional isotopic systems would be of extreme value in further refining localities of adult mobility and regions of origins for the roughly 25% of non-locals in the VBQ population. Multi-isotopic systems in bioarchaeology are not only useful for dietary analysis, as seen here, but also for mobility. The addition of strontium, lead, and sulfur would help narrow unique geological and coastal locations of interest to the more mobile VBQ and possibly reveal hidden information regarding mobility of the Lagozza peoples. Additionally, the importance of the Northern Alpine and Southern Apennine ranges as destinations for adults could also be revealed. Second, future work with this assemblage may benefit from incremental tooth root analyses of both the human sample sand the animal samples, with respect cattle and sheep. As previously discussed, modern Northern Italy has a robust and diverse dairy industry that is primarily focused on producing cheeses and other secondary products. The antiquity of these practices has previously been traced to the Bronze Age and have included a mix of vertical and horizontal transhumance of domesticates in order to take advantage of fertile spring and summer pastures in the Alps and Apennine ranges. The results from the current study indicate that some VBQ adults are traveling and staying at high latitudes for long periods of time, which could be related to spring and summer pasturing activities associated with transhumance. Incremental isotopic analysis of animal teeth can reveal seasonal usage of unique meteoric water sources and indicate that domesticates were likely moved between high altitude spring and summer pastures and low altitude autumn and winter pastures. Third, these types of additional studies can be easily complimented with the addition analyses of ceramics for evidence of fatty acids or proteins indicative of dairying. Many of the burials and surrounding sites have yielded VBQ vessel sherds that have yet to be destructively analyzed for milk proteins and fats. Evidence of earlier dairying has implications for long distance travel and subsistence as well as the roots for modern Italian shepherding identities.

Ancient DNA and Proteomics

The last recommendation for future studies would involve ancient DNA and proteomic or compound specific isotopic analyses to further investigate kinship and diet. Ancient DNA analysis of the assembled skeletal collection and the inclusion of other VBQ tombs from across Northern Italy could reveal the kinship systems employed during the Middle Neolithic and Copper Age. Based on the findings from the current study, it appears that male and females are equally mobile with similar life histories and responsibilities, but this current study did not provide any evidence for kinship. It can be assumed that like most other Neolithic societies in Europe that a matrilocal kinship system can be assumed, but that assumption must be tested for the Northern Italian

Neolithic. Further, by including Neolithic human remains from other sites across Northern Italy it may be possible to further reveal the relationships between disparate and regional sites. Currently trade relationships are only based on the material remains found and provenanced at Neolithic sites across Northern Italy, but with the addition of ancient DNA familial connection may elucidate important ties across the region and potentially critical trade routes for common raw resources and exotic goods.

Lastly, the addition of proteomics can be informative to the overall health status and narrow the dietary analysis conducted here further. The analysis of proteins from bone, teeth, and dental calculus can help inform on the presence or absence of specific pathogens or proteins produced because of acute or chronic infection. These types of analyses could be useful in assessing the presence or absence of tuberculosis in assemblages with very poor preservation of elements that would retain characteristic lesions like the one utilized for the current study. If cattle rearing was a crucial part of the Middle Neolithic and Copper Age subsistence economies, it would be expected that some prevalence of tuberculosis would be observable with the population. Additionally, the compound specific analytical techniques used in proteomic research can also reveal additional information regarding the presence or absence and relative abundance of specific essential amino acids that are components of marine and freshwater fishes and mollusks, terrestrial animals, and secondary milk products. The need to detect milk derivative proteins from digested dairy products is a critical avenue to explore to produce a more complete picture of Neolithic and Copper Age subsistence, as seen within the current project. The results of these types of analyses can help provide necessary evidence to strengthen assertions regarding the importance of cattle during the Neolithic or even provide a basis for further studies of dairying behavior in prehistory.

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APPENDIX A: DATA COLLECTION PERMISSIONS

Ministero dei Beni e delle Attività Culturali

SOPRINTENDENZA ARCHEOLOGIA, BELLE ARTI E PAESAGGIO
PER LE PROVINCE DI CREMONA, LODI E MANTOVA
– MANTOVA –

Mantova, 19 LUG 2019

Alla c.a. University of South Florida
Department of Anthropology
4202 East Fowler Avenue, SOC 107
Tampa, Florida (USA)
Dott. A. Vianello
avianello@mail.usf.edu

Lettera inviata solo tramite e-mail
SOSTITUISCE L'ORIGINALE
ai sensi art. 43, comma 6, DPR 445/2000

E p.c. Museo delle Civiltà
Museo Preistorico Etnografico "Luigi Pigorini" – Roma
mbac-mu-civ@mailcert.beniculturali.it
Dott.ssa A. Sperduti
alessandra.sperduti@beniculturali.it
Dott. Claudio Cavazzuti
claudio.cavazzuti@beniculturali.it

Prot. n. 5847 *Allegati* *Risposta a Vs prot. n.* *del*
Cl. 34.34.43 *ns prot. n.* *del*
Fasc. CV

Oggetto: **Provincia di Mantova. Sepolture di età neolitica ed eneolitica in corso di studio presso la Sezione di Bioarcheologia del Museo delle Civiltà (Museo Preistorico Etnografico "Luigi Pigorini"). Autorizzazione al campionamento di frammenti di radice dentale per indagini isotopiche.**

Con riferimento alla Vostra richiesta di autorizzazione al campionamento di frammenti di radice dentale di alcuni individui provenienti da sepolture di età neolitica ed eneolitica del territorio mantovano, attualmente in corso di studio presso la Sezione di Bioarcheologia del Museo delle Civiltà (Museo Preistorico Etnografico "Luigi Pigorini"), e facendo seguito alle comunicazioni intercorse, questa Soprintendenza autorizza Christopher Eck, dottorando di ricerca presso l'Università della South Florida, a effettuare il campionamento in oggetto, preordinato all'esecuzione di indagini isotopiche finalizzate alla ricostruzione della dieta e datazioni al radiocarbonio, esprimendo le seguenti prescrizioni.
Potrà essere effettuato un singolo campionamento per individuo e solo per gli individui che presentano più denti, in modo tale da garantire future analisi; si chiede inoltre di limitare quanto più possibile la quantità di tessuto osseo prelevato.
Nella scelta degli individui da sottoporre al campionamento e delle modalità del campionamento medesimo si chiede di fare costante riferimento ai Funzionari antropologi del Museo delle Civiltà, dott.ssa Alessandra Sperduti e dott. Claudio Cavazzuti.
Restando a disposizione per eventuali chiarimenti si porgono cordiali saluti.

IL SOPRINTENDENTE
dott. Gabriele Barucca
IL FUNZIONARIO AMMINISTRATIVO
Dott.ssa Marialuisa Ferrari

Il responsabile dell'istruttoria
dott. Leonardo Lamanna

MiBAC MINISTERO PER I BENI E LE ATTIVITÀ CULTURALI
SOPRINTENDENZA ARCHEOLOGIA BELLE ARTI E PAESAGGIO PER LE PROVINCE DI CREMONA, LODI E MANTOVA
Piazza G. Paccagnini, 3 – 46100 Mantova – tel. (+39) 0376 1709686
PEC: mbac-sabap-mn@mailcert.beniculturali.it – PEO: sabap-mn@beniculturali.it
C. F. 93071950203