Mobility and Social Organization on the Ancient Anatolian Black Sea Coast: An Archaeological, Spatial and Isotopic Investigation of the Cemetery at İkiztepe, Turkey

by

Megan Lynn Welton

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Abstract

This thesis undertakes a complete reinvestigation of the archaeology of a large Early Bronze Age cemetery at İkiztepe in northern Turkey, by utilizing oxygen and strontium isotope analysis of human remains in combination with spatial and biodistance analysis and various dating techniques to identify potential immigrants to the site and to examine larger issues of residential mobility and social organization.

The occupation of the Northern Anatolian site of İkiztepe is traditionally assigned to the Late Chalcolithic and Early Bronze Ages. However, the site's chronological framework has been challenged in recent years. These chronological issues have been addressed by applying fluoride and AMS radiocarbon dating to the skeletal remains from the İkiztepe cemetery, to develop an absolute and relative chronology for the burials. These results have shown that the cemetery dates at least a millennium earlier than previously supposed.

Oxygen and strontium isotope analyses allowed the identification of individuals whose bone chemistry suggests that they were possible long distance immigrants to the site of İkiztepe, as well as suggesting the existence of a group of mobile individuals who may represent a transhumant segment of the İkiztepe population.

Spatial and biodistance analyses suggest that principles of cemetery organization in this period were highly complex. Immigrant individuals and nomadic or semi-nomadic segments of the population do not appear to have been distinguished in any observable way from their sedentary local counterparts, displaying similar burial types, grave goods and spatial locations. Furthermore, burial within the İkiztepe cemetery does not appear to have been kin structured. These results suggest that assumptions about funerary practices as important indicators of cultural identity and lineage affiliation may represent an over-simplification of complex patterns of interaction and integration among and within populations and cultural groups.

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Chapter One: Introduction

The Early Bronze Age in Anatolia (ca. 3300-2000 BC) has frequently been described as a period of major social change, characterized by the development of complex urban societies. Moreover, it is often suggested that it is during this period that groups who later develop into the Hittite civilization first make their appearance in Anatolia. Some view these groups as immigrants originating from southeastern Europe or the Russian steppe region (Yakar 1981, 1984, 1985a, 1985b; Mellaart 1981; Backofen 1985; Mallory 1989; Anthony 1991). Others prefer to see these groups as representing the indigenous development of local Anatolian populations (Bilgi 2003a). İkiztepe, located on the Black Sea coast near the modern city of Bafra, is one of the largest and most intensively excavated archaeological sites in northern Anatolia. According to its excavators, İkiztepe was first settled during the Late Chalcolithic period (ca. 4500-3300 BC), with occupation continuing throughout the Early Bronze Age (Alkım *et al* 1988; Alkım *et al* 2003). As such, its occupation spans this crucial period of socio-cultural transformation in Anatolian prehistory. Throughout the occupational sequence at İkiztepe, archaeological evidence has been suggested to indicate connections to the Balkans, southeastern Europe and southern Russia (Yakar 1981; 1984, 1985a, 1985b; Alkım *et al* 1988; Thissen 1993; Steadman 1995; Parzinger 1993; Alkım *et al* 2003; Zimmermann 2007). The exact nature of these connections remains the subject of debate, and a variety of mechanisms are often invoked to explain them, including migration, trade and cultural diffusion.

A large cemetery at İkiztepe dated to the Early Bronze Age has produced 685 burials, which contained the remains of at least 720 individuals (Bilgi 2003a, b). The burial practices employed display limited similarities to other Anatolian sites, with only a few examples known from a small number of sites in the immediate vicinity (Kökten *et al* 1945; Özgüç 1948a; Özgüç & Akok 1958; Mellink 1972; Mellink 1974; Wheeler 1984, Bilgi 2003b, 2004). Despite the limited parallels outside this circumscribed area of Anatolia, there are also parallels to burials at sites on the western Black Sea coast (Bilgi 2003b, 2004; Ivanov 1978, 1991; Todorova 1989, 1992, 2002; Todorova & Dimov 1989). However, many of these parallels date to the Chalcolithic period, prompting suggestions that the earliest part of the cemetery at İkiztepe may in fact date to the Late Chalcolithic (Parzinger 1993, Zimmermann 2007). The skeletal material from the cemetery has also been used to support the idea of a southeastern European origin for the population at İkiztepe. Craniometric evidence has been used to suggest that the population at İkiztepe does not demonstrate characteristics of typical Near Eastern and central Anatolian populations, but instead bears more similarity to northern Black Sea populations in southeastern Europe and southern Russia (Backofen 1985).

Other similar craniometric studies have been conducted in the past to examine the origins of Anatolian populations (Krogman 1949; Şenyürek & Tunakan 1951; Cappieri 1970; Rathbun 1982). Studies of this kind have fallen out of favour in recent years, due to the fact that they rely on very limited numbers of metric variables, and due to questions about the heritability of cranial metric traits (Sjøvold 1984, Carson 2006). However, these skeletal remains have the ability to provide a direct line of evidence about the lives of Early Bronze Age Anatolian populations. Skeletal tissues such as bone and enamel take on the chemical signatures of the local environment in which they were formed. This means that chemical analysis of skeletal material can be used to identify the location of residence at the time of the formation of the tissue. As a result, it is possible to identify immigrants to a particular site, as well as to discern patterns in the chemical signatures of subgroups within the population. Analytical methods commonly used for this purpose include radiogenic and stable isotopic analyses for elements such as strontium ($^{87}Sr/^{86}Sr$) and oxygen ($^{18}O/^{16}O$), as their composition in human tissues can be directly linked to local geological and climatic patterns. Due to the fact that strontium has a similar ionic radius to that of calcium, strontium is sometimes incorporated into bone in place of calcium (Faure 1986; Price *et al* 1994). The isotopic composition of strontium ($^{87}Sr/^{86}Sr$) in bone or enamel reflects the local geology of the environment in which the tissue was formed (Price *et al* 1994; Bentley 2006). Similarly, the isotopic composition of the oxygen ($^{18}O/^{16}O$) incorporated into bone or enamel is controlled primarily by water consumed and atmospheric oxygen (O_2) (White *et al* 1998). As a result, the oxygen isotopic composition in bone and enamel reflects local geography and climate. The constant process of remodeling in bone means that the isotopic composition of human bone samples generally represents the average local conditions during the last 2-20 years of life. In contrast, tooth enamel is formed during childhood and does not remodel, and thus reflects local conditions at the time of its formation during the early years of life. As a result, it is possible to use isotopic signatures in these two tissues to identify individuals who have moved between different areas during their lifetime. There have been no previously published studies that have used isotopic data to examine human population movements in Anatolia. Both strontium and oxygen isotope studies of skeletal material have been used successfully in a variety of archaeological contexts to answer questions about mobility and migratory processes, such as Neolithic Bell Beaker and *Linearbandkeramik* cultures in Europe (Grupe *et al* 1997, Price *et al* 1998, Bentley 2001, Bentley *et al* 2002, 2004), in Central and South America (White *et al* 1998, Price *et al* 2000, Hodell *et al* 2004, Wright 2005; Knudson & Price 2007), in the Nile Valley and the Dakhleh Oasis in Egypt (Dupras & Schwarcz 2001, Buzon *et al* 2007) and in the prehistoric American Southwest (Price *et al* 1994, Ezzo *et al* 1997, Ezzo & Price 2002).

The Early Bronze Age cemetery at İkiztepe has produced a sizeable, well-preserved skeletal sample. 720 individuals have been excavated in total, and it has been estimated that over 90% of the entire cemetery was excavated (Bilgi 2003b, Backofen 1987: 175). As such, it represents an ideal case for the use of strontium ($^{87}Sr/^{86}Sr$) and oxygen ($^{18}O/^{16}O$) isotope analyses. Bone and enamel samples were collected from a subset of the İkiztepe population for isotopic analysis. This study primarily focuses on enamel samples in order to identify individuals who spent their early years outside the İkiztepe area. This is augmented by the analysis of a more limited group of human bone samples. Natural local variation in isotope values was determined by also analyzing a sample of archaeological faunal remains excavated from burial contexts within the cemetery. These results provide a baseline against which to evaluate the human population to identify non-local isotopic signatures.

In order to resolve the issue of the contemporaneity and chronology of the burials from the cemetery, a combination of fluoride and AMS radiocarbon dating was used. Fluoride dating represents an effective and relatively inexpensive means of providing relative dating of bone samples, and can be used to distinguish very small temporal differences (Schurr 1989). It has previously been shown to be useful for determining relative chronologies of burials in cemetery collections (Ezzo 1992). Fluoride dating was performed on each of the individuals selected for isotopic analysis for which bone samples were available, and were used to provide a relative sequence for the burials at the site. Finally, two samples were sent for AMS dating, in order to provide a chronological foundation for the relative sequence. Such a chronology addresses longstanding questions about the time span that the cemetery at İkiztepe represents, as well as where it should be placed in terms of its chronological relationships to other parts of the site and to neighboring regions such as central Anatolia and southeastern Europe.

The results of the strontium and oxygen isotope analyses allow the identification of individuals whose bone chemistry suggests that they were immigrants to the site of İkiztepe. This contributes an entirely new form of data to the ongoing debate regarding the question of the influence of external populations through immigration vs. the indigenous development of İkiztepe and Anatolian society in general. In addition, these analyses provide evidence for overall levels of residential mobility in northern Anatolian populations during the Early Bronze Age. The comparison of the isotope data with the spatial organization of individual burials within the cemetery contributes to our understanding of how immigrant individuals in early urban centres were integrated into their new communities, and how the internal organization of cemeteries may reflect ancient concepts of social identities. Moreover, the comparison of these lines of evidence with data regarding the artifacts found in association with each individual burial elucidates the degree to which material culture, in particular grave goods, can be associated with the geographic origin of the burial's inhabitant.

In addition, patterns in chemical signatures in bone and enamel with respect to age, sex and other variables provide further information on Early Bronze Age social structure. Differences in levels of variation in isotopic signatures between males and females have been used in previous studies to reconstruct patterns of post-marital residence (Bentley 2001; Bentley *et al* 2005). Furthermore, craniometric data for the İkiztepe population has been gathered and analyzed in the context of examining levels of phenotypic variation and biological distance between individuals and groups within the cemetery, which is then profitably integrated with the isotopic data to form a broad picture of social organization in an Early Bronze Age Anatolian community. The majority of isotopic studies of migration take an exclusively regional perspective in interpreting their data. The nature of the cemetery at İkiztepe, with its large sample size and good levels of preservation, provides a unique opportunity for the combination of this broader approach with a less commonly employed intra-cemetery perspective. This type of approach has begun to receive more attention in recent studies of biological distance, which have addressed questions about post-marital residence, kinship and cemetery structure (Stojanowski & Schillaci 2006). The use of spatial and biodistance analysis to inform the interpretation of the isotopic results provides a powerful means of examining shifting relationships between geographical origin, kinship ties and cemetery organization.

Migration and Mobility as an Archaeological Process

Because this study focuses heavily on reconstructing migration and mobility practices at İkiztepe through the use of isotopic and biodistance analyses, it is essential to consider the broader archaeological and anthropological theoretical context of mobility studies. Historically, human mobility and migration have been important concepts in archaeological theory for explaining the distribution and change in patterns of material culture, as well as for understanding population dynamics and demography. The association of particular geographical and temporal patterns in material culture with specific ethnic groups led to the identification of major shifts in material culture with the movements of particular population groups (i.e., Childe 1926). With the rise of processual archaeology, however, the use of migration as an explanation for patterns in the archaeological record became unpopular and unfashionable in anthropological circles (Adams *et al* 1978; Anthony 1990, 1997; Chapman 1997; Burmeister 2000). This trend was not so much a commentary on the lack of importance of mobility in shaping social organization as it was a result of the lack of a strong theoretical basis for the interpretation of how migration can be linked to changes in material culture (Adams *et al* 1978: 523; Anthony 1990; Burmeister 2000). In addition, many questioned the implicit assumption in most studies of migratory events, that particular aspects of the archaeological record can be associated with specific cultural or ethnic groups. However, it has also been suggested that the decline in archaeological interest in migratory processes is a reflection of modern political and cultural attitudes (Chapman 1997; Härke 1998; Burmeister 2000). It is only more recently that migration has re-emerged as an important concept in archaeological explanation, with attempts to link archaeological theory to patterns observed in the fields of population geography and demography. A series of articles have called for the resurrection of migration as an important archaeological concept, and for more thorough attempts to theorize about the archaeological manifestations of population movements (Rouse 1986; Anthony 1990, 1997; Burmeister 2000; Beekman & Christenson 2003).

Studies of population movements in biological anthropology have undergone similar shifts in academic interest. Analytical methods focusing on phenotypic variation came to have a reputation associated with racial typology, and were for many years viewed with suspicion. More recently, such studies have returned to prominence, drawing on concepts from population genetics to examine patterns of variability for inferring gene flow between populations. Furthermore, through the analysis of both ancient DNA extracted from skeletal remains and the distributions of genetic markers in modern populations, models of demic diffusion have proliferated in the scholarly literature (Ammermann & Cavalli-Sforza 1984, Renfrew 1987, Sokal *et al* 1991, Barbujani *et al* 1995, Barbujani *et al* 1998, Pinhasi and Pluciennik 2000, Bentley 2001, Bentley *et al* 2002, Bentley *et al* 2003, Bentley *et al* 2009, Steele 2009).

The need for the development of a body of theory for the archaeological identification and study of migratory processes is a crucial one, as it is clear historically that migration cannot be discounted as a significant force in social and cultural change. Migration is often viewed as a process of influx of new populations with the subsequent replacement of the original indigenous population (i.e. Rouse 1986: 12), but the reality is likely to be significantly more complex. It is rare for migration events to involve the complete replacement of one population with another. Rather, high levels of mobility lead to heterogeneous populations with complex intra-societal patterns of interaction (Barth 1969; Burmeister 2000; Stone 2003). Anthony points out that frontiers between cultural and ethnolinguistic groups are not biological ones. Instead, people frequently move back and forth across these boundaries (Anthony 2007). Ethnographic and historical studies of mobility patterns suggest that migration levels in pre-industrial populations are likely to be higher than is often assumed, particularly short-distance movements within or between neighbouring communities, through such practices as post-marital residence patterns and mate exchange (Anthony 1990; Anthony 1997: 29-30). Studies of modern migration patterns indicate that it is linked to a wide range of broader cultural processes, including changes in subsistence strategies, urbanization and social organization (Anthony 1990, Burmeister 2000). Moreover, migration is an important force in determining the demographic structure of populations, and thus any understanding of ancient demography must necessarily incorporate some understanding of migration patterns. Finally, the tendency to discount nomadic and pastoral groups as impossible to identify archaeologically has led archaeologists to overlook major segments of the population.

Despite the almost universal applicability and importance of human mobility, the development of a secure theoretical basis for its interpretation has been problematic, as its study has become segmented and compartmentalized by different methodologies and approaches. Biological anthropologists consider mobility at an intra- or inter-regional level and address it in terms of patterns of gene flow between populations, often examined through the study of phenotypic or genetic variation. Others have studied direct evidence for mobility through the analysis of the chemical and isotopic composition of ancient human tissues or by proxy through the movements of animals herded by pastoral segments of human populations. Archaeologists have begun to embrace theoretical aspects of economic and population geography to model human migrations and to discern patterns of evidence available from material culture. Other archaeologists have employed ethnographic and ethnoarchaeological studies of modern or historical pastoral and nomadic groups to interpret and understand the often ephemeral remains and signatures left by these groups, in order to access these often under-represented aspects of society in the distant past.

Rarely are these methodologies and approaches integrated and combined to provide a comprehensive picture of the nature and effects of mobility at a societal level. Mobility occurs at many different scales, both geographically and temporally. It may occur over short or long distances; it may represent a single event or a habitual practice; it may be permanent or temporary. However, each of these different types of movement can have significant effects on broader patterns of social organization at the familial, tribal, local and regional scales. An integrated approach to understanding these different kinds of movements and their interactions is essential for improved understanding of both population dynamics, demography, patterns of material culture and the expression of identity within a variable and changing population.

Despite the importance of migration as a sociocultural phenomenon, and the recent renewed interest in the topic, the archaeological identification of ancient population movements is still problematic. This can be partially attributed to simplistic understandings of how migratory movements appear in the archaeological record. Rouse (1958, 1986) developed a model with the goal of identifying migration in the archaeological record and then tested it with a number of archaeological case studies. In this model, he distinguishes three alternative hypotheses for explaining the interactions of different cultures (Rouse 1986: 13). These three hypotheses were population movement, local development and acculturation (Rouse 1986: 13). Local development involves the separate development of two or more groups of people through a series of cultural characteristics without the loss of their individual identities (Rouse 1986: 13). These groups may also influence each other through transculturation. Acculturation involves the process by which a group of people adopts the culture of another group, thus losing its own individual identity (Rouse 1986: 13). Both transculturation and acculturation are special cases of diffusion.

There are a number of issues that are identifiable with Rouse's model. First, there is no reason to consider these various explanations as mutually exclusive. Furthermore, Rouse's definition of population movement is rather unsatisfactory. He explicitly excludes immigration from his definition, considering only population movement (Rouse 1986: 13). He defines population movement as the expansion of a group into another area and the replacement of this area's original population (Rouse 1986: 13). He defines this as a macroprocess, consisting of larger groups, while immigration is a microprocess, consisting of only small numbers of individuals (Rouse 1986: 176). Rouse describes immigration as an intrusion of individuals who are either assimilated by the population at their destination or who overwhelm the local population by sheer force of numbers over time, creating a population movement (Rouse 1986: 176). This definition is too narrow to be truly representative of human mobility and its visibility in the archaeological record. Furthermore, this definition probably significantly misrepresents the reality of human population movements.

Rouse's criteria for identifying migration archaeologically are extremely stringent, and suggest that migrants must be identified as an intrusive element in their destination area and should be traceable back to their homeland through aspects of their material culture. Furthermore, it should be demonstrated that conditions favourable for migration existed at the time of the population movement and that no other potential explanation (such as local development or diffusion) could also fit the evidence available (Rouse 1958). Others have further contributed to the problem of identifying migrations archaeologically, suggesting that in order to demonstrate the presence of a migratory group, all the cultural subsystems observed in the group's homeland should be present in the destination location, rather than a small subset of these cultural subsystems (i.e. burial practices) (Sanger 1975). In fact, migrating populations are more likely to utilize simplified inventories of the cultural assemblage of their homeland (Snow 2009: 18). In addition, Snow points out that these criteria essentially put the burden of proof on migration, with an automatic null hypothesis that no movement of people was likely to be taking place (2009: 18).

Population Geography

As previously discussed, one of the problems that has plagued the archaeological study of mobility is the oversimplified views of how migrations occur and how they should appear archaeologically. This has often resulted from the view shared by many archaeologists that theories developed by population geographers about the structure of modern and historical migrations are completely irrelevant for the understanding of ancient mobility. For example, archaeologists have suggested that "a population movement resembles the passage of a wave of water, which proceeds only in one direction and along a broad front. Populations, like waves, advance areally rather than lineally" (Rouse 1986: 177). This view is, in fact, entirely contradictory to the vast body of theory developed to model patterns of migration in the field of population geography. Fortunately, in recent years, archaeologists have begun to incorporate aspects of migration theory developed by population geography into their consideration of the archaeological record. Some of the key ideas that have shaped archaeologists' ways of thinking about migration are outlined below.

Streams and Counter-streams

The idea of streams and counter-streams in migration was first described by Ravenstein (1885), who stated that for each main "current of migration", a compensatory "counter-current" of migration develops. This idea was further developed by Lee (1966), who confirmed the idea that migrations tend to take place along well-defined routes, or "streams". He also developed Ravenstein's idea of the counter-stream, which develops in response to a major migration stream. Lee also discussed patterns in the "efficiency" of the stream (which is measured by the ratio of the size of the stream to the size of the counter-stream). He suggested that this measure will be high in cases where negative factors at the location of origin were primary in the formation of the migration stream in the first place, and where intervening obstacles are difficult to overcome; he suggests that this measure will be low in areas where there is great similarity in between origin and destination (Lee 1966: 925-927; Lewis 1982: 21).

These ideas about the general structure of population movement are particularly important to archaeological understanding and interpretation of ancient migration patterns. First of all, it suggests that the view of population movements as waves of people sweeping haphazardly across the landscape is likely to be incorrect. Rather, archaeologists should view migration as a more targeted phenomenon traveling between particular areas along well-developed routes of communication. These routes may conduct not only migrants, but also ideas, and thus may represent complex combinations of migrating individuals and cultural diffusion. Furthermore, these ideas suggest that migration should not be viewed as a uni-directional phenomenon. Rather, migration should be viewed as occurring bi-directionally along "streams" of communication. Archaeologically, it is important to consider that counterstreams should have archaeological consequences, just as the original stream does. The relative archaeological influences of these bi-directional movements in each location may be determined by a number of factors, including geography and the motivations of the individual migrants. In addition, the possibility of return migration by original migrants should be considered.

Selectivity of Migration

Migration is not a random process, but is rather selective. Individuals who engage in migration do not represent a random sample of a population; instead, certain individuals are more likely than others to engage in migration. One of the most important selective factors in determining who is likely to migrate is age and/or life stage (Lee 1966: 925-927; Lewis 1982: 22). Migrants most often tend to be late adolescents or early adults, particularly those in their twenties or early thirties (Lewis 1982: 83).

A number of studies have attempted to make generalizations about the kinds of individuals most likely to migrate. However, these generalizations have not always been constant across various models. While most scholars suggest that young adults are most migratory, agreement on the relative mobility of the sexes has been less consistent. For example, recent scholars studying modern populations suggest that males tend to be more mobile than females (Lewis 1982: 83). This should be contrasted, however, with Ravenstein's early characterization of females as more migratory than males (1885). Conclusions regarding greater male mobility are based heavily on modern Western examples (Lewis 1982: 84), while in pre-modern populations the common occurrence of patrilocal post-marital residence patterns may increase female mobility.

Because modern studies of migration tend to focus heavily on economic motives for migration (see below), it is often proposed that there is a significant connection between the structure of an area's economic activities and the composition of groups of individuals who choose to migrate (Lewis 1982: 87). However, an important determining factor in the selectivity of individuals who migrate is in the nature of kin relationships; kin connections in potential destination areas greatly increase the probability of migration to those areas (Lewis 1982: 88, Curran & Agardy 2004: 211-212). The key factor in this process is the availability of information about the potential destination of the migratory movement. It is important to note that such information does not *cause* an individual to migrate, but rather affects their decision with regard to their destination (Anthony 1992: 174-175). Furthermore, this information does not necessarily have to be accurate in order to affect the selectivity of migration to a particular area (Anthony 1992: 174-175).

"Push" and "Pull" Factors

Conditions that cause individuals to make the decision to migrate result from a combination of "push" and "pull" factors. "Push" factors are negative conditions in the area of origin that result in the desire to leave, while "pull" factors are positive or attractive conditions in the potential destination that draw the individual to migrate to that location (Lewis 1982: 100). Push factors may include such conditions as declining natural resources, lack of employment or livelihood, oppression or discrimination, alienation, lack of opportunity for marriage or personal development, or catastrophe (Lewis 1982: 100; Kliot 2004: 78-84). Pull factors may include greater opportunities for employment or increased prosperity, improvement in living conditions or environment, dependency on other migrating individuals, or the opportunity to engage in different activities or with different social groups (Lewis 1982: 100-101). These factors are weighed by individuals or groups through basic cost- benefit analysis (Anthony 1997: 22-23, 25).

These studies by population geographers of modern migrations often focus on economic motivations for movement; this could be a limitation archaeologically (Anthony 1990: 898). Other factors may have been equally as important in ancient times (i.e. ideology).

Types of Migration

There have been many different methods of breaking down migration into different types (i.e. see Lewis 1982: 15-19, Peters & Larkin 1979: 170-172, Sokal 1991, Tilly 1978, Anthony 1997). A number of important distinctions between different types of migrations contribute to these various categorization schemes. These distinctions include the motivational nature of the migration (i.e. voluntary or coerced--Peters & Larkin 1979: 172; Snow 2009: 10), as well as the distance of the migration (i.e. local or international). The distances moved during migration are heavily mediated by the prevailing mechanisms of travel available (Anthony 1997: 22, Snow 2009: 10).

For example, Sokal has developed a terminology for different types of migration (Sokal 1991; Snow 2009: 10-11). These include:

- *Peopling*, which represents the initial occupation of a previously uninhabited area by humans.
- *Partial migrations*, which involve the migration of only fractions of the whole population.
- *Territorial expansion*, which involves dominant populations expanding into already inhabited areas at the expense of subordinate ones.
- *Territorial contraction*, occurring as a result of the response of subordinate populations to the expansion of dominant ones.
- *Conquest*, similar to territorial expansion, involves the expansion of a dominant population at the expense of a subordinate one, but is more intentional and forcible.

- *Coerced migration*, occurs when subordinate or conquered populations are relocated by dominant populations.
- *Colonial settlements and military garrisons* represent the movement of individuals into separate enclaves existing within other populations, most often within subordinate populations.
- *Military attacks,* often represent the first stage in conquest, but need not be followed by further population movement.

These types of migration may be difficult to identify archaeologically, particularly in cases where there are no historical records to help archaeologists understand the political relationships between populations. Furthermore, these definitions are somewhat problematic from the point of view of archaeological theory, as they focus heavily on migration and population movement resulting from strong inequalities in power structures between origin and destination populations. The focus on dominant and subordinate populations leads us back to the problems encountered in archaeological interpretations of migration, which have often assumed the dominance or replacement of one population by another, rather than focusing on more complex methods of incorporation of migrants. In addition, movements between populations that do not represent the result of a significant power imbalance between them are only described in the one type of migration, the poorly-defined category of "partial migrations". This definition system thus lumps much of the variability involved in human migration into a single category.

One of the most useful categorization schemes for types of migration for archaeologists was originally proposed by Tilley (1978) and further developed for use by archaeologists by Anthony (1997). This categorization scheme includes:

- *Local migration* (Anthony 1997: 26), which includes the vast majority of migratory movement. This group may include pastoral nomads, and also includes changes of residence that occur due to marriage practices. The basic premise, however, is that migrating individuals remain within the same network of kin, marriage and exchange systems, to areas with shared economic and geographic knowledge
- *Circular migration* (Anthony 1997: 26), which includes individuals who routinely move outside of their home range to achieve a specific goal but intend to eventually return to

their location of origin. In most cases, the motivation for circular migration is economic (i.e. migrant laborers).

- *Chain migration* (Anthony 1997: 26-27) is a particularly important type of migration for archaeologists, as it encompasses much of the theory from population geography described above. This type of migration occurs when individuals follow earlier migrants, often kin, to a specific destination using a known route. The decision to migrate is strongly affected by access to information about conditions of life in the potential destination location, and the routes for getting there. Because this information is often conveyed by kin, this leads to kin-structured migration. In such cases, the first groups of immigrants to the area ("apex families") gain social status amongst later migrants.
- *Career migration* (Anthony 1997: 27) applies to individuals such as specialized craft workers, who must migrate for the purposes of their career, and may include soldiers, artisans, clerics and bureaucrats.
- *Coerced migration* (Anthony 1997: 27) refers to migration that occurs not by choice, but by compulsion by another individual or group; this may include displaced groups, refugees, slaves or social pariahs.

Nomadism/Transhumance

Another important issue in the archaeological study of mobility is nomadism. While the problem of how to identify the signatures of purely nomadic populations in the archaeological record has received a great deal of scholarly attention (Cribb 1991, Barnard & Wendrich 2008), perhaps the greater issue is the misguided traditional disassociation between nomads and settled populations (Bernbeck 2008, Szuchman 2009, Porter 2009). Porter points out that the idea "that pastoralists have no affective, that is, social and/or emotional, ties beyond the boundaries of their own immediate group, has proved very powerful in our reconstructions of pastoralism in the past, perpetuating this pervasive idea of an innate, an endemic, separation, if not outright hostility between the sedentary/urban world and nomads" (2009: 201). While migration is often thought of as something that affects settled populations alone, the assumption of the separation of nomads from sedentary groups has separated the study of nomadism from the study of migration, fragmenting the larger study of mobility in general.

A system of transhumant pastoralism has been observed ethnographically in many areas of modern Turkey, and is known as *yayla*. This is most often practiced in many Turkish mountainous coastal areas, and in particular in the Black Sea region by the Hemşinli, Georgians and Laz populations (Yakar 2000: 289). Although the modern system was introduced by the Yörüks, a semi-nomadic Turkish tribe that entered Turkey from Central Asia in the 10th century AD (Geray & Özden 2003: 128), there is reason to believe that these practices are well-adapted to mountainous coastal environments and that ancient populations may have practiced similar patterns of transhumance (Yakar 2000: 286). In fact, these incoming 10th century populations may have adapted their versions of nomadism to transhumant practices already in place in the region (Yakar 2000: 286).

Modern Black Sea populations exploit two or more vertically differentiated environments for subsistence, through a combination of small-scale agriculture and horticulture for self-consumption and intensive animal husbandry (Yakar 2000: 286). Winter months are spent in the coastal plain engaged in agricultural production of grains, while summer months are spent in high altitude mountain pastures, grazing sheep and goats (Yakar 2000: 286-287). In addition to larger permanent settlements in the coastal plain, rural communities at higher altitudes are primarily pastoral (Yakar 2000: 287). Those residing at higher altitudes, either permanently or temporarily, may also engage in small-scale horticulture in areas cleared of trees (Yakar 2000: 287). Only a portion of the coastal plain communities engage in seasonal transhumance, however; another segment of the population remains in the settlement year-round, tending to agricultural crops (Yakar 2000: 287). Most often, the division of labour between agriculturalism and pastoralism occurs not between households, but within them. In general, the distance between the *yayla* pasture location and the permanent settlement is less than one day's walk, allowing the maintenance of a close connection between the two locations (Yakar 2000: 287). In most cases, the transhumant portion of the population tends to travel relatively short distances to the *yayla* location, and the same pasture locations are returned to every year (Yakar 2000: 192). The same routes to and from pasture locations are generally used year-to-year, but are not necessarily permanent, depending on the availability of pasturage in the accustomed locations in a given year (Yakar 2000: 209). This kind of mobility structure is what is often termed *territorial* or *long-term* mobility (Kelly 1992: 45; Chang 2006: 187) or *tethered nomadism* (Cribb 1991: 18; Wendrich & Barnard 2008: 7). According to Barth's (1973) terminology, this kind of mobility lies somewhere between *mixed economies*, where all households perform all subsistence types in a non-specialized manner, but with relatively low mobility, and *integrated communities*, in which two separate segments of society exist alongside each other, one specializing in mobile herding and one focusing on sedentary agriculture. However, these standard sets of definitions for nomadic practices generally do not include terms for the kinds of mobility in which this segmentation occurs within each household, as observed in the *yayla* of the Black Sea region (Bernbeck 2008: 47). Such a case study, particularly relevant to the geographical area under consideration in this study, makes clear the fact that nomadic and sedentary segments of ancient populations (or even modern ones) are not as easily separable as many archaeologists have assumed.

Migration in Biological Anthropology and Population Genetics

The study of migration in biological anthropology has undergone similar shifts in intellectual popularity to those observed in archaeology. Many early studies that examined population movements were heavily intertwined with racial typology (i.e. Hooton 1930). Thus, analytical methods focusing on phenotypic variation with a goal of looking at population movement came to have a reputation associated with outmoded views of human variation (i.e. with racial distinctions), and were for many years viewed with great suspicion. More recently, such studies have returned to prominence as they draw on concepts from population genetics to examine patterns of variability for inferring gene flow between populations.

Bioarchaeological studies of ancient human populations that aim to study gene flow usually display some major differences from the studies of population genetics that they emulate. First, biological anthropologists most often must focus on the phenotypic traits of skeletons, as they lack genetic material for study. Phenotypic traits have varying levels of heritability, and genetic components often interact with environmental effects to create physical traits. Second, biological anthropologists cannot work within the same parameters of random sampling within a population that population geneticists can. They have a limited skeletal sample of the population in question available for study, and this sample is not a random sample of the population. A skeletal sample, for one thing, represents the portion of the population that died at a given age, rather than surviving. Thus, it should not necessarily be considered representative of the living population (Wood *et al* 1992). Furthermore, a cemetery skeletal sample likely does not represent a random selection of individuals who are genetically unrelated to each other; rather it represents a lineage, or a group of lineages, whose individuals are not genetically independent of each other. These facts naturally limit the ability of biological anthropologists to make inferences about population movement.

From the point of view of population genetics, migration takes on a slightly different meaning, where it is essentially considered equivalent to gene flow. While biological anthropology also approaches migration in this way, and has borrowed a great deal of its underlying theory from population genetics, the two fields differ somewhat in terms of what they are measuring to study migration. In population genetics, the migration coefficient (m) is not the actual number of individuals moving between areas, but rather the proportion of gametes contributed by immigrants to the genetic pool of the next generation of the recipient population (Fix 1999:1, 78).

As in population geography models, genetics models must consider the timing of migration within the life cycle. However, these considerations have a different purpose. It is important to know whether migrations are pre-marital or post-marital; or, more to the point, prior to or after the reproductive period (Fix 1999: 75). Because population genetics considers migration from a purely evolutionary point of view, migrants are not considered significant if they do not contribute to the gene pool in their destination location (Fix 1999: 76). Thus, migration and gene flow should be considered to be two slightly different phenomena; migration involves the movement of people, while gene flow involves the contribution of genes to a new generation. Gene flow can occur without a permanent change in residence and migration does not necessarily lead to gene flow. Archaeologically, of course, this distinction does not exist, as individuals do not have to reproduce to contribute to the archaeological record.

It has been observed that most models of migration in population genetics make the assumption that human migrations occur prior to population regulation (i.e. the high mortality rate that affects very young individuals) (Rogers & Harpending 1986; Fix 1999: 77). In most models, an infinite number of newborns or gametes are considered to disperse into the new environment, where they undergo regulation along with the local population. The process of genetic drift thus occurs during the regulation of the population *after* migration has occurred (Rogers & Harpending 1986; Fix 1999: 77). However, this model does not apply particularly well to human populations, for whom migration is generally most common in early adulthood

(Lee 1966, Lewis 1982). Thus, for human populations, migration most often occurs *after* population regulation, and after the effects of genetic drift have acted on the generation in question. Rogers & Harpending (1986) therefore produce an alternative model that incorporates these aspects of human life history into the genetic modeling of the effects of migration.

Gene flow through migration will counteract population differentiation that occurs as a result of isolation by distance (Lasker & Mascie-Taylor 1988: 2). The dispersal of individuals, and thus genes, between populations prevents differentiation into different subpopulations (Ramachandran & Feldman 2009: 23). Populations can be divided into subpopulations by endogamous marriage and inbreeding or by geographical barriers, through the differential action of genetic drift or localized selection. In fact, a very low migration rate is all that is required to counteract the process of differentiation due to genetic isolation (Fix 1999: 59).

Marital migration is thus generally viewed as genetically beneficial. In addition to preventing population differentiation, "wide ranging marital ties extend affinal kinship networks potentially reducing conflict and often allowing access to resources in time of need" (Fix 1999: 4). Furthermore, exogamy is considered to lead to the avoidance of inbreeding depression (Fix 1999: 4). Fix suggests that despite this common viewpoint, the problems associated with inbreeding in human populations have never been sufficiently documented (1999: 4). However, it seems clear that a minimum population size is required for a population to be endogamous (Fix 1999: 48). Below this level, fluctuations in age and sex ratios make it difficult to find a suitable mate, and individuals may have to look outside of the community. However, with populations above this level, finding a suitable mate is not as difficult, and individuals do not need to travel larger distances (Fix 1999: 48). Overall, it has been suggested that population size and density determines mean marital distance. For example, where population densities are low and populations are small, individuals tend to marry over a larger area than in populations with higher population densities and larger population sizes (Fix 1999: 48). Due to the important of marital migration for contributing to gene flow between populations, mean marital distance thus has a direct connection to the occurrence of overall migration.

However, a distinction should be made between the effects of random versus selective migration. The preceding discussion is only applicable if, as most models assume, selection of migrants contributing to the new population's gene pool is random. As discussed above among the theories developed in population geography, human migration is not a random process, but rather is extremely selective. If migrants are not random, but rather represent an unrepresentative genetic sample of their parent population, then migration could contribute to stochastic rather than stabilizing effects (Fix 1999: 56; Bentley *et al* 2009). Selective migration was originally not paid a great deal of attention, because scholars lacked empirical evidence of significant selectivity in the migration process (Lasker & Mascie-Taylor 1988: 2). However, many recent studies have been directed toward documenting and understanding the effects of selective migration, particularly kin structured migration.

Kin structured migration may include both the inclination of family groups to emigrate together as a group at one time, as well as the longer-term effect of the increased likelihood of migration if kin are present in the destination location (i.e. see chain migration, above) (Fix 1999: 90). Rather than contributing to increased similarity between migrating populations, in such cases kin structured migration contributes to an increase in the stochasticity of migration (Fix 1999: 80). Indeed, kin structured migration may actually lead to an increase in the genetic differentiation between populations (Williams Blangero 1989a; Williams Blangero 1989b; Fix 1999: 80). Such stochastic genetic effects do not only apply to the recipient population, but also to the donor population of kin-structured migration. The kin-structured emigration of particular genotypes may also have an effect on the frequencies of particular genes in the population the migrating group has emigrated from (Fix 1999: 90).

Isotopic Studies

A final approach, and one that is of some significance to this study, is the use of isotopic analysis for studying residential mobility in ancient human populations. Two elements have received the greatest amount of attention in terms of their ability to address questions of human mobility: strontium and oxygen, although other elements have also been used for this purpose, including carbon, nitrogen and lead. Strontium has been used for mobility studies in various wide-reaching geographical areas, including Crete (Nafplioti 2008), Greece (Richards *et al* 2008), the Nile Valley (Buzon *et al* 2007), Libya (Tafuri *et al* 2006), South America (Knudson *et al* 2004, Knudson *et al* 2005, Slovak 2007, Slovak *et al* 2009, Knudson & Price 2007), Central Europe (Hoogewerff *et al* 2001, Price *et al* 2002, Bentley *et al* 2002, Chiaradia *et al* 2003, Schweissing & Grupe 2003, Bentley *et al* 2003, Bentley *et al* 2004b, Bentley & Knipper 2005, Giblin 2009, Nehlich *et al* 2009), Iceland (Price & Gestsdottir 2006), southeast Asia (Bentley *et al* 2007a, Bentley *et al* 2007b, Valentine *et al* 2008, Shaw *et al* 2009), the United States (Price *et al* 1994, Ezzo *et al* 1997, Ezzo & Price 2002, Quinn *et al* 2008), Mexico (Price *et al* 2000, Hodell *et al* 2004, Price *et al* 2006), Siberia (Havercort *et al* 2008), and England (Montgomery *et al* 2005, Evans *et al* 2006, Evans *et al* 2006b, Leach *et al* 2009). Oxygen isotopes have been used less widely, but have been applied to human populations primarily in the Valley of Oaxaca and Teotihuacan (White *et al* 1998, White *et al* 2001, White *et al* 2002), the Dakhleh Oasis in Egypt (Dupras & Schwarcz 2001) and Southern Ontario (Schwarcz *et al* 1991). There have also been a number of studies that apply both types of analysis, providing a complementary approach to human mobility studies (Budd *et al* 2004; Bentley & Knipper 2005, Bentley *et al* 2005, Evans *et al* 2006, Evans *et al* 2006b, Knudson & Price 2007, Slovak 2007, Quinn *et al* 2008). Among other elements used for the study of prehistoric migration, lead isotopes have been commonly employed, but their fairly low variation over moderately-sized geographical areas results in decreased sensitivity compared to oxygen and strontium isotope analyses (Bentley 2001).

One of the most important points for understanding the approach of isotopic studies of human remains towards modeling human mobility is its inherent conservatism (Knudson 2004: 1995). Isotopic studies can only identify first generation migrants; they reveal no conclusive evidence about the self-designated identity of migrating individuals or their descendents, nor about their integration culturally or biologically into their destination population. Furthermore, they can only identify movement *between* zones that display enough isotopic variability to detect isotopic differences; movement within isotopic zones is not detected by this form of analysis. Depending on the geographical area under consideration, certain types of elements may not be sensitive enough to describe useful levels of population mobility, if regional variation in isotopic values is not sufficiently high. In addition, isotopic studies can only identify mobility within limited parameters within the life cycle. Human tissues such as bone and enamel provide a snapshot of the location of residence during early to late childhood (different ages provided by enamel of different teeth) and the last years of life (bone). Isotopic analysis of these tissues can therefore only identify changes in residence either between these life stages, or between these life stages and the ultimate location of burial. Mobility of individuals between these events may not leave any trace in bone or enamel and may thus be undetectable. Despite these potential limitations, isotopic studies have a number of benefits compared to other approaches to mobility; isotopic analysis can provide information about individual movements that even DNA analysis cannot, as it can speak to actual residence locations, rather than simply biological relationships between individuals.

Organization and Research Objectives

This introductory chapter provides a basic introduction to the research problem and to the theoretical background to the archaeological and bioarchaeological study of mobility. This theoretical overview emphasizes the problem of compartmentalization of the study of mobility into particular foci and methodologies. Because the aim of this study is to assess mobility and social organization using a number of complementary methods, a variety of approaches to the study of mobility are addressed.

Chapter Two assesses the archaeological evidence known from Northern Anatolia in general, as well as from İkiztepe in particular. It therefore comprises two broad goals. The first is to provide a regional context for the area in which the site of İkiztepe is located. This includes a brief geographical and environmental discussion of the conditions on the Black Sea coast, as well as an investigation of available evidence from archaeological survey in the region. Archaeologically, North Central Anatolia is relatively poorly understood; this chapter thus briefly discusses the little evidence that is available from the few excavated sites in the region. The second goal is to examine the archaeological evidence from the site of İkiztepe in particular. This chapter therefore addresses the history of excavation at the site and the occupation history as reconstructed by the site's excavators. It addresses the stratigraphic sequence from each individual settlement mound at the site, and reviews the available material culture from each sequence in turn. Finally, it discusses the archaeological context of İkiztepe from the perspective of both absolute and relative chronology, by examining both the published evidence for radiocarbon dates from the site, as well as the placement of the site within the larger archaeological context within the current accepted chronological framework of Anatolian archaeology.

Because this study focuses on the skeletal remains excavated from the cemetery at the site that is presumed to date to the Early Bronze Age, it is necessary to examine this cemetery in a larger regional context, particularly with regard to the mortuary practices observed in the region under consideration. Thus, the first part of Chapter Three addresses two major goals. First, this chapter describes the excavation of the cemetery and the burial practices employed within it, drawing upon previous work that has been conducted to examine the cemetery's organization. Second, this chapter presents a larger regional summary of burial practices contemporary to the cemetery at İkiztepe, in order to place the remains from this site in a broader mortuary context. Due to the fact that the burial practices employed in İkiztepe cemetery have been linked to a variety of mortuary traditions over a wide geographical area, this review discusses mortuary evidence from both Anatolia and southeastern Europe. Furthermore, because both the chronology of the site and the date of the İkiztepe cemetery have been highly debated, the overviews from both regions discuss burial practices employed throughout both the Chalcolithic and Early Bronze Age.

Cemetery organization and burial practices can provide valuable information about larger patterns of social organization, and thus Chapter Three also conducts a more intensive analysis of the organization of the İkiztepe cemetery based on the available data. A detailed map of the cemetery is presented, as constructed using Geographical Information Systems (GIS) software. This map is then used to conduct spatial analysis of the organization of the cemetery in terms of the placement of individuals from basic demographic groups, as well as the occurrence and distribution of grave goods of various types. The results of this analysis are then discussed with regard to the kinds of information they can provide about the means of organization of the cemetery in particular, and İkiztepe society in general.

Chapter Four provides an introduction to the skeletal sample from the cemetery at İkiztepe. This includes a basic demographic breakdown of the sample, as well as a review of its curation history. This chapter also reviews previous scholarship conducted on this skeletal sample, in order to provide a larger biocultural context for the ensuing analysis of the skeletal remains.

In addition to this discussion of the skeletal sample, the primary goal of Chapter Four is to examine patterns of phenotypic variation within the İkiztepe cemetery to determine what this source of information can reveal about social organization and population mobility. Thus, this chapter first provides an introduction to the theory and practice of biodistance analysis and intra-cemetery approaches to examining phenotypic variation, including analysis of post-marital residence and kinship analysis. It then presents the results of previous biodistance analyses that have been conducted on the İkiztepe skeletal sample, and interprets their results in light of the different approach taken by this study. This chapter then presents the data collected from the measurement of craniometric variables for a subsample of the İkiztepe population, as well as the results of the intra-cemetery analysis. These results are then discussed with regard to what significance they may have for delineating patterns of post-marital mobility, kin-structured burial practices, and overall social organization.

Over the many years in which isotopic analysis has been applied to archaeological problems, a vast body of literature has appeared that addresses the various problems of methodology, preservation and interpretation that can plague the use of isotopic studies in archaeological contexts. Chapter Five thus provides an overview of this literature, by first addressing basic issues of the application of isotopic studies to archaeology, including basic principles of mass spectrometry, as well as the formation and composition of human bone and enamel. It also provides discussion with particular regard to the two types of isotopes under consideration in this study, and their application to problems of residential mobility in humans ($\delta^{18}O$ and $^{87}Sr/^{86}Sr$). The chapter sections for each of these two elements address a series of important issues relating to these archaeological questions. For each element in question (strontium and oxygen), this chapter therefore describes basic isotopic chemistry of the element, as well as basic geographic or environmental patterns of variation and occurrence of the various isotopes of the element in question. In addition, the incorporation of the isotopes of the elements in question into human and animals tissues are discussed, in addition to biological and behavioral factors that may affect isotope signatures within a population. Furthermore, the issue of levels of intra-population variation in isotopic signatures is discussed for each element, particularly with reference to the issue of the definition of local and non-local signatures. The problem of diagenesis and its effect on isotopic signatures are discussed with reference to both strontium and oxygen, as are methodological considerations that may affect the measurement of isotopic composition. Finally, for each of the elements in question, expected ranges of isotopic values are discussed for the area around İkiztepe and the Black Sea coastal region.

Chapter Six presents in detail both the sampling strategy employed for conducting isotopic analyses on the İkiztepe skeletal sample, as well as the details of the methodology employed in the analysis. It then presents the results of the isotopic analysis for both oxygen and strontium analyses, with a focus on defining non-local signatures and identifying potential non-local individuals. It also presents basic analyses that look for patterns in the isotopic values and isotopic variation based on a variety of demographic, archaeological and spatial variables that might contribute to patterns in isotopic signatures. Finally, this chapter presents a discussion of the possible significance of the results of these isotopic analyses for population mobility (both long distance and short distance) and the incorporation of non-local individuals into the community.

One extremely important issue that affects the results of all of the analyses presented in this study is the issue of diachronic change. Due to a variety of factors, including the lack of knowledge about the chronological development of material culture in North Central Anatolia, and the lack of available information to seriate the graves in the İkiztepe cemetery stratigraphically, this issue has been virtually inaccessible in all previous studies of this cemetery. In Chapter Seven, a means of relative dating through the chemical analysis of bone by measuring the concentration of fluoride in the bone matrix is presented. The methodological issues with the application of this dating technique are discussed, and the methodology employed in this study is presented. Finally, this chapter presents the results of the measurement of fluoride concentration in bones from the İkiztepe cemetery, and discusses the potential significance that the relative seriation of burials may have to the interpretation of the various patterns observed in previous chapters.

Chapter Two: The Archaeology of İkiztepe

In order to properly contextualize the results of the craniometric, isotopic and chronological analyses of the İkiztepe cemetery presented in this study, a full understanding of the current state of knowledge regarding the site of İkiztepe is required. This chapter presents a comprehensive examination of the regional context of the site, both environmentally and archaeologically, as well as a summary of the results of excavations at the site of İkiztepe itself. The occupation sequence at the site is presented and discussed, as are the absolute and relative chronological issues associated with the site. These discussions are then utilized to address the broader context of the site within the current framework of Anatolian archaeological chronology.

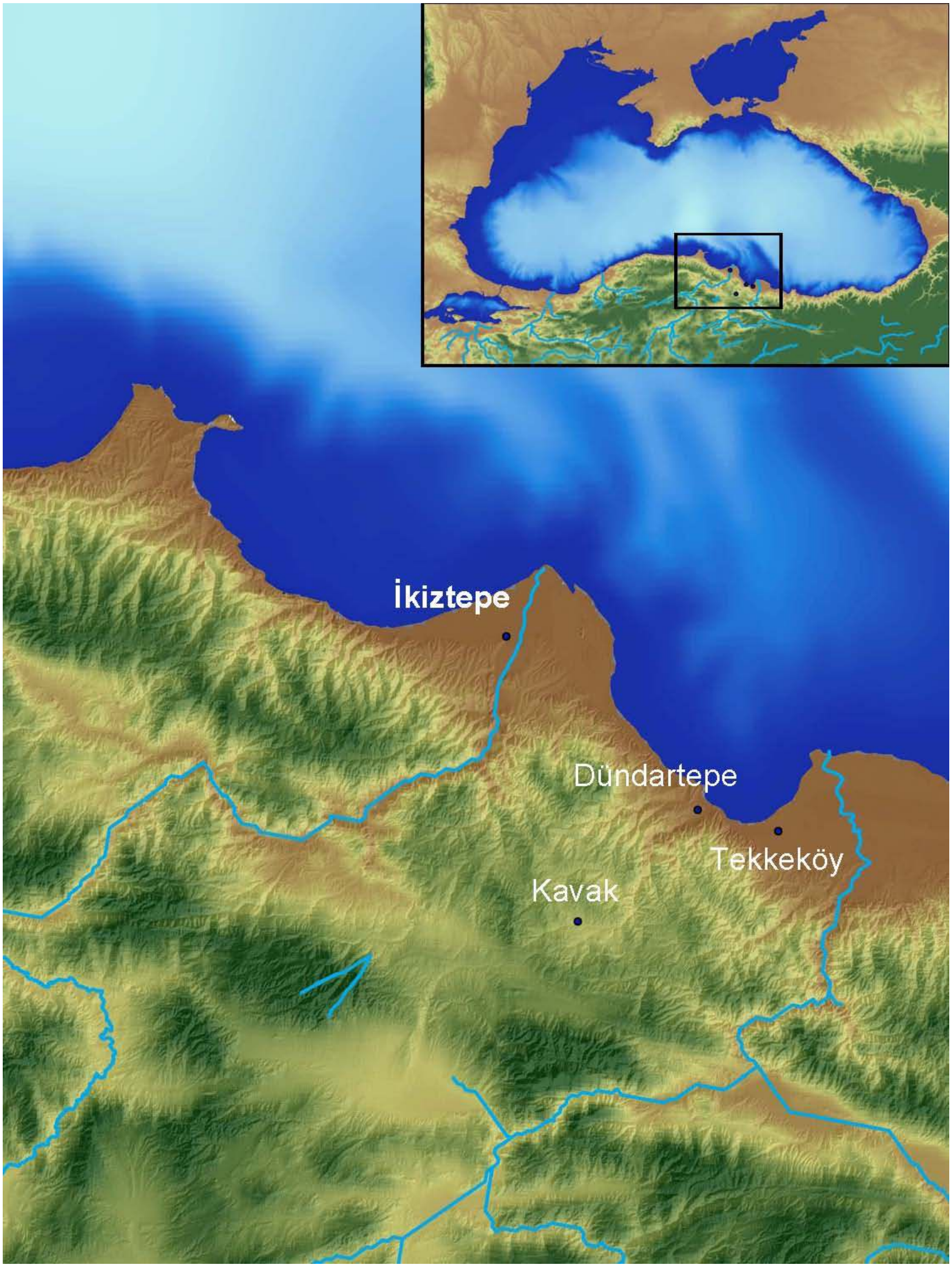
Environment

The environment of Northern Anatolia, along the Black Sea coast, is significantly different from that of the Central Anatolian plateau, possessing a wetter, milder, maritime climate, with higher rainfall and more moderate temperature variations (Burney 1956: 179, Doonan 2004: 17). The mean annual rainfall for Samsun, the nearest meteorological station, is 704.5mm with a mean annual temperature of 14.9ºC (mean January and August temperatures of 7.7ºC and 23.0ºC, respectively) (Van Zeist 2003: 548). Despite its maritime orientation, the climate is generally cooler than that of the Mediterranean coast to the south. Furthermore, rainfall in the central part of the Pontic Region, including the Bafra and Çarşamba Plains, is lower than in the area immediately to the west and east, which have more subtropical rainfall patterns (Van Zeist 2003: 548). With the exception of the alluvial plains formed by river outlets, there is very limited land between the foothills of the mountains and the Black Sea coast, and in ancient times these hills would have been heavily forested. The northern slopes of the Pontic Mountains are well watered and forested with deciduous species such as beech, chestnut, hornbeam, oriental spruce, yew and alder (Burney 1956: 178; Yakar 2000: 284). These species form the lower belt of the Euxinian forest, which spans from sea-level up to 1000m along the southern coast of the Black Sea (Van Zeist 2003: 548). Above this level, coniferous species become dominant (Yakar 2000: 284). In general, the upper limit of settlement in the Pontic Mountains is found at approximately 1000m, although small isolated hamlets may be found up to approximately 1450m (Yakar 2000: 287). Both the climate and the topography of the region have historically been factors in the determination of the construction techniques employed in the region. Today, most houses in the Black Sea coastal region are built on low wooden posts or resting on large boulders, with raised floors to provide ventilation and reduce humidity. Furthermore, wood has traditionally been, and still is, the principal building material used in the Bafra and Çarsamba plains, sometimes used in combination with stone or mudbrick construction (Yakar 2000: 295, Alkım *et al* 2003: 77-83).

Due to the barrier formed by the Pontic Mountains, natural communication routes through the area run naturally in a west-east direction, rather than north-south (Winfield 1977: 158). The simplest route into the interior is by traveling to Samsun, and from there along the Çorum road, which passes alongside the sites of Dündartepe and Kavak (Yakar 1985: 230). Transportation between this region and the Anatolian Plateau and areas further to the west (i.e. Sinop) was likely difficult (Burney 1956: 180). However, communication between the Bafra and Çarsamba plains was likely less restricted, due to the existence of a natural route between the two areas (Burney 1956: 180). In the Early Bronze Age, the Gökirmak Valley was likely an important communication route between north-central and northwestern Anatolia. This importance is suggested by the placement of a number of 3rd millennium sites along this route, including Tepecik, Çetme Höyük Tepesi, Karacaoğlu, and Bayram Tepesi (Yakar 2000: 284). Another major concentration of 3rd millennium sites is found along the lower reaches of the Kızılırmak and Yeşilirmak Rivers, as well as along the whole of the coastal region from Sinop to Bafra (Burney 1956: 181). Sites have also been recorded, although not as systematically, in the vicinity of the Çarşamba Plain, including Tepecik and Kilistepe (Yakar 1980: 81; Yakar 2000: 285). Throughout history, the Black Sea coast of Anatolia has been separated from the Central Anatolian plateau due to geographical detachment and the difficulties of communication, and instead has often had inter-connections with regions to the north, throughout the Pontic region (Doonan 2004: 8-9).

The Bafra Plain was much smaller in size during the Early Bronze Age than it is in its modern incarnation. The majority of the alluviation in the plain has occurred over the last 5,000 years and, when it was settled, İkiztepe was likely directly on the coast (Akkan 1970: Fig. 2; Alkım *et al* 1988: 145). The land available in the restricted area of the plain was likely very marshy, as was the case in the Bafra Plain until modern times, when drainage canals were created to remove the water (Akkan 1970: Fig. 5, Van Zeist 2003: 548). The resulting swampy environment has therefore traditionally led to problems with mosquitoes (Yakar 2000: 285, 297). As a result of these natural factors, viable agricultural land in the immediate vicinity of İkiztepe may have been limited. In contrast, whereas land along the Black Sea's southern coast was often geographically restricted, many of the river valleys along the northern coast have extensive fertile alluvial plains, ideal for cereal cultivation, (Doonan 2004: 10-11).

Map 2.1: Locations of Key Archaeological Sites Discussed in Text



Subsistence in the area of the Bafra Plain, and indeed throughout the coastal region likely consisted of fishing, animal husbandry and the cultivation of food products for self-consumption (Yakar 2000: 286; Doonan 2004: 9). In modern times, these practices are often seasonal, with time spent at low elevations for the planting of cereal crops in autumn, and summers passed at higher altitudes to allow the grazing of sheep, goats and cattle (Yakar 2000: 287; Doonan 2004: 6). Rural communities located in the more mountainous areas are primarily pastoral, a greater emphasis on agricultural subsistence is observed in the alluvial plains (Yakar 2000: 287). The limited agricultural land, however, suggests that cultivation primarily occurred at the subsistence level, preventing the development of intensive agricultural production. Overall, the evidence suggests a generalized subsistence pattern, drawing on a wide variety of available food sources.

From a historical point of view, early conjecture by Alkım posited that İkiztepe could be equated with Zalpa (or Zalpuwa), which is mentioned in the tablets found at Kültepe, as well as in an Old Hittite legendary text from Boğazköy (Alkım *et al* 1988: 196). In more recent publications, however, Bilgi discounts this equation of İkiztepe with Zalpa, on the basis of a lack of typical Central Anatolian-type finds that can be dated to the Assyrian Colony Period, as well as the fact that İkiztepe has produced no seals or bullae to support the idea that it was involved in trade at this time (Bilgi 1990: 169; Bilgi 2001: 40). He instead suggests a location for Zalpa to the south and further inland (Bilgi 2001: 40). It has also been suggested that during the Late Bronze Age, the Çarsamba Plain and the lower Yeşilirmak and Kelkit Valleys were inhabited by the eastern Kaska tribes (Yakar 2000: 295). Similarly, the Bafra Plain, including the lower Kızılırmak River (Hittite Marassantiya), and the hilly area to the south of the Bafra plain are thought to represent the central Kaska region (Yakar 2000: 296). The Kaska are traditionally seen as nomadic or semi-nomadic tribal groups who caused threats to towns on the northern border of the Hittite Empire, leading to political instability (Glatz & Matthews 2005). The Land of Tummanna shared a border with the Kaska in the Black Sea region, but was considered an ally of the Hittites (Yakar 2000: 296). Archaeologically, however, these historical reconstructions are difficult to examine or confirm, due to a lack of archaeological evidence dating the Late Bronze Age. The site of Kavak was inhabited, although with interruptions, during the LBA, as it was an important site on the route from Hatti proper to Kaska region (Yakar 2000: 296). Slightly further to the southwest, a few LBA sites have also been identified by the Paphlagonia Project (Glatz & Matthews 2005). In the coastal region, however, there is very limited evidence for any settlements during the Late Bronze Age, and certainly no occupation dating to this period at the main site of İkiztepe (Burney 1956: 191).

Regional Survey in the Black Sea Region

Archaeological work in the Black Sea region began in 1940, with the survey and the excavation of Dündartepe (Öksürüktepe), Tekeköy and Kavak (Kaledoruğu) by K. Kökten, N. Özgüç, and T. Özgüç. It was during the course of this work that the site of İkiztepe was first documented. The excavations at these sites provided the first, and for many years the only, excavated archaeological evidence for northern Anatolia. These sites will be discussed in more detail below. Following the Second World War, a survey of northern Anatolia was conducted by Charles Burney (1956). Burney's survey spans a much greater area than relevant to the current study, as he conducted a prospective survey in the region around Eskişehir as well as along the Black Sea coast. Burney identified a ceramic province in the Early Bronze Age in the Black Sea coastal region, defined primarily by the material that had been excavated at Dündartepe, Tekkeköy, and Kaledoruğu (Kavak), and augmented by further material collected at sites examined by his survey. Burney collected Chalcolithic and Early Bronze Age material from

İkiztepe, and recorded the nearby EBA sites of Kuşcular (near Bafra) and Gökçe Boğaz (near Alaçam) (Burney 1956: 181). He also recorded sites in the vicinity of Sinop (Demirci and Maltepe), Kastamonu (Maltepe and Tepecik) and Boyabat (Uluköy Çay) (Burney 1956: 181). While a number of sites were identified that could be dated to the Early Bronze Age, Burney's survey found many fewer sites attributable to the Middle and Late Bronze Ages (Burney 1956: 190-191).

Further survey was conducted in the region of İkiztepe (Samsun province) in 1971-1973 by Alkım and his team prior to initiating excavations at İkiztepe. This survey identified a large number of other sites with material dated by Alkım to the Early Bronze Age (Alkım 1972a,b, 1973a,b,c, 1974a,b,c, 1975b, 1976). Survey work has also continued in more recent years (1997-1998) as part of the İkiztepe project under the direction of Ö. Bilgi, whose surveys have focused on the area further to the south around Merzifon (Bilgi 2001c). One of the major goals of this survey was to identify possible local sources of raw materials required for metal production. For example, on the western side of the Emir Çayi Valley, Bilgi's survey discovered a source of arsenic, which he linked to the production of metals at İkiztepe (Bilgi 2001c: 7).

In contrast to the relatively intensive survey undertaken by Alkım in the area around Bafra, sites in the Yeşilirmak Valley and the Çarsamba Plain are not as well recorded, because alluviation has made it difficult to identify archaeological sites. Sites that are known are often found at slightly higher elevations in this area, including such sites as Tepecik and Kilistepe, both found south of Çarsamba (Yakar 2000: 285).

Dündartepe

The site of Dündartepe (also known as Öksürüktepe) is located about 3km SE of the modern city of Samsun, on the alluvial plain of the Yeşilirmak River. It was excavated in 1940-1941 by

K. Kökten, and N. and T. Özgüç. Excavations were interrupted by the Second World War, and never resumed. When excavations began, the site had already been heavily disturbed by the construction of a railway (Özgüç 1948a: 396). The areas of damage at the site guided the selection of excavation areas, and four trenches were opened at Dündartepe, in separate locations around the site. These included an area on the summit of the mound, an undisturbed area on the slope of the mound, an area disturbed by the construction of a railway (known as Area A), and an area located on the slope of the mound facing the modern road (Özgüç 1948a: 397). The material excavated from these four trenches was divided by the excavators into three periods (known as Dündartepe I, II and III), dating to the Chalcolithic (or Eneolithic), Copper Age and Hittite Periods respectively (Özgüç 1948a: 397). These levels, however, were found in different areas of the site, and were never linked together stratigraphically. Furthermore, in none of the excavation areas was virgin soil ever reached.

The oldest material was found in the area of destruction caused by the railway construction, in a 5x10m trench. In this location, they excavated to a depth of 4.5 m, when they encountered ground water and were forced to move to another area (Özgüç 1948a: 397). These levels were dated to the Chalcolithic period by the excavators, and consisted of 4 building levels with constructions of timber and wattle & daub (Özgüç 1948a: 398). In one of these levels the remains of a rectangular wooden house were uncovered (Özgüç 1948a: 398). Pottery in this level is described in the preliminary publications as black, grey or brown. Red coloured pottery was also present, but not as common. The pottery was mineral-tempered and often burnished, with incised decoration or fingernail impressions filled with white paste (Özgüç 1948a: 398; Thissen 1993: 212). Horn handles also occur (Özgüç 1948a: 398). However, the material illustrated in the preliminary report was minimal, and the pottery illustrations have since been supplemented by Orthmann (1963: Plates 65 and 66) and Thissen (1993: Fig. 2-6).

The remains dated by the excavators to the Copper Age were excavated in two locations: in the trench on the summit of the mound, as well as in the trench on the slope of the mound. On the summit of the mound, a large excavation area was opened (13x15m), which was excavated to a depth of 3.8m (Özgüç 1948a: 399). The settlement encountered in this area once again employed constructions of timber and wattle & daub, and showed signs of heavy burning and destruction (Özgüç 1948a: 399). This area also produced metal weaponry, such as axes, spears and daggers (Özgüç 1948a: 401). Thissen describes the pottery from the summit area in detail (1993: 213-215). The pottery is generally mineral-tempered, which occurs along with shell and/or chaff temper. Forms include sharply carinated bowls, open simple bowls, and jars with a narrow neck; upturned lugs were also often found. Thissen suggests that some of the bowls may in fact have been lids. Some of the ceramics were black or brown throughout, while some possessed black exteriors and reddish-brown interiors. The vessels were often burnished. Decoration is in the form of incised lines in geometric patterns, including herringbone patterns, chevrons and zigzags. In some cases, the incisions have a whitish slip or wash in and around them. Painting also occurs in the form of bundles of thin parallel dilute white lines, with the bundles lying obliquely to and crossing each other. The paint was applied after burnishing but before firing. This painted decoration occurs only on the exterior of the vessel, and most often occurs on slightly restricted bowl forms. The white painted pottery was confined to the trench on the summit of the mound, while the pottery found in the trench excavated on the slope of the mound displayed a different corpus of forms, and grooved decoration (Özgüç 1948a: 399-401; Thissen 1993: 212).

While the excavators recognized that the “Copper Age” materials originating from each of these areas were significantly different from each other, they still placed the levels contemporary with each other, with the differences explained as representing the co-habitation of the mound by different cultural groups (Kökten *et al* 1945). Orthmann, although recognizing the problem, also tentatively decided them to be contemporary (1963: 74). There is no good reason to indicate that these two assemblages are, in fact, contemporary with each other, an idea first suggested by Thissen (1993). His reanalysis suggests that the pottery from the area on the slope of the mound is consistent with the “Copper Age” (i.e. EB II-III) date originally assigned to it, displaying similarities to İkiztepe I/Sounding A (see below), Kavak, Alaca Höyük, Pazarlı, Horoztepe, Ahlatlıbel, Etiyokuşu, Polatlı, and Karaoğlan (Thissen 1993: 212). In contrast, Thissen suggests that the material from the summit of the mound should instead be dated to the Late Chalcolithic period (1993: 212).

Tekkeköy and Kavak

The site of Tekkeköy is located in the Çarsamba Plain, to the east of Samsun, and is a flat settlement. It was excavated as part of the project undertaken in 1940-1941 by K. Kökten, and N. and T. Özgüç, with a single 11x7m trench opened (Özgüç 1948a: 408). This area first produced remains dating to the Hittite period (Özgüç 1948a: 408). Below this, levels dating to the Early Bronze Age were uncovered in a deposit more than 1.5m thick (Özgüç 1948a: 408). Below this, a 4m thick deposit containing graves dating to the EBA was discovered, which rested upon virgin soil (Özgüç 1948a: 408). The graves were simple pit burials, with the bodies placed in a contracted or semi-contracted position (Özgüç 1948a: 409). Grave goods included metal weapons such as daggers (Özgüç 1948a: 410). The Early Bronze Age ceramics from both levels were chaff tempered and exhibit a black exterior surface with a red interior surface, along with grooved and incised decoration (Özgüç 1948a: 410). The pottery excavated here is similar to the Early Bronze Age (Copper Age) material excavated at Dündartepe, specifically that from the slope area (Özgüç 1948a: 410).

The site of Kavak (also known as Kaledoruğu) is located further to the south in the Kavak Plain near the modern town of the same name, on the main road from Amasya to Samsun. It was excavated as part of the same project that conducted excavations at Dündartepe and Tekkeköy. The site was small, but high and steep due to its foundation on a natural rocky slope. Three areas were opened, on the northern and eastern slopes, and on the top of the mound (Özgüç 1948a: 413). The excavations on the slopes both reached bedrock, and remains dating to later periods included the Ottoman, Roman-Byzantine and Hittite Periods (Özgüç 1948a: 413). The Early Bronze Age deposits were 1.5-2 m in thickness, and were divided into two major phases. The lowest level rested on bedrock, suggesting the site was first occupied during the Early Bronze Age. The EBA pottery was well burnished, with black exterior and red interior surfaces (Özgüç 1948a: 415). The pottery was generally decorated with grooves and incisions, occasionally filled with a white paste, although a few examples of white painted decoration also occurred (Özgüç 1948a: 415). The ceramics demonstrate similarities to both Dündartepe and Alaca Höyük (Özgüç 1948a:415), and Thissen suggests that the pottery is consistent with a date in the EBII-III period (Thissen 1993: 212). Also found at the site were a number of EBA graves located in the eastern trench, which were suggested to represent part of an intramural cemetery (Özgüç 1948a: 414). The graves consisted of simple pit burials, with the bodies placed in a crouched position, and grave goods included metal weaponry, such as daggers and shaft-hole axes (Özgüç 1948a: 414). .

İkiztepe Site Excavations

İkiztepe is located approximately 7 km northwest of modern Bafra, and is one of the largest and most intensively excavated sites in northern Anatolia. Excavations at the site first began in 1974 under the direction of U.B. Alkım, and have been continued since his death in 1981 by Ö. Bilgi (Alkım *et al* 1988). Today, İkiztepe lies in the Bafra Plain approximately 1.5 km west of the Kızılırmak (Halys) River, and 7 km from the Black Sea coast. Due to alluvial processes, however, its location has shifted over time. During the 4th and 3rd millennia BC, it was located immediately on the coast of the Black Sea, as well as on the riverbank (Alkım *et al* 1988: 145, Akkan 1970: Fig 6).

Despite the name, which means "twin mounds", the site in fact consists of four settlement mounds: two large and two small. The site was first occupied during the Late Chalcolithic, which was excavated on Mound II at the site, and was founded on virgin soil (Alkım *et al* 1988; Bilgi 2001b: 76-77). The Late Chalcolithic settlement has 8 architectural phases with constructions of timber and wattle-and-daub, which are generally grouped together into one level (Level III, Mound II) (Mellink 1992) (see **Table 2.1: İkiztepe Chronology** for the relative chronology of each mound).

The Chalcolithic settlement on Mound II at the site was destroyed in its final phase (Level III, 1) and subsequently reoccupied during the EBI (Level II, Mound II) and EBII (Level I, Mound II) (Yakar 1985a: 235; Bilgi 1984c: 96; Alkım *et al* 1988; Alkım *et al* 2003). In Level II, 6 sub-phases of EBI material were located (Phases 3-8; Phases 1 and 2 in Level II are dated to the EBII period). While there was no discernible change in architectural traditions, changes in the ceramic and lithic corpuses have been used to support the idea that a new group occupied the site at the beginning of the Early Bronze Age (Yakar 1985a: 235).

Period	**Date**	**Mound I**	**Between Mounds I/II**	**Mound II**	**Mound III**	**Mound IV**
Transitional	1700 2100	1 2 I 3a 3b 4 5 6	1 2 I		 1 2 I ?	 I 1
EBIII	 2300	 Graveyard	1 II 2 ?		1 II 2 3 4	*Virgin Soil*
EBII	 2700	1 2 3 4 II 5 6 7 8 9 10		 I 1 2	5 . . . III 10 19	
EBI	 3200	1 2 III 3 4 5		3 4 II 5 6 7 8	*Virgin Soil*	
Late Chalcolithic	 4000	*Virgin Soil*		1 2 3 III 4 5 6 7 8		
				Virgin Soil		

Table 2.1: İkiztepe Chronology (based on Bilgi 2001)

Meanwhile, EBI remains were also found on Mound I, which represents the earliest occupation found on this mound. These remains were originally known as Level III, Mound I, with at least 5 subphases excavated to date (phases 1-5). This sequence continues through the EBII, which had 10 architectural subphases (originally known as Level II, Mound I) (Bilgi 1984c: 96; Bilgi 2001b: 76-77). In the original system of naming the levels on Mound I, the cemetery was assigned no level number. In the most recent publications, "Level II, Mound I" was assigned to the cemetery, and the earlier layers on Mound I were shifted down accordingly (Level III, Mound I for the EBII remains, and Level IV, Mound I for the EBI levels). This change in terminology may cause some confusion in referring to the various levels excavated on Mound I, as may the fact that the same names (i.e. Level I, Level II, Level III, etc.) are also applied to materials from the other mounds, despite the fact that they are not contemporary. Henceforth, the levels on Mound I will be referred to by the original nomenclature, where the cemetery has no level number, as this is the terminology used in the majority of the publications on the site and will cause the least confusion.

Remains dated to the EBII period have been found on Mound I, Mound II and Mound III. On Mound I (Level III), 10 sub-phases have been identified (phases 1-10). While this level was originally treated as a single unit throughout the first excavation report and much of the second (Alkım *et al* 1988, 2003), in the final season included in the second excavation report (1980), it was divided into two separate horizons, one partially overlying the other. These were then known as IIa and IIb (Alkım *et al* 2003: Plate LV). Level IIb was originally only found in a deep sounding (Sounding H) excavated over a small area (Alkım 1981), but excavations continued in this area in later seasons.

On Mound III (Level III), 15 EBII sub-phases have been identified (phases 5-19; phases 1-4 are dated to the EBIII period) (Bilgi 1999b). These remains appear to have been the earliest known on Mound III. Only 2 EBII sub-phases were identified on Mound II (Level II, phases 1 and 2), which were the latest remains found on this mound. EBII ceramics were also found on the surface of Mound IV, where Area I was opened to examine these remains in the 1977 season (Alkım 1978). Excavations in Area I, however, rapidly reached virgin soil, and there is no evidence of a settlement on this mound (Alkım 1978).

Around the end of the EBII or the beginning of the EBIII period at the site, a significant change occurred, with Mound I being converted for use as an extramural cemetery (Yakar 1985a: 237; Bilgi 1984c: 96). The graves of the cemetery were cut into the settlement remains dated to the EBII period. However, a more definitive dating for the cemetery's use based on stratigraphy is difficult, as the graves pits were not noted during excavation, and the levels from which these pits originated are unknown. This cemetery will be the object of significantly more discussion in Chapter Three.

In addition to the Cemetery on Mound I, contemporary EBIII remains were located on Mound III (Level II). Test excavations were undertaken here in 1977 (Area J), which suggested these results, but further excavations were not conducted in this area until 1993 (due to the fact that the modern village of İkiztepe is located here), when the excavators began to look for a settlement contemporary to the cemetery. 4 sub-phases were assigned to the EBIII period. These were originally called Phases 3-6, with Phases 1-2 assigned to the Transitional Period. Later, these sub-phases were re-designated as Level II, 1-4, with Level III, 5-19 dating to the EBII period (the later nomenclature is used in the **Table 2.1: İkiztepe Chronology**) (Bilgi 1999a, c-e).

After the Early Bronze Age, the site continued to be occupied in the "Transitional" or "Early Hittite" period, dating to the 21st-18th centuries BC. On Mound I (Level I), 7 sub-phases were assigned to this period (phases 1-6, with phase 3 being divided into 3a and 3b). Remains dating to this period were also found on Mound III, Level I (2 subphases, 1-2) and on Mound IV, Level I (1 phase only). The "Transitional" Period remains on Mound III were found in Area J in 1977, and were probably originally more substantial, but were highly eroded (Alkım *et al* 2003: 33-34). Following this period, the site was abandoned and does not appear to have been occupied for the remainder of the Bronze Age. The site was re-occupied in the late Iron Age, as well as during the Hellenistic period. The majority of these later remains were concentrated on Mound III, where Level "0" excavations produced Hellenistic and Phrygian pottery (Bilgi 1999a). A dromos tomb dating to the Hellenistic period was found on Mound I, immediately to the east of the EBIII cemetery. In addition, on the northern part of Mound I, ephemeral remains were found dating to the Hellenistic period. These may be associated with the construction of the dromos tomb (Bilgi 1984a).

Mound I Excavations

Excavations on Mound I involved a series of excavation areas. The original 1974 excavations included an excavation area on the summit of the mound (Area A), and a second on the northwest slope of the tell (Area C) (Alkım *et al* 1988: Plan II). In 1975, excavations on the summit of the mound were expanded (Alkım *et al* 1988: Plan IX). Areas were opened to the east and to the west of the original area A (Area A' to the east and Area D to the west). Area A' produced the Hellenistic dromos, and after this discovery it was not excavated further. Meanwhile, Area D produced further cemetery remains, expanding the known cemetery area originally discovered in Area A. Furthermore, two areas were opened in the saddle between

Mound I and Mound II (Area F to the west and Area G to the east, see Alkım *et al* 1988: Plan IX). In 1977, the area on the summit of the mound was expanded to the north (Area H). By 1979, this area had been expanded as far northward as Area C (Alkım *et al* 2003: Plate XLVIII). In the same year, Area A was expanded further south. In 1980, Area K was opened on the north-east slope of the mound, but seems to have been rapidly abandoned. Later, Area M was opened to the north of Area A, located between Area A and Area C, producing further cemetery remains (Bilgi 2001a).

Areas A, A', D, H and M

In the primary areas excavated in the central part of Mound I, there were determined to be seven sub-phases of Level I represented, which were dated by the excavators to the "Transitional" or "Early Hittite Period" (i.e. to the early Middle Bronze Age). These levels consisted primarily of a series of beaten earth floors and *pisé* architecture. Some of these levels contain evidence of burning, including the presence of charred wooden crossbeams used in construction (i.e. Level I, phase 6). Beneath the phases of the Transitional Period on Mound I, but above the cemetery, was a layer 0.5-1.0 m thick with carbonized wood and *pisé* from destruction by fire (Alkım 1981; Alkım et al 2003: 112-113). This layer was referred to in the reports as the "mixed layer". In the 1980 season, it was realized that the formation of Mound I was more complex than had originally been understood, and that underlying the upper layers of Mound I (i.e. Level I) were two separate deposits. The later of these was termed IIa, which was located in the southern and eastern parts of Mound I. The earlier of the two was known as IIb, which was located in the northern and western portions of Mound I. In the centre of the mound, where the deep sounding conducted during the 1980 season was located, level IIa overlies IIb (Alkım *et al* 2003: LV).

Excavations conducted during the 1981 season included a deep sounding that first identified the presence of earlier remains on Mound I, dated by the excavators to the EBI period (Bilgi 1982a). Few details of these levels were published, except that they included the burnt remains of buildings constructed from wooden timbers, similar to other constructions at the site (Bilgi 1982b: 50). The description of the pottery only states that it was EB I (Bilgi 1982b: 50). It is not clear whether the date of EB I was assigned to these remains due to their similarity to the "EBA I" remains excavated on Mound II (see below), or simply due to its stratigraphic position below the EB II remains.

Excavations in the mid-1980s concentrated on examining the cemetery, as well as the EBII settlement remains into which the graves were cut. Similar to the construction techniques observed elsewhere at the site, the EBII structures on Mound I were made from timber frames, with the spaces between the timbers filled with mud plaster; the walls in these levels generally had no foundations. In the 1984 season, a cache of *in situ* metal weapons were found in the EBII levels into which the graves were dug, suggesting that the metallurgical industry at the site was already well developed in this period (Bilgi 1985b: 112). Bilgi states that these metals were found at the same level as pottery of a black colour that was well-burnished and had decorations of white paint in geometric patterns (Bilgi 1985b: 112). The EB II date for these materials seems to have been suggested primarily based upon the presence of the white-painted pottery, which had previously been dated to the EBII in the sequence excavated on Mound II (see below) (Bilgi 1985b: 112). It was in 1985 that these levels first began to be exposed over a larger horizontal area. During this season, the partial plans of two houses, both with a simple rectangular plan oriented NE-SW, were uncovered (Bilgi 1986b: 150). Other similar buildings, one with at least 8 rooms, were uncovered during the 1986 season. These buildings include ovens constructed of clay on a plastered platform (Bilgi 1987b: 174). Another similar oven was found in a partial building excavated nearby (Bilgi 1987a; Bilgi 1987b: 174). These ovens were found in association with large quantities of loomweights, leading the excavators to link these remains with textile production (Bilgi 1986b: 151, Bilgi 1987b: 174). Excavations of the EBII domestic remains continued through the 1992 season, when virgin soil was reached in area D (Mellink 1993).

Excavations on Mound I were temporarily suspended while excavations moved to Mound III in search of a settlement contemporary with the cemetery. Excavations on Mound I were only resumed in the 2000 season, when Area M was opened with the goal of excavating what remained of the cemetery. Excavations in this area have continued until the present time. During the intervening seasons, 6 architectural levels dating to the EBII have been described. Many of these levels produced only fragmentary remains, including beaten earth floors and burnt remains of wooden timbers and pisé fragments. One level (6) provided evidence for two "monumental" ovens (Bilgi 2005a: 30). Further evidence of the EB I levels was also excavated during this time, with 3 sub-phases being identified (Bilgi 2006: 117). The EB I levels also produced evidence of workshops with "monumental ovens" (Bilgi 2006: 118). One level included a kiln or oven, this time rectangular in plan, which Bilgi suggests may have been used in pottery production (2005a: 30). Once again, however, no description of the EB I ceramics is given.

Pottery from Mound I, Area A and Related Areas

Prior to the discussion of the pottery from Mound I, a general introduction to the pottery from İkiztepe should be provided. The ceramics from the site have been published primarily in the two excavation reports (Alkım *et al* 1988, 2003). These reports focus heavily on the pottery from the “Transitional Period” and the Early Bronze Age, and provide a very small amount of discussion on the Late Chalcolithic period pottery. From the point of view of the consideration of the chronology of the cemetery, these reports are of limited usefulness. Most of the cemetery was excavated after the seasons covered by the 2nd published volume, which means that most of the pottery from the cemetery is not published among this corpus.

All of the pottery from İkiztepe uses three varieties of temper: mineral, chaff and shell, in various combinations. In the first excavation report, the excavators define 8 different fabric types, designated h1-8 (Alkım *et al* 1988: 161-163, 170-172, 179, 181, 188-189). Fabrics h1-h3 were dated to the “Transitional Period”, while h4-h6 were assigned to the Early Bronze Age pottery. Only two types of pottery fabric were defined for the Chalcolithic period, h7 and h8. According to the excavators, all of the pottery was made from local clays, with no evidence of imported vessels.

Both h1 and h5 are exclusively mineral tempered. Early Bronze Age fabric h5 is thus similar to the h1 of the Transitional Period, but the ceramics belonging to this ware type are handmade, while those of type h1 are wheel-made. These two fabric groups also demonstrate different colours and firing techniques, and were found to occur with a different suite of forms. h1 had a reddish paste with shiny white mineral inclusions, while h2 contained both mineral and chaff temper, and was not as carefully made. h2 was also not fully oxidized and unburnished. h3 demonstrated red and brown fabric, with small amounts of mineral and chaff inclusions and large amounts of shell. h3, in contrast to h2, was well-fired and fully oxidized, and some of these vessels were burnished.

The other two Early Bronze Age fabric groups, h4 and h6, contain different varieties of temper from h5. h4 contained both chaff and mineral temper, while h6 contained small amounts of both of these types and larger quantities of shell. h4 was divided into 3 subcategories on the basis of the fineness of the fabric and the size of the inclusions within it (4a-c). The inclusions of the finest, 4a, were too small to be seen by the naked eye, while fabric 4b displayed mineral inclusions measuring 1-3mm and finely chopped chaff. The coarsest fabric, 4c, had large inclusions of both mineral and chaff, including limestone, and was used for coarse cooking wares. All of the Early Bronze Age ware types demonstrated vessels with different colours on the interior and exterior of the vessel. These were generally black/grey on the exterior and a reddish colour on the interior, although examples also occurred with this pattern reversed. This colour differential appears to have occurred due to the firing techniques employed; the vessels appear to have been fired in an oxidizing atmosphere, followed by a short reduction process where the vessels were covered to reduce the oxygen flow to their external surface (Thissen 1993: 214). Alkım *et al* also suggest that the colour differential is related to firing technology, and link the dark exterior colour to the use of fuel with a high sulphur content (Alkım *et al* 1988: 172).

The Chalcolithic fabrics, h7 and h8, contained only mineral inclusions. While h7 has a grayish or grayish-brown fabric, h8 has a reddish paste. The mineral inclusions in h8 are larger than those of h7. h7, however, was once again subdivided into 3 sub-categories on the basis of the fineness of the fabric (h7a-c), with similar criteria to those defined above for fabric h4.

To date, very little pottery from the earlier levels on Mound I has been published. The pottery from Mound I, Level I (i.e. the “Transitional” or “Early Hittite”) material has been treated in depth in the two excavations reports (Alkım *et al* 1988, 2003). However, the materials from the levels below this, including the cemetery and the layers of EBI and EBII material underlying it, have been published only very sparsely.

The only pottery that has been published from the cemetery are a few pieces included in the second excavation report (Alkım *et al* 2003: XL,7; XLI, 6, 8, 9; XLII, 4, 12; LXXX, 1, 2; LXXXIII, 3), and one plate in Bilgi's 1990 article on the metals from İkiztepe (Bilgi 1990b: Fig 20). Bilgi states that the pottery from the cemetery displays strong similarities to the underlying EBII pottery, and stresses its continuity (Bilgi 1990b: 167). The descriptions given for the pieces in the 1990 article show that they have a strongly developed difference in colour between the inside and outside (black exteriors, red interiors). All of the pieces are hand-made and the descriptions of their exterior surfaces are all given as being black slipped and burnished (Bilgi 1990b: 164-165, 167). The presence of a slip, however, seems unlikely, as much of the other pottery at the site displays a similar colour pattern, which is attributed to firing technology (Alkım *et al* 1988: 172; Thissen 1993: 214; see also Bilgi 1990b: 167, where he says that the appearance is *not* due to a slip).

Forms include carinated and simple bowls with inturned or simple rims and flat or ring bases (Bilgi 1990b: Fig 20: 446, 447, 448, 450, 451, 452; Alkım *et al* 2003: XL,7). These bowls often have knobs around the carination (Bilgi 1990b: Fig 20: 446; Alkım *et al* 2003: LXXX, 1,2) or the rim (Bilgi 1990b: Fig 20: 448, 450, 451, 452). In some cases, there are also double horizontally pierced lugs (Bilgi 1990b: Fig 20: 447). There are also knobs or tabs that extend upward above the rim of the bowls (Bilgi 1990b: Fig 20: 446, 448, 450, 451; Alkım *et al* 2003: LXXX, 1, 2). The bowls also often have white painted decoration on the exterior of the vessel, in bundles of parallel lines running obliquely and crossing each other (Bilgi 1990b: 167, Fig 20: 450, 451?, 452). Bilgi also makes reference to the use of "reserved slip", which he describes as resulting in a similar appearance to the use of the white painted decoration (Bilgi 1990b: 167). Jar forms also occur (Alkım *et al* 2003: XLI, 8,9; LXXXIII,3). Also appearing is a jar with a slight carination and a simple rim, which has four knobs, two at the rim and two on the carination (Bilgi 1990b: Fig 20: 449). Other forms include simple straight sided mugs with a horizontal handle (Alkım *et al* 2003: XLII, 4) and pedestal bases (Alkım *et al* 2003: XLII, 12). In addition to the painting and reserved slip decoration mentioned above, incised (Alkım *et al* 2003: XL, 7) and raised appliqué decoration also occurs (Alkım *et al* 2003: LXXXIII,3).

The EBII pottery from Mound I is also very poorly represented in the publications. There are very few examples given in the two excavation reports (Alkım *et al* 1988: XII, 6; XIV,11; XV, 16; XVI, 11,15,17; XX, 7; XLIX, 4,8; L,2,6,10; LI, 1; LII, 1-5, 7-8; LIII, 2; Alkım *et al* 2003: XLII, 2,14; LXX, 3,5; LXXI, 5,7; LXXII, 2; LXXIII,1; LXXIV, 2; LXXX, 6,10; LXXXI,1,2,5-8; LXXXIII, 2,5-7*)*, and no other pottery drawings are provided in any of the reports published since that time. The nature of the Mound I EBII pottery must thus be reconstructed based on the few available drawings, as well as a few photos and passing remarks about the pottery in the text of later seasonal reports.

In passing references during his seasonal reports, Bilgi describes the EBII pottery as being primarily black or brown, but sometimes red in colour (Bilgi 1983b: 89; Bilgi 1984b: 57). It is also hand-made and well burnished, and sometimes displays incised decoration (Bilgi 1984b: 57; Alkım *et al* 1988: XLIX, 4; LI, 1; LII,3,5,7; Alkım *et al* 2003: LXX, 3, 5; LXXI,5, LXXXI,1, 6). In another article, it is mentioned that the EBII levels on Mound I have light and grey ware pottery and brush handles (Mellink 1990*).* A group of pottery from these levels found alongside a cache of *in situ* metals is described as having a black colour, and being well burnished with white paint in geometric patterns (Bilgi 1985b: 112). These white painted ceramics apparently appear in the lower levels of the EBII layers on Mound I, but not in the later EBII levels (Bilgi 1990b: 167; see Alkım *et al* 2003: LXXXI, 2,7,8?). They reappear, however, in the EBIII pottery from the cemetery and from Mound III (see above) (Bilgi 1990b: 167). This description matches well with the few examples of Level II pottery published in the final excavation report (Alkım *et al* 2003). Another passing reference in an article describing the results of the 1990 season mentions that some of the pottery has relief decoration (Mellink 1991). Examples of relief decoration were also found in the small amount of Level II pottery already published, often in anthropomorphic or zoomorphic motifs (Alkım *et al* 1988: XVI, 11; L, 2; Alkım *et al* 2003: LXXIV,2; LXXXIII, 2). Raised knobs around the rims or carinations of the vessels were also common (Alkım *et al* 1988: LII, 5; Alkım *et al* 2003: LXX, 5; LXXI, 7; LXXXI,1,3); occasionally these rise above the level of the vessel rim (Alkım *et al* 2003: LXXXI,3).

In his report on the 1991 season, Bilgi describes a pot with an egg-shaped body and 4 horizontal handles, which was black in colour, well polished, and had white painted decoration in a geometric pattern (Bilgi 1992: 200). This vessel had a base bearing a woven basket impression; this practice appeared in the Early Bronze Age, but appears to have continued a tradition that began in the Late Chalcolithic (Bilgi 1992: 200). Other pottery included small necked jars, shallow and deep bowls and goblets (Bilgi 1992: 200). These pots were weakly burnished, and were generally red or grey in colour. The pottery showed both raised and grooved or incised decoration (Bilgi 1992: 200). The pottery with these decorations was beige in colour and well burnished.

Forms in the published EBII pottery include bowls with simple or sharply inturned rims (Alkım *et al* 1988: XLIX, 4, 8; Alkım *et al* 2003: LXX, 3, 5; LXXI,5,7). Carinated bowls, sometimes with handles, also occur (Alkım *et al* 1988: XII, 6; L, 2, 6). Jar forms with straight (Alkım *et al* 2003: LXXIV, 2; LXXXI,2,3; LXXXIII, 2) or necked (Alkım *et al* 1988: XIV, 11; LI, 1; LII, 1,4,5,7,8; Alkım *et al* 2003: LXXXI,1) upper portions also occur. Two examples of mugs with vertical handles were also found (Alkım *et al* 1988: LIII, 2; Alkım *et al* 2003: XLII,2). Fenestrated stands (Alkım *et al* 2003: LXXXI,5), bases with impressed decoration (Alkım *et al* 2003: LXXXIII,5), doubly pierced horizontal lugs (Alkım *et al* 1988: XX,7; LII, 7) and lids with appliqué knobbed decoration (Alkım *et al* 2003: LXXXIII, 7) also appear.

Little can be done to break these forms down between the upper and lower levels of the EBII remains. Some examples have been published with more specific information about which part of the EBII levels they were found in. Only a small number of examples have been published from Level IIa on Mound I (Alkım *et al* 2003: LXXI, 5,7; LXXIII,1; LXXIV, 2; LXXX, 6,10; LXXXI,1,2,5; LXXXIII, 2,5-7*)*. The pieces published in the second excavation report include wide carinated bowls with a straight inturned rim, and triangle-shaped incisions around the rim (Alkım *et al* 2003: LXXI, 5). There were also simple bowls with knobs around the rim (Alkım *et al* 2003: LXXI, 7). Jars with a short neck, decorated with vertical incised lines and knobs on the shoulder also occur (Alkım *et al* 2003: LXXXI, 1). There were also examples of raised appliqué decoration in various shapes, including a person with upraised arms (Alkım *et al* 2003: LXXIV, 2; LXXXIII, 2). Fenestrated stands occur, which may represent the remains of fruitstands, an important chronological marker in for the Late Chalcolithic period in Anatolia (Alkım *et al* 2003: LXXXI, 5*)*.

The pieces published for Level IIb in the second excavation report were even fewer in number (Alkım *et al* 2003: XLII, 2,14; LXX, 3,5; LXXII, 2; LXXXI,6-8). The forms appearing include a mug with a single vertical handle (Alkım *et al* 2003: XLII,2). Bowls with flaring sides, slightly inturned rims and very small flat bases occur (Alkım *et al* 2003: LXX, 3), as do simple bowls with upturned knobs around the edge and some incised decoration (Alkım *et al* 2003:

LXX, 5). There are also a number of body sherds with incised decorations (Alkım *et al* 2003: XLII, 14; LXXXI,6,8).

As discussed above there are no published data available that provides a description of the EBI pottery from Mound I.

The pottery of Level I on Mound I will not be discussed in detail, as it dates to the "Transitional Period", and certainly post-dates the period in which the cemetery was in use. However, the pottery from this period is generally light-coloured (red/brown), well-fired and wheel-made (see Alkım *et al* 1988: 161-171 for a more detailed discussion; Alkım *et al* 2003: 149). It is also suggested that an important feature of the Level I pottery is that it has no decoration (Alkım *et al* 2003: 149). Common forms include wide flaring cups with pointed bases, similar to cornets, as well as similar cups with a thin flat base. Wide shallow bowls with simple, bead or hammerhead rims also occur, as do carinated bowls with flaring rims. Trefoil rim and beak spouted pitchers, and teapots with long spouts are common. These forms are generally typical Central Anatolian forms, particularly at sites like Kültepe (Level IV) (Alkım *et al* 2003: 150). However, it should also be noted that the excavators state that pottery types characteristic of the EBIII period continue to appear alongside the later wheel-made "Early Hittite" pottery (Alkım et al 1988: 153). This includes pottery with impressed decoration, often made with a fingernail, placed around the widest diameter of the vessel, along with large lids with similar decoration (Thissen 1993: 212).

One of the groups of artifacts that has received the most discussion in publication is the large collection of metal artifacts excavated from the graves in the cemetery, which were treated in two articles by Önder Bilgi (1984c, 1990b). In addition to jewelry and tools, a great deal of attention was paid to a wide variety of metal weaponry included as grave gifts, such as daggers, spearheads and arrowheads. These metals were primarily made of arsenical copper, where the arsenic content varied from 0.86-12.2% (Bilgi 1984c: 73; corrected in Bilgi 1990b: 170). It has been suggested that the addition of arsenic was intentional in the metallurgical process (Bilgi 1990b: 171). Although bronze production is common in other areas of Anatolia during this period, most of the objects published show no evidence of alloying with tin, while those that do show very low levels of tin, with an average of 0.19% (Bilgi 1990b; Muhly 1993: 242). Certainly there is nothing that could be described as being bronze (Bilgi 1990b; Muhly 1993: 242). Bilgi has suggested that these metal objects were made at the site, despite the rather sparse evidence of metal production encountered (Bilgi 2001b: 35). He suggests that the source of the copper was from Bakırçay (on the Taşvan Mountain near Merzifon), while the arsenic originated from the Pırasakaya ores on Bakacak Tepe in the Peynirçay Vadisi (Bilgi 2001:b 35). For detailed descriptions of these metals, see Bilgi's articles (1984c, 1990b; see also 2001b).

Areas C and F

Area C, located on the northwest slope of Mound I, produced a series of remains including the burnt remnants of a massive *pisé* wall that appears to encircle the site, probably dating to the Transitional Period. Beneath this, pottery dating to the Early Bronze Age was found in the deepest levels of the sounding. Unfortunately, the excavators were not able to link the remains from Area C with those from Area A to the south when this sounding was undertaken (Alkım *et al* 1988: 155). After the expansion of Area H to the north, which reached a northerly point in line with Area C, making such a link should have been possible. Unfortunately, none of the sections that pass through this part of Area H are published in the second excavation report (Alkım *et al* 2003). However, given the published reconstruction of the formation of Mound I (Alkım et al 2003: Plate XL), it is plausible to believe that excavations in Area C may have passed directly from Level I, into the level designated as IIb, which is found at the northern end of the mound (Alkım *et al* 2003: LV).

A number of scholars examining the pottery from İkiztepe have made a point of separating the ceramics excavated from Areas C and F on Mound I from the remainder of the material from the mound (Thissen 1993; Parzinger 1993; Schoop 2005). In Schoop's re-evaluation of the pottery, material from this area is designated as Complex "DD" (Schoop 2005: 314). The pottery from this area consists of approximately equal parts ware of h4 and h5. Ware type h5 did not appear in Sounding B (Mound II), and it occurs only in areas A and C (Alkım *et al* 1988: 162; Schoop 2005: 314*)*. A couple of examples of ware h6 also occur in Area C (Alkım *et al* 1988: XXII, 4, 8). Forms include small deep bowls or cups with straight walls and flat bases (Alkım *et al* 1988: XI, 8-11; Schoop 2005: Pl 185: 6-8). There are also a couple of straight sided jars or hole mouths with lug handles around the rim, similar to those seen in Mound II, Level I (Alkım *et al* 1988: XIII,5; XIV, 3; XIX, 4; XX, 2-4; XXII,4; see below for Mound II discussion). None of the wide simple bowls seen on Mound II appear. Instead, large deep bowls with inturned rims occur, although with softer carinations than similar vessels from Mound II, Level I (Alkım *et al* 1988: XVIII,1-6; Schoop 2005: Pl 185: 10-12). Handles include horizontally pierced lugs, which were not seen in Mound II, Level I (Alkım *et al* 1988: XVIII, 3,5; Schoop 2005: Pl 185, 11). Hole mouth forms are common, with straight or convex upper portions (Alkım *et al* 1988: XIII; 6-8; XIX, 6-9; XX, 2-5; Schoop 2005: Pl 185:13-19). Knobs also occur around the top part of the vessel, beneath the rim (Alkım *et al* 1988: XIII, 5,8; XIV, 3; XIX,4,7,9; XX, 2-4; Schoop 2005: Pl 185: 13-14, 16-17, 19). One of these is a double vertically pierced knob (Alkım *et al* 1988: XIX, 9; Schoop 2005: Pl 185: 19), although vertical and horizontal handles also occur (Alkım *et al* 1988: XIII, 7; XX, 1; XXII,8; Schoop 2005: Pl 185: 18). Incised decoration is present in small numbers (Alkım *et al* 1988: XVIII, 9, 11; XXI, 2), but white painting occurs more commonly in diagonally running lines (Alkım *et al* 1988: XIII, 6, 8; XIX, 6; XXI, 3-4). In contrast to the decorations appearing in Mound II, Level II, these decorations are limited to the exterior of closed containers, and can extend to the base of the vessel (Alkım *et al* 1988: XX,11; XXI, 3-4; Schoop 2005: Pl 185: 16, 20, 22). Furthermore, they do not appear alongside the white incrusted incised decorations seen in Mound II, Level II.

While there are a few similarities in forms to Mound II, Level I, the assemblages are clearly not the same. There is almost no overlap in ware types, and few of the distinctive forms from Mound II, Level I occur frequently in Area C, with the exception of straight sided or hole mouth jars with lugs around the rim. Also there are more examples of decoration Area C, and the incised decoration is different (wider and deeper, compared to the couple of examples bearing very thin, shallow incisions in area B, Level I).

Area F was located 30m north of Area C, in the saddle between Mounds I and II, and was excavated in 1975. To avoid mixing as a result of erosion, a thick layer of mixed debris was removed from the area prior to beginning stratified excavation (Alkım *et al* 1988: 197). The first excavated layer contained some architectural remains, along with a large proportion of Level I Transitional Period pottery. Below this, some ephemeral *pisé* architecture was uncovered, along with some Early Bronze Age pottery, forming Area F, Level II. The excavators noted problems with the interpretation of the stratigraphy of Area F, saying that Transitional Period pottery and Early Bronze Age pottery were found at similar depths in adjacent squares within the excavation area (Alkım *et al* 1988: 200). The conclusion was that this suggested that there was a "continuity of the Early Bronze tradition in the "Transitional Period", or … the Early Bronze III people having lived together with the Transitional Period people" (Alkım *et al* 1988: 200).

In Schoop's reconsideration of the site, this material was designated as Complex "EE" (Schoop 2005: 314). Only a very small amount of pottery is published from Area F in the first excavation report, and much of it is from Level I, which was dated to the Transitional Period. Level II, on the other hand, was dated by the excavators to the EBII-III period, and grouped with Area A (and A', H and M), Level II. Notable are two cases of vertical doubly-perforated knobs (Alkım *et al* 1988: XLIX: 3,5, Schoop 2005: Pl 186: 2-3). Hole mouths occur here also (Alkım *et al* 1988: XLIX: 1; LI,3-5; LIII, 8; Schoop 2005: Pl 186: 5-8), some with knobbed decoration (Alkım *et al* 1988: LI, 4,5; LIII, 8). There are also deep bowls with inturned rims (Alkım *et al* 1988: XLIX, 3,5,6; Schoop 2005: Pl 186: 1-4). One of these is a steep walled bowl with an in-turned rim and narrow base, with an incised edge as well as decoration beneath the carination (Alkım et al 1988: L, 11; Schoop 2005, Pl 186: 1). This pottery, however, appears mixed with material from Level I above. There is decoration in the form of groups of thin lines in white paint, occurring on the exterior of closed vessels, running all the way up to the rim (Alkım *et al* 1988: XLIX: 3, 5, 6; LI,3,5). These examples are similar to the white painted decoration seen in Area C, described above.

Mound I Phasing & Dating

There has been some discussion about whether the material excavated from the various areas of Mound I have been correctly dated and phased. Among those who have discussed the issues of the chronology of this mound have been Thissen (1993), Parzinger (1993) and Schoop (2005), who suggest that the sequences on the various excavation areas have not been linked together correctly, and have not been linked properly with the material from the other mounds on the site. All of these reconsiderations are based solely on the material published in the first volume of excavation results, published in 1988 (Alkım *et al* 1988). Even the most recent of these discussions (Schoop 2005) does not include the material published in the second excavation report (Alkım *et al* 2003). Thus, there has been no significant reconsideration of the material included in the second report.

The first of those who presented new reconstructions of the dating of the Mound I materials was Thissen (1993). His study specifically focuses on archaeological evidence for a relationship between Anatolia and the Balkans during the Late Chalcolithic period, through direct reconsideration of the material excavated at Dündartepe, Tekeköy and Kavak. However, a significant part of his argument is based on the sequence at İkiztepe, which he assesses through consideration of the published material. He suggests that there is a significant gap between the occupation sequence of Mound II and that of Mound I (Thissen 1993: 210). Thissen's arguments suggest that in fact the phasing within the Mound I sequence should be revised. Three separate areas were opened on or near Mound I that have contributed to its phasing as it has been published by Alkım *et al* (1988, 2003), and later by Bilgi. These are Area A (and related areas such as A', D and M, which were opened as expansions to examine the cemetery in Area A), Area C (on the northern slope of Mound I), and Area F (opened in the saddle between Mounds I and II), all of which have been discussed in detail above. Thissen suggests that the material from Area A conforms quite well to the expected assemblage for an EBII-III date (Thissen 1993: 215). However, he suggests that the materials from Areas C and F, which have been grouped with the Area A material, are in fact substantially different from the assemblage originating from Area A, and can be more easily linked to the Late Chalcolithic period (Thissen 1993: 222). This is particularly true of the material from Area C, while there may be some later material mixed in with the assemblage originating from Area F (Thissen 1993: 215). For example, the black burnished white-painted pottery described above, as well as black burnished pottery with no paint, originally only showed up in Areas C and F, and not in Area A. The publication of additional material from Mound I (Alkım *et al* 2003) has produced a few examples of similar white painted pottery; however, these are confined to the lower levels of Mound I, Level IIb. In contrast, traditional "EBII-III" or "Copper Age" material is all from Area A, while very little of this material appeared in Area C (Thissen 1993: 215).

As discussed above, the reconstruction of the mound published in Alkım *et al* 2003 (Plate LV) may help provide an explanation for this observed pattern. This diagram demonstrates that at the northern edge of the mound, the stratigraphic sequence jumps directly from Level I (Transitional Period) into Level IIb. Level IIb is the earlier of the two portions of Level II, and was only identified in the 1980 season. Level IIa, the later portion of Level II, was found only in the southern and western portions of Mound I. As discussed above, frustratingly little pottery from Level IIb was published by Alkım *et al* (2003), so it is virtually impossible to confirm this idea. However, the few pieces that are published from Level IIb are not inconsistent with the pottery from Area C, Level II and Area F, Level II. Furthermore, there are two examples of the distinctive black burnished white-painted pottery observed by Thissen in Areas C and F published by Alkım *et al,* which were excavated from the very lowest layers reached in the deep sounding into Level IIb that was conducted during the 1980 season (2003: LXXXI, 2,7). Since this time, no further pottery has been published from the lowest settlement levels reached on Mound I, so a firm conclusion cannot be made.

Mound II

In contrast to Mound I, the sequence from Mound II has been more comprehensively published and studied, and according to the excavators, spans the period from the Late Chalcolithic to the EBII. Only two sub-phases excavated on Mound II were attributed to Level I

(I, 1-2) (sometimes also called Level II, 1-2; see Alkım *et al* 1988: 156). These remains were dated to the EB II period, but were rather ephemeral due to their location at the very upper surface of the mound (Alkım *et al* 1988: 155-56, Plan VIII). They were, as a result, highly eroded. The architecture was of wattle and daub with evidence of fragments of burnt *pisé* and wooden beams, and floors were of mud plaster or beaten earth (Alkım *et al* 1988: 156-60). All of the phases in this level were heavily burnt (Alkım 1975a; Alkım *et al* 1988: 156).

Level II on this mound, which was dated to the EB I period by the excavators, produced 6 sub-phases (II, 3-8). The upper sub-phases in Level II (3-5) produced a series of beaten earth floors, in combination with the burnt remains of *pisé* and carbonized wooden beams (Alkım *et al* 1988: 156-160). The architecture in these levels was relatively incoherent, and was presented as a composite plan in the first excavation report (Alkım *et al* 1988: Plan VII). In Level II, phase 6, no clear architectural remains were discovered, but lumps of *pisé* and timber pieces were uncovered, along with a large area of plastered floor (Alkım *et al* 2003: 65-66, Plan XXXII). These remains were suggested to belong to two separate houses. In Level II, phase 7 and 8, four distinct house structures were uncovered (Alkım *et al* 2003: 66, Plan XXXIII). These buildings had evidence of plastered floors, and one produced the remains of a hearth. Common throughout the period was the presence of refuse pits.

The first sub-phase of the Chalcolithic period remains (III, 1) contained the remains of a large wooden building with a plastered floor constructed atop a series of flat stones (Alkım *et al* 2003: 39; Alkım 1978). This building measured 4m x 20m and was oriented N-S (Alkım *et al* 2003: Plan XXXIV). It had been heavily burnt, and the remains of several timbers used in construction were found, along with the remains of what was interpreted as a wooden "balcony" (Alkım *et al* 2003: 39). Below this, the remainder of the Chalcolithic levels (III, 2-8) were excavated in a limited sounding. These levels produced domestic architectural remains with similar wooden construction techniques to that described for the building in III,1 above (Alkım *et al* 2003: 40-42; 69-75). Some of these levels provided evidence for more than one structure. Unfortunately, however, no plans for these lowest levels were published in the final excavation report. Much of the architecture displayed evidence of burning, similar to that observed in Phase 1 (Alkım *et al* 2003: 40-42, 69-75). Below the Chalcolithic occupation sequence, the sounding reached virgin soil (Alkım *et al* 2003: 42).

The pottery excavated from Mound II is extremely relevant to the discussion of the chronology of the occupation sequence at İkiztepe, as it is on these ceramic materials that recent reconsiderations of this chronology have been based. Such reexaminations have been made possible primarily because it is this sequence that has been the most completely published at the site.

Due to the fact that his work concentrated on the ceramics from the site of Dündartepe, Thissen's reconsideration of the stratigraphy of İkiztepe focused primarily on the material from Mound I that he believed to be contemporary, particularly that from Areas C and F (1993). His consideration of the material from Mound II was limited to stressing the idea that the white-painted pottery originating from Mound I is significantly structurally different from the white-painted pottery observed at Mound II (i.e. from Level II, "EBA" I). Thissen, however, was among the first to suggest that the Mound II sequence (in particular Level II) should be shifted earlier in time than the excavators had originally suggested. He places Level II in the Early to Mid-Chalcolithic, contemporary with Büyük Güllücek, Alaca Höyük "early Chalcolithic" and Alişar 14-12M, as well as with Karanovo IV (i.e. 4300-4100 BC) (Thissen 1993: 222).

Parzinger (1993) also considered the pottery from Mound II, and concluded that the entire sequence likely dated prior to the Bronze Age. Indeed, he states that the majority of the material at İkiztepe should likely be placed into pre-Bronze Age periods, but reserved final judgment until the material was adequately published (Parzinger 1993: 238).

However, the most comprehensive reconsideration of the Mound II material was conducted by Schoop (2005). Schoop recharacterized and relabelled the various assemblages of İkiztepe (including material from both Mounds I and II). His "complexes" largely correspond to the levels as defined by the excavators. Complex AA was assigned to the material excavated from Mound II, Level III, which was identified by the excavators as Late Chalcolithic. Complex BB incorporated the material from Mound II, Level II, which was identified by the excavators as "EBA I". Schoop divides Complex BB into 3 different sub-phases: BB1-BB3 (2005: 312-313). According to Schoop, these subdivisions were made arbitrarily, with the earliest level being BB1 and the latest level being BB3. Finally, Complex CC is represented by the material on Mound II, Level I, identified as "EBII" (Schoop 2005: 313-314).

The pottery from Level III is made solely from fabric groups h7 and h8, which contain only mineral temper and no chaff or shell (as described above). The large white mineral inclusions described by Alkım *et al* (1988: 188) may have been limestone, and spalling may also have occurred. Although some of the material was of fabric h8, with a reddish paste, the majority of the pottery was of fabric h7, with a paste of black, brown, or grey. Common forms include deep, straight-walled bowls with simple rims and a basic conical form (Alkım *et al* 2003: XLIV, 1-3; XLVI, 1; LIV, 1, 4; Schoop 2005: Pl 180:1-4). These sometimes have small vertical lug handles set low on the body of the bowl (Alkım *et al:* 2003: XLVI, 1*;* Schoop 2005: Pl 180: 1), or large loop handles, sometimes swinging up above the rim (Alkım *et al* 2003: LIV, 1, 4; Schoop 2005:

Pl 180: 2-3). Similar deep bowls with carinations and simple rims also occur (Alkım *et al* 2003: XXVII, 2-4; XLIV: 4, 5, 7, 10; XLVI: 4, 9; Schoop 2005: Pl 180: 10-14); these examples again sometimes have similar large loop handles (Alkım *et al* 2003: LIII, 1; Schoop 2005: Pl 180: 12). Jars typically have s-shaped profiles (Alkım *et al* 2003: XLVIII, 4; L, 1; Schoop 2005: Pl 180: 18, Pl 181: 3), and often have small vertical handles at the neck or the carination (Alkım *et al* 2003: XLVII, 2; L,1; Schoop 2005: Pl 181:3). A jug with a drain in lower section of the body was also found (Alkım *et al* 2003: XLIX, 4; Schoop 2005: Pl 181:5). Holemouth jars are also common (Alkım *et al* 2003: XXVI, 1; XVII, 1, 4, 5; Schoop 2005: Pl 181: 1,2?). Some incised decoration occurs in the form of hatched incised bands (Alkım *et al* 2003: XLIII, 8 LV, 3, 5-8; Schoop 2005: Pl 180: 17) or bands with punctuate dots (Alkım *et al* 2003: XXVI, 1; LVII, 5-13; Schoop 2005: Pl 181: 1, 2, 4). However, wavy appliqué bands are also common, often with small knobs beneath them (Alkım *et al* 2003: XXIX, 2-4; XXX, 4; XXXI, 2, 4-14; XLIV, 6; XLV, 3, 5, 7; XLVII, 1, 4, 5; XLVIII, 1; LVI, 1-13; LVII, 1-4; Schoop 2005: Pl 180: 11). Some examples of this decoration type may have been intended to represent a face; another example seems to incorporate a handle as a nose (Alkım *et al* 2003: LVII, 1; Schoop 2005: Pl 180: 20). Other forms represented include biconical cups (Alkım *et al* 2003: XLVI, 3, 6-8), rough strainer bowls (Alkım *et al* 2003: XXVII, 6-7; L, 2-3; Schoop 2005: Pl 180: 16), and flat lids with handles (Alkım *et al* 2003: LI, 1-6; LII, 1-9; Schoop 2005, Pl 180: 19). These lids often have reed or plant impressions (Alkım *et al* 2003: LII, 1-9).

This pottery was published in an article by H. Alkım (1986) and later was republished in the 2nd excavation report, which included the Chalcolithic levels (Alkım *et al* 2003). It should be noted that most of the pottery published in Alkım *et al* (1988) as Chalcolithic was later redated to Level II, Phase 6 (i.e. EBA I). Schoop's consideration of the Chalcolithic pottery was based primarily upon H. Alkım's 1986 report, and does not consider the additional material that was published in the 2003 report. For the most part, however, the pottery from the 2003 excavation report corresponds quite well with the material included in Schoop's Chalcolithic pottery plates (Schoop 2005: Plates 180 and 181). However, closer examination reveals a few problematic areas. For example, one vessel (Schoop 2005: Pl 181: 1) that Schoop places in the Chalcolithic is published in the second excavation report (Alkım *et al* 2003: Pl. XXVI: 1) as being from Level II, Phase 4 (i.e. "EBA" I). Similarly, some of the strainer pieces (Alkım *et al* 2003: Pl XXVII: 6-7) are published as Level II, Phases 6 (Alkım *et al* 2003: XXVII,7) and 7 (Alkım *et al* 2003: XXVII,6). In these particular cases, consideration of their findspots in relation to the published sections (Alkım *et al* 2003: Plates XL-XLIII), however, reveals that they are more accurately placed in the Chalcolithic levels, as suggested by Schoop.

However, other issues arise with Schoop's periodization that are not as easily solved. The key to understanding these issues is the section that Schoop uses for his stratigraphic reinterpretation, which was derived from Alkım *et al* (2003: Plate XL). Schoop suggests that this section would appear to show evidence of a hiatus between Level III and Level II (i.e. between his complexes AA and BB). This supposed hiatus corresponds to a layer of sand and loam between the two cultural levels, and represents an unknown length of time. He states that the material directly above this sand/loam layer belongs to Level II Phase 6, which, while originally published in the 1988 report as Late Chalcolithic, is clearly linked with the layer above (Level II Phase 5) and was later re-dated to the EBI by the excavators.

Although Schoop states that despite the stratigraphic issues with Mound II, his Complex AA corresponds to the Level III assemblage as defined by the excavators, this is not actually the case. Due to his characterization of the thick sand/loam layer as evidence of a hiatus, he confines his Complex AA to the levels below this layer. His Complex BB (which he defines as equivalent to Alkım's Level II) begins with the settlement levels immediately above this layer. The sand/loam level between them does not appear to be included in either of his complexes (see Schoop 2005: Beilage 2). However, examination of the descriptions of the Chalcolithic period levels in the second excavation report makes it clear that Alkım *et al* do not define the boundaries of the Chalcolithic period in a similar way (2003: 37-42, 66-70). In Alkım *et al* 's periodization, the sand/loam layer is included within the Chalcolithic Level III, as are a small number of loci containing occupational remains immediately above this (i.e. levels that are within Schoop's Complex BB). Loci overlying the sand/loam layer as high in the section as b.928 are included in Level III, according to Alkım. Loci like 522 and 914 are included in Level II, as part of Phase 7. Level II, Phase 8 seems to be very ephemeral, with only 3 small loci included in it.

It is this redefinition of the boundaries of the Chalcolithic level that causes some of the problems with Schoop's discussion of the Chalcolithic pottery. Specifically, the problem is that several of Schoop's exemplars from his Complex AA are from loci 914 and 928 (Alkım *et al* 2003: XLVI: 1, 4, possibly also 8, 13; XLIX: 4). These loci, which are visible in section XLII (Alkım *et al* 2003), very clearly appear *above* the sand/loam layer. As a result, while these vessels are included within Alkım's definition of the Chalcolithic levels, according to Schoop's definition, they should be placed within his Complex BB.

Parzinger seems to have divided these two assemblages in a less problematic fashion than Schoop (1993: 236-238). For the most part, he seems to have used the divisions published by Alkım *et al* (1988, 2003), rather than attempting to redefine any of the boundaries between the periods. However, he groups Level III and Level II, Phase 6 together, noting that II,6 can be easily separated from the later material within Layer II. Above this level, he groups II3, II4 and II5 together to form a coherent group (Parzinger 1993: 237).

The issues arising from Schoop's definition of the boundary between his Complex AA and Complex BB, spill over into his characterization of the pottery of Level II. Schoop (2005: 312-313) suggests that the characteristics of the assemblage for Complex BB change slightly over time within the complex, which he had divided arbitrarily into BB1-3. In the early part of this level, ware type h7 (characteristic of the Chalcolithic period) continues to appear. It occurs alongside the first representatives of ware type 4, as well as vessels displaying different colours on their interior and exterior surfaces (both of which have features characteristic of the "Early Bronze Age" pottery). According to Schoop, forms appearing in this early part of Complex BB (i.e. BB1) include flatter, wider bowls than those seen in the Chalcolithic period, with in-turned edges (Alkım *et al* 1988: XXIII, 3; XXXVIII, 1; Schoop 2005: Pl 181:6-7). Bowls similar to those in seen in Level III also occur (Alkım *et al* 1988: XXIV, 1; XXXVIII, 5-6; Schoop 2005: Pl 181, 9). Also occurring are bowls with concave or s-shaped upper sections outturned over the carination, with knobs appearing on the carination itself (Alkım *et al* 1988: XXX, 7, 9; Schoop 2005: Pl 181: 10-11). Jars with rounded or s-shaped profiles and vertical handles placed at constant intervals around the rim and neck are frequent (Alkım *et al* 1988: XXXIX, 1-5; Schoop 2005: Pl 181: 13-14, 16-17). Holemouth pots with straight or concave upper sections also appear (Alkım *et al* 1988: XXXVIII, 2-4, 7-9; XXXIX, 6, 9; Schoop 2005: Pl 181: 15,18, Pl 182: 2), often with handles on the body or the shoulder. Handles in this period include vertical loop handles (Alkım *et al* 1988: XXXIX, 1-5, 13-14; Schoop 2005: Pl 181: 13-14, 16-17, Pl 182: 3), as well as a few horn handles (Alkım *et al* 1988: XXXIV, 9, 17; Schoop 2005: Pl 182: 4). Flat or slightly concave bases are predominant (Alkım *et al* 1988: XXXVIII, 16-18; XXXIX, 15-16;

Schoop 2005: Pl 182: 8-9), along with one pedestal base (Alkım *et al* 1988: XXXV, 17; Schoop 2005: Pl 182: 7). Not a lot of decoration appears in this subphase, but hatched triangles occurring around the carination or around the rim occur on a couple of examples (Alkım *et al* 1988: XXX, 7,9; Schoop 2005: Pl 181: 10-11).

In BB2, ware 7 no longer occurs. In this subdivision of Complex BB, only ware type h4 occurs. The pottery was mostly monochrome; vessels with differently coloured interior and exterior surfaces were not as pronounced as in other, later complexes. The surfaces of the pottery were generally well polished. With regard to forms, flat thin-walled bowls, with simple rims occurred (Alkım *et al* 1988: XXIV, 5, 8; XXV, 4-11; XXVI, 1-4; Schoop 2005: Pl 182: 11-17). In addition, a steep-walled bowl occurs, reminiscent of the Chalcolithic type, but more rounded at the base (Alkım *et al* 1988; XXIV: 3, 6, 10, 14-15; XXV, 1; XXVII: 1-9, 14-15; Schoop 2005: Pl 182: 20-25). There are also bowls with a carination, with the upper section either straight and in-turned (Alkım *et al* 1988: XXIII, 1-7; Schoop 2005: Pl 183: 1-3) or with an s-shaped curve at the top (Alkım *et al* 1988: XXVI, 6; Schoop 2005: Pl 183: 4). A similar profile to the latter is seen in a cup with an s-shaped carinated form and a horn handle (Alkım *et al* 1988: XXX, 10; Schoop 2005: Pl 183: 6). Holemouth jars with a straight or concave upper section appear (Alkım *et al* 1988: XXIX, 1-4, 6, 8-9; Schoop 2005: Pl. 183: 9-12), along with jars with a short straight (Alkım *et al* 1988: XXIX, 7; XXX, 11-12; XXXI, 1-4, 7-8; Schoop 2005: Pl. 183: 13-15) or flaring neck (Alkım *et al* 1988: XXX, 1-6; Schoop 2005: Pl 183: 18). Jugs with small drains also occur (Alkım *et al* 1988: XXXIII, 4-9; Schoop 2005: Pl 183: 22). Schoop suggests that some deep, narrow, thin-walled vessels are bottle-like containers (Alkım *et al* 1988, Pl XXXII: 1, 4-6, 10; Schoop 2005: Pl 183: 16-17). Horn handles with either one or two horns are quite prevalent (Alkım *et al* 1988: XXXIV: 4-12, 14-16; Schoop 2005: Pl 183: 24-

25), but solid lug handles also appear (Alkım *et al* 1988: XXXV, 1-5, 7; Schoop 2005: Pl 183: 23). Concave (Alkım *et al* 1988: XXXV, 19; Schoop 2005: Pl 183: 20) and pedestal bases (Alkım *et al* 1988: Pl XXXV: 15, 16-18; Schoop 2005: Pl 183: 19) are predominant. Decoration often consists of incised triangles (Alkım *et al* 1988: XXV,6, 10; XXVI, 2, 4-5; XXVII, 1,3; XXVIII, 10; XXX, 7; XXXI,1; XXXVI: 2, 6-17; Schoop 2005: Pl 184: 2, 4-6; Pl 183: 14), sometimes occurring in multiple registers (Alkım *et al* 1988: XXVII, 3; XXXI, 1; XXXVI, 6, 9, 14; Schoop 2005: Pl 183: 6,11,13-14). In addition, deeply cut white-encrusted incised decorations are frequent (Alkım *et al* 1988: 174, 182). Furthermore, white watery painting is common, occurring in bundles of thin parallel lines going from edge to edge diagonally and overlapping with each other, appearing primarily on the *inside* of bowl forms (Alkım *et al* 1988: XXIV, 10, 14; XXV, 4-7, 9-11; XXVI: 1-4; XXVIII, 1, 3, 6, 15; Schoop 2005: Pl 182: 11-13, 15-17, 23, 25). Occasionally, usually on flat wide bowls, painting on the interior of the bowl occurs along with incisions on the exterior surface (Alkım *et al* 1988: XXV, 4, 6-7, 9-10; XXVI: 1-2; XXVII, 1, 3; Schoop 2005: Pl 182: 11-13, 15-17). Closed containers occasionally have similar bundles of lines, generally limited to the upper section of the vessel (Alkım *et al* 1988: XXXII, 12; XXXV, 22, 26; Schoop 2005: Pl 183: 5, 7, Pl 184: 1). Incised decoration and paint are not combined in these examples.

Schoop's third, and most recent, portion of this level, Complex BB3, contains an assemblage too small to make any firm conclusions, as well as probably being contaminated with ceramics from later periods (i.e. Mound II, Level I).

Based on these descriptions, the impression is that there seems to be quite a lot of continuity between Schoop's Complex AA and complex BB1, including the continuation of wavy appliqué decoration and the continuation of the "Chalcolithic" bowl forms. This continuity is also seen in the persistence of ware type h7 into BB1, the characteristic ware of the Chalcolithic period. Furthermore, the similarity between the two assemblages is underscored by the fact that, as mentioned above, several of the exemplars that Schoop uses for his Complex AA actually originated from layers above the sand/loam level that are included in his Complex BB1 (Schoop 2005: Plate 180). While Schoop suggests that the sand/loam layer must represent a period of abandonment (2005: 309), the continuity in the pottery does not particularly lend support to this idea. Nor does the fact that this layer contains a reasonable amount of pottery similar to that occurring in the layers immediately above and below it. If there was a period of abandonment, it seems unlikely that it lasted for any significant length of time. It could perhaps originate from a single notable flood event of the Kızılırmak River, resulting in the deposition of a thick layer of alluvial material. Alternatively, and perhaps more likely, it could have been deposited intentionally as preparation for a construction event in the overlying layers. For example, the so-called "Büyük Yapı", the large structure found in Level III, Phase 1, was found directly above this sand/loam layer.

Mound II Pottery and Phasing

However, the solution to the stratigraphic problem of Mound II is not as simple as accepting the excavators' original periodization, and combining Schoop's BB1 with the layers in Complex AA below it. His description of the pottery types in his Complex BB1, while demonstrating strong continuity with the Chalcolithic levels, also includes a number of examples of types that are more common in Complex BB2. These types include hatched triangle incised decoration, wide flat bowls and horn handles; the presence of these features suggests that there may in fact be some mixing between pottery types that, once resolved, could allow a more meaningful division between the Chalcolithic and EBI levels. Luckily, Schoop (2005) provides a diagram of

Alkım's section (2003: Plate XL), on which he illustrates his placement of his subdivisions between BB1, BB2 and BB3 (Schoop 2005: Beilage 2). He states that he made these divisions in an arbitrary fashion. However, consideration of the pottery in tandem with the available section drawings demonstrates that by shifting his arbitrary division slightly, a much more significant separation can be achieved between the levels with pottery displaying Chalcolithic affinities and that of the levels above. This proposed division lies very close to the Level II/Level III division proposed by Alkım *et al* (2003). However, it does involve shifting a number of key loci downward into the Chalcolithic levels that were included by Alkım *et al* in Level II. This would essentially involve moving Level II, Phases 7 & 8 into the Chalcolithic Period, as well as certain fill loci (i.e. b.123, 700, 702, 703, 914). In this sense, it is rather similar to the grouping of Levels II,6 (much of which was shifted into Phases 7 & 8 as the sequence became better understood in later seasons) and Level III, as proposed by Parzinger (1993: 237).

The shift of these levels and loci having been accomplished, this division may be defined as the boundary between the so-called "Chalcolithic" and "EBA I" assemblages. Such a division demonstrates that there is a fairly sudden shift in the pottery technology used on Mound II, with very little overlap in the pottery types between these two levels. The characteristic forms of the "EBA I" assemblage, including forms such as tab and horn handles, white-painted decoration in the form of bundles of parallel lines occurring on the interior of bowl forms, and white-encrusted incised decoration are now confined to these upper levels. It may still be valid to suggest that some kind of sub-division should exist within the "Chalcolithic" period between the levels below the sand/loam layer (i.e. Level III, 2-8) and the levels occurring above it (i.e. Level II, 7-8 and Level III, 1). While the lower levels contain only ware types h7 and h8, the upper levels also demonstrate the appearance of ware type h4 alongside them. Ware type h4 continues into the

"EBA I" period; however, the pottery of Levels II,7-8 and III,1 is certainly more accurately placed with the remainder of Level III, as it demonstrates greater affinities with the Level III material, and very few with the material above them. There is so little material available from Schoop's BB3 that it is hardly useful to maintain it as a separate stratigraphic entity. Thus, all of the Level II material above the aforementioned division can likely be considered as a single unit.

This leaves Level II as a fairly homogenous assemblage, including carinated bowls with flaring rims (Alkım *et al* 1988: XXVI, 6; XXX, 7; Alkım *et al* 2003: V,7; VI,1,3), wide simple bowls (Alkım *et al* 1988: XXV, 5-11; XXVI, 1-5; XXVII, 1-3, 5-9, 14-15; Alkım *et al* 2003: V, 1,3) and deep bowls with simple rims and rounded bottoms (Alkım *et al* 1988: XXIV: 1, 3-4, 6, 9-10, 14-15). Hole mouth jars with a straight or concave upper section are also present (Alkım *et al* 1988: 1-6; 8-9; Alkım *et al* 2003: VI, 2, 4-5; VII, 9), as are jars with very short necks (Alkım *et al* 1988: XXIX, 7; Alkım *et al* 2003: VII, 5; VIII, 3). The characteristic horn handles, of which there are many examples, are limited to this level, and may have either one or two horns (Alkım *et al* 1988: XXXIV, 1-8, 10-15; Alkım *et al* 2003: V, 2; X, 1-10; XI, 1-12; XII, 1-2). Horn handles with animal heads also occur (Alkım *et al* 1988: XXXIV, 18-19, 21), as do animal-headed or upturned knobs or lugs (Alkım *et al* 1988: XXXV, 1-5, 7; Alkım *et al* 2003: VI, 7; XII, 7). Tab handles also occur in this level (Alkım *et al* 1988: XXVI, 3; Alkım *et al* 2003: XII, 3-6). Incised decoration often occurs in the form of hatched triangles, some times in more than one register, around the rim or the carination (Alkım *et al* 1988: XXV,6, 10; XXVI, 2, 4-5; XXVII, 1,3; XXVIII, 10; XXX, 7; XXXI,1; XXXVI: 2, 6-17; Alkım *et al* 2003: VI, 6, 9; VII, 1; IX, 8, 11, 12; XIII, 6, 9, 12, 14). These incisions are often filled with a white encrusted material (Alkım et al 1988: 174, 182). The painted decoration usually occurs on the interior surface of bowl forms, and appears in the form of thin white parallel lines, arranged in groups or bundles running at angles to each other (Alkım *et al* 1988: XXIV, 10, 14; XXV, 4-7, 9-11; XXVI: 1-4; XXVIII, 1, 3, 6, 15; Alkım *et al* 2003: V, 1, 3). The paint is usually watery, and was probably applied after the burnishing of the vessel, but before firing. The paint is often difficult to see or worn away (Alkım *et al* 1988: 174, 182). The pottery in this level is generally monochrome black and is often well burnished (Alkım *et al* 1988: 182). The practice of having differently coloured interior and exterior surfaces is much less common in this level than in others. The painted decoration most frequently occurs on the interior of bowl forms, often appearing alongside incised decorations (hatched triangles) filled with a white incrusted material.

Despite the appearance of white painted decoration in both assemblages, Thissen believes that the Mound I assemblage from Areas C and F is substantially different from that found on Mound II, Level II (1993). Alkım also recognized the difference between the white painted decorations from Sounding C on Mound I and those from Mound II, and suggested that the difference between them simply represented chronological development (i.e. the Mound I ceramics date to the EBII and developed from the Mound II ceramics, dating to the EB I) (Alkım *et al* 1988: 196). Thissen, in contrast, argues that the types of white-painted pottery occurring in these assemblages represent completely different traditions, with the decoration being found in different locations and on different vessel types (1993: 216). In Sounding C, the paint is applied only to the exterior of affected vessels, while on the Mound II material, it is applied to the interior of open bowl forms and is often combined with grooved decorations on the vessel exterior that are filled with a white paste (Thissen 1993: 216). The two types of decoration are mutually exclusive with respect to findspot and they generally occur with different vessel types. Thissen believes that the "EBA I" material from Mound II should in fact be dated to the same period as Karanovo IV (i.e. Early Chalcolithic, contemporary with Büyük Güllücek, Alaca

Höyük "early Chalcolithic" and Alişar 14-12M), while the material from Mound I should be dated to the Late Chalcolithic (along with the material from the summit of Dündartepe) (Thissen 1993: 222).

The material from Mound II, Level I was labeled by Schoop as Complex CC (2005: 313-314). The pottery in this level demonstrates a clearer separation between fine and rough ceramics is seen compared to earlier complexes (i.e. 4a vs. 4b-c), with the fine variant ("a") of ware 4 dominating (Alkım *et al* 1988; Schoop 2005: 314). Ware h6, which includes shell temper, appears to be almost completely limited to this level (Alkım *et al* 1988; Schoop 2005: 314). This statement, however, may be problematic due to the manner in which the pottery is presented in the excavation reports. Since the most common ware type during the Early Bronze Age is h4, this ware is discussed in the greatest detail, and is presented according to the form typology devised by the excavators. Other ware types (h5 and h6) are only discussed and presented insofar as they present examples of new form types not seen in ware h4 (Alkım *et al* 1988: 213). As a result, the full range of forms and proveniences of ware h6 is not presented in the excavation reports. The fact that the heavy preponderance of h6 pottery that *is* presented is limited to this level suggests that it likely rarely occurred outside of this level (Alkım *et al* 1988: XXXVII). Level I also shows a stronger development of the differences in colour between the interior and exterior surfaces of the vessels than seen in the underlying Level II (Alkım *et al* 1988; 181).

Common Level I forms include carinated bowls with straight, in-turned lips, and relatively narrow bases (Alkım *et al* 1988: XXIII, 2, 7; XXVIII, 6, 8-9; XXXVII 1, 2; Schoop 2005: Pl 184: 10-15), sometimes with knobs around the lip (Alkım *et al* 1988: Alkım *et al* 1988: XXVIII, 8; Schoop 2005: Pl 184: 14) or the carination (Alkım *et al* 1988: XIII, 7; Schoop 2005: Pl 184: 13). There are also carinated bowls with straighter upper portion (Alkım *et al* 1988: XXIII, 4;

XVIII, 1 ,4). Occasionally, very deep bowls with simple slightly curved walls occur (Alkım *et al* 1988: XV, 1; Schoop 2005: Pl 184, 17). Pots with simple rounded or carinated walls, and knobs around the edges (Alkım *et al* 1988: XXIX, 12-14; XXXII, 2, 3, 7; XXXVII, 5-6; Schoop 2005: Pl 184: 18-24). There are some holemouths with a simple incurving top, or with very short neck and slightly flaring lip (Alkım *et al* 1988: XXIX, 10; XXXVII 4-6). Often these have small lug handles around the rim (Alkım *et al* 1988: XXXVII: 5-6). Jars with relatively narrow, straight or very slightly flaring necks also occur (Alkım *et al* 1988: XXXII, 2-3; XXXVII: 7-14). There are also large jars or pithoi with constricted necks and flaring rims (Alkım *et al* 1988: XV, 3-4; XXXIII, 3; Schoop 2005: Pl 185: 1-3). Horn and tab handles no longer occur; most handles are small lugs (Alkım *et al* 1988: XXVIII, 8; XXIX, 12-14; XXXVII; 5-6). Furthermore, very little decoration is seen, with the exception of small knobs, which often occur around the rim or the carination of vessels.

Mound III

Hellenistic and late Iron Age remains were both found on Mound III, and are referred to as Level "0" (Bilgi 1999e: 200). An open kiln and two burials dated to the Late Iron Age were found on this mound (Bilgi 1999a: 27). Below this, remains dating to the Transitional Period were also found, but were badly eroded and were likely originally more substantial (Alkım *et al* 2003: 34-35; Bilgi 1999e: 2000). Only 2 phases of occupation were dated to the Transitional Period (referred to as 1-2 in Bilgi's early articles discussing Mound III) (Bilgi 1999e: 200). Below this, 4 sub-phases dated to the EB III period (1-4) were found (Bilgi 1999c,d,e). All of these levels contained architectural remains with construction techniques similar to those seen elsewhere on the site. The buildings were of timber and wattle-and-daub construction, with beaten earth floors (Bilgi 1999e: 201). In some cases, there was evidence for the use of wood in the flooring of certain buildings (Bilgi 2000: 316). To prevent the decay of the wood due to moisture from frequent rain, the wood was sometimes placed on top of flat stones. The buildings are generally rectilinear in plan, with either one or two rooms (Bilgi 2000: Plan 1-2). The complexes seem to have courtyards, in which were found installations interpreted as hearths or kilns (Bilgi 1999e: 201).

Some of these kilns/hearths were dubbed “monumental” (*anıtsal)* and consisted of dome-like constructions built around a wood frame and then heavily plastered (Bilgi 1997: 324-334; Bilgi 2000: 317-318). Some of these complexes were interpreted as workshops for specialized production (Bilgi 1997: 334; Bilgi 1999e: 204). The excavators suggest that these kilns were used for pottery production, and that pits located nearby were intended for processing and tempering of clay (Bilgi 1997: 336; Bilgi 1999e: 204). They also suggest that metal production was occurring in the area, presumably in the same kilns, due to the presence of a spouted crucible nearby (Bilgi 1997: 332, 336; Bilgi 1999e: 206). However, beyond the ubiquity of metals at the site, both in the cemetery and in other contexts, and this single crucible, other evidence for the production of metal seems extremely limited (i.e. no concentrations of slags, etc.). EBIII sub-phase 2 in this area produced remains interpreted as a religious complex, containing a “hearth-altar” (*fırınlı-sunağın*) (Bilgi 1999c: 140-142; Gates 1996). This area was interpreted as being cultic in function due to the concentration of a number of idols within it (Bilgi 1995: 160; 1997: 334).

There were 15 sub-phases identified on Mound III that date to the EB II period (phases 5-19). These levels are not described in great detail, but the descriptions that are provided suggest that these levels contained a series of remains similar to those encountered in the EB III levels above them (Bilgi 1999b: 381-387). The majority of the levels seem to have contained only fragmentary remains, many of which showed evidence of heavy burning. However, one level produced the architectural remains of a building constructed of timber and wattle-and-daub (Bilgi 1999b: 382, Plan).

Mound III Pottery

The pottery of Level II on Mound III (i.e. the EB III pottery) is published in three articles, covering the material excavated between 1993-1996. The pottery is described grey, black or brown in colour, well-fired and well-burnished, although examples of reddish pottery also occur (Bilgi 1999c: 144). It is mineral and chaff tempered, with occasional examples of shell temper (Bilgi 1999c: 144). It should be noted that when excavations on Mound III were first conducted in sounding J in 1977, the Early Bronze Age pottery found there had examples with chaff and mineral temper (i.e. h4), as well as chaff, mineral and shell temper (i.e. h6) (Alkım *et al* 2003: 46) . Apart from its appearance here, h6 occurred primarily in Mound II, Level I (Alkım *et al* 1988: XXXVII). This may tentatively provide a link between these two assemblages, although this can only be suggested with extreme caution (see discussion in Mound II, Level I regarding problems describing the distribution of ware types).

Shallow and deep bowls with simple or inturned rims are common (Bilgi 1999c: Plate 3: 4-8, 10; Bilgi 1999d: Plate 2: 3, 5-8; Bilgi 1999e: Plate 1: 2-7, Plate 2: 2,7). Some of these have knobs around the rim or protruding above it at regular intervals (Bilgi 1999c: Plate 3: 5, 7, 10; Bilgi 1999d: Plate 2: 7-8; Bilgi 1999e: Plate 1: 4-6, Plate 2: 2), including doubly horizontally pierced knobs (Bilgi 1999c: Plate 3: 5, 7), or vertically elongated lugs (Bilgi 1999d: Plate 2: 8). One bowl with a similar form is set on a high pedestal base (Bilgi 1999d: Plate 4: 5). Another deep bowl demonstrates an omphalos base (Bilgi 1999c: Plate 3: 6). There are also examples of "pie crust" rims, with indentations interspersed around the lip (Bilgi 1999c: Plate 3: 9; Bilgi

1999d: 173, Plate 2: 9). Some of the bowls have decoration on the exterior of the vessel consisting of a group of parallel lines (Bilgi 1999c: Plate 3: 5; Bilgi 1999d: Plate 2: 3, 6; Bilgi 1999e: Plate 1: 3). It is not clear from the illustrations whether these decorations are incised or painted. They are very similar to painted decorations seen from Areas C and F, as well as from Level IIb on Mound I. However, the verbal description of the pottery in these articles does not mention painted decoration. Bilgi does state, however, that white painted pottery was found on Mound III in the exploratory trench "J", which was excavated in 1977 (Bilgi 1990b: 167).

Other simple bowls or cups have a flat base and vertical walls (Bilgi 1999e: Plate 2: 1, 3-4) or flaring walls (Bilgi 1999e: Plate 2: 5-6). Jars with vertical walls were also found, often with lug handles interspersed at regular intervals around the rim (Bilgi 1999c: Plate 4: 1-3; Bilgi 1999d: Plate 3: 1-2, 4, Plate 4: 3; Bilgi 1999e: Plate 4: 1); one has a rounded bottom (Bilgi 1999c: Plate 4: 3). Some of these have doubly vertically pierced lugs (Bilgi 1999c: Plate 4: 2; Bilgi 1999d: Plate 3: 2), while another has doubly horizontally pierced lugs (Bilgi 1999d: Plate 4: 3), or horizontally elongated lugs (Bilgi 1999c: Plate 4: 3). Another jar demonstrates a highly asymmetrical form (Bilgi 1999d: Plate 3: 3). Other jars have lips with multiple ridges (Bilgi 1999c: Plate 4: 4; Bilgi 1999d: Plate 4: 1). Holemouth jars are common, and may also have lugs interspersed around their rims (Bilgi 1999d: Plate 4: 2; Bilgi 1999e: Plate 3: 1-6). One holemouth jar has double registers of lug handles interspersed around its body (Bilgi 1999d: Plate 3: 5), another has horizontal handles around the rim (Bilgi 1999e: Plate 3: 4). One unique holemouth has a group of small knobs interspersed around the upper part of the body, and two vertical loop handles set lower down on the body (Bilgi 1999e: Plate 3: 6). Another holemouth has two horizontal handles set near its rim, and two further horizontal handles set near its base (Bilgi 1999d: Plate 3: 6). It is very similar in form to an example found in the EBII levels of Mound I

(Bilgi 1992: 200; see description above). Other jars include examples with globular bodies and very short (Bilgi 1999e: Plate 4: 3-4) or taller necks (Bilgi 1999e: Plate 4: 5-7). Decorations consisting of groups of parallel lines, either incised or painted, also appear on the exterior of the closed forms (Bilgi 1999d: Plate 4: 2, 9; Bilgi 1999e: Plate 4: 9, 10). Oddly shaped lugs are also present (Bilgi 1999d: Plate 4: 10-11). One highly distinctive form consists of a narrow necked jar with a globular body; it has doubly horizontally pierced lugs around the rim, small knobs around the widest part of the body, vertically incised decorations on the lower part of the body, and is supported by four feet at the base of the vessel (Bilgi 1999d: Plate 4: 4).

The above reports only provide illustrations of the pottery originating from the EBIII levels on Mound III (i.e. Level II). The material dated to the EBII (Level III) is discussed only in the report on the 1998 excavation season, and only in brief verbal descriptions (Bilgi 1999b: 381-387). The descriptions suggest that the pottery of this level is relatively homogenous and consistent, despite the fact that there are as many as 15 sub-phases within this level. The pottery is divided into two groups: a group that is roughly made and a finer group. The roughly made pottery has chaff and large and mid-sized mineral inclusions in a black-grey, grey or grey-brown paste. The forms include jars with out-turned rims and horizontal handles, or shouldered jars with straight-sided necks. Some of these jars also display small knobs or horizontal handles around the mouth of the vessel. Forms described as fruitstands also occurred. The finer pottery had similar temper types and colours, and was well-burnished. Forms included globular or shouldered jars with inturned rims or straight sided necks. These jars also often have horizontal handles around the rim of the vessel. Decoration appears to be primarily incised, but raised rope decoration also occurs in small numbers (Phase 12), as does reserved slip. There are also examples of handles with the appearance of a toothed comb.

The Radiocarbon Evidence

There have been a number of published radiocarbon dates from İkiztepe, but they are problematic, and often contradictory (see **Table 2.2: Published Radiocarbon Dates**). These dates have been reported in a number of different publications (Alkım *et al* 1981; Özbakan 1988; Alkım 1983; Alkım *et al* 2003), and have been compiled in a number of different places (Mellink 1991; Schoop 2005; TAY Project Radiocarbon Database). Many of the same radiocarbon dates have been published in different sources with inconsistent calibrations. However, it would seem that the dates published in Alkım *et al* (2003: 144) have been incorrectly calibrated and are therefore particularly problematic. It seems that these dates have been "calibrated" by simply converting BP to BC (i.e. subtracting 1950), rather than using an accepted calibration curve to account for fluctuation in atmospheric radiocarbon over time. As a result, these dates are much later than a proper calibration would suggest, and have likely contributed to the inconsistencies in the site chronology. However, it is possible to determine the correct calibrated dates using the original C14 results. Furthermore, there are very few cases where the sample type is listed (i.e. whether the samples are long-lived or short-lived samples). It seems likely, given the pervasive use of wooden architecture at the site, along with the frequency with which burnt architectural remains were discovered, that many of the dates come from long-life samples. It is impossible to determine the source of the timber, as well as the ring from which the samples may have been taken. The dates presented in the following charts have been re-calibrated using OxCal 4.0, following the IntCal04 calibration curve (see **Table 2.2: Published Radiocarbon Dates)**.

There have been a series of dates published from Mound I (see **Table 2.2: Published Radiocarbon Dates**). The majority of the published dates from Mound I, Level I suggest a date range in the early part of the 2nd millennium BC (ODTU8, HUR51, HUR52A, HUR52B). These dates are not entirely consistent with their stratigraphic locations within the sounding, but for the most part there are no major problems. The one exception to this is sample ODTU15, which produces a date in the first half of the 3rd millennium BC. This sample originated from the upper levels of Level I, and is particularly problematic because it represents a short-lived sample. According to Özbakan, this sample was charred grain, rather than charcoal (1988: 353). In addition to this, there are a series of dates published in the TAY Project Radiocarbon Database whose source I have not been able to determine, and which may have originated directly from the excavator. These dates are listed as belonging to Level I on Mound I, and present dates ranging from the late 4th millennium BC to the mid-8th millennium BC (HUR97, HUR98, HUR100, HUR101, HUR103, HUR 105). Some of these dates are older than any other dates from the site, and without further information about their context, it is impossible to reconcile them into the Mound I sequence.

There are also a series of dates published from Level II on Mound I (see **Table 2.2: Published Radiocarbon Dates**). In general, these dates fit rather well with the contexts from which they were excavated. They suggest a date for the upper part of Level II (i.e. IIa) in the late 4th millennium BC (HUR53, Bln2525/DDR), and a date for the lower part of Level II (i.e. IIb) in the late 5th millennium BC (Bln2526, Bln2526A). These dates are certainly much earlier than the dates proposed for these levels, which are traditionally dated to the EBII period. Rather, a Chalcolithic date would seem more appropriate. Once again, there are an additional 2 dates published in the TAY Project Radiocarbon Database, whose source is unknown (HUR99, HUR102). Their provenience is listed by TAY as Mound I, Level II, but beyond this no information is provided. These dates are again earlier than would be expected given the other dates presented for Level II (early 5th and mid-6th millennium BC respectively). However, it would be feasible to suggest that they might come from the Level III remains beneath Level II (i.e. which has been dated to the EBI period by Bilgi). One notable date is from Level II in Area C (ODTU16), a level which has been the object of much chronological debate based on its ceramic assemblage (i.e. Thissen 1993, Parzinger 1993, Schoop 2005). This date is located in the mid-4th millennium BC, corresponding well with attempts to re-date this level to the Late Chalcolithic period.

There have been 6 published dates from the sequence on Mound II. Two of these originate from Level III, three from Level II and one from Level I (see **Table 2.2: Published Radiocarbon Dates**). The dates from Levels III and II do not separate out particularly well, and tend to overlap. Both levels produce contradictory dates, with some in the range of the late 5th to early 4th millennia BC (HUR56, ODTU6, ODTU18), and some in the late 4th-early 3rd millennia BC (HUR 55, ODTU22). The single date for Mound II, Level I dates to the beginning of the 3rd millennium BC (HUR54).

In general, the C14 dates published from Mound II would tend to lend some support the arguments of Thissen (1993) and Schoop (2005), who have suggested that the Mound II sequence should be shifted earlier. The dates for the "EBAI" levels (i.e. Level II) indicate that it can likely be pushed earlier, into the Late Chalcolithic period. The "Late Chalcolithic" material (i.e. Level III) would in theory be pushed even earlier (i.e. into the Middle Chalcolithic period). However, it could not be much earlier than Level II, given the degree to which the radiocarbon dates overlap. It is possible that the occupation of Mound II was not as widely spaced over time as previously supposed, and should be compressed into the period from the Mid- to Late Chalcolithic.

Table 2.2: Published Radiocarbon Dates

Mound I Radiocarbon Dates

Sample No.	Context	Uncalibrated Date	Calibrated Date	Reference
"Transitional Period"				
ODTU8	Level I, Phase 2	3694±161BP	2350-1800BC	(TAY)
	Charred grains, b.421, D4/IV11	3690±160BP		(Özbakan 1988: 353)
	Level I	3694±161BP	1744±161BC	(Alkım *et al* 2003: 144)
HUR51	Level I, Phase 3b	3498±72BP	1920-1690BC	(TAY)
	Level I	3498±72BP	1548±72BC	(Alkım *et al* 2003: 144)
	Level I, Phase 3b	3498±72BP	1960-1725BC	(COWA:178, Alkım 1981: 89&144)
HUR52A	Level I, Phase 4	2997±75BP	1380-1120BC	(TAY)
	Level I, Phase 4	2997±75BP	1380-1225BC	(COWA:178, Alkım 1981:89&144)
HUR52B	Level I, Phase 4	3153±93BP	1530-1260BC	(TAY)
	Level I, Phase 4	3153±93BP	1640-1340BC	(COWA:178, Alkım 1981:89&144)
ODTU15	Level II	4267±104BP	3030-2670BC	(TAY)
	Charred grains, b.422, D4/IV12	4270±100BP		(Özbakan 1988: 353)
	Level I	4267±104BP	2317±104BC	(Alkım *et al* 2003: 144)
HUR105	Level I, Phase 2	4575±149BP	3520-3040BC	(TAY)
HUR100	Level I, Phase 4	5485±119BP	4460-4160BC	(TAY)
HUR97	Level I, Phase 5	7613±95BP	6590-6270BC	(TAY)
HUR98	Level I, Phase 5	6045±106BP	5210-4720BC	(TAY)
HUR101	Level I, Phase 5	8558±139BP	7810-7380BC	(TAY)
HUR103	Level I, Phase 6	4540±130BP	3500-3020BC	(TAY)
"EBAII"				
HUR53	Level II, Phase 2		3365-2930BC	
	Level IIA	4437±83BP	2487±83BC	(Alkım *et al* 2003: 144)
	Level II, Carbonized wood	4437±83BP	3330-2929BC	(TAY)
	Level IIA	4437±83BP	3365-2930BC	(COWA:176, Alkım 1983: 178-179)

Bln2525	Level II, Phase 4?			(Bilgi 2001: 76-77)
	Level II	4630±50BP	3520-3350BC	(TAY)
	Level IIa	4630±50BP	3520-3355BC	(COWA:176, Alkım 1983: 178-179)
Bln 2526	Level II, Phase 6?			(Bilgi 2001: 76-77)
	Level IIB	5470±60BP	4425-4320BC	(COWA:176, Alkım 1983: 178-179)
	Level II	5470±60BP	4360-4240BC	(TAY)
Bln2526A	Level IIB	5420±70BP	4415-4105BC	(COWA:176, Alkım 1983: 178-179)
	Level II	5420±390BP	4700-3750BC	(TAY)
ODTU16	Level II	4788±267BP	3950-3100BC	(TAY)
	Level IIA, Area C	4788±267BP	2838±267BC	(Alkım *et al* 2003: 144)
	Level IIA	4788±267BP	3805-3365?	(COWA:176, Alkım 1983: 178-179)
DDR	Level IIA, Area H, Phase 4, b.1237	4630±50BP	2680±50BC	(Alkım *et al* 2003: 144)
HUR99	Level II	6730±124BP	5730-5520BC	(TAY)
HUR102	Level II	5872±159BP	4940-4540BC	(TAY)

Mound II (Area B) Radiocarbon Dates
“EBAII”

HUR54	Level II, Phase 1	4270±93BP		(Schoop 2005: xxx)
	Level II, Charred Grain	4270±93BP	3030-2680BC	(TAY)
	Level II, Phase 1, Charred Grain	4270±93BP	3055-2800BC	(COWA:177, Alkım 1981:145)

“EBAI”

ODTU18	Level II, Phase 3	5552±120BP		(Schoop 2005: xxx)
	Charcoal	5552±120BP	4540-4250BC	(TAY)
	Level II	5552±120BP	3602±120BC	(Alkım *et al* 2003: 144)
	Level II, charcoal, b.116, D11/II19	5550±120BP		(Özbakan 1988: 353)
ODTU6	Level II, Phase 5	5172±171BP		(Schoop 2005: xxx)
	Level I, Phase 3a	5172±171BP	4230-3780BC	(TAY)
	Level II, charcoal, b.517, D13/II19	5170±170BP		(Özbakan 1988: 353)

	Level II	5172±171BP	3322±171BC	(Alkım *et al* 2003: 144) 3322±171BC
ODTU22	Level II, Phase 6	4028±95BP		(Schoop 2005: xxx)
	Charcoal	4028±95BP	2860-2450BC	(TAY)
	Level II, charcoal & charred grains, b.506, D13/II11	4030±100BP		(Özbakan 1988: 353)
	Level II	4028±95BP	2078±95BC	(Alkım *et al* 2003: 144)

"Chalcolithic"

HUR55	Level III, Phase 1	4480±130BP		(Schoop 2005: xxx)
	Level III, Charcoal	4480±130BP	3360-2930BC	(TAY)
	Level III, Phase 1, Charcoal	4480±130BP	3380-2940BC	(COWA: 176, Alkım 1981:146)
HUR56	Level III, Phase 4	5454±87BP		(Schoop 2005: xxx)
	Level III, Log	5454±93BP	4450-4110BC	(TAY)
	Level III	5454±93BP	3504±93BC	(Alkım *et al* 2003: 144)
	Level III, Phase 4	5454±87BP	4430-4110BC	(COWA: 176, Alkım 1981: 146)

One important observation, however, is the dates for Level II on Mound I, which are much earlier than have been previously anticipated. The radiocarbon dates suggest two distinct periods of deposition within Level II, as postulated by the excavators' reconstructions of the morphology of the tell. The earlier occupation (Level IIb) would seem to date to the Early-Mid Chalcolithic period, while the later occupation (Level IIa) would date to the Late Chalcolithic period. This raises questions regarding the date of the cemetery itself, which was excavated into these remains, and must post-date Level II. However, this leaves the possibility that the cemetery could in fact date to any time within the 3rd millennium, rather than necessitating a date in the EBIII period. To date, there have been no radiocarbon dates analyzed from any of the material originating from the cemetery. Furthermore, no analysis of material from Mound III or Mound IV has ever been published.

Regional Connections and Comparative Chronology

The chronological discussion surrounding İkiztepe highlights a number of long-standing chronological issues within Anatolian archaeology itself, which have only recently be acknowledged and examined. These problems relate back to the chronological frameworks which have long been used for interpreting Anatolian sites. The arguments are also related to the ways in which Anatolian archaeological cultures have been related to their counterparts in Southeastern Europe. The scholar who has examined this problem most thoroughly is Özdoğan, who has published a number of commentaries on the subject (1991, 1996; Özdoğan *et al* 1991). Due to the fact that, in the Late Chalcolithic and Early Bronze Age I periods, parallels with the Southeast Anatolian, Levantine and Mesopotamian assemblages have been difficult to come by (i.e. Uruk material, until the excavation of Tepecik), the archaeological material cultures of Anatolia during these periods have been difficult to pin down chronologically. Initially, archaeologists working in Anatolia were skeptical about the existence of early archaeological material there, and "it was almost taken for granted that the region was uninhabited during the Neolithic period" (Özdoğan 1991: 218). Alişar Höyük, for example, provided a 20m-deep sequence of pre-Middle Bronze Age material, but it was assumed that the earliest material in this sequence was Late Chalcolithic (von der Osten 1937: 30; Özdoğan 1991: 218; Özdoğan *et al* 1991: 63). This was pushed even later by Orthmann (1963), who produced a key comprehensive study of early Central Anatolia, and who considered the earliest levels at Alişar Höyük to be EBAI (Orthmann 1963: 16, 98). Özdoğan notes: "a vague comparison with Kültepe was made and also basal Alişar black burnished pottery was considered to be analogous to East Anatolian Karaz-Khirbet Kerak wares" (1991: 218). These parallels are now recognized to have been erroneous (Özdoğan 1991: 220). This framework then provided the chronology upon which many later studies of Central Anatolia were based. The existence of assemblages dating prior to the Early Bronze Age was not widely accepted (Özdoğan 1996: 188). Thissen also notes this problem, suggesting that the label of "Early Bronze Age", as well as a date in the 3rd millennium, has been erroneously retained for what are essentially Chalcolithic assemblages at a number of Anatolian sites (1993: 211). These problems essentially stem from heavy reliance on the chronological frameworks developed by Bittel and Orthmann, and it is only in recent years that the true depth of Anatolian occupation has been acknowledged.

Map 2.2: Locations of Archaeological Sites Included in Comparative Chronological Discussion

While parallels between Anatolian assemblages and those of Southeastern Europe had long been noted (i.e. Fewkes 1936), new chronological understandings of the Southeastern European assemblages pushed their dates much earlier. As a result, the parallels noted with Anatolian material were now considered void, as the Anatolian chronology had not undergone a significant shift toward earlier dates (Özdoğan 1991: 218). Özdoğan notes that this way of thinking resulted in material from phases earlier than the earliest Alişar levels being considered Late Chalcolithic (1991: 219). This included İkiztepe, whose "Late Chalcolithic" remains Özdoğan notes as being "almost identical" to the Vesselinovo (Karanovo III) remains from the Balkans (1991: 219). This approach is now recognized to have been flawed, with Alişar displaying cultures ranging from the Late Neolithic to the Bronze Age (Özdoğan 1991: 220; Steadman 1995: 25). As a result, the early occupational sequence in Central and Northern Anatolia must be reconsidered.

Due to the general lack of exploration and excavation in Northern Anatolia, finding good parallels for the materials excavated from İkiztepe has generally been a difficult endeavour. The majority of the parallels to the İkiztepe assemblage come from sites such as Dündartepe, Tekeköy and Kavak, located nearby. Logically, parallels can also be made with material recovered from surveys in the Sinop region (Doonan 2004). Unfortunately, very little of this material has been illustrated (Doonan 2004: 58, 66). However, these sites seem to form a separate province from the remainder of Anatolia (Burney 1956: 182; Mellink 1991: 219). Thus, it has always been a challenge to relate this province to the chronologies of the better known and better excavated areas of Anatolia, such as Central, Southern or Western Anatolia. Links to Central Anatolia are present, but remain relatively limited until the "Transitional" or "Early Hittite" Period (Alkım *et al* 1988: 195).

The pottery from Mound II, Level III, originally dated by the excavators to the Late Chalcolithic period, has the fewest obvious parallels, and has been one of the most difficult assemblages to place chronologically. Due to the fact that the material from the later Mound II, Level II was similar to the earliest material at Alişar, and this assemblage evidently pre-dated it, it was placed by the excavators in the Late Chalcolithic, who relied heavily on Orthmann's chronological framework (Özdoğan 1991: 219). Bilgi, wishing to maintain a Late Chalcolithic date for this level, places it contemporary with Büyük Güllücek and Alaca Höyük XII/XV, as well as Alişar 15M-19M (Bilgi 2001b: 76-77). However, these assemblages clearly show greater parallels to the material excavated in Mound II, Level II (see below). Steadman suggests a date for "İkiztepe III" of between 5500-5000 BC, contemporary with the assemblages of Ilıpınar V, Yarimburgaz Level 3, the later part of Can Hasan, and Hacilar I (1995: 17). Parzinger places this level with a similar group of assemblages, as well as Karain I-II, Tigani Ia-c and Emporio X (Parzinger 1993: Beilage 5). Schoop's framework differs somewhat, with Hacilar I and the entire Ilıpınar X-V sequence placed earlier (Schoop 2005: Beilage 1). He places the end of his "Complex AA" (Mound II, Level III) approximately contemporary with Kumtepe A and Emporio VIII, although he does not define a boundary for the beginning of this complex (Schoop 2005: Beilage 1). Notably, though, his absolute date for "Complex AA" does not differ significantly from that suggested by Steadman and Parzinger (i.e. ca. 5000 BC) (Schoop 2005: Beilage 1). Özdoğan suggests that this assemblage is very similar to that of the Balkan Vesselinovo culture, which would place it in a similar date range (late 6th millennium BC) (1991: 219). The common thread in the reconstructions of this material is the chronological uncertainty.

In contrast to the material from Mound II, Level III, one of the assemblages at İkiztepe that has been the easiest to find parallels for is that which directly follows it. The material from

Mound II, Level II has strong links both to the Balkans and to the Aegean, as well as more limited parallels in Central Anatolia. The connections between İkiztepe II/"EBA I", Alaca Höyük "earlier Chalcolithic" material (i.e. the earliest levels at the site) and Büyük Güllücek were identified by Alkım (Alkım *et al* 1988: 184-187). Parallels at these sites include jars with horned handles, vessels with carination and incised and grooved decoration, and white painted ceramics (Steadman 1995: 24). Particularly notable at the single-period site of Büyük Güllücek were white-filled incised rectilinear or dot decoration, common in İkiztepe Mound II, Level II (Steadman 1995: 24). While not common, a few isolated examples of white painted ceramics similar to the İkiztepe II material were also found at Alişar (19M-15M) (von der Osten 1937: 57, Fig. 63:3,4). In addition, recent excavations have provided evidence that Yarimburgaz Level 2 has produced black-burnished pottery and bowls with incised decoration filled with white paste, dating to the Middle/Late Chalcolithic (Steadman 1995: 18). İkiztepe II has recently been dated to approximately 4500 BC, and is considered contemporary with Yarimburgaz Level 2, Alişar 19M-15M, and the end of Ilıpınar V (Steadman 1995: 19). It was also placed slightly earlier than Gelveri Güzelyurt, which was recently re-examined (Steadman 1995: 17; Esin 1993). Once again, Parzinger generally agrees with these parallels, adding Beşiktepe, Tigani II and Emporio IX (Parzinger 1993: Beilage 5). Schoop, again, uses a slightly different framework, placing this level contemporary with Karain II/III, Tigani III and Gülpinar-Beşiktepe-Sivritepe (Schoop 2005: Beilage 1). Once again, however, his absolute date for this assemblage does not differ from other frameworks (4500 BC) (Schoop 2005: Beilage 1).

The similarities between these Anatolian assemblages and Aegean sites such as Tigani (I-III) on Samos, Ayio Gala, Emporio X-VIII on Chios, Kalythies on Rhodes and material from Vathy on Kalkımnos have also been recognized (Thissen 1993: 210). Horn handles, which are common in the İkiztepe Mound II, Level II assemblage, are particularly characteristic of Tigani III (Samos), and also appear at other sites in Anatolia, such as Alaca Höyük and Büyük Güllücek (Thissen 1993: 210). Tab handles, which also appear in this assemblage have parallels in both Anatolia (at Alaca Höyük, Kusura, Beycesultan, Kuruçay Höyük and Troy) and in the Aegean (at Tigani (Samos), Hagio Gala (Chios), Thermi (Lemnos), Saliagos, and Kalythies on Rhodes) (Alkım *et al* 1988 186-187, Thissen 1993: 210, note 9). Tab handles have also been found at other sites in the Black Sea coastal region, in surveys conducted in the vicinity of Sinop (Doonan 2004: 58).

Within the Balkans, the parallels have been more difficult to secure, due to the issues of chronology discussed above. Thus, while Yakar links the Mound II, Level II material to Karanovo VII, Thissen links it with the earlier Karanovo IV (Yakar 1981: 97, Yakar 1985a: 237; Thissen 1993: 211*)*. It is the latter parallel that has gained widest acceptance in recent years (i.e. Steadman 1995; Parzinger 1993; Schoop 2005; Özdoğan 1991, 1996). Steadman suggests that it is during the period just prior to İkiztepe II that ceramic parallels between Anatolia and the Balkans become most visible, particularly in the assemblages of Ilıpınar V and Yarimburgaz Level 3 (1995: 21). These sites, which have black burnished ceramics with fluting and incised decoration on the upper half of the vessels, display parallels to Karanovo III-II and early Vinça (i.e. A and B), Anza IV and Sitagroi I-II (Steadman 1995: 21). Horn handles, which provide one of the best links between Anatolian and Balkan assemblages, appear in this period and continue into Karanovo IV (Steadman 1995: 21). Horn handles, which are common in the İkiztepe Mound II, Level II assemblage, in addition to the Balkan sites already mentioned, have also been found at Nova Zagora in Bulgaria, and in northern Greece at Paradimi and Kokkinochoma (Proskinites) (Thissen 1993: 210; Steadman 1995). In addition, the "technique, location and structure of motifs of white-painted decoration…[and]…several vessel shapes" are similar to Aegean examples (Thissen 1993: 210, note 9). See Thissen for references and a more detailed list and discussion of parallels to both the Aegean and the Balkans (1993: 210, n.9).

Parallels between Anatolia and the Balkans continue into the period of the material of Areas C and F, whose placement prior to other Mound I assemblages has been discussed above. These assemblages are now widely considered contemporary with the material from the summit of the mound at Dündartepe (Thissen 1993: 222; Steadman 1995: 17; Schoop 2005: Beilage 1). These areas are also linked with the Anatolian assemblages of Alişar 14M-12M, and Ilıpınar IV (Steadman 1995: 17; Thissen 1993: 222). Furthermore, Thissen adds Alaca Höyük "later Chalcolithic", Beycesultan "Late Chalcolithic" and Yazır Höyük to this list (Thissen 1993: 222). Schoop, in contrast, lists very few parallels to his "Complexes DD/EE" (2005: Beilage 1). Overall, most scholars seem to place this assemblage within the 4th millennium BC, although there is some variation in its exact placement. Thissen and Schoop both place it in the 2nd half of the 4th millennium BC, while Steadman appears to place it slightly earlier, in the 1st half of the 4th millennium BC (Thissen 1993: 222; Schoop 2005: Beilage 1; Steadman 1995: 17). The relationship between these assemblages and that of Mound II, Level I is unclear. Thissen and Steadman do not address the relative placement of this assemblage in their considerations of the material. Schoop, however, places his "Complex CC" around 3500 BC, contemporary with Ilıpınar IV and Demirci Höyük F & G and after "Complex DD/EE", although with a question mark (2005: Beilage 1).

Parzinger's interpretation of these later layers is rather different. He does not mention the material from Area F, but links CII (Area C, Level II) and DII (Area D, Level II) together, assigning them to a relatively long period of time (Parzinger 1993: Beilage 5). He places this complex **after** Mound II, Level I, which he suggests is contemporary with the cemetery on Mound I (1993: Beilage 5). This placement of the cemetery is somewhat problematic stratigraphically, given that the cemetery would appear to be cut into the remains of Level II on Mound I (i.e. including Area D, Level II). However, Parzinger does suggest that the cemetery spans a much longer period of time than has previously been considered, and notes that its period of use may begin substantially earlier than previously thought (Parzinger 1993: 237). In addition, he does not define a temporal boundary to the final use of the cemetery. Furthermore, he suggests that the relative relationships between these layers cannot be determined with certainty due to the lack of a stratigraphic link between Mounds I and II (Parzinger 1993: 236-237). The CII-DII complex, however, he places contemporaneous with a variety of Anatolian sites (Troy I-IIc, Yortan A, Emporio VI-IV, Beycesultan XVIII-XIV, Karaoğlan Vc-a, Polatlı, Ahlatlıbel-Etiyokuşu, Alaca Höyük 5-8, Horoztepe II, Maltepe IIT, Alişar 8-11M and 13-14T, Kültepe 14-17) (Parzinger 1993: Beilage 5).

In this period, parallels are found in the form of black burnished pottery, including carinated bowls with incised or grooved decoration in geometric, zigzag and V-shaped patterns (Steadman 1995: 23). The İkiztepe and Dündartepe assemblages from this time also display white painted decoration. Thissen distinguishes this white paint from that seen on the ceramics encountered on Mound II, Level II (1993: 216; see discussion above), saying that it displays a different placement and form corpus from this earlier material, and is also mutually exclusive with regard to find context (Thissen 1993: 216). Anatolian parallels to the Area C/F painted pottery can be seen at Alişar 14M, Demircihöyük (Ware F), Beycesultan Late Chalcolithic, and Yazır Höyük, as well as Samos Tigani IV in the Aegean (Thissen 1993: 222). Thissen also points out that this type of white painted decoration actually continues into the first quarter of the 3rd millennium, at sites like Polatlı, Etiyokuşu, Ahlatlıbel, Asarçık Hüyük, Karaoğlan, Maltepe, Yortan, Troy I, Poliochni, Kusura A and Thermi B (1993: 222-223). In fact, this continuity may explain the persistence of this type of pottery throughout the use of Mound I, Level IIb and Areas C & F, as well as on Mound III. In the Balkan assemblages, ceramic parallels can be seen in Karanovo VI (Gumelnitsa) and late Vinça contexts (Steadman 1995: 22-23). However, these parallels are "conceptual", rather than direct, as there is no "classic" Karanovo VI material at either of these sites (Steadman 1995: 23; Thissen 1993: 218). Many of the key features of the Karanovo VI ceramic corpus, including graphite-painted decoration, large lids and strongly angled vessel shapes are not found in the Northern Anatolian assemblages (Thissen 1993: 218). However, the parallels to the Karanovo VI period are not limited to pottery. Thissen also cites a number of other specific connections between İkiztepe material and Balkan sites, including baked clay female figurines with pierced ears found in Area F on Mound I, which bear similarities to those of Karanovo VI/Gumelnitsa figurines (Thissen 1993: 217; Steadman 1995: 28; see also Alkım et l 1988: 216-218, 225). Fragments of similar figurines have also been found at Alişar 14M-12M (von der Osten 1937: 78, Fig. 85; Thissen 1993: 217). The metal finds from the Dündartepe summit have also been suggested to have similarities to examples found at Karanovo VI and the cemetery at Varna (Thissen 1993: 217).

White painted pottery similar to that observed from Areas C and F, Mound III and Mound I, Level II has also been found in excavations in Eastern Thrace, in two excavations near Edirne (Kumocağı/Avarız and Tepeyanı) (Erdoğu 1995). The pottery in question is well-burnished and often black, but sometimes displays the interior/exterior colour differential observed at İkiztepe (Erdoğu 1995: 268). The paint, like at İkiztepe, is applied after burnishing, and appears in the form of groups of thin parallel lines (Erdoğu 1995: 269). Significantly, he notes that with one exception only the external surfaces of the vessels are decorated (Erdoğu 1995: 269). Erdoğu compares the pottery at these two sites to both that appearing at İkiztepe Mound II, Level II and to the material from Mound I, Areas C and F (Erdoğu 1995: 271). He does not discuss his pottery with regard to the differences between these two types of painted decoration, as outlined by Thissen (1993). He states that the forms observed can only be said to correspond in general terms with Anatolian and Aegean types, and suggests parallels to material from Dündartepe and İkiztepe (Thissen 1993: Fig. 4:5 and 5:2; Alkım *et al* 1988: XIII,8; XXXII,6; XXXV, 22, 29). Many of these parallels are from the Dündartepe Summit material or from İkiztepe, Area C. Those that are not from these areas are from İkiztepe Mound II, Level II, but represent forms that are similar to those observed in Areas C and F. Furthermore, additional form parallels (also with white paint) can be found in the material published in later reports, originating from Area H (Level IIb) or from Mound III (Alkım *et al* 2003: LXXXI, 2, 7; Bilgi 1999d: Fig 4:2). Outside of the two sites described by Erdoğu, similar white painted pottery had previously been scarce at sites in Eastern Thrace, with only one sherd found at the site of Toptepe (Özdoğan 1991: Fig. 20: 4; Erdoğu 1995: 270). Based on the Toptepe sherd, Erdoğu dates the pottery found at his sites to the Karanovo IV-Vinça B/C horizon (i.e. the 5th millennium BC, equivalent to İkiztepe Mound II, Level II) (Erdoğu 1995: 271). However, it would seem more likely, given the placement of the white paint on the exterior surfaces of the vessels and the form corpus associated with the mat-painted sherds, as illustrated in his article, that they should be associated with the later form of the white painted pottery (i.e. late 4th millennium BC, equivalent to İkiztepe Mound I, Areas C and F, etc.)

Finally, despite the dearth of information published regarding the cemetery (outside of the metal collection), some links have also been made between the material originating from the cemetery and sites in southeastern Europe. Links have been made between figurines originating from the EBIII tombs and examples known from Europe, and a group of flat gold ring-shaped idols have been linked to examples from sites in the Balkans such as Varna in Bulgaria (Yakar 1981: 97, Bilgi 1984c: 74; Bilgi 1990b: 175; Zimmermann 2007). These ring idols were found both in the cemetery (SK192, SK246) and in the settlement remains beneath it (Area D, Level II), and seem to have a wide variety of parallels in Southeast Europe, where they have a long lifespan and continue into the 3rd millennium, appearing in Schönfeld and Bell Beaker contexts (Zimmermann 2007: 26). Bilgi himself relates these idols to similar examples from the Varna cemetery in Bulgaria (Bilgi 1984c: 74). The distinctive type found at İkiztepe, with a flaring "head" and centrally pierced circular body, was most common in the late 5th and early 4th millennia BC (ca. 4500-3500 BC) (Zimmermann 2007: 26). Many of the examples found at Anatolian sites were from poorly documented contexts, and were generally attributed to the Early Bronze Age (i.e. the necropolis of Göller, and Kalinkaya) (Zimmermann 2007: 28). Examples from the site of Bakla Tepe were attributed to the EB I-II periods (Zimmermann 2007: 29). In fact, İkiztepe presents the largest and best stratified collection of these idols in an Anatolian context, which were all dated by the excavators to the EBII-III. Zimmermann, however, argues that these examples should be more accurately dated to the Chalcolithic period (Zimmermann 2007: 28).

Finding comparisons for the metals excavated in the EBIII cemetery has been difficult. Bilgi points out some broad parallels to examples originating throughout the Near East, in Southeastern Anatolia, Syria and Greater Mesopotamia (Bilgi 1990b: 173-175). However, there are a number of peculiar types that have no obvious comparisons, and approximately 90% of the corpus have no parallels outside the Central Black Sea region (Bilgi 2001b: 37). Bilgi suggests that this indicates that the metallurgical industry employed at İkiztepe was locally developed (Bilgi 2001b: 37). Yakar, in contrast, comes to the opposite conclusion. As the İkiztepe artifacts were composed of arsenical copper rather than tin bronze, Yakar suggests that this metalworking tradition did not develop locally, as it represents a significant change from the earlier EBII metal industry (Yakar 1985a, b). Rather, he suggests that it was introduced by a new population at the site in the EBIII (Yakar 1985b:30-33). Bilgi, however, suggests that Yakar's characterization of the metallurgical industry is incorrect, as he was working with faulty data (Bilgi 1990b: 166 n.36, 170 n. 54, 172 n. 63). Muhly has also suggested that there is no evidence of any significant difference between the EBII and the EBIII metals, based on the published information in Bilgi's studies (1984c, 1990b), as Yakar had postulated (Muhly 1993: 242). While the excavator has characterized the metal objects found in the cemeteries as being the result of local development rather than outside influence, he originally acknowledged that no evidence for metal production had yet been found at the site (Bilgi 1990b: 170, 173). Since this time, Bilgi has suggested that evidence of metallurgical production at İkiztepe has been found, although it remains extremely limited and does not represent the scale of production required to manufacture the volume of metal objects found in the cemetery.

Another potential problem can be seen in the ceramic assemblage excavated in Mound I, Level I. Thissen notes that Sounding A on Mound I has produced an assemblage of classic EBII-III pottery, as described by scholars such as Orthmann (Orthmann 1963; Thissen 1993: 212). He describes this pottery as having the characteristic impressed decoration, made by a fingernail or other implement, located in a zone around the widest diameter of the vessel; large lids with similar impressed decoration are also present (Thissen 1993: 212; Alkım et al 1988: XI, 13, 15-17; XII; XIII, 1; XIV; XVI). This statement, however, is slightly problematic, as the first excavation report, upon which Thissen would primarily have based his conclusions, consisted almost exclusively of material from Level I in Sounding A, with very little material from Level II (Alkım *et al* 1988). A glance through this material confirms Thissen's description, and many of these typical EB II-III vessels were certainly found in Level I (Alkım *et al* 1988). Similar material is found in Level I in the material published in the second excavation report (Alkım *et al* 2003: XXIII,2; XXXIX, 4; XLI, 3; LXX, 2,4; LXXI, 1-3; *LXXXI, 3; LXXXII, 1-4, 7*). The presence of this pottery was recognized by Alkım, who said that "simultaneously with this 'Early Hittite' culture, an additional Early Bronze type culture had lived alongside it, with numerous examples illustrating the continued influence of this earlier tradition" (Alkım *et al* 1988: 153). He also postulated that "the discovery of a few complete pots and sherds of EB III beside Early-Hittite pottery suggests that the tradition of EB III was continued or both the inhabitants of the EB III and the Early-Hittites continued to live together for a while" (Alkım 1977: 42). A stratigraphic explanation for this mixture of pottery types would be more satisfactory, although it is difficult to construct. The Early Bronze and "Transitional Period" pottery certainly seem to cluster within particular excavated loci, but the majority of these loci cannot be found on the published sections for Mound I. However, this mixing of EB and "Transitional Period" pottery within the layers of Level I certainly raises questions about the possible existence of EBII-III layers overlying the cemetery, which would push the *terminus post quem* for the cemetery earlier than previously supposed.

In general, the trend in recent reconsiderations of the İkiztepe material has been to push the entire sequence into earlier periods. Although most studies have focused their attention on the Mound II sequence, this earlier shift is not limited to this mound. Thissen and Parzinger's early reconsiderations included discussions of the material from Mound I, Areas C and F, which were placed in the Late Chalcolithic (Thissen 1993; Parzinger 1993). There have also been other arguments suggesting that other portions of the Mound I sequence should perhaps be shifted earlier, particularly given the similarities between the Area C/F assemblage and that from Mound I, Level II. In fact, Thissen has gone so far as to suggest that there are also indications that much of the EBII/III material in North and Central Anatolia should be pushed slightly earlier in the 3rd millennium than is generally accepted (Thissen 1993: 219). However, this shift is based quite heavily on parallels with various Eastern European assemblages, particularly the Cernovoda III-II material (Thissen 1993: 219). While the "Early Hittite" period İkiztepe ceramics have a number of parallels throughout Anatolia (Dündartepe, Tekkeköy, Boğazköy-Büyükkale [NW slope levels 8b,8c,8d,9, lower city levels 4 and 5], Alaca Höyük, Alişar, Polatlı, Ahlatlıbel, Beycesultan, Mersin), the "Early Bronze Age" assemblage has much more limited parallels, principally restricted to nearby sites in the Black Sea region (Dündartepe, Tekkeköy, Kavak), along with Alaca Höyük.

The difficulty of finding parallels for the "EBII" and "EBIII" assemblages from Mounds I and III may be related to the unique northern Anatolian assemblage represented by İkiztepe, but it creates difficulties in placing the Mound I sequence chronologically. Certainly, there appears to be no evidence in the "Early Bronze Age" İkiztepe assemblage of any of the Early Bronze Age pottery types found in the Aegean or Troad regions. Classic Troy I and II forms, such as beak rim jugs, do not appear until the "Transitional Period" and there is no evidence of the distinctive *depas amphikypella*. The most important link is the one to Alaca Höyük. The clearest parallels to the EBII-III pottery at İkiztepe, which occur alongside the "Transitional Period" material, are from Alaca Höyük Levels 5-8, originally attributed by Orthmann to the EBII-III period (1963: 73).

New Radiocarbon Evidence

As part of the current study two bone samples from the İkiztepe cemetery were submitted for radiocarbon dating (from skeleton numbers ITSK643 and ITSK602). For each of these samples, a rib sample weighing approximately 1g was sent to the Accelerator Mass Spectrometry Laboratory at the University of Arizona. The results of radiocarbon dating for these samples are presented in the tables and figures below.

Table 2.3: Results of Radiocarbon Dating

Skeleton No.	Years BP ± 1σ	Calibrated Results (calBC)
ITSK602	4620 ± 61	3629-3585 (4.6%) **3531-3311 (74.1%)** 3295-3286 (0.5%) 3275-3265 (0.6%) 3239-3105 (15.5%)
ITSK643	4457 ± 57	**3347-3007 (87.6%)** 2988-2931 (7.8%)

Figure 2.1: Calibration Curve for ITSK602

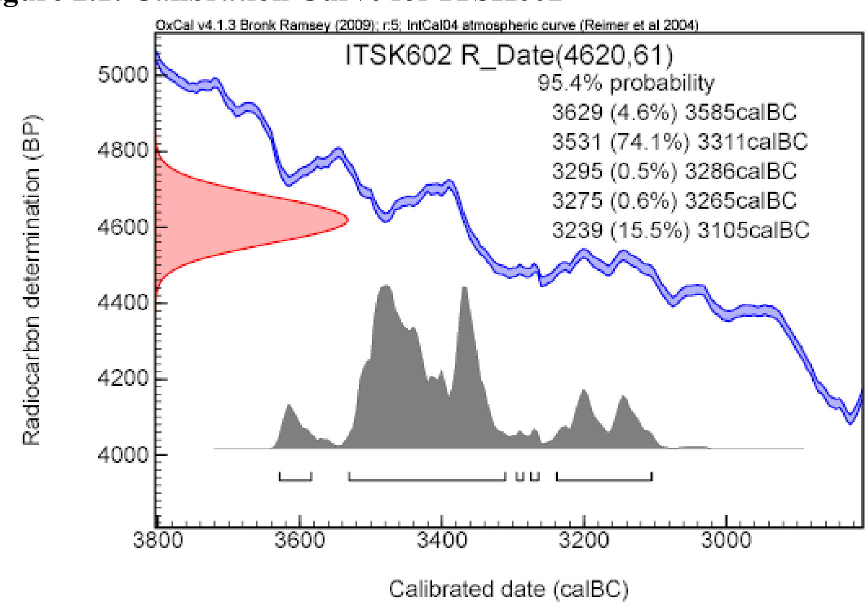
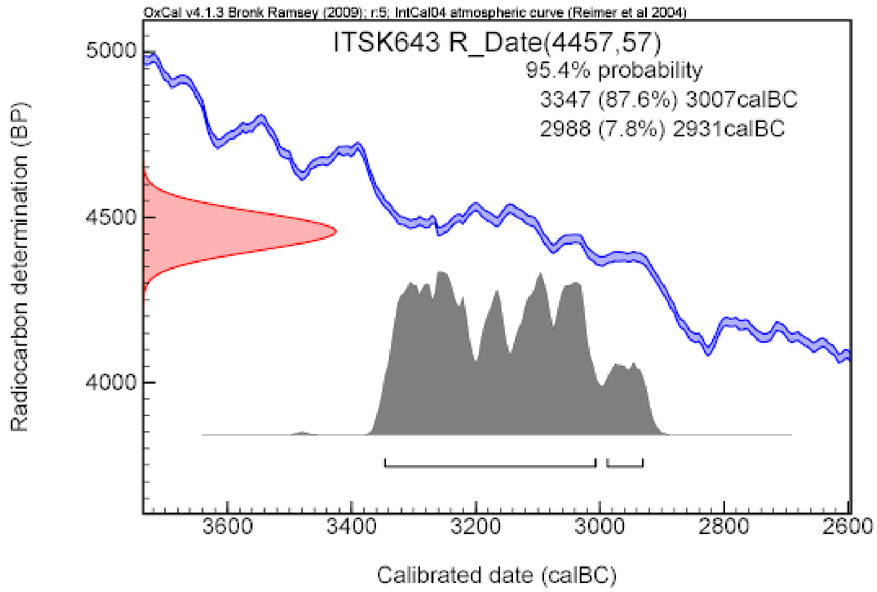


Figure 2.2: Calibration Curve for ITSK643



The chronometric results provided by these two burials suggest a date for the cemetery in the region of 3500-3000 calBC. In the context of the preceding discussions, these dates are extremely significant, given that the cemetery has traditionally been given a date in the EBII-III period, between 2400-2100BC. Rather, these results would suggest that the İkiztepe cemetery seems to date to the Late Chalcolithic-Early Bronze I transition. These dates correspond quite well with the stratigraphic evidence discussed above, which is suggestive of a *terminus post quem* for the cemetery in the EBII-III period, due to the fact that ceramics from this period with distinct parallels to Central Anatolian forms are concentrated in the levels overlying the cemetery. These dates also correspond well with the overall trend for scholars to suggest that the entire occupation sequence at İkiztepe should be shifted toward dates significantly earlier than previously supposed.

Summary

This chapter emphasizes the fact that the archaeological context of the site of İkiztepe is poorly understood, as it represents the only comprehensively excavated site in the region of Northern Anatolia. Furthermore, it demonstrates that despite more than 30 years of excavation at the site of İkiztepe, the lack of comparative material for the İkiztepe corpus has led to significant discussion and disagreement regarding both the absolute and relative chronology of the site's occupation sequence.

Most significantly, new radiocarbon dates from skeletal material from the İkiztepe cemetery were presented that suggest that the cemetery should be dated to the Late Chalcolithic-Early Bronze I transition period, rather than to the EBII-III period. As a result, when considering the context of the cemetery at İkiztepe with regard to the contemporary burial customs observed throughout Anatolia and the Black Sea region, parallels should be sought in both the Chalcolithic and Early Bronze Ages.

Chapter Three: Burial Practices at İkiztepe

While the preceding chapter examined the archaeological context of the site as a whole, this chapter focuses on the particular context of the cemetery itself within the sphere of mortuary practices observed in the neighboring regions of Anatolia and southeastern Europe. This chapter therefore summarizes the excavation of the İkiztepe cemetery and the basic burial practices observed therein, as well as presenting a sample of comparative mortuary data from Chalcolithic and Early Bronze Age periods in the surrounding regions. The evaluation of these burial customs facilitates the contextualization of the mortuary practices observed at İkiztepe, as well as providing a sense of the information available about the skeletal remains analyzed in this study. Following this comparative analysis, a more detailed examination of the burial practices observed in the cemetery is conducted, with a particular focus on the spatial distribution of particular demographic groups and grave good types.

The cemetery excavated at İkiztepe had produced 685 burials at the end of the 2003 season, which have been described as containing at least 720 individuals (Bilgi 2003a; 2005). Further seasons of excavations have produced small numbers of additional graves, but these are not considered as part of this study (Bilgi 2009). With few exceptions, the graves within this cemetery consisted of simple earthen burials, and in the majority of cases, the body was placed on the back with the arms beside the body (Bilgi 1984c, 2003a). Despite the homogeneity observed in burial positions, there was no common orientation evident in the placement of the bodies (Bilgi 1984c: 34). Several different levels of burial activity could be identified, which suggested that the cemetery was likely in use for several generations (Bilgi 2003a). In fact, the absolute vertical depth of the cemetery area measured as much as 6.7 m (Bilgi 1984c: 34; Parzinger 1993; Zimmerman 2007).

At the end of the 1986 season, when 608 burials had been unearthed, it was estimated that 90% of the cemetery had already been excavated (Backofen 1987: 175; Bilgi 2003b, 2004). At this time, two small soundings in the original trenches had reached virgin soil, and only a small number of additional burials were anticipated outside of these areas (Backofen 1987: 175). The majority of the remaining burials excavated after this date (41 graves) were found during the 2000-2002 seasons during excavations in Trench M, to the north of the original cemetery excavation area (Bilgi 2003b, 2004: 25,28).

In addition to the burials found within the cemetery itself, occasional intramural burials outside the cemetery area were also excavated, generally consisting of pot burials of infants in habitation areas (Bilgi 2003b, 2004: 25, 2005: 17-18). These burial types were found in levels dated by the excavators to the Early Bronze I and the Middle Bronze periods, but none appear to date to the period during which the cemetery was in use (Bilgi 2005: 17-18).

Excavation of the Cemetery

The first burials from the cemetery at İkiztepe were discovered during the 1975 season, which was the second season of excavation at the site. During this season, 21 burials were excavated, and were described in the site's first excavation report (Alkım *et al* 1988). Further excavations were aimed at continuing to investigate this cemetery, with more than 10 additional burials being excavated over the next two years. Many of these latter burials, however, display different burial practices from the remainder of the cemetery, and thus probably date later than the cemetery proper (i.e. to the "Transitional Period").

In 1978-1979, 34 additional cemetery burials were uncovered. This group of graves was originally known as "Necropolis II", because they displayed a difference in depth of 2-2.5m compared to those excavated in earlier seasons (Alkım *et al* 2003). It was not until the 1980 season, when 79 more graves were excavated between the "two" necropolises that it was realized that they in fact constituted a single, sloping necropolis on Mound I (Alkım *et al* 2003).

After this, significant numbers of burials were uncovered in each successive season of excavation. The largest number of graves was excavated during the 1984 season, when almost 200 burials were found, bringing the total to over 500 burials excavated within the cemetery. Further graves, although in smaller numbers, were excavated between 1985 and 1987. At this point, it was believed that the majority of the cemetery had been discovered, and excavations focused on other areas of the site for the next few seasons. However, between 1993-1995 and 2000-2004, excavations were again conducted in this area, and found some additional burials. Preliminary results of these seasons of excavation have been published in *Kazı Sonuçları Toplantısı* and/or *Anadolu Araştırmaları*, as well as in a series of other articles examining the metals from the cemetery (Bilgi 1984c; 1990b). However, final reports on the cemetery have never been published.

A number of burials at the site have been found that were not part of the cemetery, and thus are not considered as part of this study. Three burials (SK22-24) were found in Area G, and date to the Transitional Period. Nine further burials (SK25-31, SK637-638) were found on Mound I, but seem to be part of a separate phenomenon from the cemetery itself, as they were found significantly shallower than the remainder of the cemetery burials. In addition, these burials were interred in pots, and most likely date to the Transitional Period. One burial each were found in Area J (SK32) and Area K (SK68). A number of burials were also found on Mound III in Area

L. Two of these (SK627-628) date to the Late Iron Age, while another (SK630) dates to the Hellenistic period. For the remainder of the Mound III burials (SK629, 631-635), the date is not clear.

İkiztepe Burial Practices

The most comprehensive study of the burial practices and cemetery at İkiztepe published to date is the doctoral thesis of Nuran Doğan (2006). Much of the primary data used for the following descriptions relating to burial positions and grave goods comes from this thesis.

Placement of the Body

With the exception of a few pithos and pot burials dating to the "Transitional Period", which should not be considered part of the cemetery itself, the burials in the İkiztepe cemetery consist almost exclusively of simple pit burials. As previously mentioned, the majority of the graves demonstrate the body placed on the back, legs extended and arms placed beside the body. According to Doğan, who presents data for 511 burials, 305 burials (or 59.7%) were placed in this position (2006: Table 26). A further 17 (or 3.3%) burials were placed on their back with legs extended and arms placed in various positions over the body (Doğan 2006: Table 26). A total of 22 (4.4%) burials were placed on the back, with the legs displaced either to the right or left side, or placed akimbo; of these, equal numbers were displaced to the right and left sides (Doğan 2006: Table 26). Additionally, a total of 15 (3%) burials were placed on their side, with their legs slightly flexed; significantly more (11 or 2.2% vs. 4 or 0.8%) were placed on their left side as opposed to the right (Doğan 2006: Table 26). Finally, the remaining 152 burials (or 29.7%) were described as having an unknown body placement (Doğan 2006: Table 26).

Overall, there is no immediate pattern apparent in the orientation of the burials, in terms of a consistent direction of burial (Bilgi 1984c: 34). However, in plotting the burial orientations in relation to the reconstructed ancient slope of the mound, it seems that the burials may have been placed preferentially in order to lie parallel to the ancient slope of the mound (see below and **Map 3.3: İkiztepe Cemetery)**. A significant proportion of the burials had a south-north or southeast-northwest orientation (259 or 50.7%); a further 61 (or 11.9%) burials were oriented northwest-southeast (Doğan 2006: Table 28). The remaining 5 directions are represented by 103 burials (20.2%), and the majority of these (58 or 11.4%) were oriented in a west-east direction (Doğan 2006: Table 28). Finally, the remaining 87 burials (or 17.2%) had an unknown orientation (Doğan 2006: Table 28).

Grave goods

Some of the objects included as grave goods, particularly the metals, have been described in detail by Bilgi (1984c, 1990b); other types of objects, including the pottery, have received less attention. A catalogue of the objects associated with particular burials is provided by Doğan (2006), although no illustrations are provided.

Backofen also examined the distribution of grave goods within the cemetery (1987). This study was undertaken after the 1986 season of excavation, when a total of 608 graves had been excavated (Backofen 1987: 175). Backofen considered only undisturbed graves, which she numbered at 329 (Backofen 1987: 176). Of these, 81 (25%) were found without any grave goods, while 247 (75%) contained at least one object. The proportions of graves with no grave goods included varied very little across different demographic groups within the population, including between males and females and between adults and children (Backofen 1987: 176). In all of these groups, the ratio of graves with one or more grave goods to those with none was consistently 3:1 (Backofen 1987: 176). In general, however, when burials are characterized according to the total number of grave goods found within them, male burials tend to be richer than those of females and children (Backofen 1987: 177). This was demonstrated by an average grave good number of 2.53 for men, compared to 1.94 for women and 1.97 for children (Backofen 1987: 177). In particular, men display much greater numbers of burials containing 10 or more objects (Backofen 1987: 177).

There is also a differentiation between men and women in the types of grave goods contained in the burials. Men are most commonly buried with metal weaponry and tools, and the occurrence of amulets is also primarily restricted to male burials (Backofen 1987: 177). Idols and ornamental spirals are also more frequent among men. Weapons occur less frequently among females, although they do occur; pottery and jewellery are more common in female burials. Children's graves typically contain jewellery; there are some occurrences of tools, but these are generally confined to the graves of older children. In general, the number of grave goods was found to increase with increasing age (Backofen 1987: 178).

Table 3.1: Distribution of Grave Goods (Backofen 1987 vs. Doğan 2006)

Number of Objects	**Backofen 1987**						**Doğan 2006**					
	Male		**Female**		**Children**		**Male**		**Female**		**Children**	
	#	%	#	%	#	%	#	%	#	%	#	%
0	23	23.4	22	24.7	34	25.8	48	39.0	50	45.0	117	56.3
1	24	22.4	25	28.1	32	24.2	19	15.4	24	21.6	26	12.5
2	14	13.1	18	20.2	24	18.2	25	20.3	26	23.4	30	14.4
3	10	9.4	9	10.1	14	10.6						
4	5	4.7	2	2.3	12	9.1	13	10.6	3	2.7	23	11.1
5	7	6.5	7	7.9	8	6.1						
6	7	6.5	3	3.4	2	1.5	11	8.9	6	5.4	10	4.8
7	5	4.7	1	1.1	3	2.3						
8	5	4.7	1	1.1	1	0.8						
9	0	0	1	1.1	1	0.8						
10	2	1.8	0	0	0	0	7	5.7	2	1.8	2	0.9
11	1	0.9	0	0	0	0						
12	1	0.9	0	0	0	0						
13	0	0	0	0	0	0						
14	1	0.9	0	0	1	0.8						
Total	107		89		132		123		111		208	

Graves												
Total Objects	271		173		260		279		173			
Average Objects	2.53		1.94		1.97		2.27		1.56			

Doğan later studied the distribution of grave goods after a number of additional seasons of excavation, and in general found similar patterns to those described by Backofen years earlier. Doğan had 511 burials available for study; all age and sex categories had increased in number since Backofen's study, which examined only undisturbed contexts. The number of male burials had increased the least (from 107 to 123), females had increased by a greater number (from 89 to 111). However, the greatest increase was in the number of children, from 132 to 208. Doğan also identified a higher average number of grave goods among males than females (2.27 as compared to 1.56; 2006: 61), although both of these averages are lower than those suggested by Backofen in 1987. Doğan also found a similar pattern to that observed by Backofen with regard to a trend of increasing occurrence of grave goods with increasing age (see **Table 3.2: Distribution of Grave Goods by Age Group**). However, Doğan also demonstrated a different and unexpected pattern, with younger children (aged 1-6 years) possessing, on average, more grave goods than young and medium adults. In fact, the only age group that possessed a higher average number of grave goods than younger children were adults over the age of 50 years (Doğan 2006: Table 35). Due to the fact that metal objects were the most common type of grave good found in the cemetery, a similar pattern can be found with regard to the average number of metal objects in age/sex groups. Once again, older adults (50+ years) demonstrate the highest average occurrence of these objects (at 2.43), with children aged 1-6 years in second place (with an average of 1.91) (Doğan 2006: Table 42). Males again tended toward more metal objects than females, with an average of 2.04 compared to 1.31 (Doğan 2006: Table 41). Among the different types of metal objects, Doğan found (similar to Backofen 1987) that weaponry was more common in male graves, although not limited exclusively to them, occurring in women's graves as well (Doğan 2006: Table 59). A similar pattern was observed with tools. Among adults, the occurrence of these object types increased with increasing age (Doğan 2006: Table 60). Jewellery, in contrast, was more common among adult females than adult males, but was most often found in the graves of children (Doğan 2006: Table 60). The link between male burials and the appearance of idols and spiral plaques was also supported by Doğan's work (2006: Tables 142, 147).

Table 3.2: Distribution of Grave Goods by Age Group (From Doğan 2006: Table 35)

Age Group	**Total Number of Graves**	**Total Number of Objects**	**Average Number of Objects**
Fetus	4	0	0
Infant (0-1)	50	10	0.2
Child (1-6)	97	208	2.14
Old Child (6-12)	57	77	1.35
Young Adult (12-20)	57	76	1.33
Middle Adult (20-50)	130	224	1.72
Older Adult (50+)	87	237	2.72

Bilgi identified a group of burials that he describes as "distinguished" burials (2005b), This group included 46 of the burials excavated in the İkiztepe cemetery, which were predominantly males (36 of 46), with smaller numbers of females (5 of 46), children (3 of 46) and infants (2 of 46) (Bilgi 2005b: 16). The burials characterized as "distinguished" were determined based on "the findings they yielded, which are notable in quantity, quality and also in function" (Bilgi 2005b: 16). Among these burials, double and quadruple spiral and horned plaques, as well as certain other types of weaponry and tools only occur in male burials (17). Weaponry occurring in female graves consisted of simple spearheads and daggers (17). Within the group of distinguished burials, jewellery such as necklaces, earrings and bracelets, as well as spiral wires and harpoons were common to all demographic groups (17). Bilgi suggests these burials must "belong to the male rulers of the settlement and their families" (Bilgi 2005b: 17); he also suggests they must belong to rulers of different phases at the settlement, due to their locations at various depths.

Multiple burials

It has been suggested that a reasonable number of the burials within the cemetery at İkiztepe included multiple individuals. The most recent estimate suggests that there were 52 burials found to contain the remains of two individuals, seven with three individuals, two with four individuals, one with five individuals and one with six individuals (Doğan 2006: 39). The combinations of individuals found in these burials were varied, with adults of both sexes and children occurring together (Doğan 2006: 40). These burials were spread throughout the cemetery, and contained similar numbers and types of grave goods to other graves containing single individuals (Doğan 2006: Tables 4 &5).

Examination of the drawings associated with these burials suggests that in many cases, it is possible that the material identified as originating from secondary individuals were in fact fragments of bones from other graves that were scattered from their original locations and were mixed with primary interments within the graves during excavation. It is possible, therefore, that the proportion of burials within the cemetery that contain the remains of multiple individuals may have been overestimated to some degree.

Use of wood

In some cases, pieces of wood were determined to have been placed both under and covering the body; these "floors" were found in approximately 20 of the burials (3.9%; Doğan 2006: Table 168). The first half of this number was found in the early 1980's. The second half of this group of wooden "floors", however, was found in a single season (2001), with all of these examples found in a single square. There are two possible explanations for this pattern. The first is that this square represents a cluster of burials which display an uncommon burial technique in the cemetery. The second of these is that wooden "floors" were more readily identifiable in this square than in other areas. If this is the case, it is possible these wooden floors were more common than the number of examples actually found would suggest, but that they were not identified in all cases. Doğan theorizes that the cluster of burials in this square might be due to the presence of soil conditions in this particular area causing better preservation, and enabling easier identification of the wood remains (Doğan 2006: 116).

Ochre

In 11 cases within the cemetery, there was evidence of red colouring on the skeletal remains that has been interpreted as ochre decoration of the bodies (Doğan 2006: Table 159). Much has been made of the occurrence of ochre in the graves at İkiztepe, which has been used to link the burial practices at İkiztepe to those of the Ochre Grave culture of Eastern Europe and Northern Pontic regions (Zimmerman 2007: 30; Backofen 1985: 424). There are, however, a number of reasons why this parallel should be treated with caution. Firstly, Bilgi raises the question of whether this ochre in fact was not an intentional treatment of the body, but was the result of staining from burnt red earth in which the burials were placed (Bilgi 1990b: 165). However, even he suggests that if the use of ochre can be attributed to intentional decoration, "it should be accepted without any hesitation that people buried at İkiztepe in the last quarter of the Third Millennium B.C. were racially identical to, and thus originated from, the people who lived in Southern Russia and on the Northern Black Sea coast" (Bilgi 1990b: 165).

He also, however, suggests that apart from the potential use of ochre in the burials, there are few similarities to the overall burial practices employed in Southern Russia. This assertion will be examined further below. However, it should also be recognized that it is not unusual for burials in Anatolia itself to be decorated with ochre, and thus the link with other Black Sea cultures should not be considered unequivocal.

Anatolian Burial Practices

The cemetery at İkiztepe has traditionally been dated to the Early Bronze III period, ca. 2400-2100BC. Comparative studies of Anatolian burial practices thus have focused primarily on finding parallels to İkiztepe in Early Bronze Age cemeteries. Considerably less discussion, however, has been directed towards Chalcolithic parallels, despite suggestions that the cemetery at İkiztepe may have been founded much earlier. Some scholars have placed the founding of the İkiztepe cemetery within the Late Chalcolithic period rather than in the Early Bronze III period, suggesting that the cemetery was in use for a much longer period of time than previously suspected (Zimmermann 2007, Parzinger 1990). The new radiocarbon dates performed on skeletal material from the cemetery in fact suggest that the entire phase of the cemetery's use may in fact be significantly earlier than previously supposed, in the Chalcolithic-Early Bronze I transitional period. As a result, the following survey of Anatolian burial practices will examine known practices from both the Chalcolithic and Early Bronze Age periods, for comparison with the İkiztepe cemetery.

Chalcolithic

In general, as well as in comparison to those observed during the following periods, burial practices during the Chalcolithic are poorly understood. Chalcolithic graves tend to be found in much smaller numbers than observed in later periods, particularly during the Early Bronze Age, when the use of large extramural cemeteries became common. The majority of Chalcolithic burials known in Anatolia are clustered within the Late Chalcolithic, and earlier sub-periods are exceptionally poorly represented in terms of burial practices.

A number of sites in Central Anatolia provide examples of burials dating to the Late Chalcolithic. In addition to the better-known tombs at Alaca Höyük dating to the Early Bronze Age (see below), both cist graves and simple inhumations dating to the Late Chalcolithic period were found at the site. In these burials, the body was placed in a flexed position, and grave goods found within them included pottery and copper jewellery (Özgüç 1948: 11, 42). Late Chalcolithic burials were also found at Alişar Höyük (Levels 14 and 13). One grave was found in Level 14, while ten burials were found in Level 13 (von der Osten 1937: 43-44). These represented a variety of burial types, including three simple inhumations, four pot burials, two small cists, and one burial which was placed in a wooden box (von der Osten 1937: 43-44, 51; Özgüç 1948: 23). These burials consisted mostly of children and infants buried under the floors of houses, although a few adults also occurred (von der Osten 1937: 32). In all burial types, the bodies were generally placed in a flexed position on their right side with their head toward the west (von der Osten 1937: 32; Özgüç 1948: 23). These burials generally were found to have very few mortuary gifts (von der Osten 1937: 32).

Intramural burials of infants or children were fairly common in Central Anatolia during the Chalcolithic period. At Can Hasan, a group of 12 child skeletons were found in Early Chalcolithic levels (Level 3) with whole vessels and potsherds placed around them (French 1968: 50). Other burials of both children and adults were also found beneath the floors of Middle Chalcolithic houses at the site (French 1968: 45). The site of Çadır Höyük, which spans the transition from the Chalcolithic to the Early Bronze Age, produced two heavily disturbed child jar burials, which were most likely placed under the floors of Late Chalcolithic houses (Gorny *et al* 1999:152-153). In addition, a number of pithos graves were found that were dated to the period of the transition to the EBI *(http://pubpages.unh.edu/~tia2/Pages/summary06.html)*. At Köşk Höyük**,** more than 30 graves containing infant remains were found under the floors of Early Chalcolithic buildings in Levels I and II during the 2002 season (Özkan *et al* 2004: 195-196, 2001). Similar infant burials dating to the Chalcolithic period were also found at sites in Western Anatolia. At Beycesultan, infant burials in both earthen graves and jars were found in Levels XXIX, XXVIII and XXII (Lloyd & Mellaart 1962: 23-26*)*. Adult graves were extremely rare at the site; it has been suggested that the burials of the adult population at Beycesultan probably took place extramurally (Lloyd & Mellaart 1962: 23-26). However, no evidence for an extramural cemetery was ever excavated at the site.

Among adults, simple earth burials are the most common form of burial observed during this period, although some examples of pithos/jar and cist burials are found. Frequently, simple pit burials have bodies placed in the Hocker or a flexed position. One of the largest groups of Chalcolithic burials is known from the site of Ilıpınar, where more than 40 graves dating to the Late Chalcolithic period (Level IV) were found (Roodenberg 2001: 351). These burials consisted of simple earthen graves, with the deceased placed in a flexed position (Roodenberg 2001: 351). In many cases, pairs of skeletons were found placed face to face. The graves included a variety of grave goods, such as bronze/copper weaponry and ceramic vessels (Roodenberg 2001: 352). At Kumtepe A, a number of burials were found in Late Chalcolithic Phase I ("pre-Troy I") levels, originating from both excavation campaigns at the site. This included three simple burials which were placed in Hocker position, from the first excavation campaign, as well as a number of similar burials from the second excavation campaign (Özgüç

1948:12; Korfmann 1996:50). Of these, a burial from Phase Ic was found with the body in the Hocker position on the right side with the head to the north (Özgüç 1948: 13).

A few sites also produce evidence for burial practices dating to the early part of the Chalcolithic period. The site of Hacılar also produced a number of burials, which were found in various Early Chalcolithic levels; many of these were the burials of children (eight in Level IV, two in Level III, three in Level IIA). Those found in Level IV were placed beneath the floor of a courtyard area. These burials were simple inhumations placed in a contracted position and were accompanied primarily by pottery (Mellaart 1961: 40). Furthermore, two separate double burials, each containing the remains of an adult and child, were found below the floor of a building in the IIA settlement (Mellaart 1960: 102). These individuals were buried in a tightly contracted position and contained few funerary gifts (Mellaart 1960: 102). At Kuruçay, a total of seven burials were found dating to the Neolithic and Early Chalcolithic levels at the site (Duru 1994: 101). Of these, three burials found that were dated to the Early Chalcolithic period (Duru 1994: 101). Two of these contained the remains of adults, one was a child. All of these burials were intramural and displayed different orientations, although the body was consistently placed in a contracted position (Duru 1994: 101). No grave goods were found associated with these graves (Duru 1994: 101). Also at Kuruçay, a total of 50 jar burials and five simple inhumation burials were found that date to the Late Chalcolithic (Levels 6A and 6) (Duru 1996: 120). Like the Early Chalcolithic burials, these graves were intramural and were placed under the floors of buildings within the settlement, as well as under courtyard and street areas (Duru 1996: 120). Jar burials were found to contain the bodies of infants and children, while the simple inhumations contained adults (Duru 1996: 120). The jar burials were generally closed with stones, and contained no grave goods (Duru 1996: 120). It is suggested that most adults were probably interred in an extramural cemetery that was never located (Duru 1996: 121).

One other site produced evidence for Early Chalcolithic burials. At Menteşe Höyük near the modern town of Yenişehir, 8 skeletons were discovered in the upper levels of the site, dated to the Early Chalcolithic (Stratum 1, approximately the mid-6th millennium BC) (Alpaslan-Roodenberg & Maat 1999: 37-38; Roodenberg *et al* 2003: 22). Of these skeletons, three were determined to be children and five to be adults (Alpaslan-Roodenberg & Maat 1999: Table 2, Alpaslan-Roodenberg 2001: Table 1). Additional skeletal material was also uncovered that was dated to the late 7th millennium BC (Alpaslan-Roodenberg 2001). The Chalcolithic burials were simple inhumations, with the bodies generally placed in a crouched position on the right side; these graves demonstrated no specific orientation and few grave goods (Alpaslan-Roodenberg & Maat 1999: 41-42, Fig. 1-3*)*. In one burial of an adult female, some evidence was found to suggest that the body may have been placed on wood beams (Alpaslan-Roodenberg & Maat 1999: 41).

In Southeastern Anatolia, similar patterns were observed to those previously described in Central and Western Anatolia. Most of the sites in this area produce small numbers of burials. At Yumuktepe (Mersin), a number of poorly preserved intramural burials were found placed under the floors of the Chalcolithic houses within the settlement (Levels XVIII-XVII), consisting mostly of children, but also occasionally of adults (Garstang 1953: 110-111). In the graves, the body was generally placed in a contracted position (Garstang 1953: 110-111). The site of Arslantepe produced flexed burials that were found under the floors of houses in the Level VII (Late Uruk) settlement (Frangipane 1993). At Samsat, infants were found in jar and pit burials with few grave goods (Özgüç 1988:294*)*. At Hacınebi, a cist grave constructed from mudbrick was found in a large open area inside the site's enclosing wall. The cist contained the remains of a single adult, whose body was placed in an extended position (Stein *et al* 1998: 149). This burial was only partially excavated, so little additional information is available (Stein *et al* 1998: 149). Excavations at Hassek Höyük produced 4 graves, which were found in the Late Uruk settlement (Parsche & Ziegelmayer 1992:78-81). 2 of these belonged to children and two to adults; three of the four were placed in pithoi, and traces of red paint or ochre were found near the head of the child skeleton (Parsche & Ziegelmayer 1992: 78-81). At Korucutepe, Late Chalcolithic graves were found in the northwest corner of the mound in Levels XXXVII-XXXIX (van Loon 1978: 10, Table 3). Two of these graves were placed in rectangular mudbrick constructions which were then covered with a roof; one of these tombs seemed to have had a wooden roof and one a mudbrick roof (van Loon 1978: 10). One of these tombs was a double grave, and contained the remains of an adult man and woman (van Loon 1978: 10-11).

Some Southeastern Anatolian sites produced slightly larger numbers of Chalcolithic burials. At Oylum Höyük, a Late Chalcolithic cemetery containing at least ten graves with burial pits lined with mudbrick was found (Özgen & Helwing 2003: 64). The body in each of these graves was placed in a crouched position, sometimes within a large pithos or storage vessel (Özgen & Helwing 2003: 64). Grave goods accompanying these burials were generally simple, consisting of jewellery and pottery (Özgen & Helwing 2003: 64). Burials in other areas of the site during the Late Chalcolithic included both children and adults, in simple pits and in pithoi, but were generally poorly preserved (Özgen & Helwing 2003: 64). At the site of Tilkitepe, a large number of simple intramural graves were found, along with a group of infants in pithoi, in Levels I and II (Özgüç 1948: 11; Korfmann 1982: 35). All bodies were placed in the Hocker position, usually with an east-west orientation and in some cases ochre was spread on the deceased

(Korfmann 1982: 35; Özgüç 1948:11-12). Three examples were found of double graves, containing the remains of two individuals, in each case an adult and a child (Özgüç 1948: 11).

As is evident from the preceding discussion, the vast majority of known burials from this period were intramural, often occurring below house floors and in other public areas, and occurred in relatively small numbers at each site. These generally range from a single burial to small groups of less than 10-15 individuals. Exceptions to these small numbers occur at sites such as Ilıpınar, Köşk Höyük and Kuruçay. These sites generally have between 30 and 60 excavated graves, comparatively large numbers compared to other sites of the same period. However, these numbers do not compare to the known numbers of burials from Early Bronze Age cemeteries in the following period. Many of the burials known from the Chalcolithic period, and particularly from the sites containing larger numbers of burials, belonged to children, who were often buried in jars and/or under the floors of houses. This tradition is common throughout the Near East during a number of periods. In some cases, burials of adults dating to the Chalcolithic period were also found, generally in smaller numbers. Adults were commonly buried in pithoi or simple pit graves. At some sites, the rarity of adult burials was suggested to indicate the possibility of the presence of extramural cemeteries, but there have been no Chalcolithic extramural cemeteries ever excavated. While large portions of the Chalcolithic population remain unrepresented in the current available burial record, the burial practices employed by the majority of the population during this period remain unknown.

Map: 3.1: Locations of Anatolian and Southeastern European Archaeological Sites with Burials

Early Bronze Age

At the beginning of the Early Bronze Age, the volume of information on burial practices significantly increases. In this period, we see the appearance and widespread use of large extramural cemeteries, in contrast to the pattern of small-scale intramural burial groups seen in the Chalcolithic period. However, these cemeteries in large part demonstrate some degree of continuity in burial practices that first appeared in the Chalcolithic period, including the use of pithoi and cists for adult interments. The single most common form of burial in Western and Central Anatolia during the Early Bronze Age was the pithos burial, which tended to occur in large numbers in extramural cemeteries. Such cemeteries were excavated at Aphrodisias, Yortan and Babaköy, and were observed but not excavated at the sites of Budur and Balikesir (Wheeler 1974: 415).

One of the best known pithos cemeteries in Western Anatolia was found at the site of Yortan. The original plan from the Yortan excavations shows a total of 107 burials, all but one of which were pithos burials (Kamil 1982: 7). The last of these burials was a cist burial. The burial jars from the cemetery at Yortan generally opened to the northeast, east, or southeast, and were closed with large slabs of stone (Kamil 1982: 8). A similar alignment of burials within the cemetery is also seen at Babaköy (Özgüç 1948: 18), as well as at Sardis-Ahlatlı Tepecik, Sardis-Eski Balıkhane, Aphrodisias, and Karataş-Semayük (Kamil 1982:8). At Yortan, grave goods were most commonly ceramics, although other types of objects were also found, including a few metal objects (Kamil 1982).

The burials found at the site of Babaköy display many similarities to those described from the Yortan cemetery. The deceased individuals were placed in funerary jars which were positioned in a relatively unorganized manner within the cemetery. The pithoi were covered with cap stones or had their mouths filled with small stones (Özgüç 1948:27). Some of the pithoi contained more than one individual; it was suggested that the burials were reopened to accommodate the secondary burial (Kökten 1949). Babaköy was looted prior to its excavation, which has caused problems for interpreting the burial customs utilized in the cemetery. However, despite the damage, it is estimated that the cemetery may have contained as many as 150 pithos burials (Özgüç 1948: 52). Babaköy is considered to be virtually identical to Yortan in terms of burial practices, and is thus part of the so-called "Yortan Culture" (Kamil 1982: 6; Kökten 1949). Both Yortan and Babaköy seem to have not been associated with a contemporary settlement (Kamil 1982: 6).

Kökten suggested at Babaköy that the fragmentary nature of the skeletal remains suggested they were used for secondary burials (Kökten 1939; Kamil 1982: 9). Similar levels of preservation were found at Yortan; but the remains from Sardis and Karataş-Semayük were better preserved and argue against this theory (i.e. the issue may be simply one of preservation) (Kamil 1982: 9). Bittel had suggested that at Babaköy the deceased had been placed in a contracted position on one side (Kamil 1982: 9). However, at both Yortan and Babaköy, there is evidence for the pithoi being used for multiple interments; with earlier burials being moved aside for the addition of a later individual's remains (Kamil 1982: 9). At Babaköy, pithoi are said to contain 2-3 individuals, while the greatest number at Yortan was 6 individuals in one pithos (Kamil 1982: 9). At Karataş, the greatest number observed in a single pithos was 8 individuals (Kamil 1982: 9).

Ovabayındır also produced an extramural cemetery of pithos burials which had been badly damaged by looting. These pithos burials demonstrated a great deal of similarity to those encountered at Yortan and at Babaköy, and the cemetery is considered to be part of the wider

"Yortan Culture". Grave goods included ceramic vessels as well as copper objects (weaponry such as knives, daggers, etc.) (Bittel 1955:113-118).

The cemetery at Göndürle Höyük**,** near Harmanören, contained another extramural cemetery of pithos burials, which was once again exposed by looting activities, resulting in excavations beginning in 1993 directed by M. Özsait (Özsait 2000; Özsait 2003: 87). The proximity of the burials to the surface has resulted in a great deal of disturbance by looters, but these excavations have produced more than 150 pithos burials along with a single cist grave (Özsait 2000: 150; Özsait 2003: 87). As seen at other contemporary cemeteries, the vessels are oriented east-west with the opening facing toward the east, with the mouth often covered by large stone slab (Özsait 2000: 150; Özsait 2003: 87). Small pithoi were found between the larger pithoi containing the human remains; these have been variously explained as "memorial" pithoi, or as serving as markers for the larger burial pithoi (Özsait 2000: 150; Özsait 2003: 87*)*. The deceased was generally placed inside the pithos in the Hocker position, most often on the right side; secondary burials were sometimes positioned within the pithoi after moving aside the original burial remains (Özsait 2000: 150; Özsait 2003: 87-88).

Pithos burials also dominated in the Early Bronze Age cemetery at the site of Ilıpınar-Hacılartepe**,** located to the west of Iznik Lake. This cemetery was located on the western slope of the site, and dates to the EBI-II period. It is believed to be associated with the small settlement of Hacılartepe, located slightly to the southeast (Alpaslan-Roodenberg 2002: 91; Eimermann 2004: 23-24). The majority of the 24 burials excavated at the site were placed in horizontally-laid pithoi that were oriented with the opening to the south or southwest (Alpaslan-Roodenberg 2002: 91; Eimermann 2004: 23). Poor skeletal preservation sometimes precluded the identification of the position of the body within the pithos; however, it is suggested that there was a tendency to place females on their left side, while males were placed on the right side (Alpaslan-Roodenberg 2002: 95). Several of the pithoi contain the remains of more than one individual, and Alpaslan-Roodenberg suggests that the pithoi were in fact reopened in order to allow the deposition of further individuals, with the earlier remains pushed to the back of the jar or partially removed (Alpaslan-Roodenberg 2002: 91). In addition to the 13 pithoi, two simple pit burials were also found in the cemetery (Alpaslan-Roodenberg 2002: 94). Furthermore, two burials of very young infants were placed on large pithos sherds, rather than within a full pithos (Alpaslan-Roodenberg 2002: 93-94). Grave goods were predominantly simple objects, including beads and pottery (Alpaslan-Roodenberg 2002: 92-95).

Another Early Bronze Age cemetery was excavated at Ulucak Höyük**;** excavations were originally conducted between 1995 and 2002 by Z. Derin, and were continued in more recent years by a number of other excavators. This cemetery was extramural and was located on the plain to the south-east of the settlement site (Çilingiroğlu *et al* 2004: 53). It was used during both the Early and Middle Bronze Ages. Twelve pithos burials dating to the Early Bronze Age were found in this cemetery (Çilingiroğlu *et al* 2004: 54). The deceased was placed into the pithos in a crouched position, and tended to be oriented in a northwest-southeast direction, with the mouth generally toward the east and capped by large flat stones (Çilingiroğlu *et al* 2004: 54). In some cases, the burial jars were found to be empty; it is suggested that this may indicate that these burials were intended as cenotaphs (Çilingiroğlu *et al* 2004: 54). Generally, the number of grave goods associated with these burials was very few (Çilingiroğlu *et al* 2004: 56).

The site of Karataş-Semayük also produced an extramural cemetery of pithos burials dating to 2700-2300 BC, from which 897 burials were excavated (Angel & Bisel 1986: 12). A number of these burials were found to contain no preserved skeletal material, and skeletal remains were recovered for only 584 people (Angel & Bisel 1986: 12). From the sizes of the pithoi employed for the burials, as well as from the skeletal remains, it was determined that both infants and children were buried in this cemetery along with adults, rather than being placed in a separate intramural location (Angel & Bisel 1986: 12, Wheeler 1974: 416, Mellink 1967: 251). As seen in the cemetery at Ilıpınar-Hacılartepe and other contemporary cemeteries, approximately one quarter of the pithoi at Karataş-Semayük were determined to have contained multiple interments (Wheeler 1974: 417, Mellink 1967: 251). The disarticulated and neatly stacked skeletal material in some of the pithoi suggests that the burials were likely reopened after the primary interment for further burials, a practice which would likely have necessitated tomb markers (Wheeler 1974: 417). This suggestion is supported by the neatly organized layout of the burials in rough rows, and Wheeler suggests that the tombs may have been marked by a small circle of stones, some evidence for which has been found at Karataş (Wheeler 1974: 417).

One exception to the overwhelming pattern of the ubiquity of pithos burials is the cemetery at the site of Iasos, which does not demonstrate any examples of pithos burials, but rather contains cist burials with large stone caps (Wheeler 1974: 418). As often seen in the pithos cemeteries, these cists have a consistent orientation. The deceased were generally placed in the cist in a flexed position. Where secondary burials occurred, the primary remains were moved to the side prior to the interment of the later individuals (Wheeler 1974: 418-419). Heads were generally positioned toward the east (Wheeler 1974: 418). A few intramural graves exist, but the burials at the site were found predominantly in an extramural cemetery, which contained about 90 graves (Wheeler 1974: 418). These graves contained limited numbers of grave goods, which generally consisted of ceramics; many of these grave goods are suggested to show influence from the Cyclades (Wheeler 1974: 418-419).

These two types of burials occur alongside each other at many sites. For example, the site of Sardis has examples of both pithos and cist burials. A similar pattern is seen at the site of Kusura A**,** which is represented by an extramural cemetery that is believed to be contemporary to Troy I (Özgüç 1948: 17). 14 graves are known from Layer A; one of these was a pit burial; 10 were pithoi and 3 were cists (Özgüç 1948: 17, 24, 43). The pit burial contained an individual placed in a flexed position on the right side with the head positioned toward the west (Özgüç 1948: 14). Individuals buried in pithoi and in cist graves were also placed in a flexed position; in cists, the head was positioned toward the west (Özgüç 1948: 24).

The site of Kücük Höyük also produced a combination of burial types**.** The cemetery at this site was unearthed as part of a salvage excavation after its discovery during the construction of a gas pipeline. The cemetery was determined to be extramural and contained 204 graves (Gürkan & Seeher 1991: 42-70, 72). The majority of these were pithos graves (127 burials), while cist graves (74 burials) and pit graves (3 burials) were also found (Gürkan & Seeher 1991: 42-70, 72). Pithos burials were generally placed in a southeastern orientation, with the body placed in a flexed position and the mouth of the vessel capped with large stones (Gürkan & Seeher 1991: 72-74, 76). Cist graves were oriented in a northwest-southeast direction, with the body once again placed in a flexed position (Gürkan & Seeher 1991: 74-76). Pottery was a common grave offering; metal objects were also included, including some made of silver and gold, although no weaponry was found (Gürkan & Seeher 1991: 76-94).

Two separate cemeteries, dated to the EBI and EBII respectively, have also been discovered at the site of Bakla Tepe. The EBI cemetery, found on the eastern side of the mound, was extramural, reasonably small (< 20 burials), and contained a combination of simple earth graves, pithos graves and cist burials (Erkanal & Özkan 1998: 340-341; Erkanal & Özkan 1999: 264).

Bodies were generally placed in a flexed position, with an east-west orientation (and the head toward the west). Pithos mouths were often covered with large slabs or with pottery fragments. Graves of all types contained of pottery, metal weaponry and jewelry (Erkanal & Özkan 1998: 340-341; Erkanal & Özkan 1999: 264). The EBII cemetery was larger than that of the EBI (>60 burials), and was located in the southeast part of the mound. Unlike the EBI burials, which were of various types, the EBII cemetery contained only pithos burials. However, these pithoi were oriented in a similar manner to those observed in the EBI (east-west), with bodies placed in a flexed position, and were covered with large slabs and small stones (Erkanal & Özkan 1999: 265-266). Grave goods included metal weaponry and pottery, and were placed both inside and outside of the pithoi (Erkanal & Özkan 1999: 265-266).

A combination of pithos and cist graves was also found at the Central Anatolian site of Kaklik Mevkii**.** The group of 32 burials found at the site has been dated to the EBII-III period (Topbaş *et al* 1998: 33). The earliest of these burials included pithoi and cists (Topbaş *et al* 1998: 33). Pithoi were generally oriented with their mouths to the east or southeast, with cists organized east-west (Topbaş *et al* 1998: 33-35). The later graves include a few pithoi, but consist primarily of simple inhumations and "pseudo-chamber tombs" (Topbaş *et al* 1998: 35). Burials from both periods contain few grave goods; these objects were primarily pottery, although a few stone idols were also found (Topbaş *et al* 1998: 33-36, 45-46). The site of Alişar Höyük also produced a combination of burial types dating to the Early Bronze Age, including 31 jar burials, 14 simple pit burials, 3 stone cists, and one cist built of mudbrick (von der Osten 1937: 135-150, 223-230, Wheeler 1974: 424). Finally, a total of 34 burials were excavated at the site of Kalinkaya dating to the period between 3100-2300 BC, which contained the remains of 72 people (Angel & Bisel 1986: 12). These burials consisted mainly of simple pit burials, which made up 20 of the 34 burials, but 13 pithoi and one cist burial were also found (Angel & Bisel 1986: 12).

A large number of pithos burials occurring alongside other burial types were also excavated at the site of Demircihöyük-Sariket. A total of 497 burials were excavated in a cemetery located at the north-eastern edge of the site, of which 361 were pithos burials (Seeher 2000: 241). Approximately two thirds of these burials were found in single pithoi, while one third were found in double pithos burials, placed mouth to mouth (Seeher 2000: 18). The pithoi were generally oriented in a northwest-southeast direction and were capped with large stones. The deceased was placed inside the pithos in a contracted position (Seeher 2000: 241). 100 pit burials and 20 cist burials were also found in this cemetery (Seeher 2000: 241). Pit burials were surrounded by stones, and were often covered by wooden beams before being covered with earth. In these pit burials, as in others at the site, the deceased was placed in a flexed position. The graves were likely unmarked, as later burials were found to have damaged earlier ones. There is no apparent differentiation in terms of burial goods based on the type of burial used (Seeher 2000). Grave goods included pottery and some weaponry; gold and silver objects were also encountered. This cemetery was used in both the EBA and MBA, using similar burial practices, but was primarily used during the EBII period (Seeher 2000).

Few burials are known from some of the major Early Bronze Age sites in Central and Western Anatolia. For example, the site of Troy has produced few burials dating to this period; 6 infant burials were discovered in the early levels of Troy I, generally under the floors of houses. 4 of these were in pithoi, while 2 were found in pit burials (Özgüç 1948: 13, 28). Troy II produced a single grave of a woman, in a simple earth burial, placed in the Hocker position (Özgüç 1948: 16-17). The grave pit was surrounded by stones, and no grave goods were found within the burial. In addition to this single adult burial, two infant burials were found, along with a single child burial under the floor of a Level IIg house (Özgüç 1948: 17). Similarly, only a small number of intramural burials were uncovered by excavations at the site of Beycesultan. In level XVIII, the earliest Early Bronze Age phase at the site, two intrusive infant pot burials were found, while in level XVIIa, three more infant jar burials were located in area that was interpreted by the excavators to be cultic (Lloyd & Mellaart 1962). Similar intramural jar burials of infants and children have also been found at other Anatolian sites, including Ovabayındır and Kusura (Wheeler 1974: 418).

Finally, one of the best-known groups of burials in Early Bronze Age Anatolia, the "royal" tombs at Alaca Höyük**,** was also found intramurally. The tombs consisted of rectangular pits dug into the ground, into which the body was placed in a crouched position, with the head oriented toward the west (Koşay 1951: 154). The pit was then covered by a layer of stones, and a series of wooden beams was then placed over the tomb and covered with clay and earth (Koşay 1951: 154). These burials were frequently associated with the burnt remains of animals, including sheep, goat and pig, which were presumably made as offerings (Koşay 1951: 154). The burials were richly furnished, often with objects and jewellery made from gold and silver (Koşay 1951: 156-171). A number of pithos burials that were covered by large jar sherds were also found at the site, and have been dated to the Early Bronze Age, although the total number of burials of this type is unclear (Koşay 1951: 154).

Black Sea Region

The preceding summaries of Chalcolithic and Early Bronze Age Anatolian burial practices make clear that the İkiztepe cemetery does not fit well with the general patterns of burial practices seen in either period. Unlike Chalcolithic burials, which tend to occur in small groups, and are often intramural or within habitation areas, the İkiztepe cemetery is extremely large and extramural. In this sense, it is similar to the trend toward large extramural cemeteries seen in the Early Bronze Age. However, the burial practices observed within this cemetery are different from those observed in the majority of known Anatolian Early Bronze Age cemeteries. Most of these cemeteries contain predominantly pithos burials, which often occur alongside cist burials. Pit burials also often occur in these cemeteries. However, the cemetery at İkiztepe, contains only pit burials, with no occurrences of pithos or cist burials. Furthermore, the majority of pit burials known from both the Chalcolithic and Early Bronze Age periods have burials placed in a flexed or Hocker position; in contrast, the vast majority of İkiztepe burials are placed in a dorsal extended position. The potential use of ochre in the graves at İkiztepe finds few parallels, with the exception of the Chalcolithic burials at the sites of Hassek Höyük and Tilkitepe. The use of wooden beams in various forms within the graves has been reconstructed in burials at a number of sites, including Chalcolithic burials at Menteşe Höyük and Korucutepe and the Early Bronze Age burials at Demircihöyük-Sarıket and Alaca Höyük. Beyond these details, few clear parallels to the burial practices observed at İkiztepe can be found in cemeteries from Central, Western or Eastern Anatolia, during either the Chalcolithic or the Early Bronze Age. Unsurprisingly, the best parallels to the İkiztepe cemetery can be found in Northern Anatolia, in the immediate vicinity of the site itself.

At the site of Tekkeköy, a cemetery was found underlying a level that was dated by the excavators to the Early Bronze Age. In total, 17 burials were uncovered in a level 4m thick and resting upon virgin soil (Özgüç 1948a: 408; Özgüç 1948: 68). The cemetery was divided into 3 sub-levels; there were 4 burials found in the lowest level, and 6 each in the middle and upper levels (Özgüç 1948a: 408; Özgüç 1948: 68-69). Burial occurred in simple pits, with floors made of packed earth or cobbles (Özgüç 1948: 69). The bodies were placed in various positions, including extended on the back, or in a crouched position on the right or the left side; the burials also demonstrated no consistent orientation (Özgüç 1948a: 409; Özgüç 1948: 68). Grave goods included copper objects and weaponry, as well as pottery (Özgüç 1948: 69). The site of Kavak also produced a number of graves that were dated to the Early Bronze Age, and which were located in the eastern trench, and were suggested to represent part of an intramural cemetery (Özgüç 1948a: 414; Özgüç 1948: 70). The graves consisted of simple pit burials, with the bodies placed in a crouched position, and grave goods included metal weaponry, such as daggers and shaft-hole axes (Özgüç 1948a: 414; Özgüç 1948: 70). The site of Dündartepe produced a single burial dated to the Early Bronze Age; that of a child, 6-7 years old, who was found beneath the floor of a house (Özgüç 1948:70).

Slightly further away, at the site of Horoztepe**,** two graves were found. One of these graves was a simple pit burial (Özgüç & Akok 1958: 41). The bones of the individual interred were disturbed and broken, so the position of the body could not be determined, but it is believed that the head was pointed toward the east. The impressive collection of grave goods seemed to have been placed around the feet of the deceased (Özgüç & Akok 1958: 41). These grave goods included pottery figurines, and the well-preserved remains of wooden furniture, as well as a collection of metal objects made from bronze, silver, gold and electrum (Özgüç & Akok 1958: 41-42). Both this tomb and the objects within it are compared extensively by the excavators to the graves from Alacahöyük (Özgüç & Akok 1958: 52-59).

Southeastern European Burial Practices

Despite the rarity of large extramural cemeteries in Anatolia prior to the 3rd millennium BC, multiple examples of such cemeteries exist throughout southeastern Europe, in coastal Bulgaria and throughout the Balkans and the interior of Bulgaria and Romania. These cemeteries most often consist of simple pit burials, with bodies placed in extended or flexed positions, and in some cases accompanied with rich burial goods. Links between these Southeastern European cemeteries and the burials at İkiztepe have also been proposed (Zimmerman 2007, Parzinger 1993). As a result, we will also consider the burial practices observed in these areas during the time periods in question.

Varna

The site of Varna is located on the Black Sea coast in Bulgaria, and consisted of a large and richly adorned cemetery dating to the 5th millennium BC. Recent radiocarbon dates have refined the chronology of the site, placing the cemetery around 4600-4400 BC, with a likely use-life of less than 200 years, and perhaps less than 100 years (Chapman *et al* 2006; Higham *et al* 2007). The cemetery was discovered by accident in 1972, and was excavated by I. Ivanov under the auspices of the local museum. This cemetery had no associated settlement (Bailey 2000: 197-8), and contained 294 burials dating to the Late Chalcolithic (Ivanov & Avramova 2000: 9). The excavators were able to identify three different types of burials based on the presence/absence of skeletal remains and the position of the body: "symbolic" burials (i.e. cenotaph burials or those with parts of skeletons secondarily buried), graves with the body of the deceased in a supine position, and graves with the deceased placed in a crouched position to one side (Ivanov & Avramova 2000: 9). At Varna, 32% of the graves had bodies placed in a fully extended position, while only 23% were found in a crouched position (Bailey 2000: 205). Furthermore, cenotaph burials formed >17% of the burials in the cemetery at Varna (Avramova 2000: 19). The body placement within the grave was particularly significant, and the pattern observed at Varna demonstrated a clear distinction from inland cemeteries, where burials occurred predominantly in crouched position.

It rapidly became clear that this cemetery was unique, due to the unprecedented concentration of gold and copper artifacts associated with the burials. Some burials in the cemetery were associated with spectacular numbers and varieties of personal ornaments (36% contained >10 grave goods—Bailey 2000: 205). The majority (61%--Bailey 2000: 205) contained between 1-10 grave goods, while others were associated with no grave goods at all (8%--Bailey 2000: 205). The most common grave good found was pottery, found in 80% of the graves (Bailey 2000: 205); gold objects were found in 22% of the graves. Interestingly, cenotaph burials often contained rich grave goods, and 60% of all gold was found in cenotaphs (Bailey 2000: 205).

Durankulak

The site of Durankulak was also located on the Black Sea coast of Bulgaria, and consisted of one of the largest cemeteries in the Balkans for this period or any period preceding it (Bailey 2000: 203). However, unlike Varna, Durankulak is associated with a contemporary settlement (Bailey 2000: 207). The burials in this cemetery spanned from the Late Neolithic to the Late Chalcolithic, with 484 burials from the Late Neolithic/Early Eneolithic, 365 burials from Middle/Late Eneolithic (Yordanov & Dimitrova 1989: 326,328). 270 of these burials date to the Hamangia phase (end of 6^{th} to beginning of 5^{th} millennia BC) (Bailey 2000: 197).

In the Neolithic period, males in the cemetery were generally placed in an extended position and females in a flexed position, with the head pointing toward the north (Todorova 1989: 356; Avramova 2000: 18). The graves dating to the Chalcolithic period demonstrate similar burial positions for men and women to those seen in the Neolithic (Avramova 2000: 19). This is characteristic of the Hamangia and Varna cultures of the NW coast of the Black Sea (Todorova 1989: 356). Some of the burials from the later period bear traces of ochre (Yordanov & Dimitrova 1989: 333)

In contrast to the cemetery at Varna, copper found in the burials at Durankulak was used for personal ornaments, rather than for weaponry (Bailey 2000: 207). Furthermore, *spondylus* shells were more common as an exotic grave good than gold (Bailey 2000: 207). Exotic grave goods were also common at Durankulak, but gold objects were much less frequent here than at Varna; similar differentiation in the number and quality of burial goods were visible at Durankulak to that seen at Varna (Bailey 2000: 207).

Cernovoda

One of the largest cemeteries of the period (5500-3600BC), with over 400 burials, was found at the site of Cernavoda in Romania, which is contemporary with the Hamangia Phase of the Durankulak cemetery (Bailey 2000: 196). Unfortunately, little anthropological information about the skeletal sample from the site has been published, and little information about the cemetery in general is available (Bailey 2000: 196). Similar to the pattern observed at Durankulak, the majority of burials were placed in an extended supine position (Price 1993: 186). Pottery and stone tools were frequent grave goods (Bailey 2000: 196).

Other West Pontic Necropolises

There are a number of other Late Chalcolithic cemeteries that have been found throughout the Pontic region, such as Golyamo Delchevo, Vinitsa and Devnya. In these cemeteries, there generally appears to be a tendency toward an increased status for people of advanced age (Todorova 1978: 76). In most cemeteries, infants generally had no grave goods and children very few (Todorova 1978: 76). Among adults, males generally had more grave goods than females (Todorova 1978: 75-76; Bailey 200: 200). Males were also generally more common in terms of numbers than females (Bailey 2000: 200). Cenotaph (body-less) burials are also common, and tend to contain similar numbers of grave goods to males (Bailey 2000: 202).

Many cemeteries in the interior of Bulgaria have been found close to settlement sites (such as Ovcharovo, Turgovishte, Radingrad, Golyamo Delchevo) (Bailey 2000: 197). In these interior sites, including Golyamo Delchevo, Vinitsa, and Turgovishte, the vast majority of burials were placed in a crouched position (Todorova 1978: 78). These bodies generally faced east, which was usually the direction of the accompanying tell site (Bailey 2000: 202). On the Black Sea coast, extended burials placed on the back were more common, appearing alongside contracted burials (Todorova 1978: 78). These extended burials were more common among men than women (Todorova 1978: 78).

In contrast to most other inland cemeteries, Devnya, which is the inland cemetery closest to the coast, had a large proportion of burials (75%) laid out on their backs (Bailey 2000: 205). Devnya dates to the Late Chalcolithic, and has 26 burials with a north-south orientation. Men were generally placed in a supine position, and women most often in a contracted position. Funeral offerings also point to significant differentiation between men and women (Avramova 2000: 17-18).

In general, different patterns in burial practices are observed between coastal and inland cultures. Coastal cultures tended to have larger, extramural cemeteries with a high proportion of extended burials (i.e. Durankulak, Cernavoda, etc), while cultures in the interior of Bulgaria and Romania tended to have smaller cemeteries, with predominantly flexed burials on the left or the right side (Price 1993: 186). Bailey suggests that the appearance of exotic and metal objects as grave goods increases in cemeteries with a closer proximity to the Black Sea coast (Bailey 2000:

206). Coastal sites tend to have more elaborate grave goods, while in inland cemeteries, grave goods are comparatively rare. One notable exception to these general patterns is the cemetery at Cernica, which is contemporary with other Hamangia culture cemeteries such as Durankulak and Cernavoda, but is located inland. This cemetery had 350 burials; most were extended supine burials, although some were flexed on the left or right side (Price 1993: 186). This cemetery is a lone example inland that shows patterns similar to those observed in coastal cemeteries, but is one of the only cemeteries from the interior dating to the Early Chalcolithic. Later, in the Middle-Late Chalcolithic, burials in the interior show the patterns previously described. Grave goods at Cernica also bear more similarity to Hamangia coastal cemeteries than to other, later inland cemeteries.

Baden, Ezero and Coțofeni Cultures

The Baden culture, dating to approximately 3600-2800 BC is an Eneolithic culture, covering the areas of Slovakia, Hungary, Moravia and Austria. It is considered related to the Ezero culture of Bulgaria (ca. 3300-2700BC), and is contemporary with the Coțofeni culture of Romania. The Baden culture burials date to the Early Bronze I and consist of simple earth burials, generally in a crouched position on either the right or left side with the hands positioned in front of the face. Some cases of a crouched position on the back or and extended position on the chest were also found (Nikolova 1999: 349). Generally, these burials contain either no burial goods, or simple ceramic offerings (Nikolova 1999: 350-351). However, in some cases, they also contained entire animal skeletons as offerings (Bailey 2000: 249).

These burials often occur within settlements; burials occurring within settlements are also popular in Bulgarian Thrace in the EBI period, from the Yunatsite and Ezero cultures (Nikolova 1999: 351). This tradition continues into the EBII period for the Yunatsite culture (Nikolova

1999: 353). However, the main mode of burial in the Final Copper and EBI periods is actually in "flat" necropolises (i.e. extramural cemeteries), although this pattern is poorly understood due to lack of excavation (Nikolova 1999: 359). Burial types occurring in these settlements are similar to those seen in the intra-settlement burials, where flexed burials lying on the left or right side are the most common (Nikolova 1999: 360). Similar burial practices were also observed with respect to grave goods, with the majority of burials displaying either no grave goods or ceramic containers (Nikolova 1999: 360). Sites with these patterns are seen at such sites as Vinča, Durankulak, Stara Zagora and Devnya, and date to the Final Copper through EBII periods (Nikolova 1999: 359).

Pit Grave Culture

Also associated with the Baden, Coțofeni and Ezero cultures was the appearance of a new burial tradition previously unknown in the Western Pontic region. The contrasting patterns of burial that began to appear at the beginning of the 4th millennium BC were quite notable. As seen previously, burials from the 4th and 3rd millennia BC continued to be made in flat necropolises and within settlements, and crouched inhumations remained typical of north-eastern and south-central Bulgaria (Bailey 2000: 245). However, at the beginning of the 4th millennium, the appearance of tumulus burials was also seen, forming part of the "Pit Grave Culture", which was associated with the Baden, Coțofeni and Ezero cultures (Nikolova 1999: 369).

These tumuli consisted of pit burials covered with an earth mound. Cemeteries with this type of burial are found in northern and south-central Bulgaria, eastern Hungary and western Romania (Bailey 2000: 246). The deceased was often placed in a crouched position, and sometimes was placed on top of a floor covering, which could consist of matting, textiles, grass or a layer of thin planks (Nikolova 1999: 370). Tumulus burials with the deceased placed in an extended position are also documented in certain areas (Nikolova 1999: 370). In many cases, ochre was sprinkled on the body and burial goods (Bailey 2000: 246; Nikolova 1999: 369). The grave pit was then covered with timber beams, followed by an earthen mound (Bailey 2000: 246; Nikolova 1999: 369). These mounds then became the new ground surface, into which further inhumations were made and new mounds were placed (Bailey 2000: 246). In some cases, these mounds were used for secondary burials, which were often placed off-centre around the edges of the tumulus (Bailey 2000: 246). These tumulus graves generally contain few burial goods, although sometimes there are exceptional burials with adornments and metal implements (Nikolova 1999: 369).

This burial type has its earliest parallels in the Final Copper Age of the Ukraine, preceding the Pit Grave Culture (Nikolova 1999: 388). These early examples are characterized by ochre colouring, the presence of copper ornaments, and the presence of offerings near the graves (Nikolova 1999: 388). In the Caspian Steppe region, the Yamnaya culture demonstrated burials occurring in clusters of tumuli (Shishlina 2008: 80). They demonstrate similar construction to the Pit Grave Tumuli further west, and have predecessors in the tumuli of the Majkop Culture (Shishlina 2008: 80). Mats were placed below the body and wooden tomb constructions were also present (Shishlina 2008: 81). The typical body position was flexed on the back with extended arms, although in some regions fully extended burials were also observed (Shishlina 2008: 81).

The preceding review of mortuary customs observed in southeastern Europe during periods roughly contemporary with the İkiztepe cemetery demonstrates an interesting pattern. While large extramural cemeteries currently remain unknown in Anatolia during the Chalcolithic, they are much more frequently observed in southeastern Europe during this period. Other similarities between the İkiztepe cemetery and southeastern European cemeteries are also apparent. During the Anatolian Early Bronze Age, pithos burials became the standard burial type, but during the Chalcolithic period burials also often included simple inhumations. These burials, however, occurred almost exclusively in flexed positions. In the İkiztepe cemetery, in contrast, flexed burials were rare, and instead extended dorsal burials were the norm. Southeastern European cemeteries were similar in the relative frequency of extended dorsal body positions, despite their rarity in Anatolian contexts. Coastal Bulgarian cemeteries in particular displayed higher proportions of extended burials, especially among men; inland cemeteries, in contrast, displayed a propensity toward flexed burial positions. Bulgarian coastal cemeteries also displayed a trend toward the increased use of elaborate grave goods, which were rarely observed in either inland Bulgarian sites or in contemporary Anatolian graves.

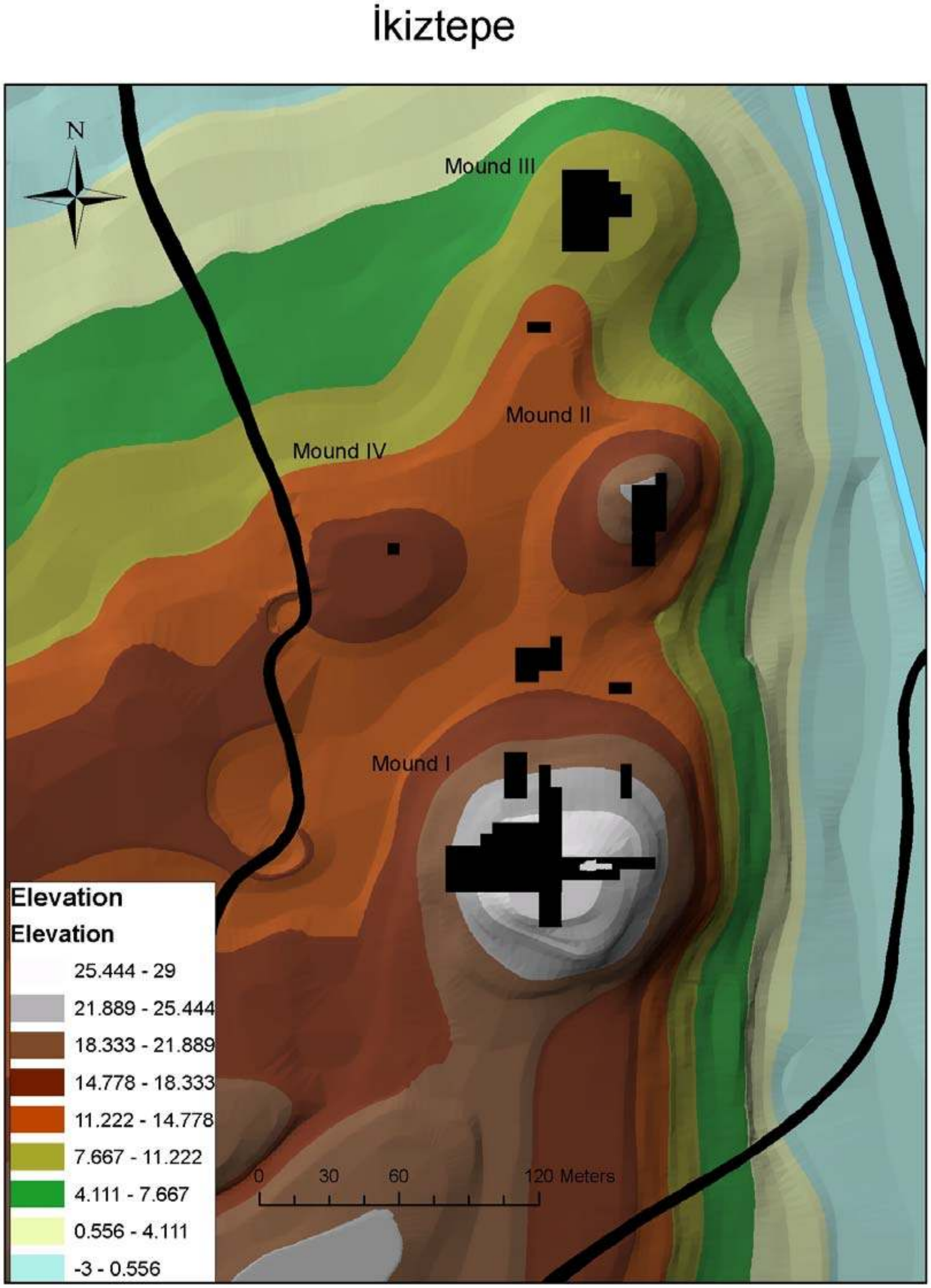
Detailed Analysis of İkiztepe Burial Practices

The following section consists of a detailed examination of the burial practices at İkiztepe, with the ultimate goal of creating a better understanding of the organizational principles that determined the cemetery's structure. Thus, this examination focuses predominantly on the cemetery's spatial organization, with particular regard to the placement of specific demographic categories and the distribution of grave goods.

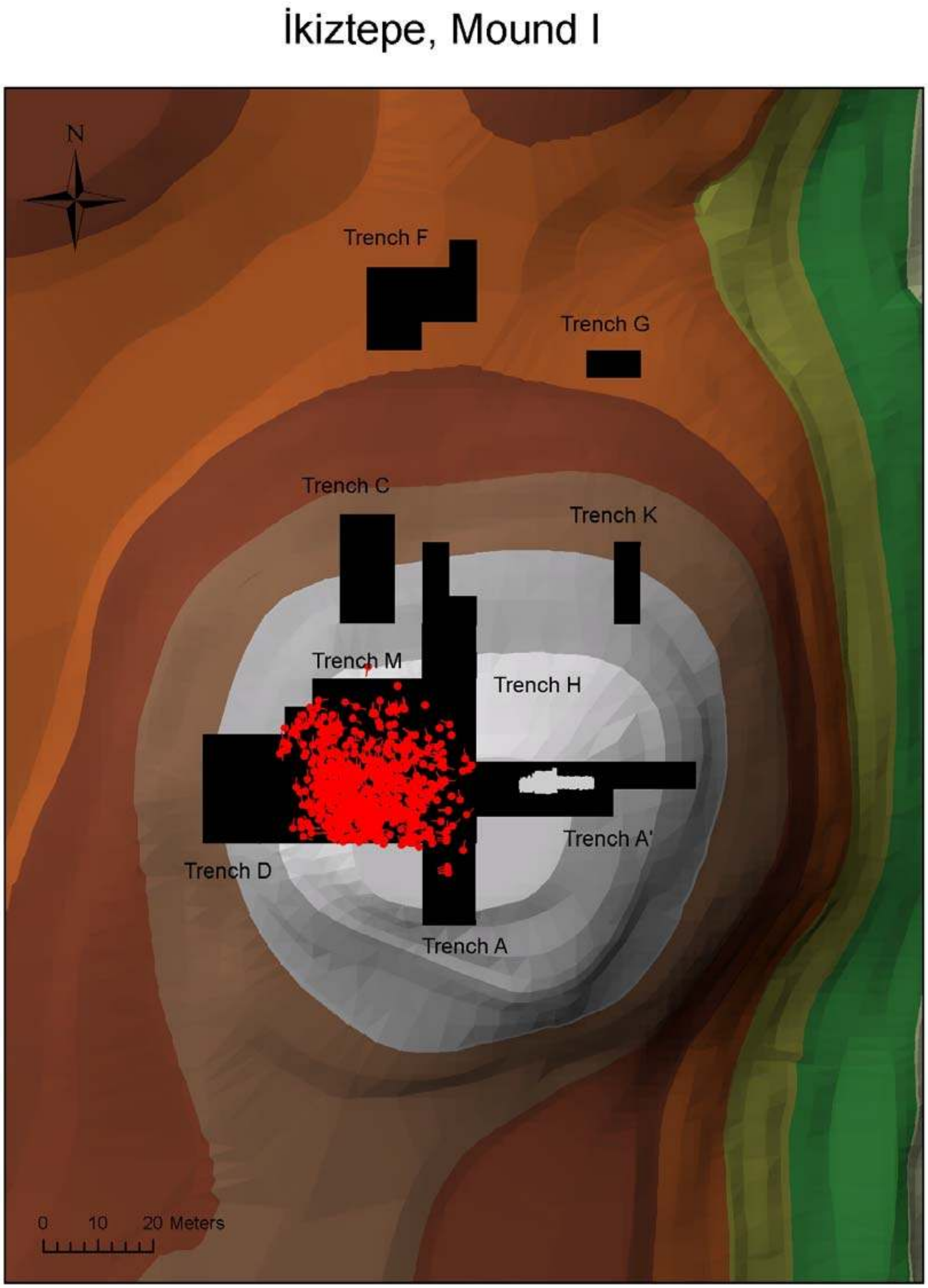
The most pressing need for a better understanding of the spatial organization of the İkiztepe cemetery is a comprehensive map. A GIS map of the İkiztepe cemetery was developed by scanning and georeferencing plans of the site and its excavation areas, based on those published in the two main volumes of excavations at the site (Alkım *et al* 1988, 2003). The plan of the site can be seen in **Map 3.2: İkiztepe**, and **Map 3.3: İkiztepe, Mound I**. The locations of the individual burials within the cemetery were determined from various plans originating from a number of different publications (Alkım *et al* 1988, 2003; Bilgi 1984, 1990, 2003; Doğan 2006). The orientations of the burials were also recorded in this GIS database based on published drawings of individual skeletons. The cemetery itself, with the locations and orientations of individual burials can be seen in **Map 3.3: İkiztepe, Mound I** and **Map 3.4: İkiztepe Cemetery**. Where orientation is known, head and body are included in the plan (i.e. ⚲); where it is not known, the burial location is marked by a simple dot (i.e. •).

The total number of burials included in this GIS map is 642. For some burial numbers, no spatial information on location could be found on any of the available published plans (SK146, 195, 202, 584, 588, 613, 619-626, 636, 649). These burials are thus absent from this GIS database. Furthermore, some burials with known locations were excluded from the map for a variety of reasons. Some of these were excluded because they were located on other mounds or excavation areas within the site, and were thus clearly not part of the cemetery proper (i.e. SK22-24, Area G; SK32, Mound III, Area J; SK68, Area K; SK627-628, Mound III, Area L, Late Iron Age; SK629-630, Mound III, Area L, date unclear; SK631-635, Mound III, Area L, date unclear but possibly EBA). Other burials that are located on Mound I were excluded because they were found at depths significantly above the upper levels of the cemetery, and were dated by the excavators to the "Transitional" period. These later burials also generally displayed distinctly different burial practices from those observed in the cemetery, with interments in large jars or pithoi (SK25-31, SK637-638).

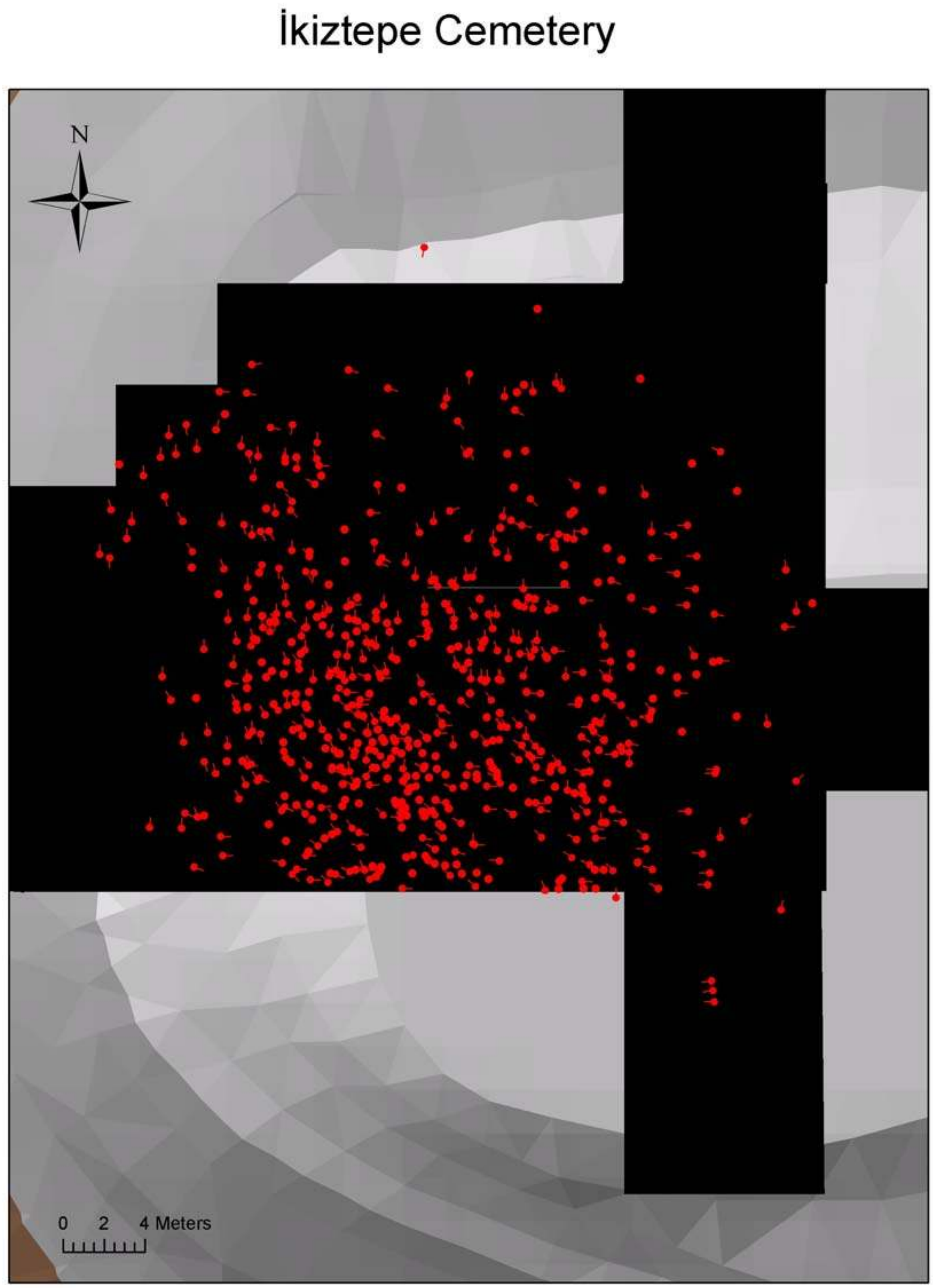
Map 3.2: İkiztepe



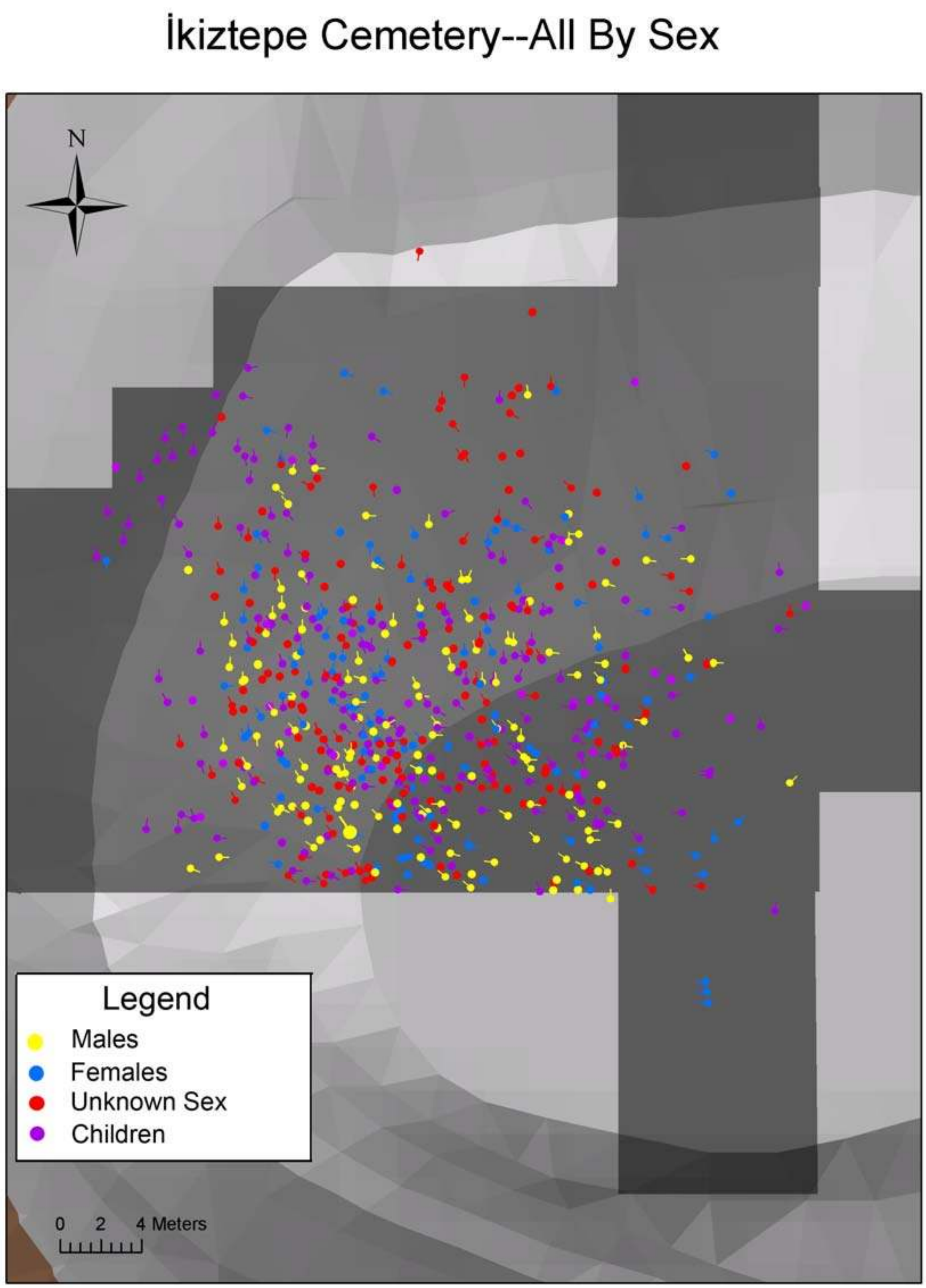
Map 3.3: İkiztepe, Mound I



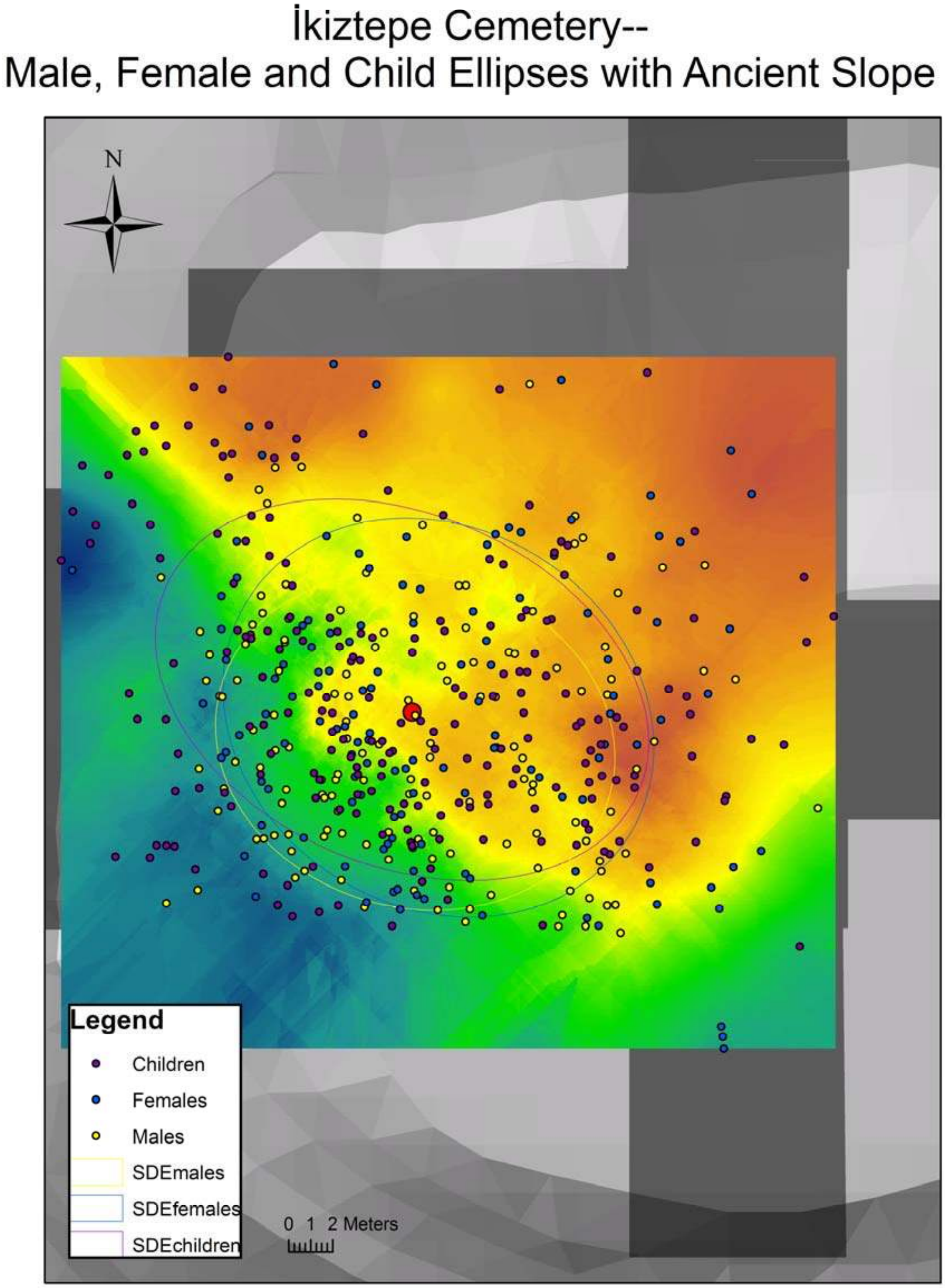
Map 3.4: İkiztepe Cemetery



Map 3.5: İkiztepe Cemetery—Locations of Burials, Displayed by Sex



Map 3.6: İkiztepe Cemetery—Ellipses for Males, Females and Children



The overall horizontal extent of the cemetery appears to be fairly well known. Excavations to the west (Area D), north (Area M) and east (Areas A and A') of the cemetery have demonstrated that there are no further interments to be found in these areas. The only unexcavated area that may still contain burials is found to the south. Some human skeletal material is visible in the southern section of Area D, but test pits to the south suggest that the remaining cemetery material is quite limited (Yılmaz Erdal, personal communication). Excavations in recent seasons have moved below the cemetery material within the area of the main cemetery, and are now examining earlier layers predating the cemetery (Bilgi 2004, 2005, 2006).

Spatial Patterning With Regard to Population Demography

It has been proposed that there is a patterned organization of the burials within the cemetery with respect to age and sex. It was proposed by Doğan that males were concentrated in the centre of the cemetery, while females and children both displayed a higher tendency to be buried on the periphery of the cemetery (2006: 28-29). Doğan evaluated this pattern by comparing male/female burial ratios in squares at the centre and periphery of the cemetery (2006: 28). The distribution of the burials by age and sex can be seen in **Map 3.5: İkiztepe Cemetery—Locations of Burials, Displayed By Sex**, where adult males are represented by yellow, adult females by blue, adults of unknown sex by red, and infants and children by purple.

In order to further test Doğan's assertion, the spatial centroid of the burial distribution was determined for each group and the standard distance deviation was determined from that centroid. This centroid can also be described as the centre of minimum distance of the spatial distribution, and involves calculating the location at which the sum of the distances to all of the individual points is at a minimum (Levine 2004). The standard distance deviation represents the standard deviation of distances of points in each group from the mean centre (Levine 2004). Standard deviation ellipses are created using the standard deviations of the locations in each group on the X and Y coordinates and then rotating the axes so that the sum of squares of the distances between points are minimized (Levine 2004). All of these calculations were performed using CrimeStat software, and the results for each group are presented in the table below.

Table 3.3: Standard Distance Deviations and Ellipse Areas by Age and Sex

	Standard Distance Deviation (m)	**Area of Ellipse (m^2)**
Males	8.42	218.49
Females	9.44	276.22
Children	10.03	294.21

The standard distance deviations and the ellipse areas both provide estimates of the degree of dispersion observed in the burials of each group. The resulting ellipses for each group are shown in **Map 3.6: İkiztepe Cemetery—Ellipses for Males, Females and Children,** providing a visual representation of dispersion. Both sets of results demonstrate that male burials are the most clustered in the centre of the cemetery, with female and children's burials increasingly dispersed toward the peripheries.

It may be that the deposition of individuals was complicated by the use of the cemetery over a long period of time. While men were originally buried centrally, the density of burials forced the expansion of the cemetery over a greater spatial area, leading to the overlapping of later "central" male burials with earlier "peripheral" female and children's burials. If this were the case, the female and child burials located more centrally within the cemetery might be considered earlier than those found around the exterior of the larger cemetery.

In order to further test these theories regarding the internal organization of the cemetery, average distances to the centre of the cemetery were calculated based on potential sub-groups within the population. The table below displays the average distances to the centre of the cemetery divided by age and sex into basic demographic groups.

Table 3.4: Average Distances to Cemetery Centre by Basic Demographic Groups

	Average	**Standard Deviation**	**n**
Infants	10.17149	5.15743	47
Children	8.567423	4.34732	163
Adult Males	7.812766	3.333155	141
Adult Females	8.353307	4.407059	127
Unknown Adults	7.723493	3.413596	147

In general, these results parallel Doğan's theories regarding the cemetery's organization (2006). Average distance to the cemetery's centre decreases with increasing age, and males generally have a lower average distance to the centre than females. This suggests that, on average, males tended to be buried slightly closer to the centre of the cemetery than females and children. These two groups were buried at similar average distances from the cemetery's centre; infants, in contrast, were buried much further from the centre of the cemetery.

Paired t-tests were conducted to test for significant differences in these average distances from the centre of the cemetery between the different groups. The results of these t-tests are presented in the table below; significant results are presented in italics.

Table 3.5: Results of Paired T-Tests for Absolute Distance from Cemetery Centre by Demographic Groups

	Infants	**Children**	**Males**	**Females**	**Unknown Adults**
Infants		*t=2.1345 p=0.033971*	*t= 2.9376 p=0.004704*	*t=2.3052 p=0.022352*	*t=3.0463 p=0.003450*
Children			t= 1.7101 p=0.088288	t= 0.4136 p=0.679453	t= 1.9074 p=0.057415
Males				t= -1.1229 p=0.262631	t=0.2241 p=0.822866
Females					t=1.3055 p=0.192997

These results suggest that there are significant differences in the average distances from the centre of the cemetery between infants and most other groups, including children. Infants are significantly more likely to be placed peripherally in the cemetery than all other groups. Differences between the average distances obtained for children and adult males, as well as between children and adults of unknown sex, were also significant at the level of $\alpha=0.1$. Differences in average distances to the cemetery center between children and adult females were not determined to be significant, and nor were differences between adult males and adult females.

Average distances from the cemetery centre were also calculated for age groups broken down into more finely defined categories; these categories included infants (0-1 years), young children (1-6 years), older children (6-12 years), adolescents (12-18 years), young adults (18-30 years), middle adults (30-45 years), and older adults (45+ years). Individuals of unknown age, and adults whose age could not be more finely divided into one of the three age categories were excluded from these calculations. The average distances for these age groups are presented in the table below.

Table 3.6: Average Distance from Cemetery Centre by Age Groups

	Average	**Standard Deviation**	**n**
Infants (0-1 years)	10.04545	5.170367	44
Young Children (1-6 years)	8.564876	4.453892	121
Older Children (6-12 years)	7.968148	3.961006	54
Adolescents (12-18 years)	8.09	3.593418	55
Young Adults (18-30 years)	8.591356	3.845604	59
Middle Adults (30-45 years)	8.116224	4.101731	98
Older Adults (45+ years)	7.899518	3.782933	83

These results suggest a slightly different pattern from those discussed above. Infants are still buried much further from the centre of the cemetery than other age groups, as observed above.

However, a difference is observed between younger and older children with regard to their placement relative to the cemetery centre. Older children are buried closer to the cemetery centre than younger children. Furthermore, among adults, burials are placed closer to the centre of the cemetery with increasing age; thus, older adults are placed closer to the centre than younger adults. Interestingly, the average distances observed are similar between older adults and older children; older children are in fact buried, on average, closer to the cemetery centre than the two younger adult age categories. Adolescents generally appear to have been buried at an average distance from the cemetery centre that was intermediate between older children and younger adults.

Paired t-tests were conducted to look for significant differences in the average distance to the cemetery centre between these age groups. The results of these t-tests are presented in the table below; significant results are in italics.

Table 3.7: Results of Paired T-Tests for Absolute Distance from Cemetery Centre by Age Groups

	Infants (0-1)	**Young Children (1-6)**	**Older Children (6-12)**	**Adolescents (12-18)**	**Young Adults (18-30)**	**Middle Adults (30-45)**	**Older Adults (45+)**
Infants (0-1)		t=1.8072 p=0.072568	*t=2.1920 p=0.031316*	*t=2.1306 p=0.036450*	t=1.5696 p=0.120647	*t=2.1855 p=0.032285*	*t=2.4298 p=0.017752*
Young Children (1-6)			t= 0.8462 p=0.398601	t= 0.7521 p=0.453405	t= -0.0391 p=0.968856	t= 0.7678 p=0.443470	t= 1.1472 p=0.252705
Older Children (6-12)				t= -0.1683 p=0.866688	t= -0.8471 p=0.398768	t= -0.2156 p=0.829594	t= 0.1019 p=0.919020
Adolescents (12-18)					t= -0.7179 p=0.474337	t= -0.0396 p=0.968439	t=0.2954 p=0.768146
Young Adults (18-30)						t=0.7194 p=0.472952	t=1.10666 p=0.287977
Middle Adults (30-45)							t= 0.3670 p=0.714086

Despite the existence of the general patterns discussed above, the t-tests suggest that these trends are not significant. The only exception is the differential treatment of infants, placed significantly further from the cemetery centre than all other age groups, tending toward the peripheries of the cemetery.

Grave Good Distribution with Regard to Population Demography

In addition to calculating average distances to the cemetery centre for these demographic groups, other statistics were also calculated for the same groups relating to the distribution of grave goods amongst various demographic subgroups of the İkiztepe population. The results of some of these tests may be slightly different than those obtained by Doğan (2006), who limited analysis to 511 burials due to various factors. In contrast, these calculations make use of all available burial information. It should also be noted that total numbers of grave goods associated with particular individuals are influenced by a number of factors that may cause some degree of arbitrariness in the calculation of grave good totals. For example, items made of perishable materials like wood or textiles may not have been adequately preserved to allow identification during excavation. Furthermore, materials such as seeds and faunal remains may not have been recovered or deemed to be significant during excavation, but may have had significance in funerary rituals. Finally, the methods used by archaeologists for counting grave goods may also include some degree of arbitrariness, particularly when dealing with jewelry items like beads and earrings, which are sometimes grouped together and sometimes separated. In the calculations that follow, care was taken to ensure consistency in counting of items that were likely from a single item (i.e. groups of beads); however, in some cases object descriptions were not clear, and may have created some inconsistencies. All of these factors may contribute to inaccurate counting of grave goods, and may affect attempts to reconstruct patterns of grave good distribution. However, these potential inaccuracies should not be sufficient to completely obscure such patterns as they relate to basic demographic groups.

The assessment of the distribution of grave goods of various types was conducted in two ways. Firstly, average values for each grave good type were calculated for the various demographic subgroups within the population. This approach, however, should only be used as a heuristic tool for comparisons between subpopulations, as it requires the assumption of a normal distribution of grave good frequencies in the population, an assumption that is unlikely to be met. Thus, parametric tests that identify differences between these mean values cannot viably be conducted. Instead, the distribution of grave goods within the population is likely to be more accurately modeled as a Poisson distribution, which deals with the probability of a certain number of events occurring within a fixed time period, and is often viewed as a means of modeling rare events. This distribution requires the assumption that the probability of an event occurring is independent of the time since the last event occurred, which is likely to be the case with grave good distribution in individual burials. Thus, the number of grave goods occurring in various population subgroups were treated as a Poisson distribution, and differences between the groups were tested using non-parametric methods. Two separate kinds of tests were completed to look for differences between demographic groups. Differences in the presence/absence of grave goods between the various groups were tested using chi-square tests. In addition, amongst individuals with one or more grave goods, differences in the distribution of absolute grave good numbers between groups were identified using a Kruskal-Wallis test.

Calculations were first conducted for the total number of grave goods associated with different groups. The table below presents average numbers of grave goods for the basic demographic groups divided by age and sex.

Table 3.8: Average Numbers of Total Grave Goods by Basic Demographic Groups

	Average	Standard Deviation	N
Infants	0.1914894	0.5762811	47
Children	1.809816	2.259553	163
Males	2.078014	2.935183	141
Females	1.472441	2.30192	127
Unknown Adults	0.8082192	1.743224	147

These results suggest an interesting pattern. While infants are buried with very few grave goods, children seem to be buried with substantially more objects, more similar in numbers to adults than infants. In fact, children seem to be buried with more objects, on average, than adult females and adults of unknown sex. The only group who tends to be buried with more objects than children was adult males, who generally had more objects associated with them than adult females.

Further tests regarding the total numbers of grave goods were based on the frequency distribution of grave goods amongst basic demographic groups by age and sex, which is presented in the table below.

Table 3.9: Frequency Distribution of Total Grave Goods By Basic Demographic Groups

	Number of Grave Goods														
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
Infants	41	4	1	1	0	0	0	0	0	0	0	0	0	0	47
Children	70	25	18	15	14	11	3	2	0	4	1	0	0	0	163
Males	62	24	17	5	9	4	5	5	3	2	1	2	1	1	141
Females	59	26	18	11	1	4	3	1	1	0	0	1	2	0	127
Unknown Adults	101	19	11	4	4	2	2	1	0	1	0	1	0	0	146

The frequency distribution displayed in this table immediately suggests differences in the occurrence of total numbers of grave goods. The distribution of grave goods amongst infant burials drops off much more quickly than is seen for the burials of children. Similarly, the adult female distribution drops off more quickly than that of adult males. The distribution among adults of unknown sex suggests a higher occurrence of graves with no grave goods compared to other adult demographic groups with the exception of infants. This observation is likely related to issues of preservation. Adults whose remains could not be identified as either male or female are probably more likely to be poorly preserved due to disturbance, and thus may be associated with fewer grave goods due to the effect of this disturbance. Chi-square tests conducted on all of these demographic groups together to look for difference in presence/absence of grave goods suggests that a significant difference does exist (χ^2= 50.8797, df=4, p=0.000000). Tests comparing presence/absence of grave goods between adult sex groups (M, F, U) also suggest a significant difference (χ^2=22.109074, df=2, 0.000016). A Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups also suggests that significant differences between the demographic groups exist (H=55.00938, p=0.000000).

The average numbers of grave goods were also calculated for the same more specific age groups as defined above; the results are presented in the table below.

Table 3.10: Average Numbers of Grave Goods by Age Groups

	Average	**Standard Deviation**	**N**
Infants (0-1 years)	0.1590909	0.5682769	44
Young Children (1-6 years)	1.867769	2.265473	121
Older Children (6-12 years)	1.296296	2.079819	54
Adolescents (12-18 years)	1.145455	1.495898	55
Young Adults (18-30 years)	1.288136	1.939168	59
Middle Adults (30-45 years)	2.265306	3.31989	98
Older Adults (45+ years)	2.072289	2.565166	83

Infants, once again, display a much lower average number of grave goods than all other age groups. Interestingly, however, young children display a higher average number of grave goods than older children. This is slightly different than the pattern suggested by Doğan (2006), who found that older children had higher numbers of grave goods than young children. Adolescents have a lower number of grave goods, on average, than the numbers observed in either younger or older children, while young adults have a similar average to older children. Again, differing from the conclusions of Doğan (2006), the adult age groups do not fully show an increasing number of grave goods with increasing age. Older adults, while having an average higher than most other age groups, have slightly lower numbers of grave goods, on average, than middle adults.

The table below presents the frequency distribution of grave goods amongst the various age groups.

Table 3.11: Frequency Distribution of Total Grave Goods By Age Groups

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Infants (0-1 years)	40	2	1	1	0	0	0	0	0	0	0	0	0	0	44
Young Children (1-6 years)	50	18	16	10	10	9	3	1	0	4	0	0	0	0	121
Older Children (6-12 years)	30	9	3	4	4	2	0	1	0	0	1	0	0	0	54
Adolescents (12-18 years)	24	16	7	3	3	1	0	1	0	0	0	0	0	0	55
Young Adults (18-30 years)	31	11	4	6	2	2	2	0	0	1	0	0	0	0	59
Middle Adults (30-45 years)	41	17	16	4	2	3	2	3	2	1	1	3	2	1	98
Older Adults (45+ years)	32	14	12	6	4	4	5	3	1	1	0	0	1	0	83
Unknown Adults	70	10	5	2	2	0	1	0	1	0	0	1	0	0	92

This frequency distribution once again suggests that significant differences exist in the occurrence of total numbers of grave goods between the different age groups. The distribution of grave goods amongst infant burials drops off much more quickly than all other age groups, including young children. In addition, a different and more dispersed distribution of grave good numbers is observed among middle adults. Chi-square tests conducted on these age groups to look for differences in the presence/absence of grave goods suggest that a significant difference does exist between groups (χ^2= 41.191099, df=6, p=0.000000). A Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups also suggests the existence of significant differences between the demographic age groups (H=73.23264, p=0.000000).

In addition to calculating average numbers of grave goods for the various demographic groups, the average numbers of weaponry included in the graves were also calculated for the same groups. The table below presents average numbers of weapons for the basic demographic groups by age and sex.

Table 3.12: Average Numbers of Weapons by Basic Demographic Groups

	Average	Standard Deviation	N
Infants	0	0	47
Children	4.907975E-02	0.3103897	163
Males	0.7446808	1.136437	141
Females	0.1889764	0.4668755	127
Unknown Adults	0.2054795	0.4830622	146

No weapons were found in the graves of infants; in children's graves weapons are rare, but not completely absent. The graves of adult females contained greater numbers of weapons than those observed in those of both infants and children. Adult males, however, had a much greater average number of weapons that observed in any other group.

Similar frequency distributions to those shown above for total grave goods were also constructed for the distribution of weaponry amongst the various demographic groups. The table below displays the frequency distribution of weaponry for basic demographic groups within the population.

Table 3.13: Frequency Distribution of Weaponry By Basic Demographic Groups

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Infants	47	0	0	0	0	0	0	0	0	0	0	0	0	0	47
Children	158	3	1	1	0	0	0	0	0	0	0	0	0	0	163
Males	85	27	17	4	8	0	0	0	0	0	0	0	0	0	141
Females	107	16	4	0	0	0	0	0	0	0	0	0	0	0	127
Unknown Adults	121	20	5	0	0	0	0	0	0	0	0	0	0	0	146

The frequency distribution displayed in this table suggests that differences can be observed in the occurrence of weaponry between these groups. Amongst infant burials, no occurrences of weaponry were observed, and few were observed among children and adult females. Rare cases of weaponry amongst these groups occur, although the occurrence of one or two weapons within a grave appears to have been more common for adult females than for children. Adult males display the highest numbers of weapons. Chi-square tests conducted on all of these demographic groups together to look for differences in presence/absence of weapons suggests that a significant difference does exist (χ^2= 83.810205, df=4, p=0.000000). Tests comparing presence/absence of weapons only between adult sex groups (M, F, U) also suggest a significant difference (χ^2=27.279069, df=2, 0.000001). A Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups also suggests significant differences between the demographic groups (H=88.01778, p=0.000000).

The average numbers of weapons were also calculated for the same more precise age groups as defined in previous tests; the results of these calculations are presented in the table below.

Table 3.14: Average Number of Weapons by Age Groups

	Average	Standard Deviation	N
Infants (0-1 years)	0	0	44
Younger Children (1-6 years)	8.264462E-03	09.090909E-02	121
Older Children (6-12 years)	5.555556E-02	0.3019851	54
Adolescents (12-18 years)	0.4	0.7097208	55

Young Adults (18-30 years)	0.2033898	0.5179422	59
Middle Adults (30-45 years)	0.7244898	1.128639	98
Older Adults (45+ years)	0.5180723	0.9154693	83

These results suggest a trend toward an increase in the average number of weapons with increasing age. The average number of weapons increases between infants and adolescents. There is a decrease in the average number of weapons between adolescents and young adults. However, the average number of weapons increases noticeably between young adults and middle adults, before decreasing slightly among older adults.

The table below presents the frequency distribution of weapons amongst the various age groups.

Table 3.15: Frequency Distribution of Weaponry By Age Groups

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
Infants (0-1 years)	44	0	0	0	0	0	0	0	0	0	0	0	0	0	44
Young Children (1-6 years)	120	1	0	0	0	0	0	0	0	0	0	0	0	0	121
Older Children (6-12 years)	52	1	1	0	0	0	0	0	0	0	0	0	0	0	54
Adolescents (12-18 years)	39	11	4	1	0	0	0	0	0	0	0	0	0	0	55
Young Adults (18-30 years)	50	6	3	0	0	0	0	0	0	0	0	0	0	0	59
Middle Adults (30-45 years)	59	21	10	2	6	0	0	0	0	0	0	0	0	0	98
Older Adults (45+ years)	56	17	6	2	2	0	0	0	0	0	0	0	0	0	83
Unknown Adults	81	8	3	0	0	0	0	0	0	0	0	0	0	0	92

This frequency distribution once again suggests that significant differences exist in the occurrence of weapons between the different age groups. Again, infant burials display no occurrences of weaponry, and the numbers of weaponry among young children appear to drop off more quickly than observed in older children. In addition, higher numbers of weaponry are observed most frequently among middle and older adults. Chi-square tests conducted on these age groups to look for differences in the presence/absence of weaponry suggest that a significant difference does exist (χ^2= 88.484544, df=6, p=0.000000). A Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups also suggests significant differences between the demographic groups (H=99.1152, p=0.000000).

In addition to calculating average numbers of grave goods and weaponry for the various demographic groups, average numbers of tools included in the graves were also calculated for the same groups. The table below presents average numbers of tools for the basic demographic groups by age and sex.

Table 3.16: Average Numbers of Tools by Basic Demographic Groups

	Average	Standard Deviation	N
Infants	6.382979E-02	0.2470922	47
Children	0.1595092	0.4434208	163
Males	0.5106383	0.827685	141
Females	0.4330709	0.8872157	127
Unknown Adults	0.260274	0.9251639	146

These results suggest that infants and children displayed relatively low numbers of tools as grave goods. These values increase in adulthood, and although adult males display slightly higher average numbers than adult females, these groups have quite similar averages.

In addition, similar frequency distributions to those used above were also constructed for the distribution of tools amongst the various demographic groups. The table below displays the frequency distribution of tools for basic demographic groups within the population.

Table: 3.17: Frequency Distribution of Tools by Basic Demographic Groups

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Infants	44	3	0	0	0	0	0	0	0	0	0	0	0	0	47
Children	141	19	2	1	0	0	0	0	0	0	0	0	0	0	163
Males	92	32	12	4	1	0	0	0	0	0	0	0	0	0	141
Females	89	30	4	1	2	0	1	0	0	0	0	0	0	0	127
Unknown Adults	124	17	0	4	0	0	0	0	0	1	0	0	0	0	146

The frequency distribution displayed in this table suggests that differences can be observed in the occurrence of tools between these groups. The distribution of tools amongst infant burials drops off much more quickly than observed in children or adults. Children display slightly fewer tools than observed in adults, but adult males and females display comparatively similar distributions. Chi-square tests conducted on all of these demographic groups together to look for differences in presence/absence of tools suggests that a significant difference does exist (χ^2= 36.16632, df=4, p=0.000000). Tests comparing presence/absence of tools between adult sex groups (M, F, U) also suggest a significant difference (χ^2=15.546271, df=2, 0.000421). In addition, a Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups suggests significant differences between the demographic groups (H=37.67768, p=0.000000).

The average numbers of tools were also calculated for the same age groups as defined in previous tests; the results of these calculations are presented in the table below.

Table 3.18: Average Number of Tools by Age Groups

	Average	Standard Deviation	N
Infants (0-1 years)	6.818182E-02	0.2549717	44
Younger Children (1-6 years)	0.1322314	0.3638257	121
Older Children (6-12 years)	0.2222222	0.5718777	54
Adolescents (12-18 years)	0.2727273	0.4494666	55
Young Adults (18-30 years)	0.440678	0.8763401	59

Middle Adults (30-45 years)	0.5918368	1.19135	98
Older Adults (45+ years)	0.626506	1.067375	83

The average number of tools is the first category of grave goods that displays an unbroken trend towards increased numbers with increasing age. The average number of tools encountered increases from infancy through adolescence, increasing more significantly in young adults, and then again in middle adults. Older adults display only slightly higher averages than middle adults.

The table below presents the frequency distribution of tools amongst the various specific age groups.

Table 3.19: Frequency Distribution of Tools by Age Groups

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
Infants (0-1 years)	41	3	0	0	0	0	0	0	0	0	0	0	0	0	44
Young Children (1-6 years)	106	14	1	0	0	0	0	0	0	0	0	0	0	0	121
Older Children (6-12 years)	45	7	1	1	0	0	0	0	0	0	0	0	0	0	54
Adolescents (12-18 years)	40	15	0	0	0	0	0	0	0	0	0	0	0	0	55
Young Adults (18-30 years)	44	8	3	4	0	0	0	0	0	0	0	0	0	0	59
Middle Adults (30-45 years)	63	24	6	3	1	0	0	0	0	1	0	0	0	0	98
Older Adults (45+ years)	51	21	7	1	2	0	1	0	0	0	0	0	0	0	83
Unknown Adults	83	8	0	1	0	0	0	0	0	0	0	0	0	0	92

This frequency distribution table once again suggests that significant differences exist in the occurrence of tools between the different age groups. Again, infant burials display fewer occurrences of tools, and the distributions of tools amongst younger children, older children and adolescents all tend to drop off relatively quickly. In addition, higher numbers of tools are observed more frequently among middle and older adults. Chi-square tests conducted on these age groups to look for differences in the presence/absence of tools suggest that a significant difference does exist (χ^2= 34.917307, df=6, p=0.000004). A Kruskal-Wallis test that looks for differences in the overall frequency distribution between groups also suggests significant differences between the demographic groups (H=53.10703, p=0.000000).

The Issue of Internal Chronology and Burial Elevations

Another major concern for the interpretation of the İkiztepe cemetery remains relates to the internal chronology of the cemetery, and the seriation of the burials found within it. The lack of knowledge regarding the seriation of the burials hampers interpretations of both burial patterns and of the temporal development of the cemetery. This includes the reconstruction presented above regarding patterns of burial by age and sex groups, and relative distances to the cemetery centre, which may have been time dependent.

Unfortunately, the excavation strategy employed at the site does not seem to have allowed for the identification of grave pits. Thus, the depths of the burials presented are based on the absolute depth of the skeletal material found in the burials themselves. It might be suggested that a rough seriation of burials could be accomplished by comparing the absolute elevations of the individual burials, if it was possible to assume a relatively consistent depth of burial at the time of interment. However, if graves were excavated to different depths for different individuals, the identification of the level from which the burials originated is virtually impossible.

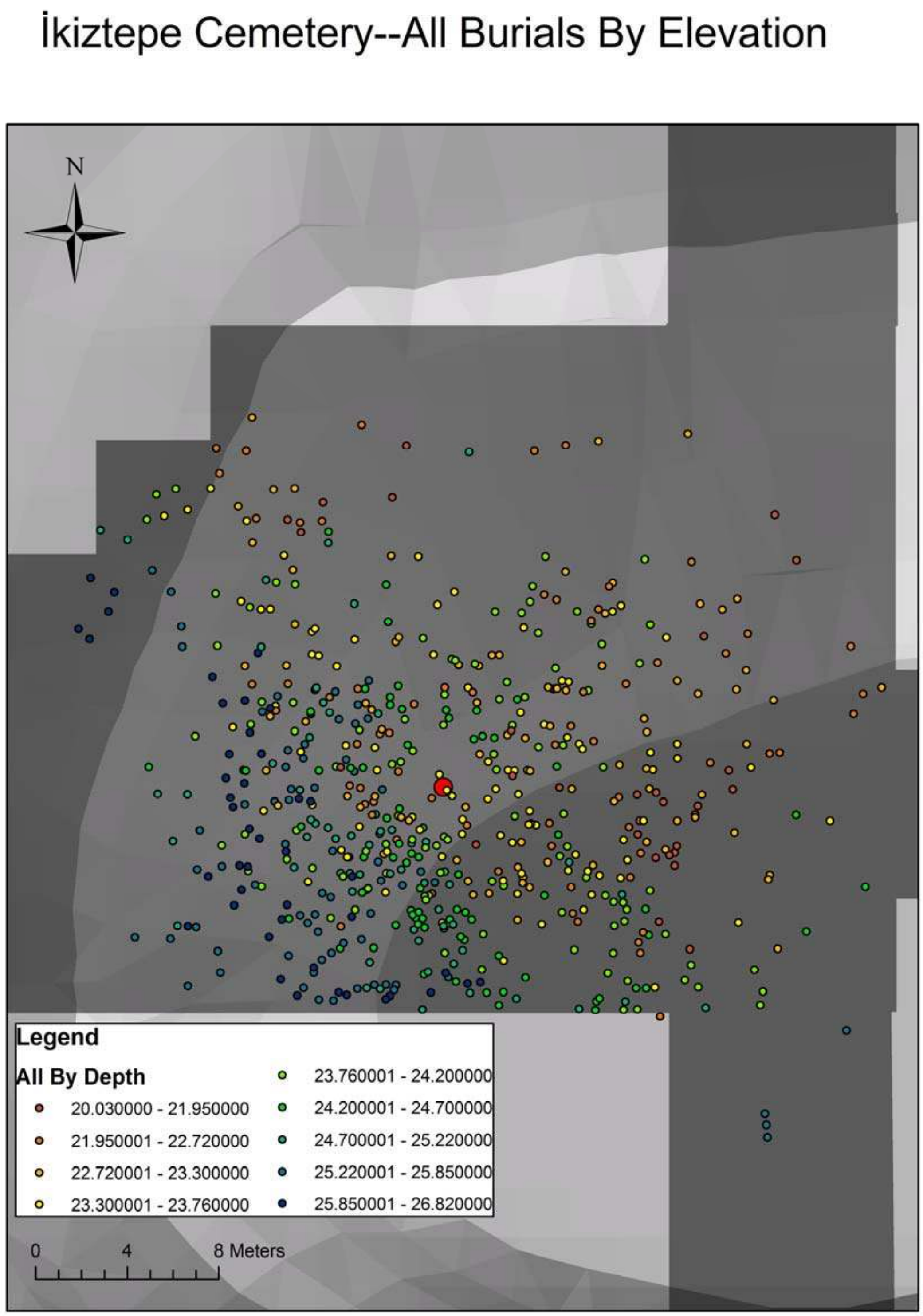
Furthermore, the scant nature of the published material from the cemetery precludes the identification of parallels outside the site. Even if this material had been more comprehensively published, the relatively scarce archaeological evidence (see **Chapter Two**) for Northern Anatolia during this period means that there are very limited possibilities for identifying parallels that might be of assistance in seriating the burials based on the grave goods included with them.

Despite this, however, plotting the burials with regard to their depth does provide some useful information about the cemetery and its chronology. It is tempting to assume a fairly standard practice of burial with regard to the depth of the burial pit employed, and to interpret the relative depths of the burials as representative of relative ages. However, a map of the burials according to their depth clearly demonstrates that such an approach is problematic (see **Map 3.7: İkiztepe Cemetery—All Burials, Displayed by Burial Elevation**; these data represent absolute elevations taken from database presented in Doğan 2006). It is clear from this map that there is a pattern within the cemetery with regard to the elevations of the burials. In the southwestern portion of the cemetery, the graves are generally located at higher elevations, while in the northeastern portion of the cemetery, they were found at lower elevations. This pattern is in general disagreement with the modern topography of Mound I in the cemetery's vicinity, which slopes downward toward the southwest. However, this is in agreement with the reconstruction of the ancient topography of the mound, as presented in the second excavation volume (Alkım *et al* 2003). In this volume, they suggest that Mound I was originally formed of two separate, smaller mounds, one located to the northeast and one to the southwest of the current area of Mound I.

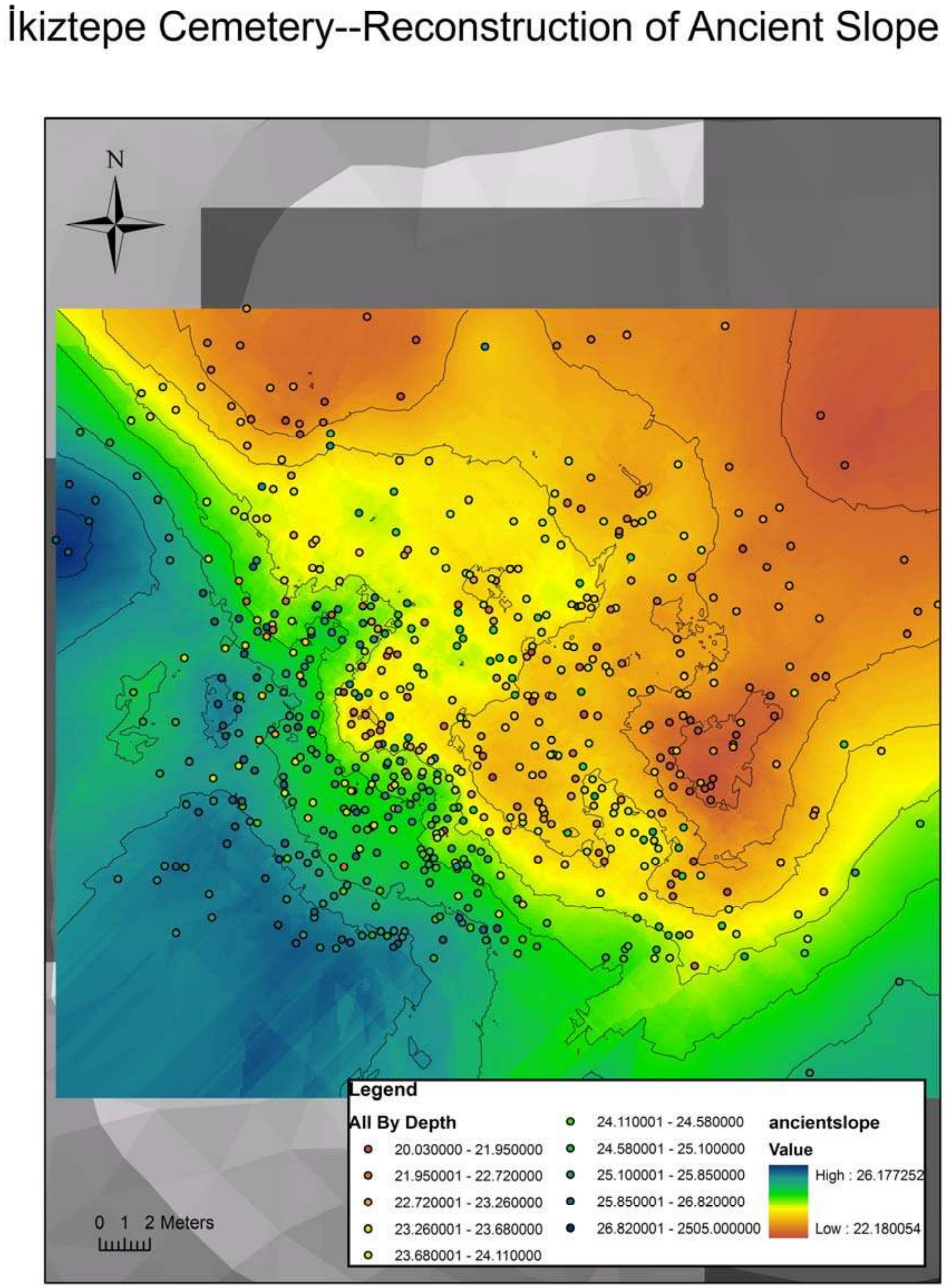
The cemetery, then, would seem to have been located on the northeastern (downward) slope of the southwestern of these two mounds, and into the dip located between them.

An attempt was thus made to reconstruct the nature of the ancient slope based on the placement and depths of the burials. Using the kriging function in ArcMap, which interpolates a surface using a series of point data, the ancient slope of the mound was interpolated (see, **Map 3.8: İkiztepe Cemetery—Reconstruction of Ancient Slope**). Using the original reconstructed slope, which represents the average burial elevation at any given location, some of the burials actually fell above this reconstructed surface. This reconstructed slope was thus raised by 3m. This value was selected somewhat arbitrarily, but was used to ensure that all of the mapped burials fell below the potential surface. Having reconstructed the surface of the ancient mound, its elevation can then be used to calculate the relative depths of the burials. These depths can then be used as a potential estimate of relative chronology, rather than using depths below the modern surface of the mound, which are likely to be meaningless. The elevations of the burials were then compared to the elevation of the slope at each burial's precise location in order to calculate the burial depths.

Map 3.7: İkiztepe Cemetery—All Burials, Displayed by Burial Elevation



Map 3.8: İkiztepe Cemetery—Reconstruction of Ancient Slope



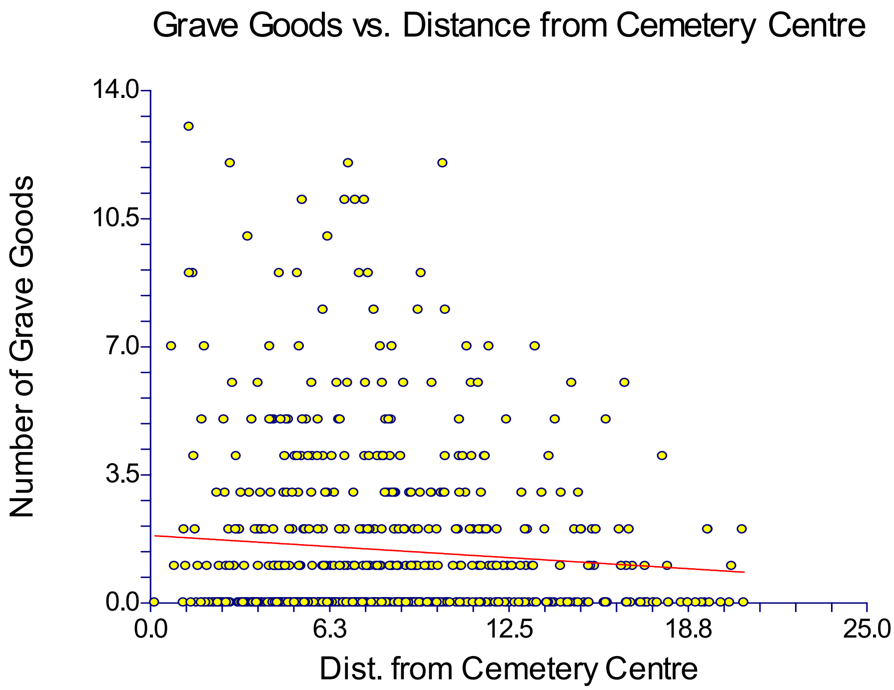
These new depth measurements were then used to reconstruct a potential seriation of the burials, based on the assumption that the depth to which individuals were buried remained relatively constant. Depth data below the slope of the mound is presented for all individuals on which isotopic analysis was undertaken, and was used to propose a relative chronology of burials, from earliest to latest. This proposed relative chronology is compared to the results of the fluoride dating of the skeletal material from these graves in **Chapter Seven**.

Furthermore, it should be noted, with regard to the 6.7 m difference in elevations observed between the burials within the cemetery, that much of this difference in depth can be explained by the existence of a sloping cemetery. Interpretations that have suggested a substantially longer period of use for the cemetery based solely on these elevations may thus be based on faulty assumptions (i.e. Parzinger 1993, Zimmermann 2007).

Spatial Patterning in Grave Goods

In order to examine the spatial patterning in the occurrence of particular types of grave goods, a variety of different plots were made to examine their relationships to various spatial variables, and to determine if any significant correlations were identifiable. The spatial variables used included: 1) location on X coordinate (i.e. east-west axis of cemetery), 2) location on Y coordinate (i.e. north-south axis of cemetery), 3) distance from the cemetery centre on the X axis, 4) distance from the cemetery centre of the cemetery on the Y axis, 5) absolute distance from the cemetery centre, and 6) absolute burial elevation. The cemetery centre was calculated using CrimeStat software as the centre of minimum distance, at which the sum of the distances to all of the individual points is at a minimum (Levine 2004). These spatial variables were each compared to total number of grave goods, total number of weapons, total number of jewelry items and total number of tools occurring in each burial. Significant correlations were calculated using R^2 and the associated p-value of this value.

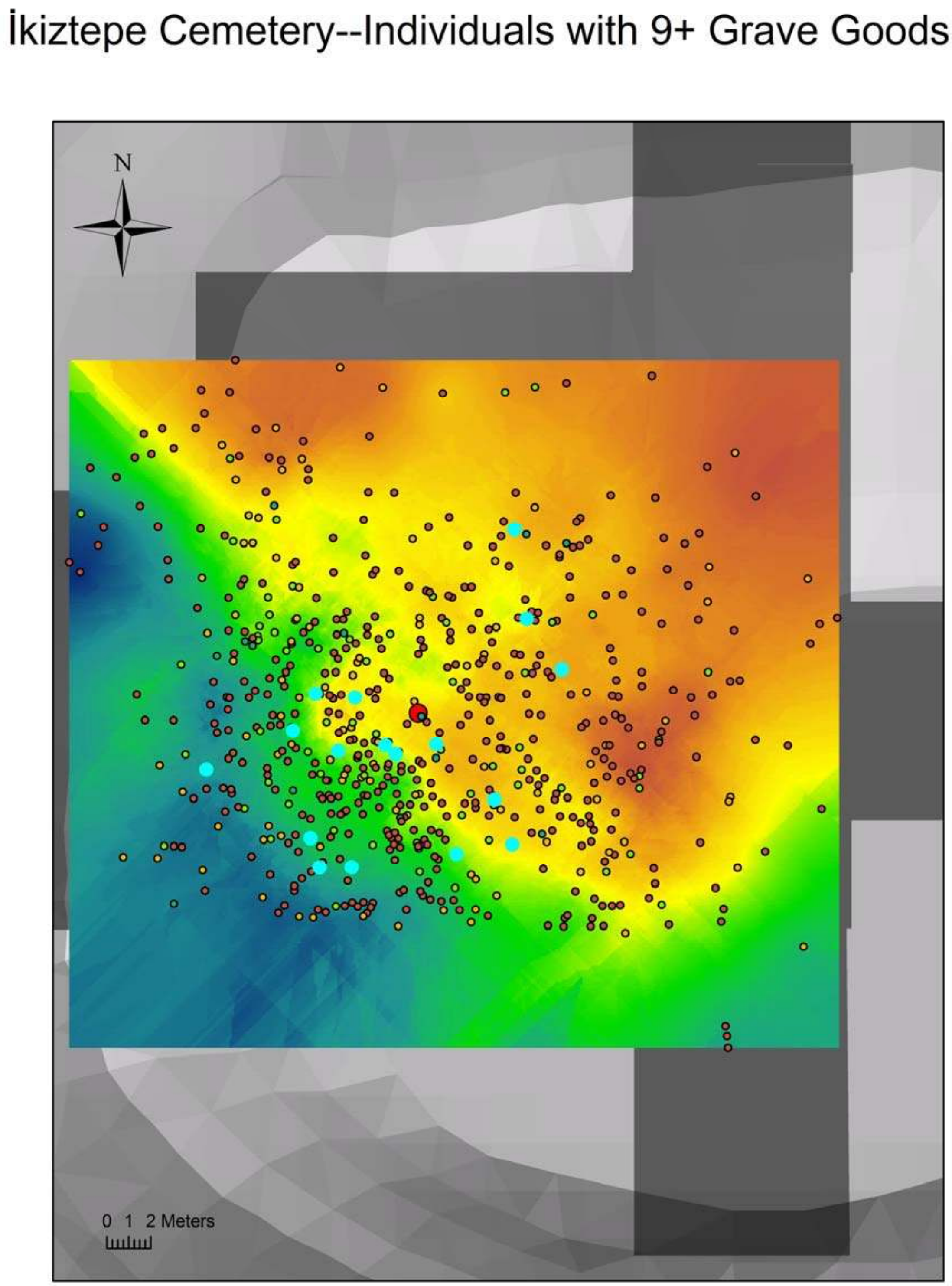
Figure 3.1: Total Number Grave Goods vs. Absolute Distance from Centre



R^2= 0.0078, y= 1.84 - 4.83x, p=0.0278

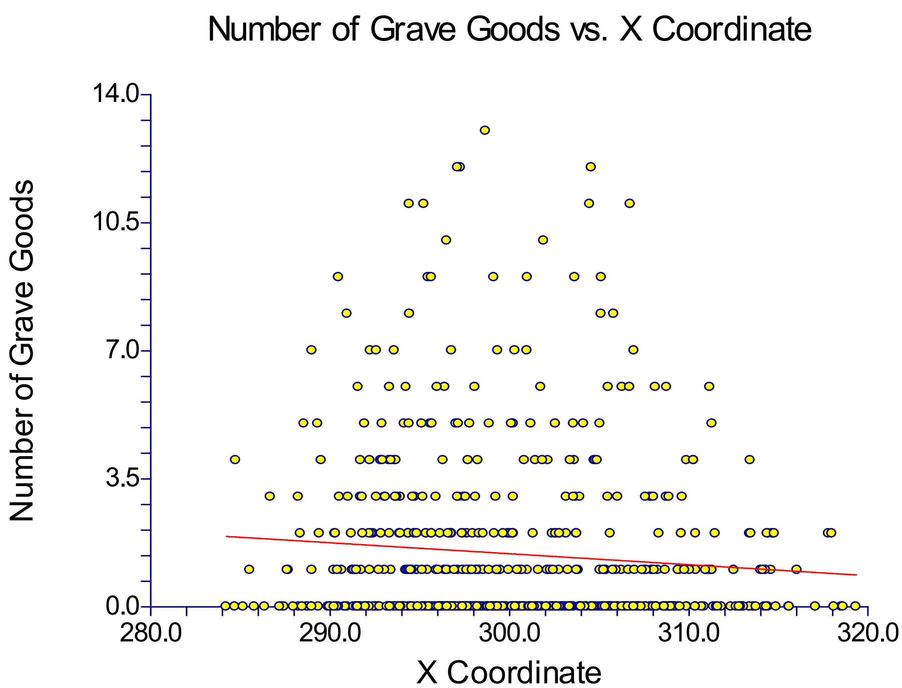
The general pattern appears to be that there is a significant relationship between the number of grave goods and the distance of the grave from the centre of the cemetery. While the r^2 value indicates that this variable explains only a very small proportion of the variation in the number of grave goods, the p-value indicates that the slope value of the regression line is significantly different from zero. This suggests a significant relationship between the two variables, an idea supported by the plot above. While individuals with no grave goods are found throughout the cemetery, and are located at a variety of distances from the cemetery centre, the individuals with the highest numbers of grave goods appear to be concentrated close to the centre of the cemetery.

Map 3.9: İkiztepe Cemetery—Locations of Individuals with 9+ Grave Goods



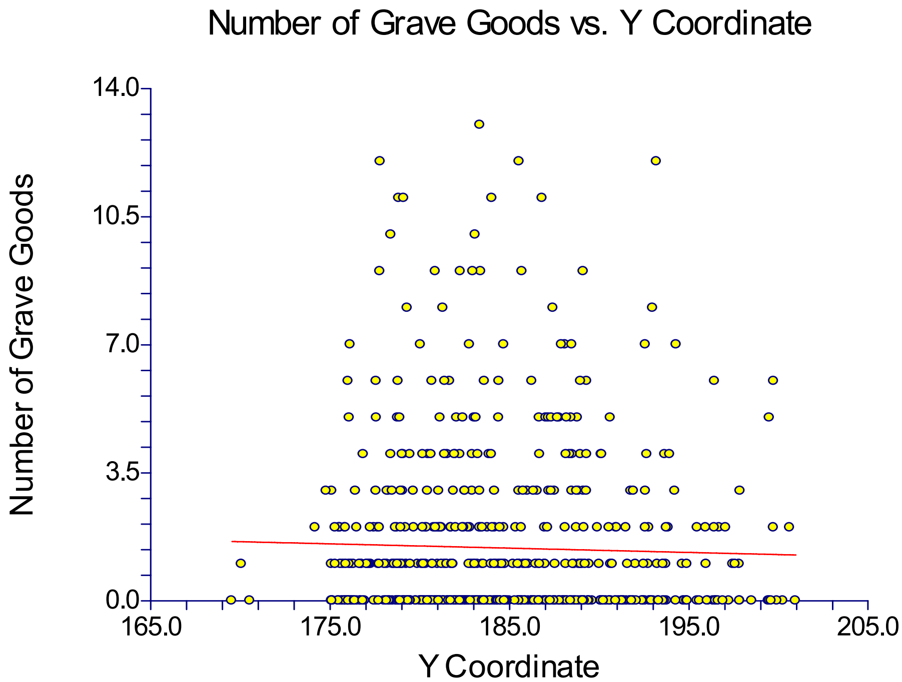
This pattern is also borne out by the map which shows that the individuals with the highest numbers of grave goods (i.e. ≥ 9) are concentrated in one particular area of the cemetery (see **Map 3.9: İkiztepe Cemetery—Locations of Individuals with 9+ Grave Goods)**. When these graves are plotted overlaying the reconstructed ancient slope of the cemetery, the results are particularly telling. These burials are concentrated in the middle to lower part of the slope in the southern part of the cemetery, lying within a small curving niche in the slope. The centroid of the cemetery is also located in this area. It thus appears that individuals with higher numbers of grave goods are concentrated in one particular area of the cemetery.

Figure 3.2: Total Number of Grave Goods vs. Location on X Axis (East-West)



R^2=0.0082, y=10.45 - 0.030x, p=0.0234

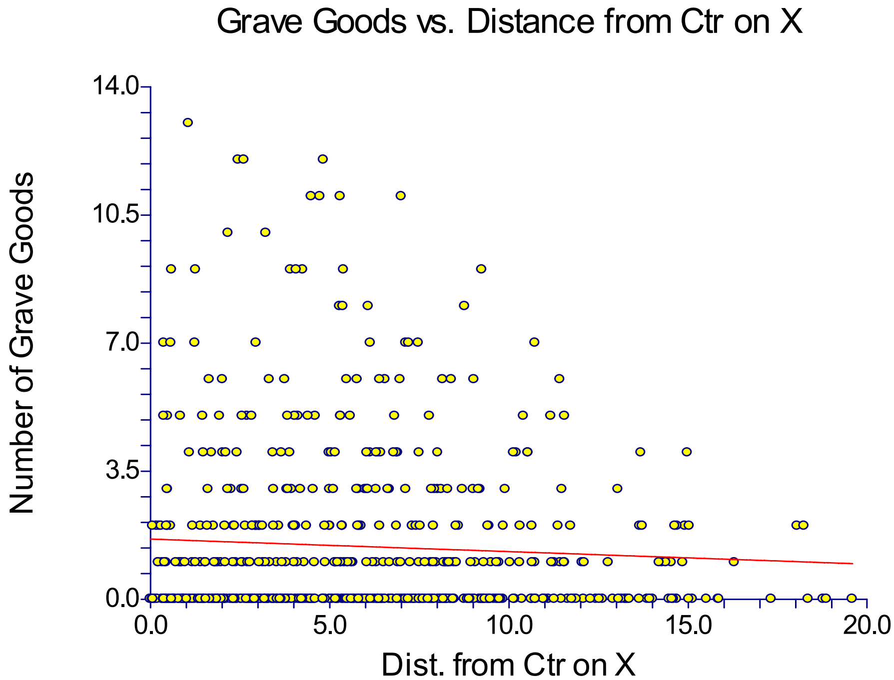
Figure 3.3: Total Number of Grave Goods vs. Location on Y Coordinate (North-South)



R^2=0.0009, y=3.61 -1.17x, p=0.4540

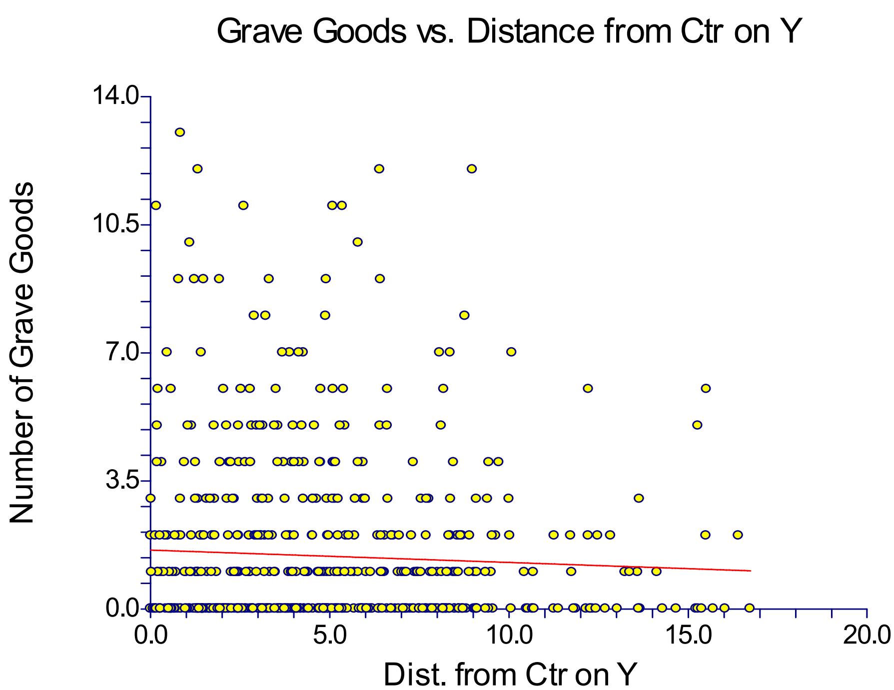
While the relationship between the number of grave goods and the X coordinate of the cemetery (i.e. east-west axis) is significant, the corresponding relationship to the Y coordinate (i.e. north-south axis) is not. In both cases, the r^2 value is very low, indicating that these relationships do not account for a large proportion of the variation in the number of grave goods. However, in the case of the location of the burial on the x axis, the slope of the regression line is determined to be significantly different from zero, suggesting that there is a significant relationship between the two variables. In both cases, as described previously, while the individuals with no grave goods were spread throughout the cemetery, the individuals with the highest numbers of grave goods are concentrated in particular areas of the cemetery; this pattern corroborates the pattern described above.

Figure 3.4: Total Number of Grave Goods vs. Distance from the Cemetery Centre on the X Axis (East-West)



R^2=0.0035, y=1.64 -0.03x, p=0.1392

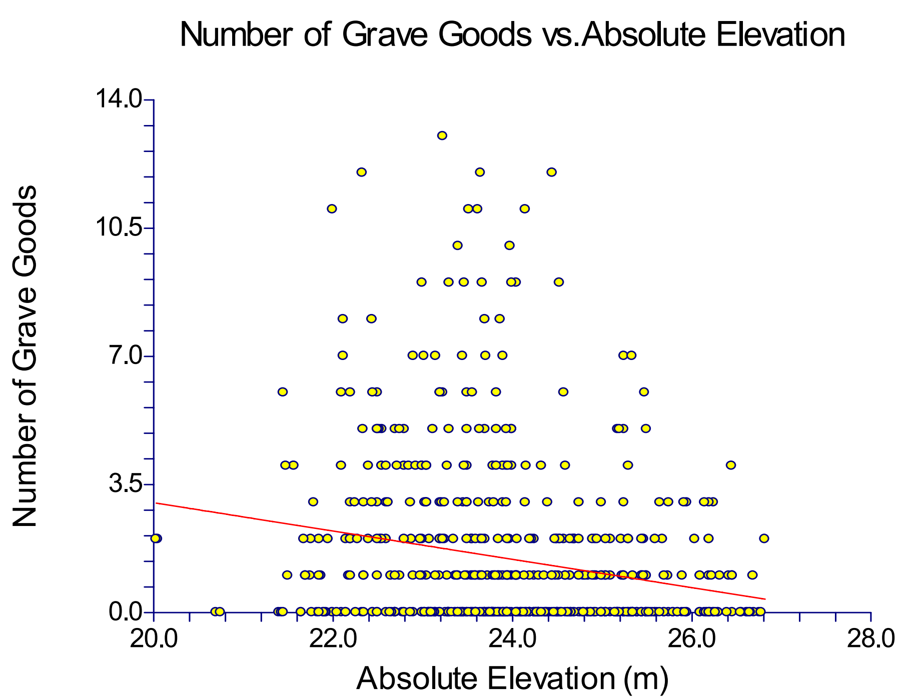
Figure 3.5: Total Number of Grave Goods vs. Distance from the Cemetery Centre on the Y Axis (North-South)



R^2=0.0025, y=1.61 – 0.03x, p=0.2083

In both cases, the r^2 values indicate that these variables explain only a very small proportion of the variation in the number of grave goods. Furthermore, in both cases, the slope values could not be determined to be significantly different from zero, indicating that there is no evidence for a significant relationship between either of these variables and the number of grave goods included in the grave. The plots shown above, however, suggest that the number of grave goods decreases with increasing distance from the centre of the cemetery in an east-west direction; individuals with the highest numbers of grave goods are clustered in the centre of the cemetery. The relationship between grave goods and the distance from the centre of the cemetery on the Y coordinate (i.e. north-south) is not as clear, but generally follows the same pattern of decreasing grave goods with increasing distance from the centre of the cemetery in a north-south direction.

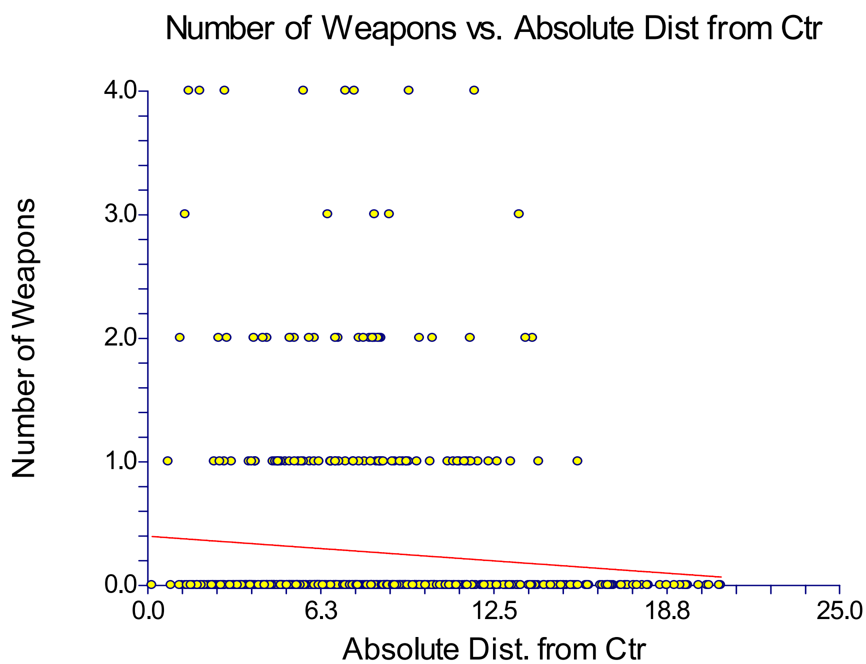
Figure 3.6: Total Number of Grave Goods vs. Absolute Elevation



R^2= 0.0412, y=10.72- 0.39x, p= 0.0000

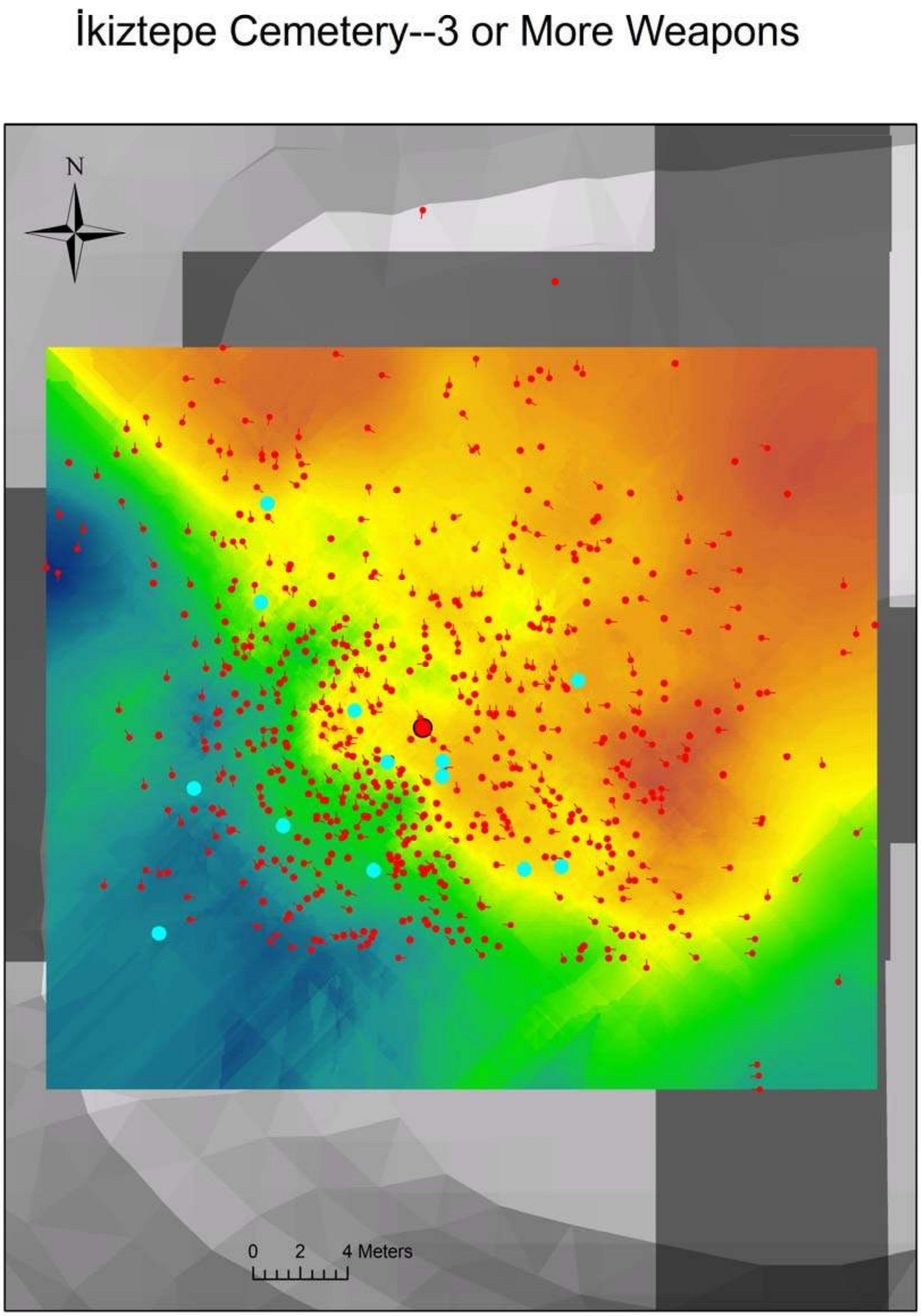
This graph shows that there is a significant relationship between the number of grave goods and the absolute elevation of the burial. The r^2 value remains small, but the slope value of the regression line is significantly different from zero, suggesting a relationship between the two variables. As discussed above, due to the location of the cemetery on a slope, this does not imply anything significant about the depth of the burial, but rather relates to the burial's location on the slope of the cemetery. It is clear that individuals with the highest numbers of grave goods are clustered at one particular elevation, an elevation corresponding with the cluster of burials with high numbers of grave goods observed in **Map 3.9: İkiztepe Cemetery—Locations of Individuals with 9+ Grave Goods**. This graph also suggests a slight tendency for individuals with high numbers of grave goods to be buried at mid-slope locations or lower, rather than being placed higher on the slope.

Figure 3.7: Total Number of Weapons vs. Absolute Distance from the Cemetery Centre

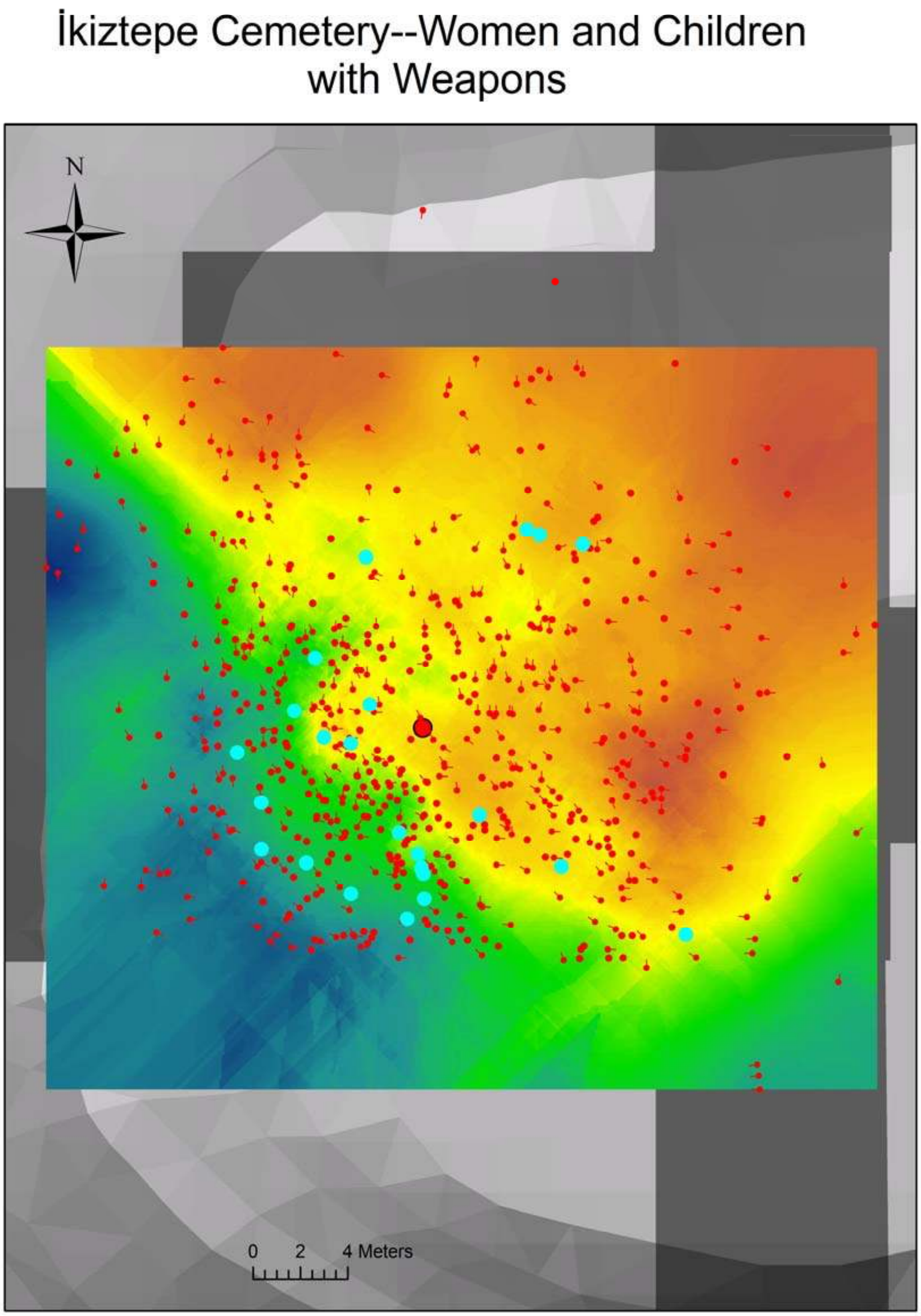


R^2=0.0094, y= 0.40 -1.59x, p=0.0154

Map 3.10: İkiztepe Cemetery—Location of Graves with 3 or More Weapons

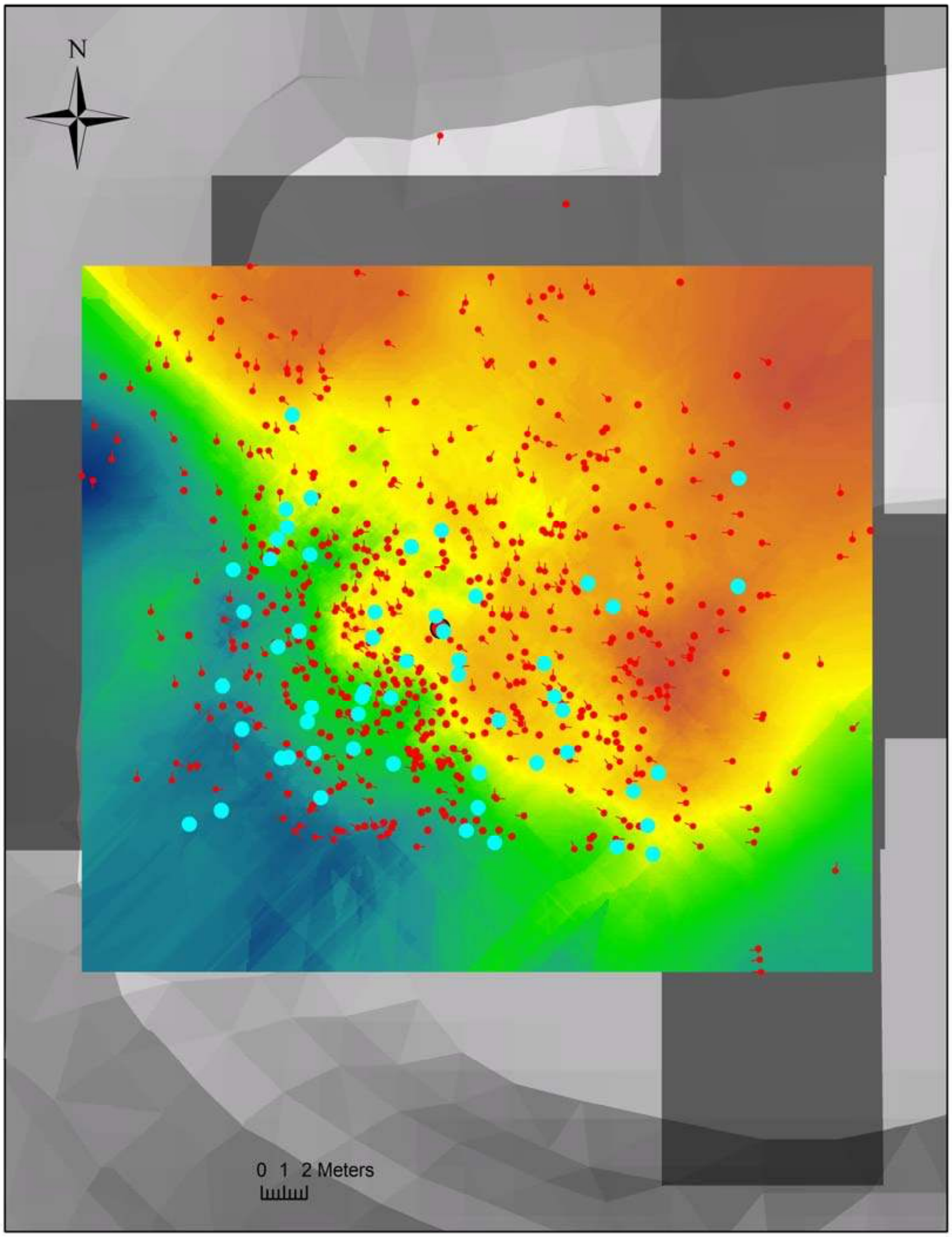


Map 3.11: İkiztepe Cemetery—Women and Children with Weapons



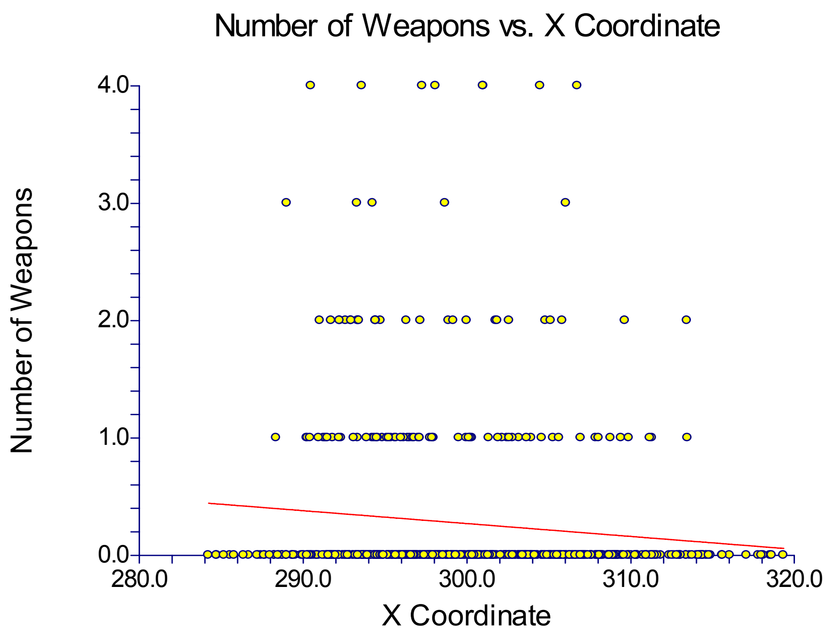
Map 3.12: İkiztepe Cemetery-Men with Weaponry

İkiztepe Cemetery--Men with Weaponry



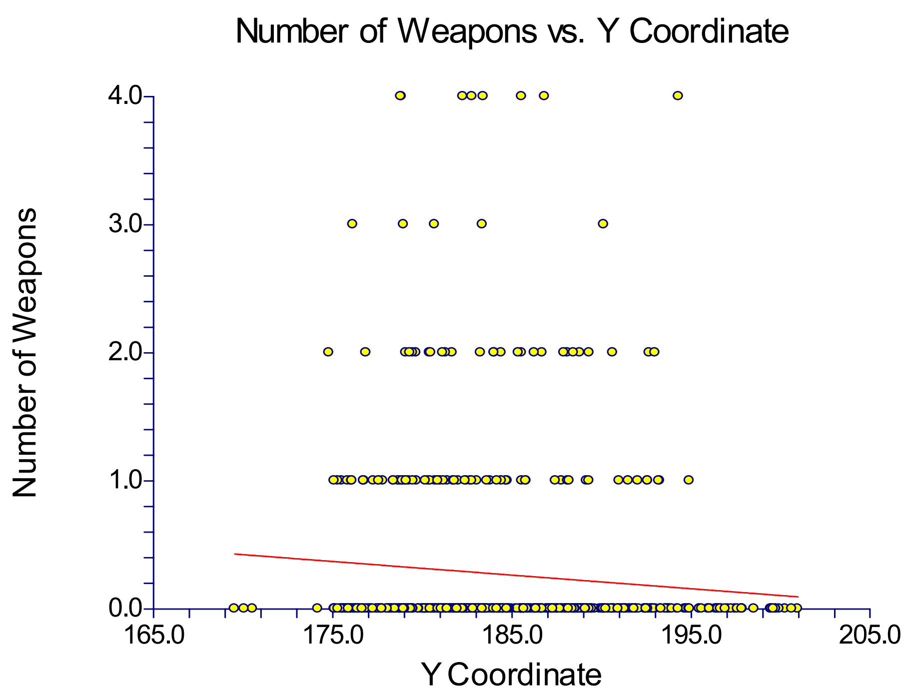
Spatial patterns of the occurrence of weaponry in graves generally follow similar patterns to those observed for the total numbers of grave goods. The relationship between the number of weapons in the grave and its distance from the cemetery centre was determined to be significant. While the r^2 value indicates that this variable explains only a small portion of the variation in the number of weapons appearing in the grave, the slope value of the regression line was determined to be significantly different from zero, indicating a significant relationship between the two variables. It is seems that in general, the individuals with large numbers of weapons tend to be located moderately close to the centre of the cemetery, while individuals with no weapons are spread out throughout the cemetery. This pattern, however, is not as clear as that observed with total numbers of grave goods, a fact that is borne out in **Map 3.10: İkiztepe Cemetery—Locations of Graves with 3 or More Weapons.** While a number of these individuals are found in the same central area as the individuals with high numbers of grave goods, others are more spread out spatially than those seen in that map. Women and children with weapons tend to cluster more noticeably in the centre of the cemetery than do men buried with weaponry (see **Map 3.11: İkiztepe Cemetery—Women and Children with Weapons** and **Map 3.12: İkiztepe Cemetery—Men with Weaponry**).

Figure 3.8: Total Number of Weapons vs. Location on X Axis (East-West)



R^2=0.0123, y=3.56 - 0.01x, p=0.0056

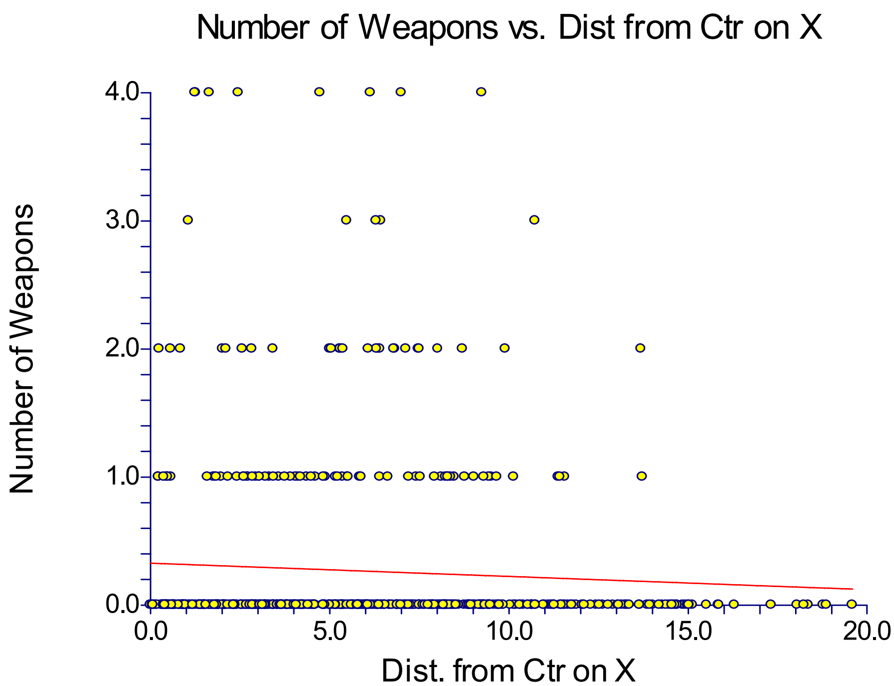
Figure 3.9: Total Number of Weapons vs. Location on Y Axis (North-South)



R^2=0.0082, y=2.23 -0.01x, p=0.0235

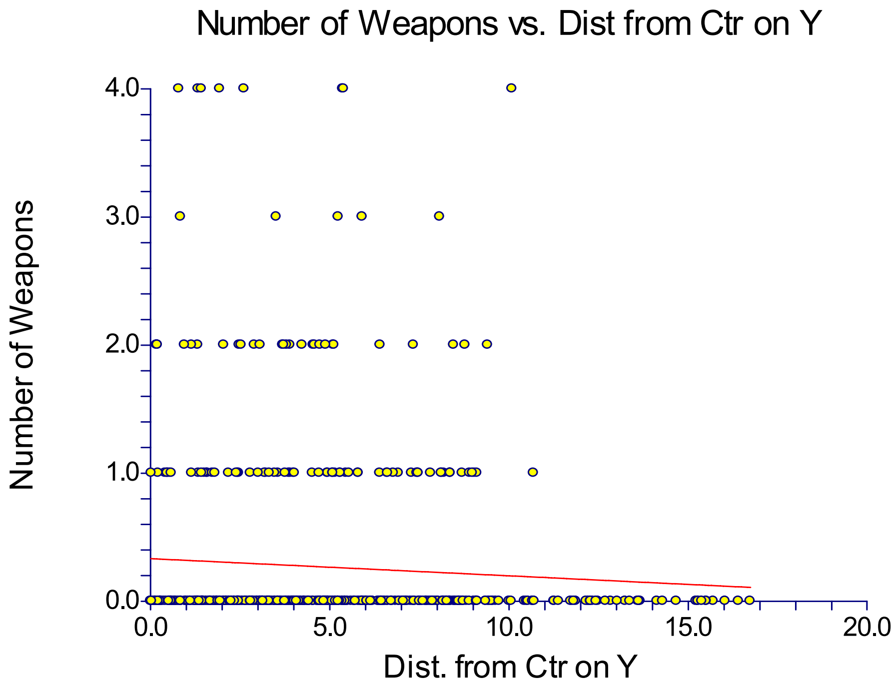
Both the relationship between the number of weapons and the X (i.e. east-west) and Y (i.e. north-south) coordinates were determined to be statistically significant. Although the r^2 values for both variables are low, indicating that these variables explain a very low proportion of the variation in the number of weapons occurring in the grave, the slope value for the regression line was determined to be significantly different from zero. This suggests a significant relationship between the number of weapons in the grave and these variables. However, in both cases, there is a visible concentration of individuals with high numbers of weapons in the central part of the cemetery. The clustering of these individuals is less clear than that observed with total numbers of grave goods.

Figure 3.10: Total Number of Weapons vs. Distance from Cemetery Centre on X Axis (East-West)



R^2=0.0036, y=0.33 -0.01x, p=0.1359

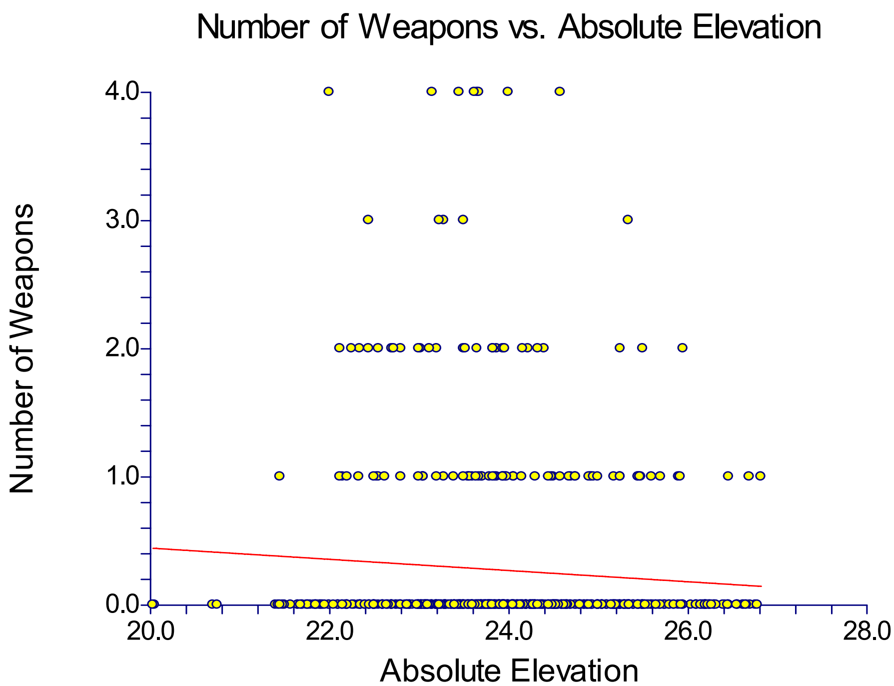
Figure 3.11: Total Number of Weapons vs. Distance from Cemetery Centre on Y Axis (North-South)



R^2=0.0045, y=0.33 -0.01x, p=0.0953

Correlations between the number of weapons in the grave and the distance of the grave from the centre of the cemetery along both the X (east-west) and Y (north-south) axis were calculated. In both cases, there is a general decrease in the number of weapons occurring in a grave with increasing distance from the centre of the cemetery on both the X (east-west) and Y (north-south) coordinates. The r^2 values for these relationships were both low, indicating that they explain a very low proportion of the variation in the number of weapons occurring in the grave. However, in the case of the distance of the grave from the centre of the cemetery on the y axis, the value of the slope coefficient was determined to be significantly different from zero at a level of α=0.1, suggesting that a relationship with this variable does exist. The same was not true of distance from the centre of the cemetery on the x axis. From visual inspection of the graphs, this decreasing relationship is not clear, due to the tendency for individuals with high numbers of weaponry to be more dispersed from the centre of the cemetery compared to total numbers of grave goods. However, few individuals with high numbers of weapons appear to have been buried in peripheral areas extremely distant from the cemetery center.

Figure 3.12: Total Number of Weapons vs. Absolute Elevation

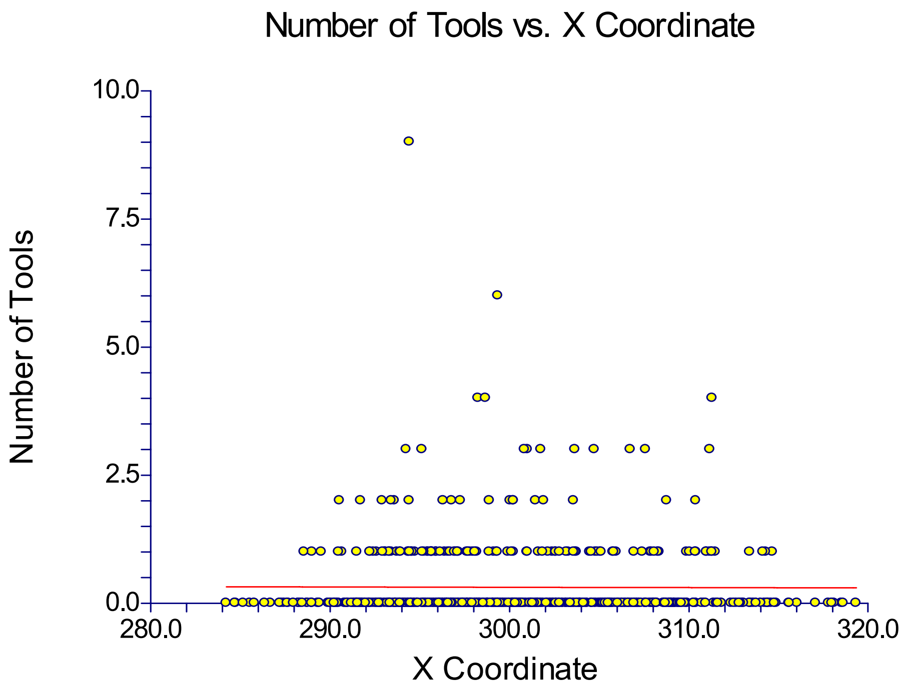


R^2=0.0059, y=1.32 -0.04x, p= 0.0560

Similar to the relationship observed with the overall number of grave goods, the relationship between absolute elevations and the number of weapons is a significant one. The r^2 value for this relationship remains low, indicating that this variable explains only a small portion of the variation in the number of weapons occurring in the graves. However, the slope value of the regression line was determined to be significantly different from zero at the level of α=0.1, suggesting that a relationship between these variables does exist. The individuals with the highest numbers of weaponry are predominantly clustered around particular elevations, and in general they tend toward mid-slope to lower slope locations, rather than occurring in upslope locations higher on the hill.

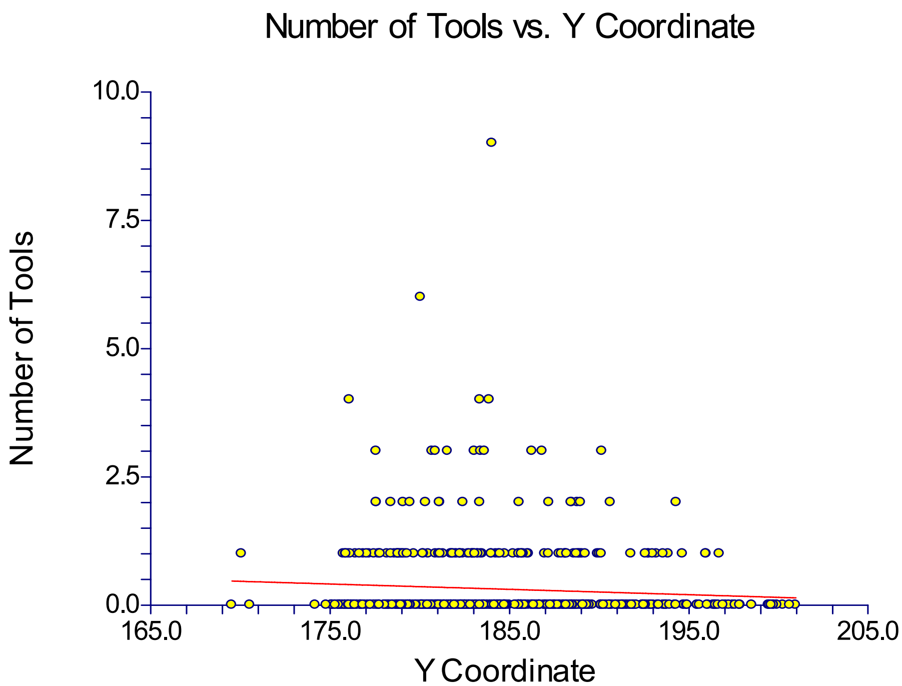
In addition to examining the spatial distribution of total numbers of grave goods and weaponry, the distribution of tools within the cemetery was also plotted against various spatial variables.

Figure 3.13: Number of Tools vs. Burial Location on the X Coordinate (East-West Axis)



R^2=0.0000, y=0.48 -0.0005x, p=0.8954

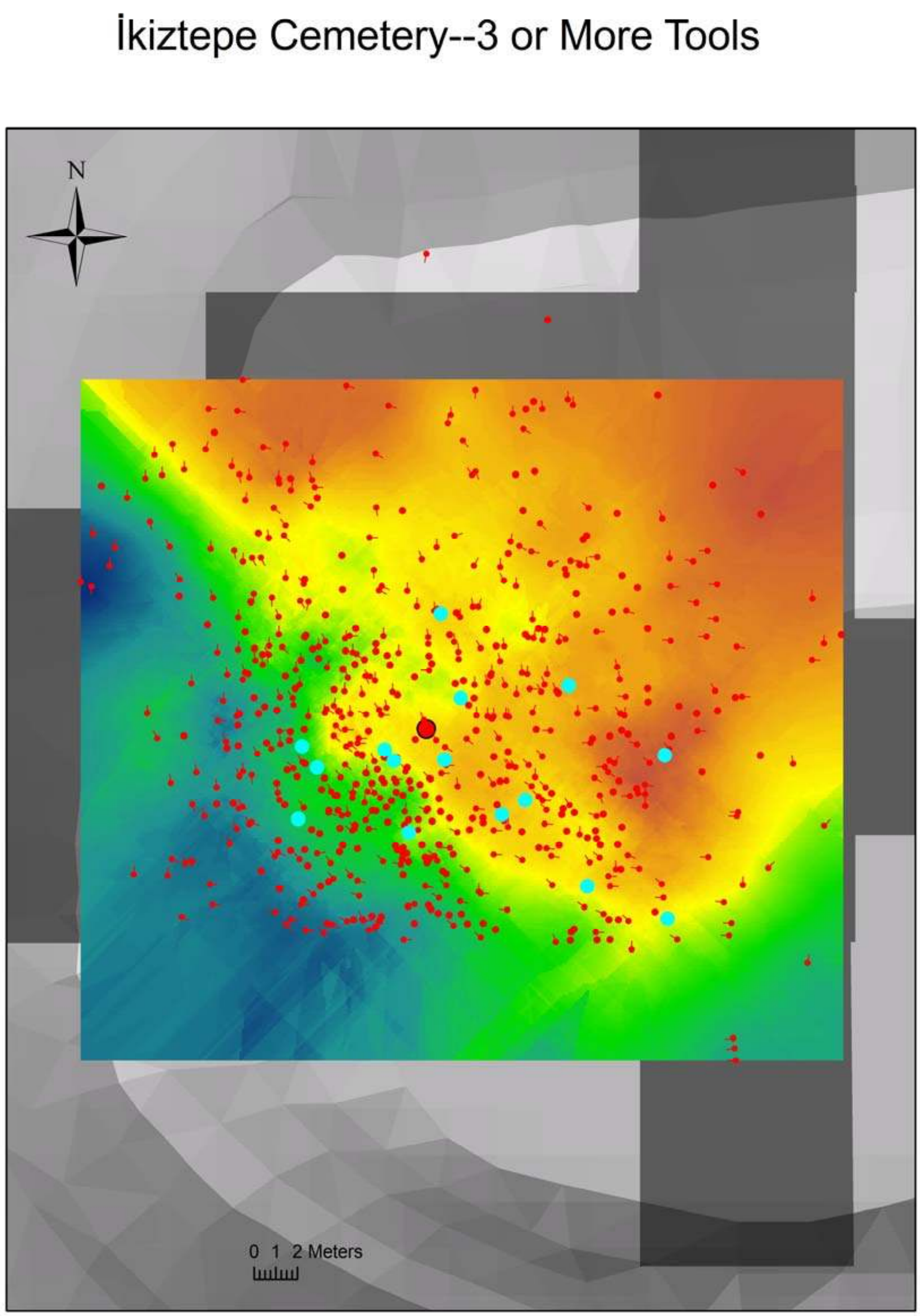
Figure 3.14: Number of Tools vs. Burial Location on the Y Coordinate (North-South Axis)



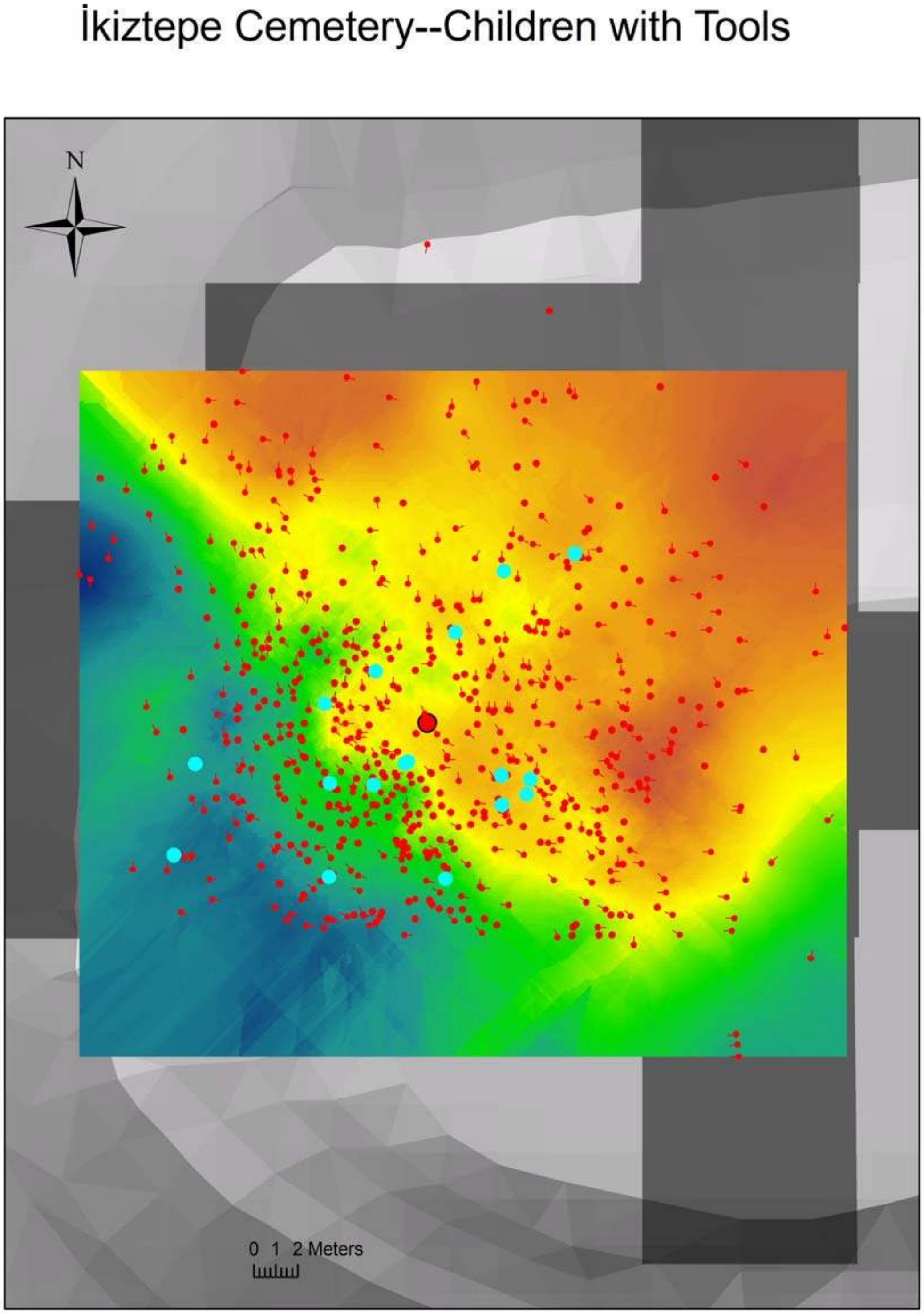
R^2=0.0065, y=2.23 -0.01x, p=0.0441

These graphs suggest that while there is a significant relationship between the number of tools and the location of the burial on the Y coordinate (north-south), there is no such relationship visible with the X coordinate (east-west). The r^2 values for both variables are low, suggesting that they only explain very small percentages of the variation in the number of tools associated with the graves. However, in the case of the y axis, the slope value of the regression line was determined to be significantly different from zero, suggesting a relationship exists between the number of tools and this variable. One individual with a particularly high number of tools is located centrally on the Y axis, but is offset slightly to the west along the X axis. In addition, a number of individuals with moderate numbers of tools are more commonly encountered in the central and eastern parts of the cemetery.

Map 3.13: İkiztepe Cemetery—Locations of Graves with 3 or More Tools

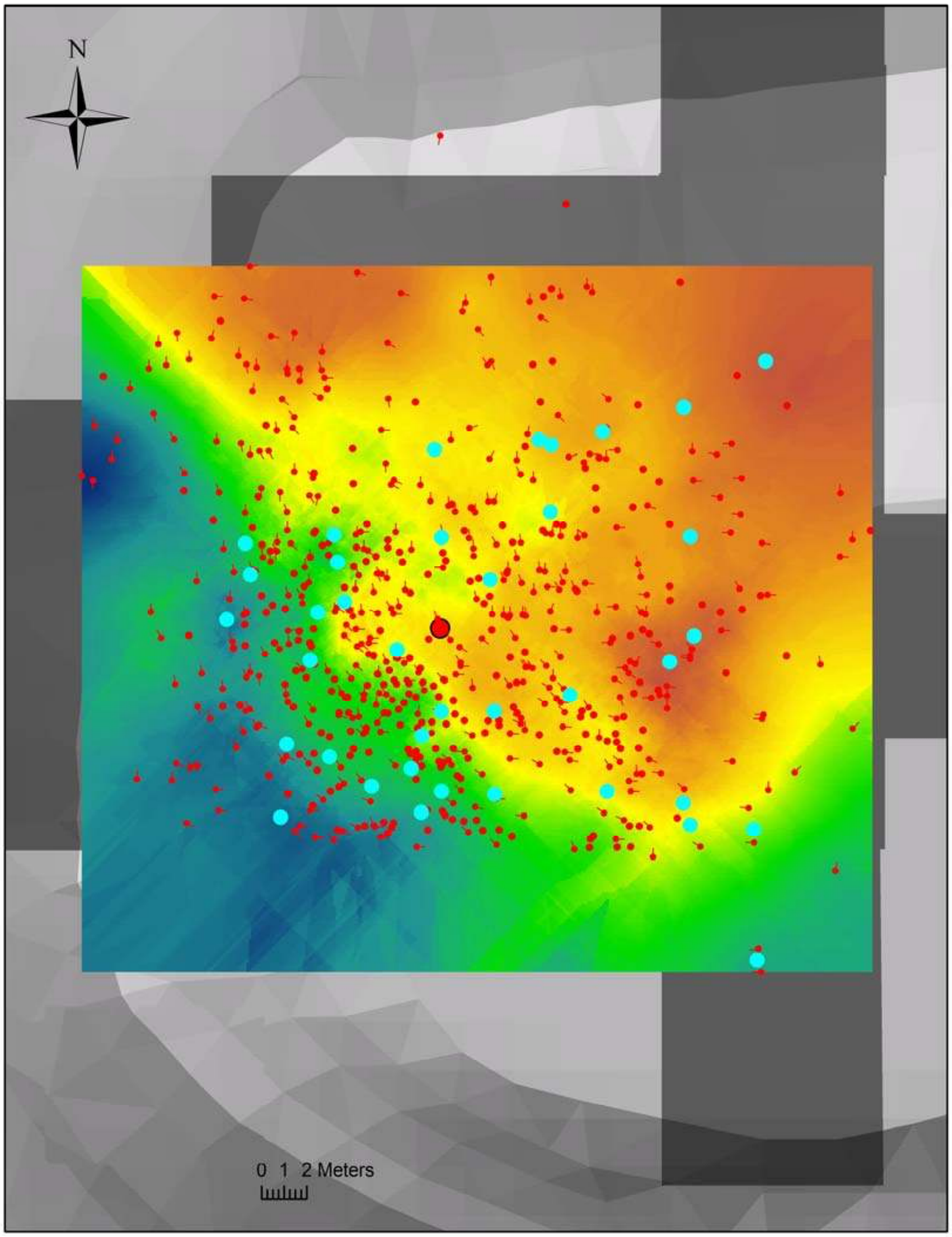


Map 3.14: İkiztepe Cemetery—Children with Tools



Map 3.15: İkiztepe Cemetery: Women with Tools

İkiztepe Cemetery--Women with Tools



Map 3.16: İkiztepe Cemetery—Men with Tools

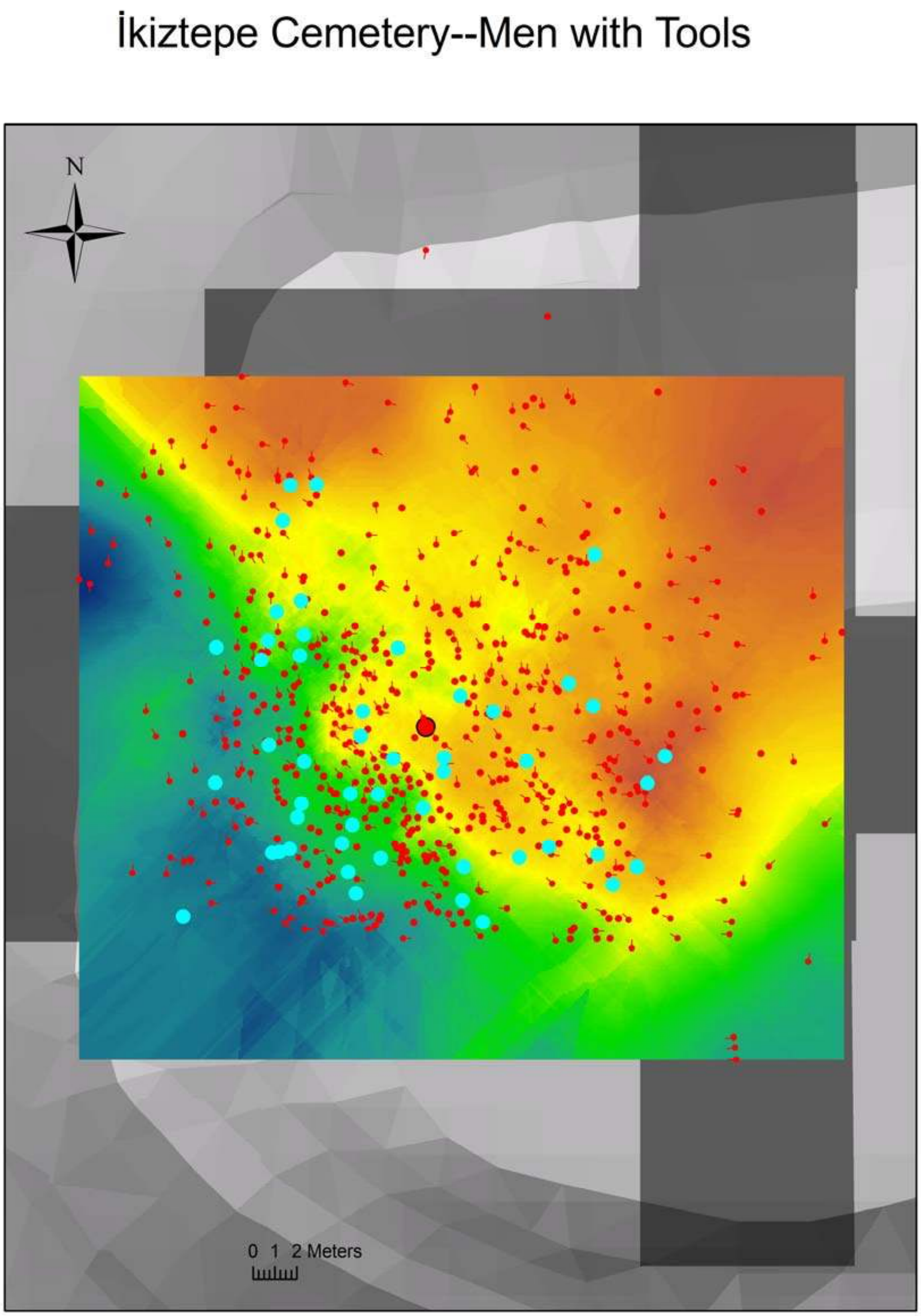
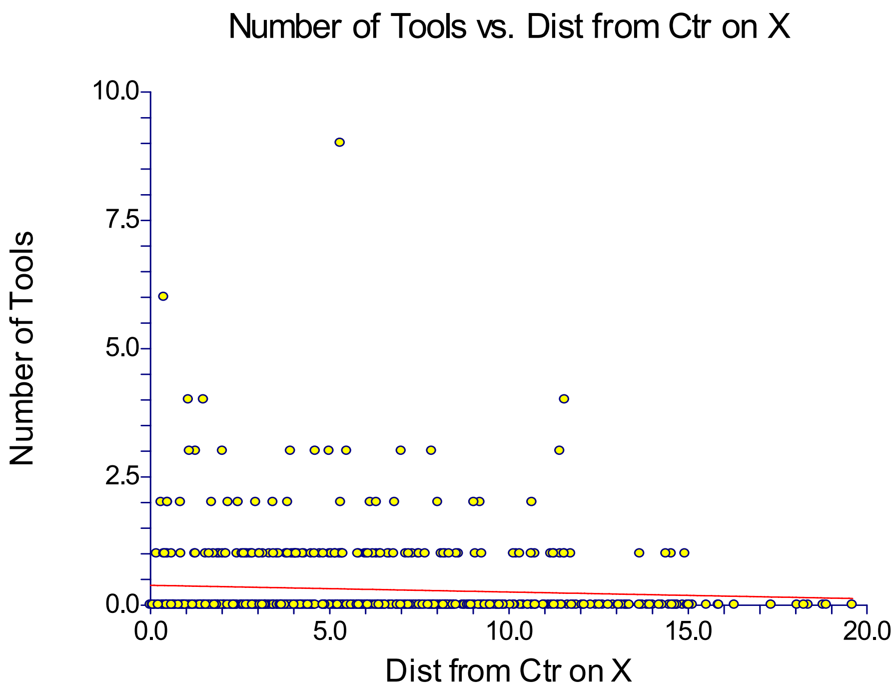
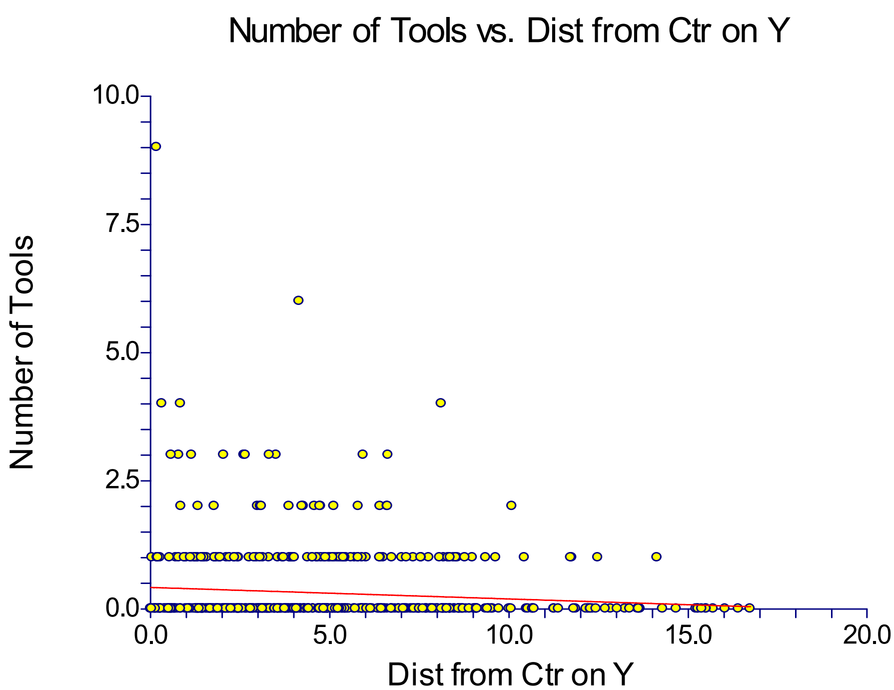


Figure 3.15: Number of Tools vs. Distance from Cemetery Centre on X Coordinate (East-West Axis)



R^2=0.0047, y=0.39 -0.01x, p=0.0858

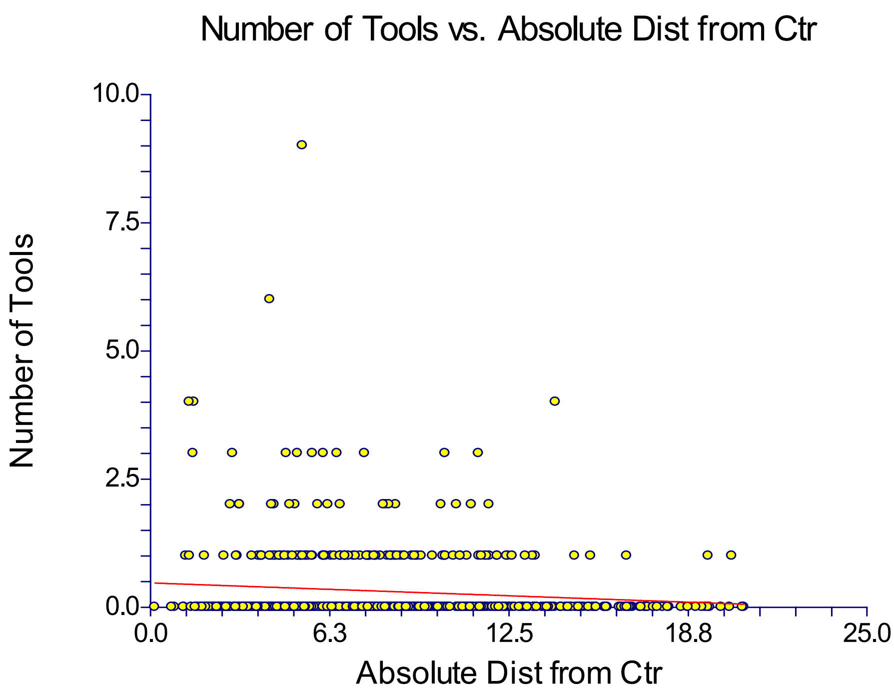
Figure 3.16: Number of Tools vs. Distance from Cemetery Centre on Y Coordinate (North-South Axis)



R^2=0.0103, y=0.42 -0.02x, p=0.0114

The r^2 values obtained for both variables are low, suggesting that these variables explain only a small proportion of the variation in the number of tools occurring in the graves. However, the slope value of the regression line was determined to be significantly different from zero for distance from the cemetery centre on the y axis, and the same was true for the x axis at α=0.1. This suggests that relationships exist between the number of tools in the grave and both of these spatial variables. Both graphs demonstrate a general trend toward decreasing numbers of tools with increasing distance from the cemetery center on each axis. However, the relationship on the X coordinate appears to be heavily affected by one particular individual with a high number of tools, who was buried at a reasonable distance west of the cemetery centre.

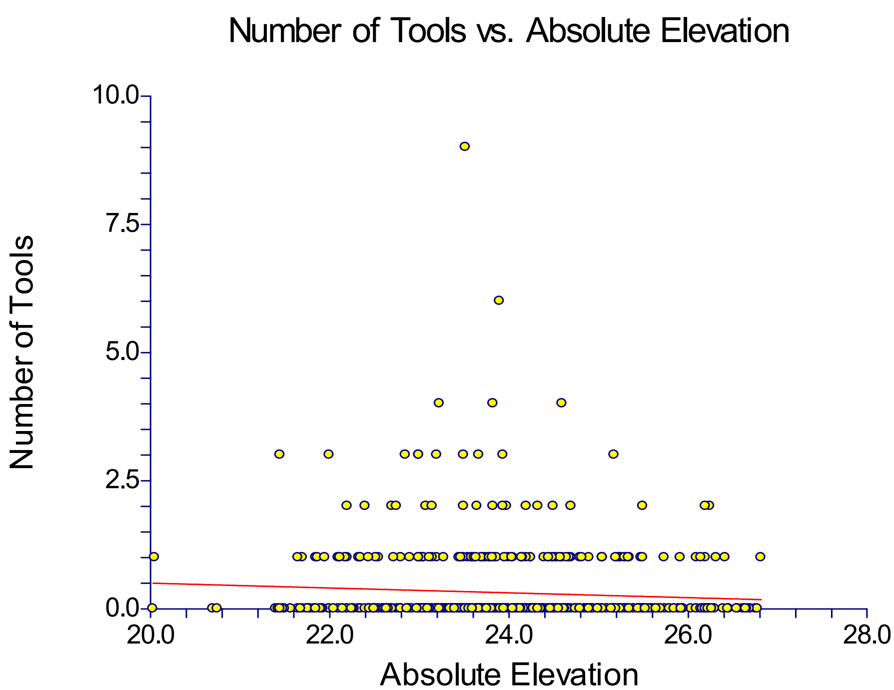
Figure 3.17: Number of Tools vs. Absolute Distance from Cemetery Centre



R^2=0.0122, y=0.48 -0.02x, p=0.0058

The r^2 value between these variables is low, suggesting that this variable does not explain a large amount of the variation in the number of tools occurring in the graves. However, the slope value of the regression line was determined to be significantly different from zero, suggesting that a relationship between these two variables does exist. The graph, however, appears to indicate that the individuals with the highest numbers of burials are centered slightly away from the cemetery centre. In addition, individuals with no tools are spread throughout the cemetery. **Map 3.13: İkiztepe Cemetery—Locations of Graves with 3 or More Tools** demonstrates the burial locations of individuals with high numbers of tools. Despite the higher degree of dispersal than was seen in individuals with the highest number of grave goods, individuals with three or more tools were concentrated in a similar area of the cemetery. Children buried with tools tended to be more clustered in the central part of the cemetery than adults of either sex (see **Map 3.14: İkiztepe Cemetery—Children with Tools, Map 3.15: İkiztepe Cemetery—Women with Tools,** and **Map 3.16: İkiztepe Cemetery—Men with Tools**).

Figure 3.18: Number of Tools vs. Absolute Elevation of Burial

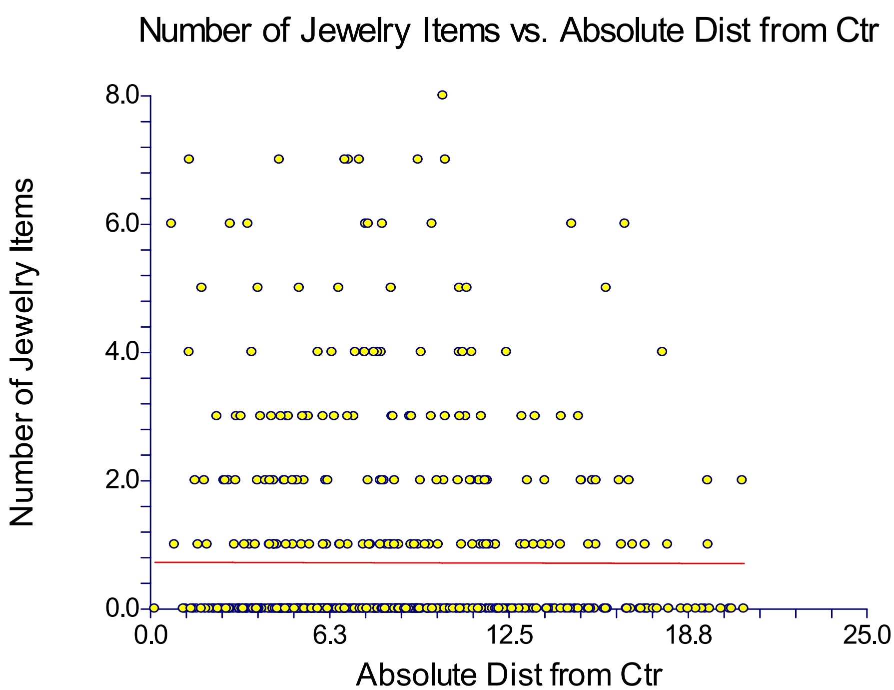


R^2=0.0056, y=1.44 -0.05x, p=0.0621

Although the r^2 value for these variables is low, suggesting that absolute elevation explains only a small proportion of the variation in the number of tools occurring in the graves, the slope value of the regression line was significantly different from zero at α=0.1. This suggests that a relationship does exist between these two variables, with decreasing numbers of tools as elevation increases. Visual examination of the graph, however, suggests that individuals with the highest numbers of tools are concentrated in midslope locations. These individuals were also more likely to occur at lower elevations than higher ones.

Finally, the distribution of jewelry items within the cemetery was examined spatially through similar plots to those used above for total grave goods, weaponry and tools.

Figure 3.19: Total Number of Jewelry Items vs. Absolute Distance from Cemetery Centre



R^2=0.0000, y=0.73 -0.0009x, p=0.9472

Spatial patterns in the occurrence of jewelry items are slightly different from those observed in overall grave good numbers, weaponry and tools. In this case, there is a less obvious clustering of individuals with high numbers of jewelry items close to the centre of the cemetery. The r^2 value associated with these two variables is zero, suggesting that this variable explains none of the variation in the number of jewelry items occurring in the graves. Furthermore, the slope value of the regression line is not significantly different from zero, suggesting that there is no significant relationship between these variables. There may also be a cluster of individuals with high numbers of jewelry items slightly further away from the centre of the cemetery. **Map 3.17: İkiztepe Cemetery—Locations of Graves with 5+ Jewelry Items** demonstrates the higher level of dispersion observed for individuals with high numbers of jewelry items compared to other categories of grave goods.

Map 3.17: İkiztepe Cemetery—Locations of Graves with 5+ Jewelry Items

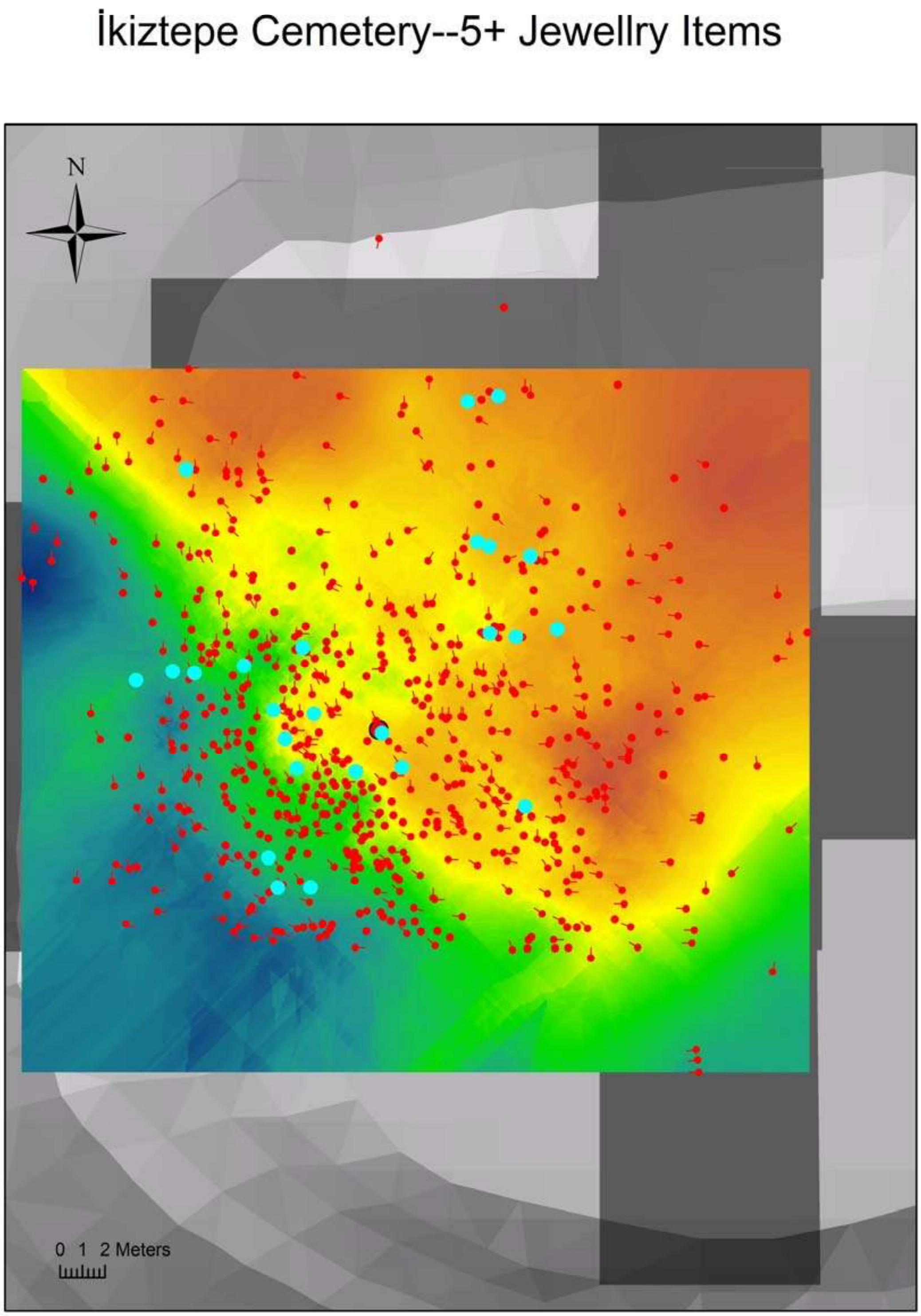
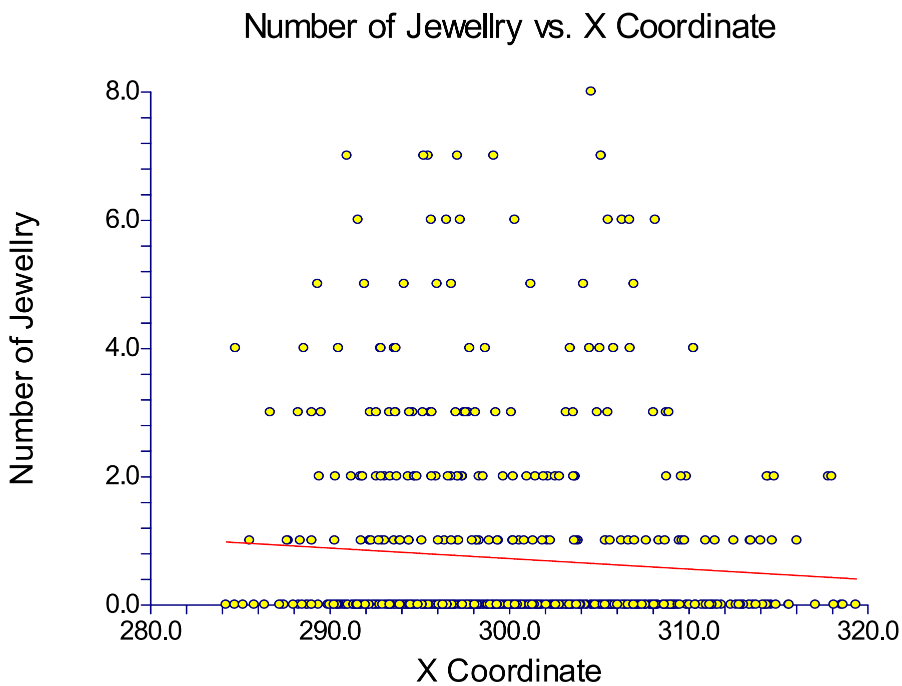
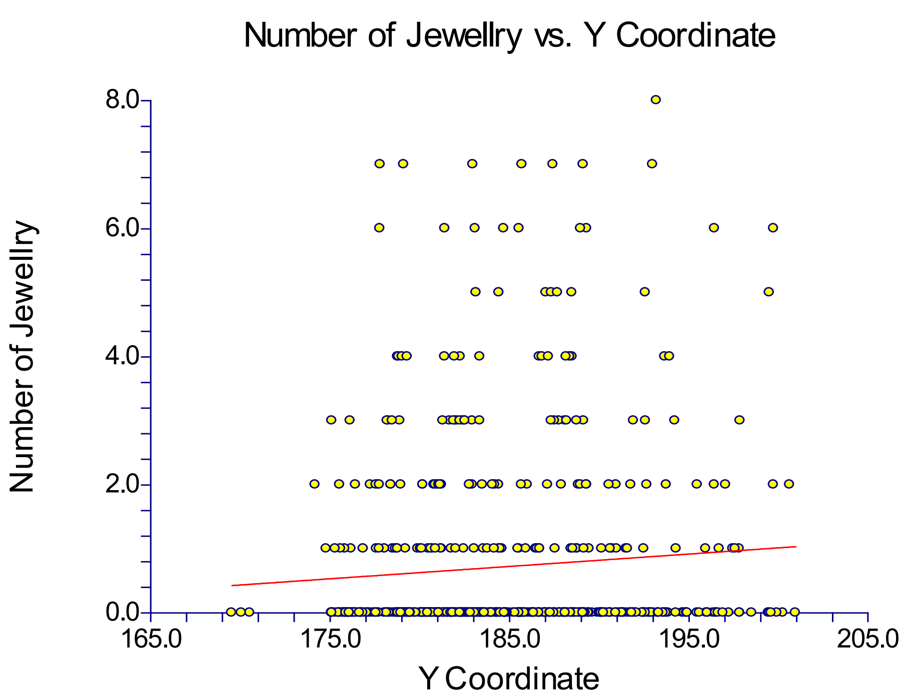


Figure 3.20: Total Number of Jewelry Items vs. Location on X Axis (East-West)



R^2=0.0061, y= 5.64 – 0.02x, p=0.0507

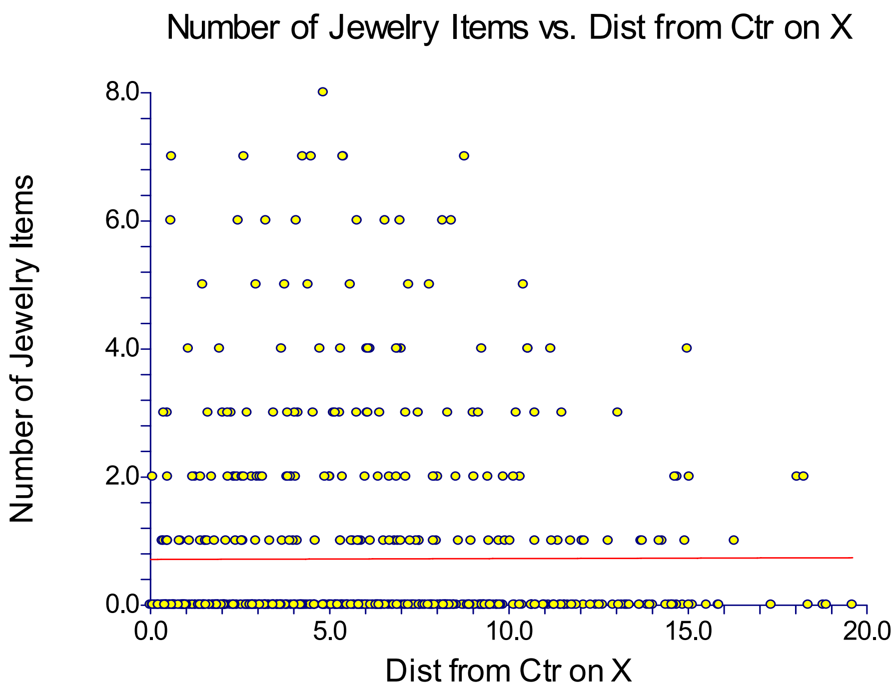
Figure 3.21: Total Number of Jewelry Items vs. Location on Y Coordinate (North-South)



R^2=0.0061, y=-2.84 + 0.02x, p=0.0519

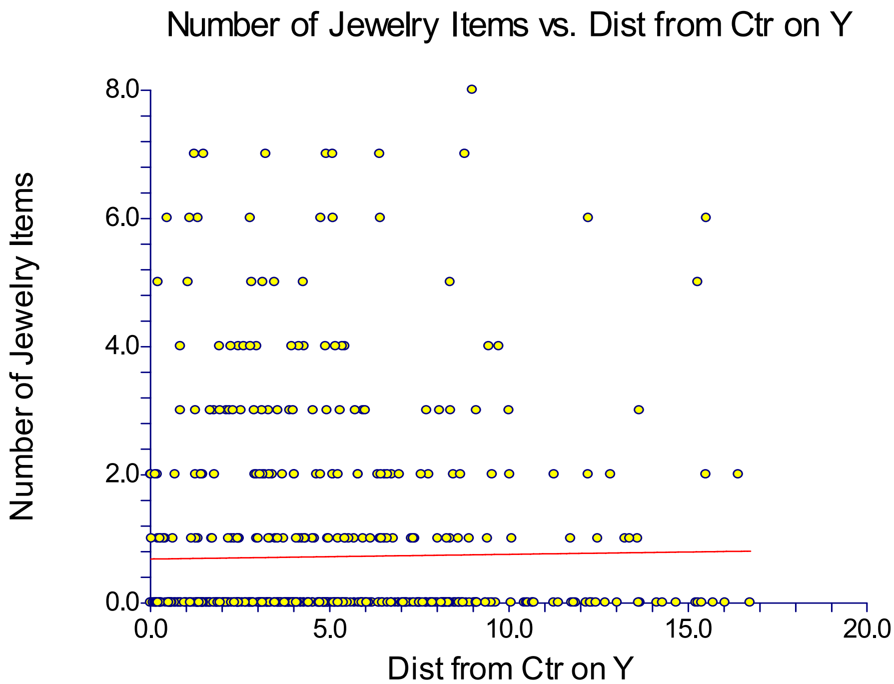
In both cases, the r^2 values are low, suggesting that only a very small proportion of the variation in the number of jewelry items occurring in the graves can be attributed to these variables. However, in both cases, the slope value of the regression line was determined to be significantly different from zero at the level of α=0.1, indicating the the number of jewelry items does have a relationship with these two variables. Contrasting patterns are seen along the X and Y axes; number of jewelry items increases from south to north and decreases from west-east. Furthermore, the individuals with high numbers of jewelry items are more spread out than in other grave good groups, but still demonstrate a tendency away from being buried in the most peripheral areas of the cemetery.

Figure 3.22: Total Number of Jewelry Items vs. Distance from the Cemetery Centre on the X Axis (East-West)



R^2=0.0000, y=0.71 + 0.001x, p=0.9283

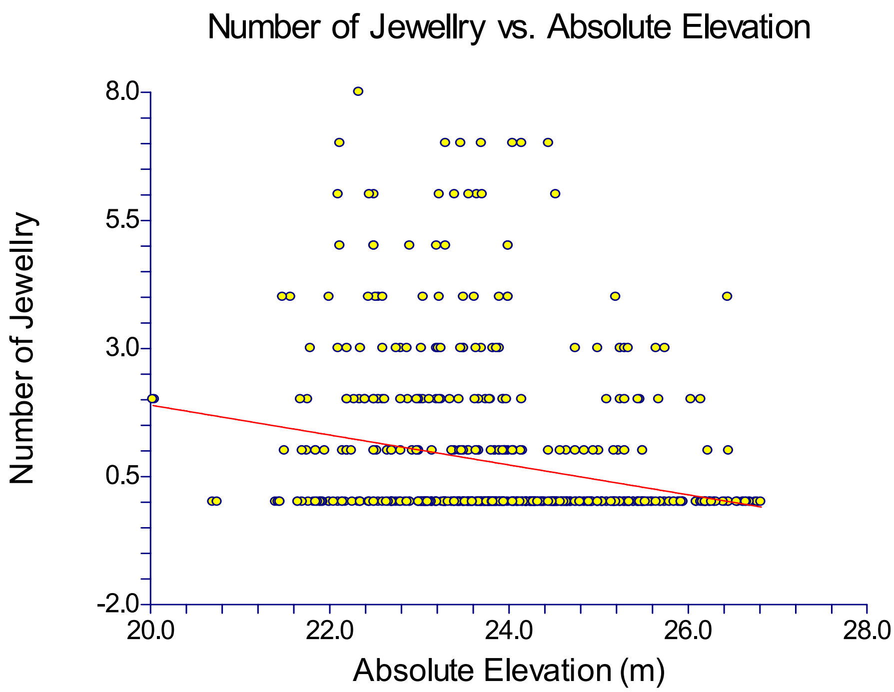
Figure 3.23: Total Number of Jewelry Items vs. Distance from Cemetery Centre on Y Axis (North-South)



R^2=0.0003, y=0.69 + 0.007x, p=0.6663

As seen with the relationship between number of jewelry items and the absolute distance from the cemetery centre discussed above, the relationships between jewelry and the distance from the centre on the X (east-west) and Y (north-south) coordinates are not statistically significant. In both cases, the r^2 values are close to zero, suggesting that these variables do not explain any of the variation in the number of jewelry items associated with the graves. In addition, neither of the slope values of the regression lines were determined to be signicantly different from zero, suggesting that there is no significant relationship between number of jewelry items and these variables. Furthermore, there is a movement of individuals with the highest numbers of jewelry items away from the centre of the cemetery on both the X and Y coordinate, compared to the patterns seen in overall grave goods, in weaponry and in tools. Combined with the graphs above, which depict the relationship with the absolute X and Y coordinates, this suggests that there is a general trend toward a dispersed spatial pattern in graves with high numbers of jewelry items.

Figure 3.24: Number of Jewelry Items vs. Absolute Elevation



R^2= 0.0584, y=7.72 -0.29x, p= 0.0000

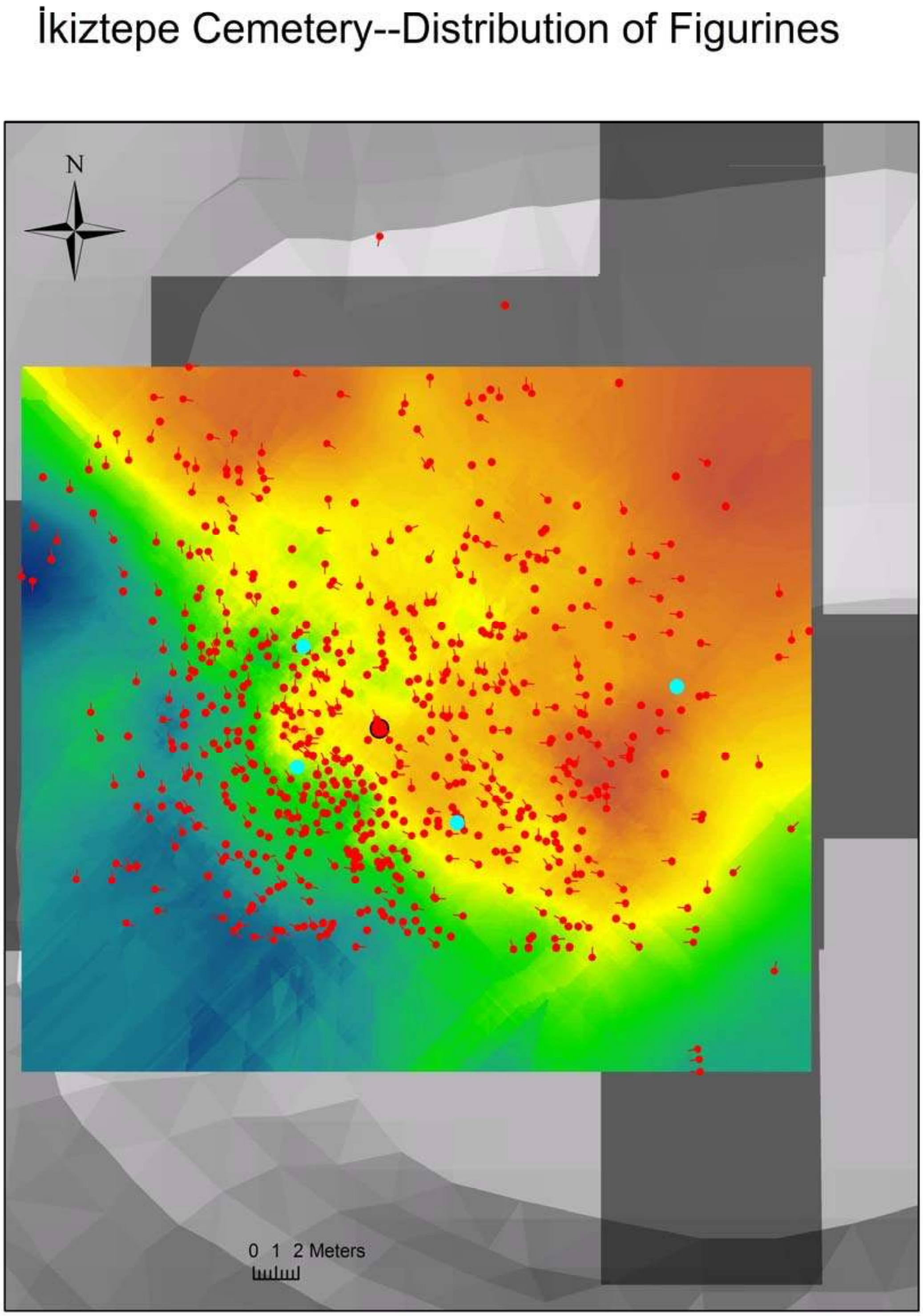
The relationship between the number of jewelry items in the grave and its absolute elevation is statistically significant, and decreasing with increasing elevation. Although the r^2 value for these two variables is low, suggesting that absolute elevation does not explain a large proportion of the variation in the number of jewelry items associated with the graves, the slope value of the regression line was determined to be significantly different from zero. This indicates that there is a significant relationship between these two variables. Individuals with the highest numbers of jewelry items are concentrated in a cluster at lower elevations, with some individuals in mid-slope locations, but few occurring at upslope elevations. There also seems to be a cluster of high jewelry individuals concentrated in a different area of the cemetery from the highest total numbers of grave goods and particularly weaponry; this area seems to be located further northeast and downslope than these groups which were clustered in mid- to low elevations. This secondary cluster is visible in **Map 3.17: İkiztepe Cemetery—Locations of Graves with 5+ Jewelry Items**, in the lowest elevations toward the northeast of the cemetery. However, also visible in this map is the overall dispersed pattern of individuals with high numbers of jewelry, compared to the pattern observed for weaponry, tools and total grave goods.

In addition to plotting numbers of different types of grave goods in relation to various spatial variables, a number of additional maps were created that show the distribution of other types of grave goods within the cemetery, which occurred too rarely to calculate correlations. These maps were made to examine the distribution of figurines, idols and pottery. **Map 3.18: İkiztepe Cemetery: Distribution of Graves with Figurines** demonstrates the fact that figurines are quite rare; where they do occur, they occur only singly. This fact makes it difficult to make conclusions about its spatial distribution, but the map seems to suggest a relatively dispersed pattern of occurrence.

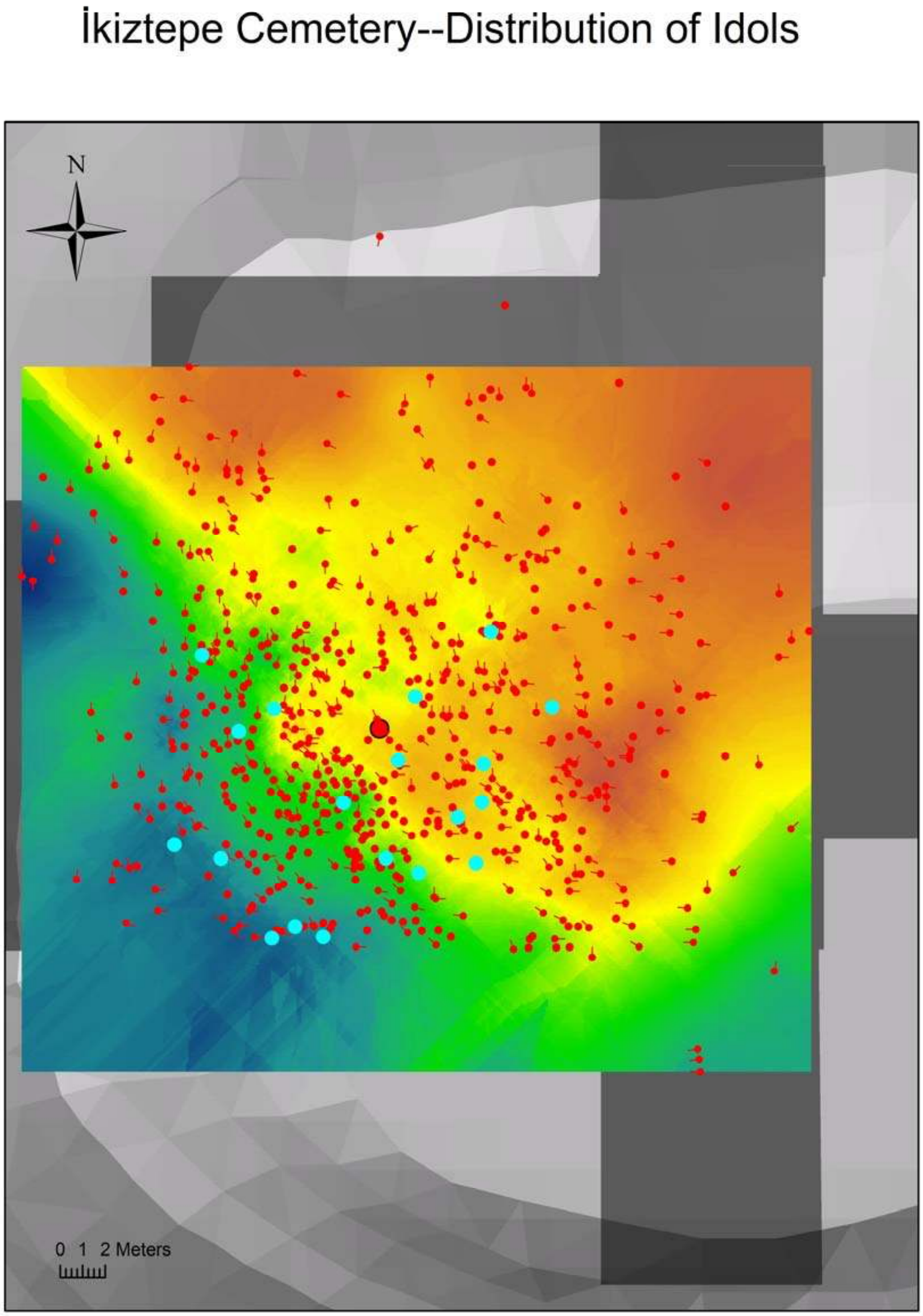
The distribution of idols within the cemetery is displayed in **Map 3.19: İkiztepe Cemetery—Distribution of Graves with Idols.** These idols are generally four-spiral or two-spiral metal plaques, and they occur in very small numbers. In two cases (SK176, SK194), two idols were found within a grave, but in the remainder of cases, the idols occur only once within an individual grave. The map demonstrates that the burials with idols, while not highly clustered together, predominantly occur within or in close proximity to the central area where individuals with the highest number of grave goods are concentrated.

The distribution of pottery vessels within the cemetery is displayed in **Map 3.20: İkiztepe Cemetery—Distribution of Graves with Pottery.** Pottery as a grave offering is not as common as might be expected, only being recorded in a small number of the graves in the cemetery. As with many of the other less common grave good types, pottery generally occurs singly within graves. The map of its distribution suggests that graves containing pottery as a grave good are dispersed spatially throughout the cemetery.

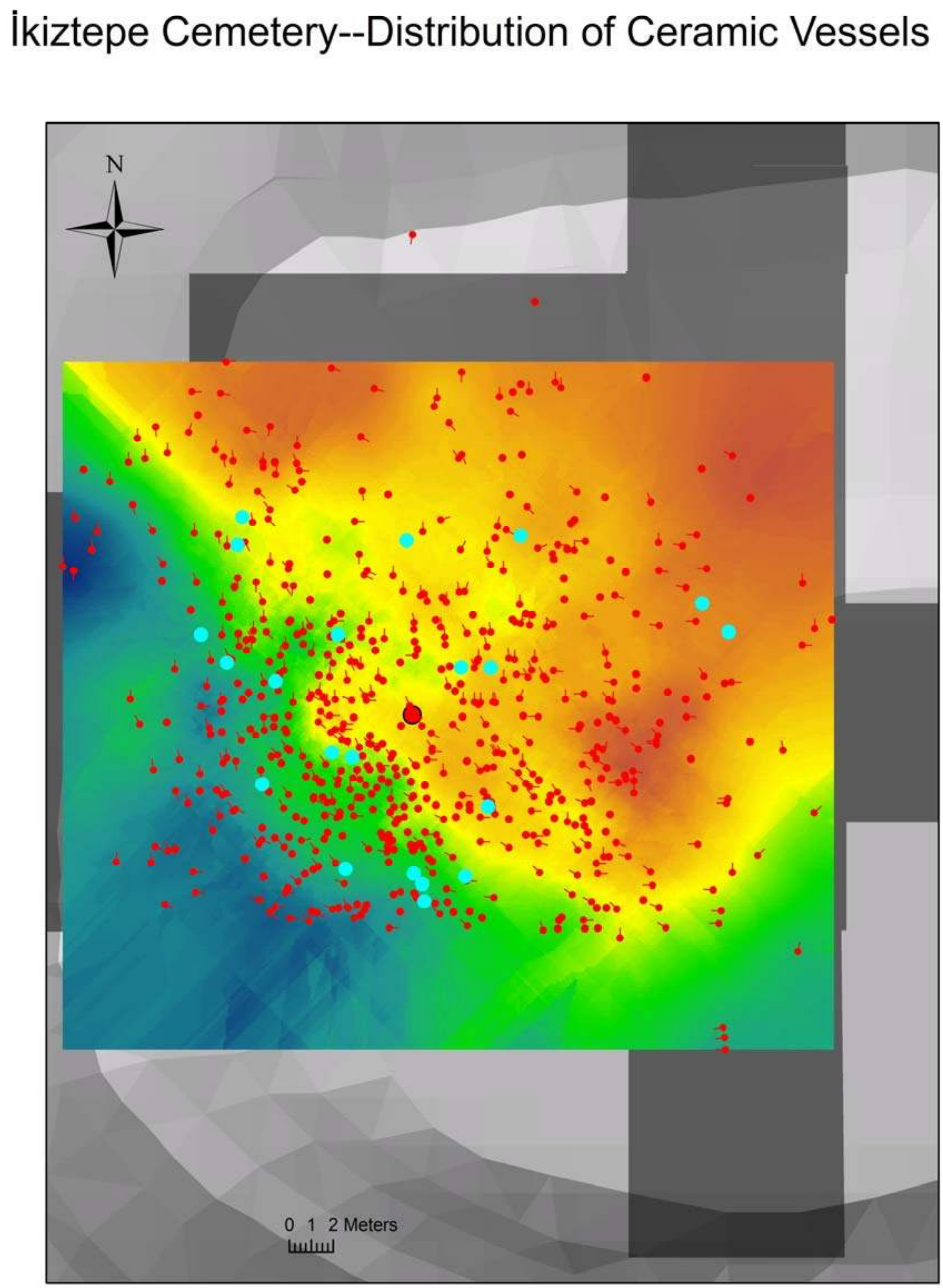
Map 3.18: İkiztepe Cemetery—Distribution of Graves with Figurines



Map 3.19: İkiztepe Cemetery—Distribution of Graves with Idols



Map 3.20: İkiztepe Cemetery—Distribution of Graves with Pottery



Discussion

The review of the comparative burial database from Chalcolithic and Early Bronze Age Anatolia clearly demonstrates the contrast observed between the İkiztepe cemetery and other contemporary mortuary practices. Firstly, the size and preservation of the cemetery is rare even among Early Bronze Age Anatolian cemeteries, where large extramural burial grounds are common. However, the date of the cemetery within the Late Chalcolithic-Early Bronze I transitional period makes it truly unique. Large extramural cemeteries dating to the Anatolian Chalcolithic period are heretofore completely unknown. The majority of Anatolian Chalcolithic burials occur in small numbers in intramural locations, predominantly in domestic contexts. These burials almost exclusively represent the remains of infants, and adult burials dating to this period are rare. This pattern may perhaps be due to inadequate excavation, rather than reflecting a true absence of extramural cemeteries during the Anatolian Chalcolithic. However, the ubiquity of such cemeteries during the following period suggests that their rarity during the Chalcolithic must somehow represent a difference in the disposal of adult bodies, at least to some degree. Chalcolithic burials are of varied types, including pithos burials and simple inhumations. In most of these cases, however, the bodies are placed in a flexed position. In the Early Bronze Age period, flexed burial within pithoi becomes the standard burial practice. It is clear that the İkiztepe cemetery, which contains only inhumation burials with the vast majority placed in an extended dorsal position, does not fit well within this context. The few parallels that can be found for the cemetery originate from sites in its immediate area in the Black Sea coastal region, such as Tekkeköy and Kavak. Southeastern European cemeteries, in contrast, demonstrate a somewhat greater degree of similarity to the İkiztepe burials. Firstly, large extramural cemeteries in this region are much more common during the Chalcolithic period, including a number of cemeteries of comparable size to that found at İkiztepe. Secondly, elaborate grave goods, which are rare in Anatolia outside of Alaca Höyük, Horoztepe and sites from the Black Sea region, are particularly common in Bulgarian coastal sites. Finally, extended dorsal burials are much more frequent in southeastern European sites, particularly in cemeteries from the Black Sea coast of Bulgaria.

The results of the spatial analysis that examined the placement of different demographic groups within the cemetery generally parallel Doğan's theories regarding the cemetery's organization (2006). Average distance to the cemetery's centre decreases with increasing age from infants to adults, and males generally have a lower average distance to the centre than females. This suggests that, on average, males tended to be buried closer to the centre of the cemetery than females and children. However, the majority of these results do not seem to be statistically significant. The exception to this rule is with infants, who are buried significantly further from the centre of the cemetery compared to all other age groups.

When examined by specific age groups, spatial patterns in the placement of burials reveal an interesting pattern. The trend toward decreasing distance from the centre of the cemetery with increasing age does not follow a consistent pattern throughout the age groups. Distance from the centre of the cemetery is greatest for infants, and continues to decrease through younger and older children. At this point, average distance to the centre of the cemetery increases again, through adolescence and into young adulthood. Young adults are placed at similar distance to the cemetery centre as young children. From young adulthood on, the average distance to the centre of the cemetery decreases throughout the adult age groups. Older adults are, on average, placed closest to the centre of the cemetery. Interestingly, older children are located at similar distances to the centre. Once again, however, the differences between the age groups were not determined to be statistically significant, with the exception of infants who were buried significantly peripherally compared to other age groups.

The numbers of grave goods appearing with each basic demographic group follow a slightly different pattern. Infants, unsurprisingly, display the lowest average number of grave goods, significantly fewer than all other age groups, as well as significantly greater numbers of individuals buried with no grave goods at all. Children, however, have a higher average number of grave goods compared to adult females. Younger children have a higher average grave goods compared to older children, and occurrences of individuals with higher grave good numbers are more frequent. Interestingly, young children have higher average numbers of grave goods then both adolescents and young adults. Adult males, in general, have the highest average number of associated grave goods, and also display more frequent occurrences of individuals with high grave good numbers. Within more specific age groups, the average number of grave goods increases through adolescence into middle adulthood. Middle-aged adults have the highest average number of grave goods, which decrease slightly in older adults. This contrasts slightly with Doğan's results, which suggested that the average number of grave goods increases throughout adulthood, with the highest numbers of grave good observed in older adults (2006). Middle and older adults also appear to display a much more frequent occurrence of high numbers of grave goods than observed in other age groups, with the possible exception of younger children. The results of both chi-square and Kruskal-Wallis tests suggest that the presence/absence of grave goods and their overall distribution within the graves were significantly different between different age and sex groups. Demographic factors thus appear to have been significant in determining the numbers of grave goods associated with particular burials.

The average number of weapons occurring in graves is lowest in infants, who had no occurrences of weapons in any burials. These numbers are only slightly higher in children, both in the younger and older age categories, where very few individuals were buried with weapons. Adult females display higher average numbers of weapons compared to children, and a more frequent occurrence of small numbers of weaponry, but generally had fewer than adult males. In general, weapons increase with increasing age, throughout childhood and adolescence, although they tend to decrease between adolescence and young adulthood. A significant increase appears to occur between young and middle adults, at which point the average number of weapons appearing in the grave appears to more than triple. While older adults display very slightly lower average numbers of weapons than middle adults, the distributions of weapons are quite similar between both age groups. The results of both chi-square and Kruskal-Wallis tests suggest that the presence/absence of weaponry and the distribution of weapons between graves were significantly different amongst different age and sex groups. As observed with total grave goods, demographic factors appear to have been significant in determining the numbers of weapons associated with particular graves.

The incidence of tools is the only category of grave good where the average numbers were determined to continually increase with increasing age. The distribution of tools appears to be quite different between infants and children, and between children and adults. The numbers and distributions of tools found in male and female burials were relatively similar. In general, tools appear to have been more frequent in the graves of middle and older adults compared to younger age groups. As observed with total numbers of grave goods and weaponry, demographic factors appear to have influenced the numbers of tools occurring with particular graves, as chi-square and Kruskal-Wallis tests suggest that the distribution of tools was significantly different amongst different age and sex groups.

The presence of richly furnished children's graves in a cemetery is often interpreted as an indication of vertical social status (Peebles & Kus 1977: 431, Brown 1995: 8, Baxter 2005: 103-105). The fact that children, particularly young children, at İkiztepe have higher average numbers of grave goods than many older age groups could be viewed as significant in that vein. However, the majority of the objects associated with this group consist of jewelry items, with few occurrences of object types associated with adults, such as weaponry and tools. This hints at horizontal social status differentiation as a possible explanation for the pattern of grave good distribution. Despite this, the existence of a few children's burials with weaponry and tools, objects typically associated with adult burials, might be interpreted in the context of vertical social status differentiation, in which the social status of the parents is ascribed to the child. Certainly, this is the interpretation proposed by Bilgi (2005), who suggests the "distinguished" burials at the site, which include infant and child burials, represent the "male rulers of the settlement and their families" (Bilgi 2005: 17). Philip (1989: 156) suggests that in burial contexts, weapons function as markers of distinction, and serve to convey personal status and group identities. He believes that metal weaponry and its placement in tombs may be particularly linked to the demonstration of high status in males, as weapons are rarely found in contexts where they have been clearly associated with female or child interments (Philip 1989: 156). The importance of weapons as markers of social status among males may have been related to the fact that weapons were associated with power and conquest, as well as with the ability to take tribute, which led to the acquisition of wealth and reputation (Philip 1989: 156, Philip 1995: 153). The appearance of weaponry in a small group of burials associated with women and children suggests the attribution of such status to these individuals, despite the low likelihood or impossibility (in the case of young children) of these individuals having fulfilled this role within society.

The reconstruction of the existence of an ancient slope into which the burials in the cemetery were placed provides an explanation for the 6.7 m difference in elevations observed between the burials within the cemetery. While some have suggested that these differences in elevation suggest that the cemetery was used for a substantially longer period of time than postulated by the excavators (i.e. Parzinger 1993, Zimmermann 2007), the existence of this slope suggests a lengthy period of use is not necessary to explain the large elevation distances, and thus a shorter period of use may be a possibility.

Analysis of the spatial patterning of the occurrence of grave goods within the cemetery suggests that total numbers of grave goods decreases with increasing distance from the centre of the cemetery. The graves with the highest number of grave goods are concentrated in the centre of the cemetery. When these burials are mapped, the cluster of individuals with the highest numbers of grave goods is located in the south-central portion of the cemetery in a slight curve of the hill in the mid- to lower portion of the slope. Few individuals with the highest numbers of grave goods are located outside of this area. Even fewer are located in the area of the cemetery where no provenienced individuals were available for sampling. This suggests that the majority of the burials from the centre of the cemetery, as represented by the concentration of graves with the highest numbers of grave goods, are present within the area for which provenienced skeletal material is available (see **Chapter Four: Skeletal Sample**).

Spatial patterns in the occurrence of particular types of grave goods demonstrate slightly different patterns in their distribution. Individuals with the highest numbers of weaponry also demonstrate a tendency to occur in the same central area of the cemetery as those with high total numbers of grave goods. However, some individuals with higher numbers of weaponry also fall outside of this central area, suggesting a slightly more dispersed spatial distribution. When the distribution of weaponry is broken down into age and sex categories, it is clear that females and children buried with weaponry cluster more noticeably in the central area of the cemetery compared to males buried with weapons. Males buried with this grave good type demonstrate a much more dispersed pattern of distribution. Similarly, individuals with three or more tools are generally concentrated in a similar area to those with high numbers of both total grave goods and weaponry. Furthermore, children buried with tools are more centrally concentrated spatially when compared to both adult males and adult females, who display much more dispersed patterns of distribution. Patterns in the numbers of jewelry items occurring in burials, however, follow a slightly different pattern. Individuals with higher numbers of jewelry items tend to be distributed in a much more dispersed pattern throughout the cemetery, with greater distances to the cemetery's centre than observed in other grave good types. Of the rare grave good types, only idols displayed a spatially concentrated distribution similar to that observed with total numbers of grave goods, as well as weapons and tools. Both figurines and pottery displayed a tendency toward increased dispersal throughout the cemetery, similar to patterns observed in jewelry distribution.

Chapter Four: Skeletal Sample and Biodistance Analysis

Having addressed the mortuary practices employed in the İkiztepe cemetery in detail in the previous chapter, the focus now turns to the skeletal material excavated from these burials. This chapter encompasses two main goals. The first is to provide an overview of the nature and composition of the skeletal sample originating from İkiztepe, as well as reviewing the corpus of available literature that has studied the skeletal sample in the past. The second goal of this chapter is to conduct phenotypic analysis of craniometric data collected from the İkiztepe skeletal sample, with the aim of examining patterns of variability within the population, as well as examining the possibility of kinship structuring as an organizing principle within the cemetery.

Discussion of İkiztepe Skeletal Sample

The İkiztepe skeletal sample is remarkable both for its size and for its preservation, and particularly for the preservation of the juvenile remains in the sample. It thus offers a great opportunity for reconstructing the lives of ancient Anatolian populations. Despite this, bioarchaeological work that focuses on the İkiztepe skeletal sample has been limited. The primary barrier to the full appreciation of the importance and potential of the İkiztepe cemetery and skeletal sample has resulted from the incomplete publication of the material, and the fact that the majority of bioarchaeological work that has been directed at the sample has been published only in Turkish, and thus has remained relatively inaccessible to the majority of Western scholars.

The total number of burials excavated at the site of İkiztepe as of the 2003 season was 685 (Bilgi 2004: Fig. 8; Doğan 2006: 37). Of these, 25 are known to have been located outside of the cemetery currently under examination. This leaves 660 burials within the cemetery itself. 63 of these burials (9.5%) are described by Doğan as containing more than one individual (between 2 and 6 individuals) (2006:5). Based on these numbers, the total number of individuals in the cemetery should therefore be 741. The most recent total number of individuals given is 766 (Doğan 2006: 37*).* In more recent seasons since 2003, little excavation work has been done that focuses on the cemetery area, but small numbers of additional burials have been excavated since this time (Bilgi 2009).

The most recent breakdown of the skeletal sample from İkiztepe is presented by Doğan (2006), and is presented in the tables below. This breakdown includes a total of 511 individuals, whose ages and sexes were determined primarily by Ursula Wittwer-Backofen (although more recently excavated burials were sexed and aged by Yılmaz Selim Erdal; Doğan 2006: 6). In this tabulation, there were 303 adults and 208 children; with 111 adult males, 123 adult females and 69 adults of unknown sex (Doğan 2006: 37). The remainder of the individuals excavated were excluded from this study due to poor preservation (Doğan 2006: 37).

An earlier demographic breakdown of the cemetery dates to 1985, and in fact includes a greater number of individuals, at 582 (Backofen 1985: Fig 1, 1987). This breakdown suggests that the İkiztepe sample includes 216 juveniles under 12 years of age, 70 adolescents between 12 and 19 years of age, 152 adult males older than 20 years, 152 adult females over 20 years of age and 13 adults of unknown sex (Backofen 1985: Fig. 1, 1987, 1997).

Table 4.1: Basic Demographic Breakdown of İkiztepe Cemetery (Adapted from Doğan 2006: Tables 6, 7 and Backofen 1985: Fig. 1)

Age/Sex Group	**Count (Backofen)**	**Count (Doğan)**
Adult Male	168	111
Adult Female	152	123
Adult Unknown Sex	46	69
Children	216	208
Total	**582**	**511**

Table 4.2: Age Distribution of İkiztepe Cemetery (Adapted from Doğan 2006: Table 7)

Age Group	**Count**
Fetus	4
Infant (0-1 years)	50
Young Child (1-6 years)	97
Old Child (6-12 years)	57
Young Adult/Adolescent (12-20 years)	57
Mature Adult (20-50 years)	130
Old Adult (50+ years)	87
Adult >40 years	24
Adult of Unknown Age	5
Total	**511**

At the end of the 1984 excavation season, 521 burials had been excavated, and it was on this sample that Backofen's 1985 study was based (Backofen 1985: 421). At the end of the 1986 season, this number had risen to 608 graves (with 659 individuals) (Backofen 1987: 175). Thus, since Backofen's demographic breakdowns were tabulated, a further 77 burials had been excavated (bringing the total to 685 burials). These later burials included a higher proportion of adult females and juveniles, who were under-represented in the earlier sample due to the tendency toward these individuals being buried in peripheral locations (Bilgi 2003b; 2004). The higher proportion of adult females to males is reflected in the most recent demographic breakdown (Doğan 2006). However, the greater numbers of juveniles are not. It is likely that these additional juvenile individuals are among those that were excluded from the analysis due to poor preservation (Doğan 2006: 37).

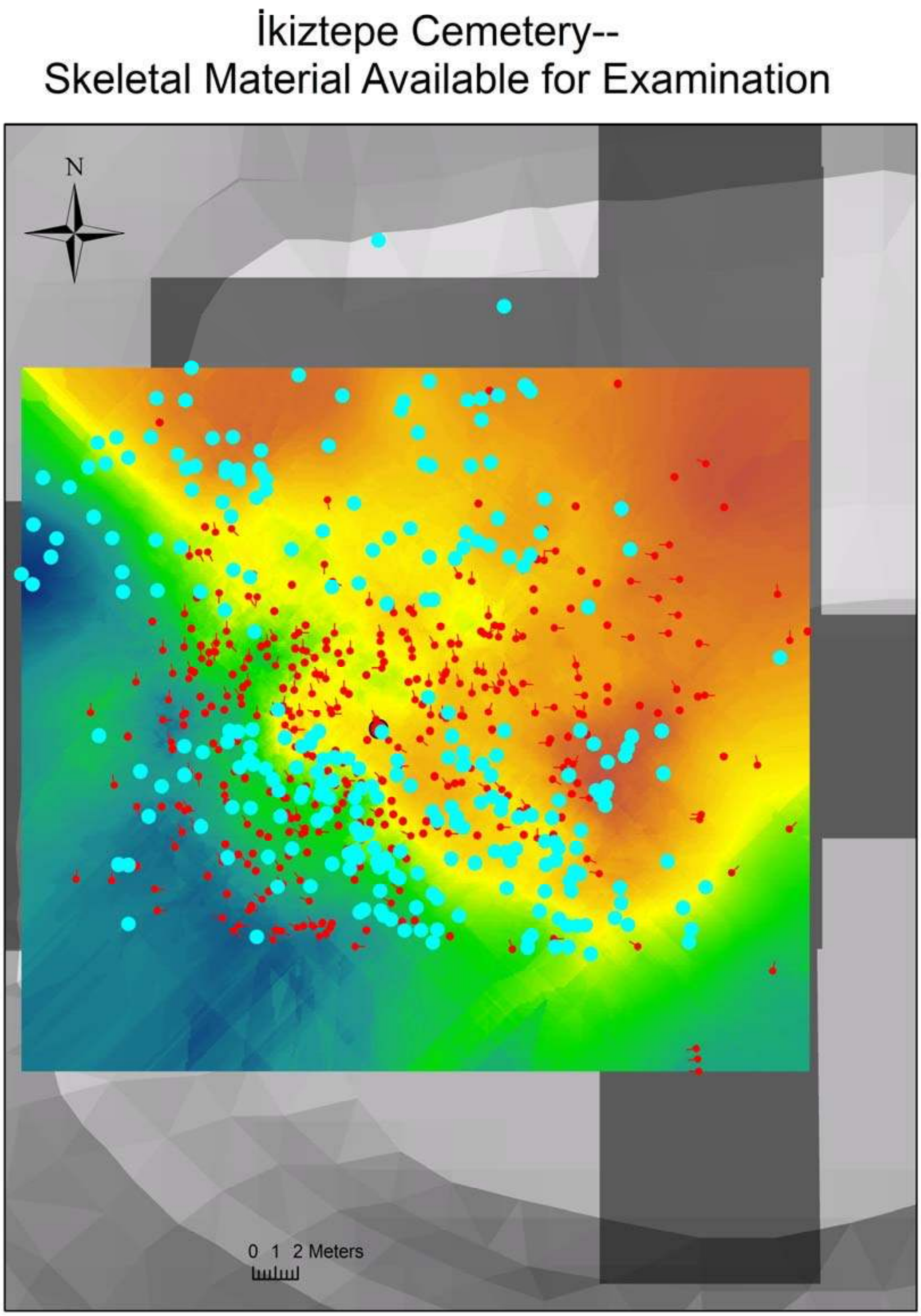
Later palaeodemographic analyses performed by Wittwer-Backofen cite total numbers of individuals around 673 (Luy & Wittwer-Backofen 2005; Luy & Wittwer-Backofen 2008). The source of the additional 14 individuals is not clear; it does not seem likely that they represent burials excavated in later seasons; rather they may represent additional individuals that were identified within the burials of Backofen's original sample.

Provenienced vs. Unprovenienced Skeletal Remains

The skeletal sample from the İkiztepe cemetery was originally studied by Ursula Wittwer-Backofen, while work on the juvenile remains was conducted by Michael Schultz. Wittwer-Backofen's association with the project appears to have concluded after the 1986 season of excavation; however, she has continued to publish palaeodemographic articles that examine the İkiztepe population (Luy & Wittwer-Backofen 2005, 2008). Michael Schultz has continued to address palaeopathological issues for the İkiztepe population (Schultz 2001, see also Schultz report in Alkım *et al* 2003). After they had finished their data collection for the sample, a large portion of the skeletal sample was reburied. These skeletal remains were later re-excavated. The reburial process appears to have been accomplished in such a manner that the skeletal materials of different individuals remained separated. Labels of the original designations of skeleton numbers, however, seem to have been lost. As a result, at the time of re-excavation for further analysis, the original provenience of these individuals could not be determined. These re-excavated remains were given numbers including the letter "N" ("new" numbering system, i.e. ITSKN###), while those that had not been re-buried retained their original skeleton numbers (ITSK###). The result is that the skeletal sample, as it exists at present, is composed of two groups: those that can be linked to their original provenience in the cemetery and those that are unprovenienced as a result of their re-burial. All burials excavated after the conclusion of the work of the original scholars are included in the provenienced sample, as well as some individuals from the original sample who were not reburied. In the craniometric analyses that follow, provenienced and unprovenienced groups are treated separately and as a pooled sample. This allows a general overview of the craniometric variation at the site, as well as the ability to link craniometric data directly to provenience data. Isotopic analysis and fluoride dating were only conducted on provenienced individuals.

The focus on provenienced skeletal remains for chemical analysis results in a slight bias in the spatial distribution of samples available for analysis. The spatial distribution of all provenienced individuals available for sampling can be seen in **Map 4.1: İkiztepe Cemetery—Skeletal Material Available for Examination**. This map demonstrates a dearth of available provenienced samples in squares ranging from C19-D3 IV11. These squares are concentrated in a swath through the middle of the cemetery. The burials that were originally excavated in these squares were among the earliest excavated from the cemetery at İkiztepe. Early excavations focused on the central area of the cemetery, and thus skeletal remains from the centre formed the majority of those remains that were re-buried. Individuals from the more peripheral areas of the cemetery were excavated during later seasons of excavation, and therefore are proportionally better represented among the provenienced sample. Those from the centre of the cemetery are thus poorly represented in the provenienced portion of the sample, but likely form the majority of the unprovenienced skeletal remains. The assertion that adult males may have been preferentially buried near the centre of the cemetery compared to adult females and children may suggest that there is also a slight bias in the provenienced individuals available for sampling toward adult females and away from adult males.

Map 4.1: İkiztepe Cemetery Skeletal Material Available for Examination



Methods of Age and Sex Determination

Age and sex determinations were taken from work previously undertaken by two different examiners of the skeletal sample. The original study of the skeletal sample was undertaken by Ursula Wittwer-Backofen; in recent years, the skeletal sample has been examined by Yılmaz Selim Erdal.

Wittwer-Backofen appears to have based sex estimates on morphological characteristics of the pelvis and skull, as outlined in Ferembach *et al* 1980; Erdal used similar, although unspecified, morphological characteristics. Wittwer-Backofen used the multi-variate "complex" method of age estimation (based on Nemeskeri *et al* 1960; see Luy & Wittwer-Backofen 2008: 122). Yılmaz Selim Erdal, in contrast, used cranial suture closure, pubic symphysis (McKern & Stewart method) and costal aging methods (Y.S. Erdal, personal communication).

Due to problems previously discussed regarding the large number of unprovenienced skeletons whose age and sex cannot currently be confirmed with existing skeletal remains, the original sex and age estimates made by Ursula Wittwer-Backofen (hereafter "UWB" age and sex estimates) were used for producing the map of the cemetery, and thus for performing the spatial analysis of burial patterns (taken from Doğan 2006). Exceptions to this were made for burials excavated after Wittwer-Backofen ceased analysis of the skeletal sample; in these cases, age and sex estimates by Yılmaz Selim Erdal were used (hereafter "YSE" age and sex estimates) (as published in Bilgi 2003b and Doğan 2006).

For craniometric and isotopic analysis, in order to ensure the accuracy and consistency of age and sex estimates, the results produced by both scholars were compared. Where major discrepancies were found (i.e. disagreement on sex, or gross age category such as child vs.

adult), ages and/or sexes were marked as "undetermined". Agreement on sex categories between the two scholars was found in 57 of 72 (79%) individuals included in either craniometric and/or isotopic analysis. Of these, 10/15 disagreements were discrepancies where one individual listed the remains as of "unknown" sex, while the other identified it as either male or female. Only 5/15 cases of disagreement resulted from one individual categorizing the remains as male, while the other individual suggested they were female.

Palaeodemographic Analyses of the İkiztepe Population

A number of palaeodemographic analyses have been conducted on the İkiztepe population, both from the perspective of the juvenile portion of the populations, as well as the adult portion.

Schultz suggests that the juvenile mortality rate in the İkiztepe population is high, particularly in the first two years of life (1989). 3.1% of the juvenile skeletal sample consists of fetuses, and 3.5% of newborn infant (Schultz 1989: 115). 6.8% of children died in the first six months of life, and 5.6% in the second six months, while in the second year of life a further 12.6 percent of children died (Schultz 1989: 115). A further 32.4% of children died between the 2nd and 6th year of life, while 20.5% died between years 6 and 10 and a further 11.9% of children died before the 13th year of life (Schultz 1989: 115-116). The reason for these high juvenile mortality rates compared to other ancient populations is likely due to the greater preservation of infant and juvenile remains compared to most ancient cemeteries. In fact, the proportion of individuals under the age of 20 is high compared to most archaeological skeletal populations (48% of the population); however, individuals under 5 are still under-represented in comparison to mortality rates observed in the life tables modern pre-industrial populations (Luy & Wittwer Backofen 2008: 122).

Luy & Wittwer-Backofen (2005, 2008) used a newly developed method for life table analysis that accounts for a degree of uncertainty in age estimates to analyze the palaeodemographic profile of İkiztepe population. Due to traditional issues of infant and juvenile preservation in ancient skeletons, however, they focus on the mortality patterns of the adult portion of the population (Luy & Wittwer-Backofen 2005: 2). The life table analysis suggests a high mortality rate during middle-late adulthood, around the age of 50, which differs substantially from modern model life tables (Luy & Wittwer-Backofen 2005: 4). In earlier studies, Wittwer-Backofen suggested that the greatest mortality risk for women was associated with child birth, and that mortality was higher for women during the fertile period (1987: 181). In contrast, adult males have a high mortality risk throughout their adult life, suggesting that women who survive the fertile period live to older ages, on average, than men (Wittwer-Backofen 1987: 181).

Biodistance Analyses of the İkiztepe Population

The skeletal material from the cemetery at İkiztepe has been used in two separate biodistance studies to examine the relationship of the İkiztepe population with populations from surrounding regions, including Southeastern Europe, Anatolia, and the greater Near East (Backofen 1985; Eroğlu & Erdal 2005).

The original analysis of craniometric data from the İkiztepe population suggested that the population at İkiztepe did not demonstrate characteristics of typical "proto-Mediterranean" populations, in contrast to the majority of Near Eastern and central Anatolian populations at this time (Backofen 1985: 423). Based on multivariate analysis of craniometric data, the İkiztepe population was suggested to bear more similarity to northern Black Sea populations in Southeastern Europe and southern Russia (Backofen 1985: 423,428). In contrast, a more recent biodistance study found similarities between the İkiztepe population and other Anatolian and

Near Eastern sites (Eroğlu & Erdal 2005). This study, however, did not include data from any comparative skeletal populations from southern Russia or southeastern Europe. Further and more detailed discussion of these studies is provided below.

Another study looked at the frequency of a non-metric skeletal trait, the palatine torus, in various Anatolian populations, including İkiztepe (Eroğlu & Erdal 2008). The frequency of this trait is 44.6% in the İkiztepe population, although the majority of the cases in the sample demonstrate only a slight expression of the trait, rather than a strong expression (Eroğlu & Erdal 2008: 373). It is suggested that the observed increase in the frequency and strength of expression of the trait between the Bronze Age and the Ottoman period is due to significant gene flow between Anatolian and Asian populations (Eroğlu and Erdal 2008: 379).

Palaeopathological Studies of the İkiztepe Population

No comprehensive palaeopathological study of the İkiztepe population has ever been completed. Preliminary analyses have been completed for some sub-groups of the population, and other articles have focused on particular types of pathological conditions, but firm conclusions cannot be drawn about the general health status of the population at the site.

One publication has documented pathological skeletal changes for a small proportion of the İkiztepe population that has been excavated in recent seasons, beginning with skeleton ITSK599 and continuing up to ITSK677 (i.e. not including remains excavated during the 2003 season). These skeletons were examined by Yılmaz Selim Erdal (Bilgi 2003b: 31-33). Within this sub-sample, a number of different types of pathological conditions were identified. However, specific details of the severity or the anatomical locations of these pathological conditions were not included; nor were details of preservation that might have affected the observation of pathological skeletal changes.

The most systematic study of the palaeopathology of the İkiztepe population has completed by Schultz, who published the results of his macroscopic observations of 141 children's skeletons from İkiztepe (1988, 1989). He later published the results of his microscopic pathological investigations of a number of samples, including the İkiztepe remains (2001). The table below presents the frequencies of a number of pathological conditions in the juvenile remains from the site, as determined by Schultz (1989, 2001).

Table 4.3: Frequencies of Pathological Conditions in İkiztepe Children (adapted from Schultz 1989: 116, 2001: Table 1)

Pathological Condition Type	Observable n	Frequency
Anemia (Malnutrition)	129	4.7%
Vitamin C Deficiency (Scurvy)	123	13.8%
Vitamin D Deficiency (Rickets)	129	3.9%
Cribra Orbitalia	82	52.4%
Transverse Enamel Hypoplasia	87	28.7%
Harris Lines (X-Ray)	39	79.5%
Sinusitis	60	6.7%
Meningoencephalitis	117	9.4%
Osteomyelitis (skull)	129	4.7%
Osteomyelitis (long bones)	39	5.1%
Caries	91	2.2%
Peridontitis	88	18.2%
Stomatitis	64	15.6%

A number of these frequencies of pathological conditions were different, however, from the results obtained from macroscopic examinations, due to additional differential diagnostic input based on polarized light microscopic examinations of bone thin-sections (Schultz 2001). Cases of anemia decreased from an original macroscopic frequency of 7% to the 4.7% reported above, as did cases of osteomyelitis, which decreased from 8.5% to 4.7% (Schultz 2001: Table 1). The microscopic examinations, however, increased the incidence of both rickets (from 0% to 3.9%) and meningeal irritation (from 6.8% to 9.5%) (Schultz 2001: Table 1).

Based on the examination of the remains of 141 children from the site, the incidence of rickets was determined to be 3.9% in the İkiztepe population (n=129 observable remains; Schultz 1989: 116, Büyükkarakaya & Erdal 2008: 132). However, there has been some discussion as to the likely etiology of this disease in the İkiztepe population. Schultz suggests that while rickets is often associated with inadequate vitamin D due to lack of sunlight exposure, the amount of sunlight available in the Black Sea coastal region means that this is not likely the cause of rickets in the population (1989: 117). Rather, he suggests a genetic etiology due to inherited kidney disease resulting from several generations of endogamous marriage among the population (1989: 117). Büyükkarakaya & Erdal (2008), however, challenge this interpretation, suggesting that there is evidence for genetic heterogeneity among the older adults of the population that argues against practices of endogamy among the population (2008: 133, Eroğlu 2005). Instead, they suggest that due to weather conditions and architectural practices that may have limited sunlight exposure, this could still be a viable explanation for the occurrence of rickets at İkiztepe (Büyükkarakaya & Erdal 2008: 134-135).

Schultz also comments on the likely etiologies of other pathological conditions in the İkiztepe population. For example, he suggests that the role of meningeal reactions is frequently underestimated in prehistoric populations, and that the frequency of these pathological conditions increases steadily from the Bronze Age to the Medieval Period in Central Europe and Anatolia due to increasing population and changes in economic and political situations (Schultz 2001: 129). In some cases, these meningeal reactions can represent a response to trauma (i.e. epidural hematoma), but that more frequently they are due to inflammatory diseases of the meninges, such as meningitis (Schultz 2001: 128-129). Further, he suggests that the prevalence of scurvy is probably related to seasonal shortages of foods high in vitamin C (Schultz 2001: 137). In addition, Schultz attributes the frequency of anemia in the İkiztepe population to malaria (2001: 137; 2003: 187). The Bafra Plain has traditionally been a marshy environment, with a high frequency of mosquitoes; and malaria has long been endemic in this area. Angel suggested a similar etiology for the frequency of anemias at the site of Troy and other sites in the Aegean area (Angel 1971: 77-84).

A study conducted on the incidence of cranial trauma in the İkiztepe population demonstrates that there is a relatively high frequency of observed traumatic injury to the cranium (16-18% among the general population; Erdal 2005: 108, Erdal in prep). Few occurrences of cranial trauma are seen among infants and children, while among adults, the frequency of cranial trauma rises to between 25 and 29% (Erdal 2005: 108, Erdal in prep). Among adults, the frequency of evidence for cranial trauma increases with increasing age, probably due to increased length of exposure to risk factors (Erdal in prep). Furthermore, the occurrence of cranial trauma was significantly higher among males than females (42% compared to 12%; Erdal 2005: 109; Erdal in prep). This is consistent with anthropological investigations of skeletal manifestations of violence and conflict in a variety of populations, and Erdal suggests that the İkiztepe population was engaged in long-term violent conflict and warfare (Erdal 2005: 109; Erdal in prep). Furthermore, a number of cases of trephination were identified in the İkiztepe population. 5 cases were described by Erdal (2005), but a total of 7 cases were observed in the cemetery as a whole (Doğan 2006: 103). A number of post-cranial traumatic injuries were also observed, including fractures of the arm, leg, clavicle and rib (Bilgi 2003b: 31-33). It is unclear from the descriptions given, however, whether these wounds are peri-mortem, or whether they show signs of healing. One further individual (ITSK635) displays a wound likely caused by a metal tool or weapon, which has a piece of the offending metal still lodged within the bone (ITSK635; Bilgi 2003b: 32).

Chemical Analyses of the İkiztepe Population

Prior to this analysis, only one other study has been conducted involving chemical analysis of the İkiztepe remains, which is currently in press (Özdemir *et al* 2010). This study involves trace element analysis of a group of skeletal remains from the site by ICP-MS, which measured the levels of arsenic, copper and lead in bone. The results of this analysis suggested that the levels of these trace elements were due to diagenetic uptake rather than *in vivo* exposure (Özdemir *et al* 2010). Concentrations of the elements were directly related to the number of metal objects found in the grave, which suggests a post-mortem origin (Özdemir *et al* 2010). Due to the fact that the exposure to elements such as arsenic does not appear to have occurred during life, the authors interpret this as evidence that these individuals were likely not responsible for the manufacture of these metal weapons (Özdemir *et al* 2010). Instead, they suggested that they were imported to the site, but that they likely have a source in the Middle Black Sea region (Özdemir *et al* 2010).

Biodistance Analysis of Phenotypic Data

Studies of biological distance aim to estimate genetic relationships within or among populations through the observation of metric or non-metric phenotypic traits, often taken from cranial or dental observations. These studies borrow concepts from population genetics, and aim to understand population structure based on the actions of four major forces: natural selection, gene flow, mutation and genetic drift. Of these, genetic drift and gene flow are the most important for determining population structure (Relethford & Lees 1982: 116). However, for anthropological and archaeological purposes, gene flow is particularly interesting for understanding past human behavior. Most anthropological biodistance studies have tended to focus on analysis of relationships between populations to understand patterns of gene flow, migration and population origins; however, intra-population approaches are also possible and have been gaining popularity in the scholarly literature (i.e. see Stojanowski & Schillaci 2006). The basic premise of biodistance analyses is that "populations that exchange mates become more phenotypically similar over time and those that do not become more dissimilar at a rate determined by the effective population size" (Stojanowski & Schillaci 2006: 50-51). With regard to metric variables such as craniometric measurements, means between populations will become more similar, and between-sample variability will decrease as gene flow between populations continues.

A large number of early studies examining biological distance had a typological approach, aiming to categorize populations into "types" and chart their movements between areas of the world. This typological approach was very closely linked to ideas of race, and was typified by the work of Hooton at Pecos Pueblo (1930). Generally, these approaches tended to treat racial groups as static entities with little internal variation (Stojanowski 2001: 39). A backlash against this approach began to appear in the 1960's, with the introduction and increased use of concepts originating from population genetics (Stojanowski 2001: 40). These approaches appreciated the variability within populations, and viewed them as dynamic, changing entities. Along with this shift in focus came the realization of the importance of environment and plasticity on development, which meant that migration was not the only cause of phenotypic variation and population structure.

Biodistance studies, however, have had trouble shaking their reputation for racial and typological description, and many scholars have traditionally viewed them as unhelpful and outdated (i.e. see Armelagos and Van Gerven 2003). However, there has been a vast increase in the modeling of phenotypic variation as a proxy for quantitative genetic variation (Stojanowski & Buikstra 2004). Recent studies have increased the use of intra-population approaches that are able to describe and characterize the large amount of human genetic variability that exists within populations, in order to understand kinship and social structure, rather than focusing on populations as static types with little internal variability. In fact, studies that focus on the regional level are generally aimed at understanding the forces at work affecting local demography and social organization, such as population size, turnover and aggregation and intra-regional migration, rather than examining population origins or broad issues of affinity with typological groups (Stojanowski & Schillaci 2006: 51). Furthermore, understanding of biological relationships between populations are essential for interpreting other kinds of bioarchaeological studies focusing on other aspects of human life (Buikstra *et al* 1990; Stojanowski & Buikstra 2004).

Most recent criticisms of biodistance studies based on craniometric variables have been leveled at two issues in particular. First, that craniometric variables are phenotypically plastic, and therefore cannot be used to study migration or gene flow, and second (a related point), that the low heritability of craniometric variables made them not useful for the same purpose (see Relethford 2004).

Relethford, studying the effects of developmental and environmental plasticity on craniometric variables, reaches the conclusion that while phenotypic change may occur following a move to a different environment (especially if this migration occurs early in the developmental process), it does not obscure the ability of phenotypic analysis to detect underlying population structure (2004: 385). Furthermore, it should be noted that geographically proximate populations are more likely to share mates as well as a common environment, meaning that similarities in phenotype result from both genetic and environmental proximity (Relethford 2004: 385).

Critiques regarding the heritability of craniometric traits have usually dealt with this matter in regard to narrow-sense heritability. Heritabilities for craniometric traits cluster around h^2=0.55 (Stojanowski & Schillaci 2006: 53; but see Carson 2006, who suggests a wide range of heritabilities for different craniometric variables). Many studies have stressed the importance of using traits with high heritabilities, but reliance on a concept of narrow-sense heritability may have inherent problems. For example, such measures do not consider aspects of dominance which may affect transmission, particularly in relatively rare non-metric traits (Stojanowski & Schillaci 2006: 59). Furthermore, these measures also ignore the potential contribution environmental variation and cultural practices in heritability of phenotypic traits; such factors "could result in similar within-family phenotypes and divergent between-family phenotypes, but for non-genetic reasons" (Stojanowski & Schillaci 2006: 59-60). For further discussion on the issue of heritability and its relationship to biodistance studies, see Stojanowski & Schillaci (2006: 59-60).

In many cases, the modes of inheritance of phenotypic traits are complex, polygenic and poorly understood (Relethford & Lees 1982: 114-116). However, phenotypic studies are based on the assumption that despite unknown methods of genetic transmission, there are relationships between allele frequencies and phenotypic expressions of traits (in this case, particularly those that can be observed in skeletal populations) (Stojanowski & Schillaci 2006: 51). Furthermore, phenotypic traits are assumed to be the result of the additive effects of multiple alleles, each of which has a small effect on phenotypic expression (Relethford & Lees 1982: 114, Stojanowski & Schillaci 2006: 51). As a result, close relatives, who share a large portion of their genetic material, should be phenotypically similar. Phenotypic expression is complicated by the fact that it represents the effects of both genetic *and* environmental influences; while the effect of environment on phenotype is not ignored, it is generally assumed that environmental effects are minimal and/or randomly distributed among and between the populations being studied (Relethford & Lees: 1982: 115-116, Stojanowski & Schillaci 2006: 51). In addition, certain statistical procedures and careful selection of variables for analysis can aid in controlling for certain kinds of non-genetic variation (Relethford & Lees 1982: 115). Furthermore, it is important to recognize the nature of the composition of a cemetery population. Cemeteries represent the accumulation of one or more biological lineages, and not a population that gives an accurate representation of a living population at any given point in time (Stojanowski & Schillaci 2006: 51, 53). As with any population-level bioarchaeological study, sex and age biases are a concern. However, the biggest concern when conducting comparative studies of cemeteries should be with differences in cemetery composition, organization and "catchment" (i.e. it may not be appropriate to compare small family burial plots to aggregated community or multi-community cemeteries) (Stojanowski & Schillaci 2006: 53).

Two broad approaches exist for the study of genetic structure of populations through physical traits, which can be classified as model-free or model-bound (Relethford & Lees 1982: 116). Model-free approach uses statistical methods to examine the pattern and extent of genetic variability, while model-bound approach incorporates specific theoretical models or genetic parameters into the research design in order to draw conclusions about the population in question (Relethford & Lees 1982; Simic & Rudan 1990: 114-115).

Recent studies have developed a number of different approaches for analyzing aspects of social organization through analysis of phenotypic data (for an overview of these approaches, see particularly Stojanowski 2001; Stojanowski & Schillaci 2006), including analysis of post-marital residence patterns, identification of kin groups within cemetery, and analysis of temporal depth in a sample; many of these kinds of approaches focus on analysis of sample variability as a proxy for biological diversity. These approaches are described in more detail below.

Previous Biodistance Studies on İkiztepe Sample

There have been two divergent and conflicting theories regarding the origins of the İkiztepe population. The first of these theories was suggested by the results of a biodistance analysis by Ursula Wittwer-Backofen (1985), who found a close relationship between the İkiztepe population and the populations of Eastern Europe, suggesting this area as a place of origin for the people at İkiztepe. This study is described in more detail below. The other theory has been advanced by the site's excavator, Önder Bilgi, who believes that the inhabitants of İkiztepe are native Anatolians and represent the Indo-European predecessors of the Hittites (Bilgi 2001: 40, Bilgi 2005: 18). Despite the fact that he believes that the İkiztepe population did not originate from outside Anatolia, he appears to acknowledge the possibility of a relationship with Eastern European populations (Bilgi 2001: 40). The contentiousness of the issue of the origin of the İkiztepe population has led it to be the focus of two separate studies aimed at performing biodistance analysis to identify the site's similarities to surrounding populations.

The first of these biodistance studies was conducted by Wittwer-Backofen in 1985. Her study was based on measurements of 5 craniometric variables, including maximum cranial length, maximum cranial breadth, minimum frontal breadth, bizygomatic breadth, and upper facial height. The averages of the İkiztepe population for these variables were then compared to a database of similar craniometric measurements from a variety of sites in Near East and South Eastern Europe ranging from the Paleolithic to the Middle Bronze Age. Multivariate cluster analysis was performed on the population averages from these sites. While the raw data are not presented, the resulting dendrogram is included in the publication (Wittwer-Backofen 1985: 428).

The İkiztepe population was found to be most closely related to those from the sites of Cernavodă (Romania) and Vinča (Serbia). The next most closely related group of sites included the Romanian Ochre Grave Culture (sites included in this group were unspecified), Tepe Hissar 3C (Iran), Fatjanovo (Central Russia) and the Polish Corded Ceramic culture (again, including unspecified sites). While the sites that demonstrated the closest relationships to İkiztepe were thus from Southeastern European sites, the Anatolian populations that showed the greatest similarity to İkiztepe were Şeyh Höyük and Tilkitepe. The most distant group from İkiztepe, unsurprisingly, contained a combined sample of early *Homo sapiens* and Neanderthal skulls including those from Amud, Shanidar, Qafzeh and Skhul. More surprising, however, is the fact that one of the most distant groups from İkiztepe was the so-called "Western Anatolian Complex". Although the sites included in this group are not specified, the dates for this complex range from the Early Bronze Age to the Late Bronze Age. Also unexpected is the distance of such sites as Alaca Höyük and Alişar Höyük (including samples from both from the EBA and MBA periods. Thus, Backofen's results would seem to suggest that populations at contemporary Central and Western Anatolian sites are only distantly related to the İkiztepe population, while Southeastern European sites demonstrate much closer genetic relationships. Potentially problematic, however, is the fact that in a number of cases, sites are grouped together to form "Complexes". This may be the result of small sample sizes available at each individual site, but the variability between sites that have been grouped together is not addressed. Furthermore, the variability within sites that have been included in the analysis is not addressed by Wittwer-Backofen (1985).

More recently, a second study has been performed on the İkiztepe population that aims to use biodistance analysis to characterize the relationships of the İkiztepe population to other groups (Eroğlu & Erdal 2006). This study was performed on 87 individuals, using measurements on 6 different craniometric variables, taken from Martin-Saller (1928). These variables included: greatest cranial length (M1), greatest cranial breadth (M8), bizygomatic breadth (M45), upper facial height (M48), nasal breadth (M54), nasal height (M55). The averages of these variables for the İkiztepe population were then compared to 12 Anatolian groups and 25 groups from outside Anatolia. Cluster analysis was performed twice, once with only Anatolian sites (from a variety of periods spanning from the Early Bronze Age to modern populations), and then a second time including contemporary Anatolian sites as well as sites outside Anatolia. The Early Bronze Age Anatolian sites included in this analysis were Troy, Hanaytepe, Alişar Höyük and Tilkitepe. A number of groups are included for the site of Troy, one under the name Hisarlık and two under the name Troy. The "Hisarlık" sample is from publications by Cappieri (1969), while the "Troy 1" sample is from Angel's publication of the Early Bronze Age sample (Angel 1951) (the second Troy group, "Troy 2" is from the Byzantine period). All of these sites grouped together in the results of the cluster analysis (with the exception of the Byzantine population of Troy 2). Interestingly, it should be noted that this study, in contrast to Backofen's results, found Alişar Höyük populations (both group 1 and group 2) to be more closely related to İkiztepe than the population at Tilkitepe.

In this study, when compared with Anatolian populations, the İkiztepe sample also clustered closely with Kovuklukaya, a Byzantine Black Sea population near Sinop (dating to the 9th

century). This suggests the possibility that there may have been some long-term genetic continuity in the Black Sea coastal region of Turkey, potentially as a result of the geographic isolation of the area from Central Anatolia. The Anatolian population with the most distant relationship from İkiztepe was the Iron Age site of Hakkari. Furthermore, the majority of the later populations (i.e. from the modern and Byzantine periods, with the exception of Kovuklukaya) were clustered together in another group distant from the population of İkiztepe.

After this intra-Anatolian analysis, the analysis was performed a second time, using sites from throughout the Near East. In this analysis, all Anatolian sites except for the contemporary Early Bronze Age populations were removed. The populations included in this analysis formed two main groupings, with the Late Neolithic-Early Bronze Age population of the site of Kish (located in modern Iraq) as an outlier. All of the Anatolian sites fall into one of these two main groups, along with sites from the Levant and Mesopotamia. In the second group are sites from Iran, the Caucasus and Central Asia. Egyptian sites included in the analysis seem to fall in both categories. In this analysis, İkiztepe clustered closely with the Late Chalcolithic-EBI population from Ras Shamra. It was also closely linked with the Anatolian sites of Hısarlık (the Cappieri Troy sample), Alişar Höyük and Hanaytepe, along with the Egyptian site called "Misir26".

The authors suggest that Backofen's study did not include enough Anatolian sites to adequately examine the relationship between İkiztepe and Anatolian populations. They, however, were not able to obtain the data used by Backofen for Southeastern European sites, and no available published Eastern European sites had sample sizes large enough for inclusion in their study (Eroğlu & Erdal 2006: 45). Thus, they were not able to evaluate the relationships between the İkiztepe population and Southeastern European populations. The results of the two studies are thus not comparable, and neither adequately addresses the issue of the genetic relationships of the İkiztepe population to other populations in the surrounding area. Furthermore, neither of these studies has examined the variability within the İkiztepe population in light of new methodologies in biodistance studies that characterize population structure, gene flow and other concepts from population genetics.

Description of Sample and Variables

For the purposes of this biodistance study, cranial measurements were collected for 15 variables for a total of 102 individuals. The sample included all those individuals whose crania were adequately preserved for the observation of the craniometric variables (individuals with high numbers of missing values were removed prior to further analysis, see discussion below). The variables were defined according to Buikstra & Ubelaker (1994), and are presented in the table below. The basic breakdown of the sample is also provided below, divided according to the availability of provenience data as well as sex.

Table 4.4: Cranial Variables Measured

Variable	**Abbreviation**
Upper Facial Height	UFH
Upper Facial Breadth	UFB
Left Orbit Height	LOH
Left Orbit Breadth	LOB
Inter-orbital Breadth	IOB
Nasal Breadth	NAB
Nasal Height	NAH
Internal Palate Length	IPL
External Palate Breadth	EPB
Internal Palate Breadth	IPB
Bi-Orbital Breadth	BOB
Bi-Zygomatic Breadth	BZB
Maximum Cranial Length	MaxL
Maximum Cranial Breadth	MaxB
Basion-Prosthion Length	BaPr

Table 4.5: Breakdown of Cranial Measurements Taken

Provenience Known	**64**
Males	23
Females	24
Unknown	17
Provenience Unknown	**38**
Males	16
Females	22
Total Males	**39**
Total Females	**46**
Total Unknown	**17**
Grand Total	**102**

Measurements were taken for a total of 64 provenienced individuals and 38 unprovenienced individuals. The total number of males measured was 39, while the total number of females measured was 46, with 17 individuals of unknown sex. In many of the analyses presented below, provenienced and unprovenienced samples were treated separately, particularly when examining spatial patterning in burial practices. In other analyses, the provenienced and unprovenienced samples were pooled to provide a larger sample size.

Where measurements were uncertain due to the reconstruction of the skulls or due to pathological changes, these measurements were marked with a star (*) during measurement. Where particular variables could not be measured due to absence or breakage, this was noted with a "Bro" designation. All cranial measurements were taken by the author with digital sliding calipers to the nearest 0.01 mm; the exceptions were maximum cranial length and maximum cranial breadth, which were taken with spreading calipers to the nearest 0.1 mm.

Summary Statistics

Summary statistics for males and females for each of the craniometric variables are presented in **Table 4.6: Summary Statistics of Craniometric Data for Pooled Sample**. This table presents these statistics for the pooled sample of provenienced and unprovenienced individuals together.

Table 4.6: Summary Statistics of Craniometric Data for Pooled Sample

	Female (n=48)			Male (n=47)		
	n	**Mean**	**SD**	**n**	**Mean**	**SD**
UFH	47	67.87	4.7659	47	69.38	4.1947
UFB	47	104.18	3.8548	43	106.60	3.8897
LOH	48	33.00	2.2851	47	32.48	1.9418
LOB	46	37.44	2.4282	45	39.27	2.8209
IOB	46	23.71	2.6164	46	23.41	2.3398
NAH	46	49.66	4.1252	47	51.69	3.1321
NAB	41	23.64	1.9857	44	24.29	1.7656
IPL	47	37.90	3.1480	46	38.78	3.8319
EPB	46	61.63	3.3657	45	63.73	3.2374
IPB	46	35.64	3.1757	45	36.61	2.8770
BOB	39	95.83	3.9037	39	96.98	4.4147
BZB	35	113.33	5.4156	39	116.38	4.4428
MaxL	42	181.81	9.5515	45	186.71	9.1269
MaxB	46	134.60	6.0889	47	136.85	6.7645
BaPr	36	90.76	4.7828	26	93.43	6.7288

Table 4.7: Summary Statistics of Craniometric Data for Provenienced Sample and **Table 4.8: Summary Statistics of Craniometric Data for Unprovenienced Sample** present the same statistics for the provenienced and unprovenienced samples separately.

Table 4.7: Summary Statistics of Craniometric Data for Provenienced Sample

	Female (n=26)			Male (n=31)		
	n	**Mean**	**SD**	**N**	**Mean**	**SD**
UFH	25	67.48	5.2008	31	68.86	4.7887
UFB	25	103.05	3.9832	27	105.99	2.8797
LOH	26	32.46	2.4655	31	32.33	1.9920
LOB	24	36.39	2.5638	29	39.14	2.8809
IOB	24	24.14	2.6413	31	23.33	2.0250
NAH	24	49.01	4.5607	31	51.61	3.4560
NAB	23	23.31	1.6844	29	24.24	2.0054
IPL	26	37.28	3.2386	30	37.95	4.0327
EPB	24	60.27	3.1736	29	63.60	3.1083
IPB	24	34.74	3.1660	29	36.42	3.0126
BOB	19	93.92	3.9594	23	95.91	3.7949
BZB	18	111.63	4.8317	23	116.06	4.5224
MaxL	20	175.15	7.9490	30	183.93	8.8938
MaxB	24	133.56	5.5032	31	136.24	7.2525
BaPr	18	89.01	5.1013	14	91.23	6.2646

Table 4.8: Summary Statistics of Craniometric Data for Unprovenienced Sample

	Female (n=22)			Male (n=16)		
	n	Mean	SD	N	Mean	SD
UFH	22	68.32	4.2950	16	70.40	2.5340
UFB	22	105.45	3.3454	16	107.64	5.1148
LOH	22	33.62	1.9198	16	32.76	1.8706
LOB	22	38.60	1.6564	16	39.51	2.7841
IOB	22	23.24	2.5651	15	23.57	2.9612
NAH	22	50.37	3.5591	16	51.85	2.4813
NAB	18	24.07	2.2931	15	24.37	1.2325
IPL	21	38.67	2.9261	16	40.34	2.9416
EPB	22	63.12	2.9703	16	63.97	3.5513
IPB	22	36.61	2.9548	16	36.96	2.6720
BOB	20	97.64	2.9223	16	98.52	4.8949
BZB	17	115.14	5.5483	16	116.84	4.4292
MaxL	22	187.86	6.3493	15	192.27	6.9536
MaxB	22	135.73	6.6121	16	138.05	5.7287
BaPr	18	92.50	3.8276	12	95.99	6.5765

Methods

Transformation of Data and Imputation of Missing Values

Raw values for each variable within each sex were adjusted using a z-score transformation to the sex-specific average for each variable. This was done so sex-related differences in size (sexual dimorphism) could be accounted for in the data to allow the consideration of inter-individual biological distance measures.

Prior to conducting multivariate examinations of the data, the number of missing variables in the data matrix were imputed. Variables that had more than 25% of their values missing were removed, which resulted in the removal of three variables: biorbital breadth, bizygomatic breadth and basion-prosthion length. This left 12 remaining variables: UFH, UFB, LOH, LOB, IOB, NAH, NAB, IPL, EPB, IPB, MaxL and MaxB. Two individuals with a large number of missing values were removed (ITSK342 with 7 missing values, and ITSK277 with 5 missing values). Removing these variables and individuals ensured that less than 5% of the total data matrix was missing. Missing values were imputed for z-transformed data for the remainder of the variables and individuals using the multivariate normal algorithm available in NCSS software (Hintze 2005). The greatest number of imputed values for an individual was three, and this only occurred with one individual; the remainder of the sample had a maximum of two imputed values for any given individual.

Post-marital Residence Analysis

Post-marital residence patterns are a specific aspect of social organization that has often been studied by archaeologists and biological anthropologists alike, in the hope of better understanding ancient social structure. Social rules about post-marital residence provide a structured means of incorporating new individuals and new genetic material into a community. A number of kinds of post-marital residence patterns are known anthropologically, including uxorilocal (female-based) and virilocal (male-based) patterns, of which matrilocal (living within or close to the wife's mother's residence) and patrilocal (living within or close to the husband's father's residence) practices, respectively, are the most common. Other types of residence practices include neolocal (living in a new location unrelated to the relatives of either individual), bilocal (living in close proximity to either the wife's *or* the husband's relatives) and duolocal (couple living separately, each with their own relatives). Ethnographic cross-cultural studies suggest that patrilocal residence patterns are, by far, the most commonly recorded (Divale 1977).

Archaeological attempts to characterize post-marital residence patterns on the basis of intra-site distributions of material culture have been problematic and highly criticized because of poorly understood connections between material culture and identity. However, biological anthropologists have also developed methods of examining post-marital residence using patterns of sex-specific phenotypic variation.

The sex-specific migration that results from specific post-marital residence patterns affects male and female genetic and phenotypic variation. Within a particular society, the more mobile sex is expected to exhibit more within-sex variability; furthermore, the more mobile sex is expected to exhibit smaller between-community biological distance estimates with communities with whom they are exchanging mates (Corrucini 1972, Lane & Sublett 1972, Spence 1974, Schillaci & Stojanowski 2003: 7; Stojanowski & Schillaci 2006: 67). Phenotypic variation resulting from environmental factors is assumed to affect each sex equally, with no sex-specific environmental influences (Stojanowski & Schillaci 2006: 67). Furthermore, there is assumed to be no kin structured migration or kin-structured exogamous marriage practices within the society under consideration (Williams Blangero 1989a, 1989b, Williams Blangero & Blangero 1989, Stojanowski & Schillaci 2006: 67). Studies have shown that if this assumption is violated, and kin structured migration does exist within a particular society, it may result in significantly different genotypic and phenotypic variation than predicted by this model (i.e. Williams Blangero 1989a, 1989b, Williams Blangero & Blangero 1989).

Methods of examining post-marital residence through patterns of phenotypic and genotypic variation were originally proposed by Lane & Sublett (1972), who focused on between-population genetic distance, and Spence (1974), who focused on sex-specific within-population variability. Konigsberg (1987, 1988) further tested and developed these ideas, using an “infinite islands model of sexual migration” (1988: 472). Konigsberg’s model represented a significant step in introducing explicit population genetic models into the study of post-marital residence. Konigsberg used F_{ST}, a measure of genetic variance that demonstrates the cumulative effects of forces such as genetic drift and gene flow, and partitioned it into its male and female components (1987, 1988). In doing so, he countered criticisms that suggested that multiple generations of gene flow would obscure patterns of differential sex specific variability and negate the validity of phenotypically based studies of post-marital residence (Konigsberg 1987, 1988, i.e. contra Kennedy 1981). A variety of different methods of assessing within-group and between-group sex-specific variation have been developed since this time. Between-groups distance analyses have often used measures such as Mahalanobis distances (Mahalanobis 1936), F_{ST} and the mean measure of divergence (MMD), as well as a relationship matrix known as the R matrix, which is based on Mahalanobis distance (Relethford *et al* 1987, Relethford & Blangero 1990). Studies of within-group variability have often used univariate tests of differences in variance, such as the F-test or the Levene's test, as well as multivariate methodologies such as the Van Valen's test and determinant ratio analysis, discussed below.

For this study, univariate tests were performed for each variable under consideration using Levene's tests. Prior to performing these tests, the data was tested for normality using the Wilk-Shapiro test of normality. Significant deviations for normality were observed in a number of variables. As a result, Levene's tests were selected as the best means of testing for univariate differences in variation between the sexes, as these tests are more robust under non-normal conditions. F-tests assume a normal distribution, an assumption that was not satisfied for much of the İkiztepe craniometric data (see results below). In addition, post-marital residence was assessed using two different multivariate methods: determinant ratio analysis and a Van Valen's test.

Variance-covariance matrices were constructed for both the male and the female samples, using raw data with no transformations. The determinant of the covariance matrix is a scalar value that provides an estimate of within-matrix variability. The determinants of the two sex-specific covariance matrices were then compared in order to compare within-sex variability for males and females. Covariance matrices and their determinants were calculated using NCSS software; the natural log of the ratio of male:female determinants was then used to compare the values: ln(|C♂|/|C♀|) (Relethford 1988, Schillaci & Stojanowski 2005). This value is expected to be close to zero when mobility and phenotypic variability are equal between the sexes. This situation is expected when a society has no firm residence rules, or in an endogamous society containing multiple unrelated descent groups (Schillaci & Stojanowski 2005: 407). Greater mobility among one sex or the other will result in greater phenotypic variability in this sex due to the introduction of new genetic material through gene flow. A positive value results from greater male mobility (suggestive of a matrilocal residence pattern), while a negative value results from greater female mobility (suggestive of a patrilocal residence pattern). The significance of the resulting value was calculated by jackknifing the results of the analysis by removing each variable in turn and recalculating the covariance matrices, their determinants, and the resulting natural log of the determinant ratio. The p-value of the statistic is calculated by determining the percentage of these jackknifed calculations that have values greater than or equal to the observed value. Furthermore, the standard error of the jackknifed average value was calculated and used to calculate a 95% confidence interval for the determinant ratio.

In addition to determinant ratio analysis, the comparative multivariate variability between the sexes was evaluated using a Van Valen's test. The test statistic is calculated using the following formula:

$$d_{ij}=\sqrt{\{\Sigma^{p}_{k=1} (X_{ijk} - \overline{X}_{jk})^{2}\}}$$

where X_{ijk} is equal to the observed value for variable k for individual i in sample j, and $\overline{X}_{jk}$ is equal to the population average for the same variable k for population j (Stojanowski 2001: 258). The two populations in this case are the values for males and females. The d_{ij} values will be larger for the sex that exhibits the greater variable; the d_{ij} for the two sexes can then be compared using a t-test to determine the significance of the difference between the values. Prior to the calculation of the test statistic, the data were transformed to mean 0 with unit variance to ensure that all variables included in the analysis were weighted equally.

Kinship Analysis

Kinship analysis aims to identify kinship or groups of related individuals within cemeteries, based on the assumption that genetically related individuals are phenotypically more similar than other contemporary non-related individuals. These kinds of analyses often focus on the distribution of rare and highly heritable non-metric traits among a population, particularly in the dentition, as metric traits are seen as more variable due to environmental influences (Rösing 1986). Non-metric data, however, is not available for the İkiztepe population. Future research should aim to examine non-metric trait occurrence in the İkiztepe sample, with a view to providing a more reliable method of determining kinship structure compared to the metric traits used here. Metric data, however, can also be used successfully for kinship analysis in these contexts (see for example, Bartel 1981, Strouhal 1992, Stojanowski 2001, 2005, Stojanowski & Schillaci 2006: 53, 59-60).

The internal structure of the cemetery is inextricably linked with kinship analyses, and can have a significant effect on these forms of analysis. Studies that examine cemeteries where interments occur in groups within easily separable funerary contexts (i.e. group mound burials, or group shaft tomb burials) often focus on confirming the hypothesis that individuals buried together in these contexts represent related individuals from nuclear or extended family groups (i.e. Bentley 1987, 1991). Barring these types of group burials, cemeteries may also be spatially structured, with clearly defined burial areas for particular kin groups. In these cases, it is most often archaeological and/or stratigraphic evidence that provides the necessary information for determining potential axes of spatial structure; this may include spatially distinct burial areas within a site or the spatial distribution of grave goods, by numbers or particular kinds of objects (Bartel 1981, Corruccini & Shimada 2002, Stojanowski 2005). In contrast, cemeteries may display no clear evidence for distinct spatial patterning or separation that may indicate defined locations for the burial of different kinship groups. These situations are particularly problematic for understanding kinship structure and its relationship to spatial organization of burial practices (Sjøvold 1975, 1976-1977, Vach & Alt 1993, Alt & Vach 1991, 1992). The reliance of most kinship analytical methods on the existence of *a priori* groupings of individuals severely limits the abilities of kinship analysis in situations where such groupings are not immediately evident. This is very clearly the case in the İkiztepe cemetery, where no clear spatial differentiation is visible, and where remarkably homogeneous burial practices limit the identification of potential sub-populations within the cemetery.

It should be noted that kinship analysis aims to identify individuals who are likely to be closely related, but does not aim to specify the exact nature of the familial relationship between these individuals. While many different degrees of genetic relatedness exist based on the expected proportion of shared genes among different types of relatives (i.e. see Blouin 2003), phenotypic analysis is generally unable to accurately assess the type or degree of relationship between two individuals on the basis of phenotypic similarity. Instead, kinship analysis often focuses on archaeological and contextual data about phenotypically similar individuals to infer aspects of ancient social structure and social organization.

The various kinship analyses described below were conducted on within-sex z-transformed data to eliminate sexual dimorphism as a potential confounder of determining kinship relationships.

Two methods were used to determine the likely number of lineage groups contained within the cemetery: the matrix decomposition method and finite mixture analysis.

Stojanowski's matrix decomposition model (Stojanowski 2003b) was developed as a means of determining the likely number of kin groups found within a cemetery. This is an important issue, because in a cemetery containing a single lineage group practicing kin-structured burial, correlations between the biological distance between individuals and the spatial distance between individuals can be detected by means of a Mantel test to examine matrix correlation levels. However, if multiple lineage groups are contained within a cemetery, each practicing kin-structured burial within their own lineage group, and each with a complex system of overlapping spatial areas for burial within the cemetery, a Mantel test may not be powerful enough to detect kinship-based spatial patterns in burial (Stojanowski 2003b: 217). Stojanowski's method uses a biological distance matrix (d_{ij}) and a spatial distance matrix (b_{ij}), and calculates a residual matrix by subtracting them ($r_{ij} = d_{ij} - b_{ij}$) (Stojanowski 2003b: 217-218). The original distance matrices must be scale-free or scaled accordingly prior to subtraction (Stojanowski 2003b: 225); where there is a perfect correlation between the two matrices (i.e. a perfect correlation between biological and spatial distance), the values in the residual matrix will all approach zero (Stojanowski 2003b: 218). If all comparisons are within a single group, all the residuals in the residual matrix will be negative (Stojanowski 2003b: 218). Thus, the proportion of negative values in the residual matrix (i.e. where spatial distance between burials is greater than expected based on the degree of biological relatedness) is used to calculate the likely number of lineages buried within the cemetery. The formula for calculating the number of lineages is simplified as: proportion of negative residuals=1/m, where m is the number of lineages in the cemetery (see Stojanowski 2003b: 218 for the derivation of this formula). For more information on the matrix decomposition model, see Stojanowski 2001 and Stojanowski 2003b. For the purposes of this calculation, biological distances in the biological distance matrix were found using Mahalanobis distances (d^2). Spatial distances were calculated using Euclidean distances based on the coordinates of the individual burials extracted from the GIS cemetery map. Because biological distances were calculated from z-transformed data, spatial distances were also calculated on z-transformed coordinate data. Both distance matrices were calculated using PASSAGE software. Both matrices were scaled accordingly by creating non-parametric distance classes based on the range of values included in each distance matrix using PASSAGE software (10 distance classes were used in each case). Distances were then ranked from one to ten, in order to ensure the same scale for both matrices. The matrices were then subtracted in order to find the residual matrix and the likely number of lineages was calculated from the proportion of the resulting residuals that were negative.

A second method was used to determine the likely number of lineage groups contained within the cemetery: finite mixture analysis. This method aims to identify potential groups within the population based on the variability of values of a particular variable, rather than attempting to identify the group membership of individuals (Dong 1997: 142). The method basically involves drawing a histogram of the distribution of a particular variable in a population, and looking for evidence of biomodality (Dong 1997: 142). However, arbitrary decisions about the size and starting point of the intervals used for constructing the resulting histogram can seriously affect the shape of the distribution, and therefore the results of such an analysis (Dong 1997: 142-143). Thus, finite mixture analysis uses computer simulation to run numerous iterations in order to create a maximum likelihood estimate of the number of populations mixing to make the observed distribution (Dong 1997: 145). The benefit of this method is that it does not require a “training” sample, as other multivariate methods such as discriminant function analysis do (Kramer & Konigsberg 1999: 410). In bioarchaeology, finite mixture analysis has been used particularly profitably in examining sexual dimorphism in fossil hominid assemblages where there is no prior knowledge of the sex of the individuals involved (Dong 1997; Kramer & Konigsberg 1999). For more information on mixture analysis and its application in anthropology and archaeology, see Dong 1997 and Kramer & Konigsberg 1999. The mixture analysis procedure using an Expectation-Maximization (EM) algorithm was run in PAST software on each variable separately, and for each variable the number of groups that provided the lowest Akaike Information Criterion number was selected as the best solution, as suggested in the PAST manual (Hammer *et al* 2009: 22). The mixture analysis was run on the z-transformed data for each variable, in order to eliminate sexual dimorphism as a reason for the existence of several groups within the population.

Following these procedures to determine the most likely number of lineages within the cemetery, k-means analysis was performed on the z-transformed craniometric data, using NCSS software in order to assign individuals into clusters approximating these lineages. Outputs were conducted for all numbers of clusters between 2 and 10. However, the number of clusters ultimately used for kinship analysis was determined using the results of the matrix decomposition method and finite mixture analysis as described above. The clusters produced by k-means analysis based on phenotypic data were examined for spatial patterning, as well as for patterns in terms of numbers and types of grave goods appearing in the graves.

In addition to k-means analysis, a number of other methods were used to examine distance relationships between individuals within the cemetery, and to explain the phenotypic variation within the population. Cluster analysis was performed on the z-transformed craniometric data, with Gower coefficients as a distance measure using PAST software. In addition, Principal Coordinates Analysis was performed on the biological distance matrix constructed for the z-transformed craniometric data using NCSS software.

Matrix Correlation Analysis

As part of the kinship analysis undertaken here, it was necessary to test for correlations between biological distance and physical distance within the cemetery (Smouse & Long 1992). This procedure can be used in cemeteries that lack clear spatial structure for the burial of different lineage groups within the cemetery. This test aims to identify hidden kin structuring within a spatially undifferentiated cemetery. If kin structured burial exists, individuals who are mostly closely related to each other will be more likely to be buried in close spatial proximity to each other. In such a case, a significant positive correlation will be observed between the biological distance matrix and the spatial distance matrix for a given cemetery. The most common method used for estimating correlations between distance matrices is the Mantel test, which calculates the tests statistic based on the cross-products of the corresponding cells of the distance matrices under consideration (Mantel 1967, Smouse & Long 1992, Sokal & Rohlf 1995). The significance of the test result is calculated using a randomization test with a large number of permutations (i.e. 999) (Sokal & Rohlf 1995). Tests for correlations between these matrices, however, may not be powerful enough to detect kin structure when multiple lineage groups, each practicing kin-structured burial, are buried in overlapping or poorly defined areas within a cemetery (Stojanowski 2001, 2003b). As a result, matrix correlation should be performed on the population as a whole, as well as on potential population sub-groupings, in order to determine the organizational level of kin structuring, if it is practiced.

A biological distance matrix was constructed using PASSAGE software, which calculated the (Mahalanobis) biological distance between pairs of individuals using *z*-transformed craniometric data. For the same individuals included in the biological distance matrix, a physical distance (Euclidean) matrix was constructed using the coordinates for the respective burials exported from the GIS cemetery map. Two versions of the physical distance matrix were made, one that included the depth of the burials as a Z coordinate to calculate a three dimensional distance and one that calculated a 2-dimensional distance using only the X and Y coordinates. The biological and physical distance matrices were then compared to determine the relationship between biological distance and physical distance using a MANTEL test. In order to detect hidden patterning, MANTEL tests were conducted for the population as a whole, for separate male and female samples, and for each of three clusters of individuals suggested by the results of the k-means analysis.

Using the results of the fluoride analysis (see **Chapter Seven**), which provides a relative sequence for the burials under consideration, a similar distance matrix was created representing distance in time. These time distances were calculated using both the rank of the individual's fluoride concentration within the group and with the raw concentration itself, creating two different time matrices. This third matrix was then was held constant using a partial Mantel test, to examine the relationship between biological and physical distance while controlling for the effect of the distances between the burials in time. For each sample, both time matrices (using rank and concentration) were tested, along with both versions of the physical distance matrix (2-dimensional and 3-dimensional).

Results

Tests of Normality

In order to determine the best method of assessing univariate differences in variation, the data was tested for normality, using the Wilk-Shapiro test of normality. The results of these tests are presented in **Table 4.9: Wilk-Shapiro Tests of Normality for Pooled Sample, Table 4.10: Wilk-Shapiro Tests of Normality for Provenienced Sample** and **Table 4.11: Wilk-Shapiro Tests of Normality for Unprovenienced Sample.** Statistically significant deviations from normality are marked with an asterisk (*).

Table 4.9: Wilk-Shapiro Tests of Normality for Pooled Sample

	Females		Males	
	W Value	**P-Value**	**W Value**	**P-Value**
UFH	0.9254444	5.195628E-03*	0.967094	0.2047869
UFB	0.9713653	0.2983274	0.986974	0.9005858
LOH	0.982702	0.694043	0.9768269	0.4683014
LOB	0.9833772	0.7457737	0.9699442	0.2882424
IOB	0.9920822	0.9872966	0.9723129	0.3367179
NAH	0.9355971	1.345139E-02*	0.9643495	0.1599026
NAB	0.969286	0.326747	0.942346	0.0287522*
IPL	0.9807897	0.6251216	0.9018912	9.476515E-04*
EPB	0.9939405	0.997467	0.9640175	0.1736177
IPB	0.9567239	8.545975E-02	0.9886999	0.9350776
BOB	0.9852906	0.8810632	0.9768476	0.5898593
BZB	0.9723399	0.51068	0.9688098	0.3449506
MaxL	0.9663574	0.2479055	0.9487756	4.565937E-02*
MaxB	0.9715934	0.3170795	0.9744689	0.3876501
BaPr	0.9802442	0.7535715	0.9563515	0.3248391

Table 4.10: Wilk-Shapiro Tests of Normality for Provenienced Sample

	Females		Males	
	W Value	**P-Value**	**W Value**	**P-Value**
UFH	0.9060494	2.490415E-02*	0.959823	0.2886291
UFB	0.9296407	8.526441E-02	0.9619838	0.4096606
LOH	0.9556917	0.3138554	0.9778156	0.7495682

LOB	0.949515	0.264468	0.962882	0.3862496
IOB	0.9768584	0.8316866	0.9547688	0.2110166
NAH	0.8683228	4.878216E-03*	0.9581486	0.2604408
NAB	0.9831011	0.9515559	0.9264299	4.449706E-02*
IPL	0.9713605	0.6588521	0.8163886	1.323686E-04*
EPB	0.9632381	0.5068441	0.9673762	0.4909019
IPB	0.9215356	6.316245E-02	0.9778923	0.7823271
BOB	0.9679418	0.7346738	0.9746202	0.79761
BZB	0.9752273	0.8881243	0.9755933	0.8192767
MaxL	0.9145824	7.797321E-02	0.9239433	3.398544E-02*
MaxB	0.9190042	5.552455E-02	0.9734277	0.6176019
BaPr	0.9213821	0.1367679	0.8597955	3.024903E-02*

Table 4.11: Wilk-Shapiro Tests of Normality for Unprovenienced Sample

	Females		**Males**	
	W Value	**P-Value**	**W Value**	**P-Value**
UFH	0.9109746	4.956119E-02*	0.8980497	7.479787E-02
UFB	0.9655046	0.6077023	0.9562971	0.5954188
LOH	0.9491689	0.3040558	0.9432875	0.3912504
LOB	0.9420798	0.2184303	0.9253098	0.2052612
IOB	0.983093	0.9572178	0.8779475	4.421971E-02*
NAH	0.9519587	0.3451988	0.8887424	5.321157E-02
NAB	0.9412534	0.3044109	0.9231005	0.2147483
IPL	0.9793938	0.9164184	0.9312094	0.2547734
EPB	0.9472421	0.2781948	0.8028689	2.973949E-03*
IPB	0.92874	0.1155002	0.9579059	0.6240017
BOB	0.9622099	0.5888818	0.9431173	0.3889673
BZB	0.955588	0.5505819	0.873008	3.024458E-02*
MaxL	0.9419203	0.2167901	0.9271564	0.2473385
MaxB	0.9757087	0.837555	0.9696367	0.8326897
BaPr	0.9665694	0.7312738	0.9498933	0.6354254

In general, variables that show a deviation from normality were not consistent between the sexes. For females, upper facial height and nasal height tended to demonstrate significant deviations from normality. For males, the distributions of nasal breadth, internal palate length and maximum cranial length were determined to deviate significantly from normality for the pooled sample. The same variables were non-normal in the male provenienced sample, with the addition of the basion-prosthion length distribution. Completely different variables deviated from normality for the male unprovenienced sample: inter-orbital breadth, external palate breadth and bizygomatic breadth.

Univariate Variance Tests

Each of the craniometric variables were individually tested for significant differences in variance between males and females. For this purpose, univariate Levene's tests were performed. Levene's tests were selected instead of standard F-tests because they are generally more robust for evaluating differences in variance under conditions that deviate from a normal distribution. The results of the Wilk Shapiro tests above suggest that many of the variables display significant deviations from normality. The results of these tests are presented in **Table 4.12: Univariate Levene's Tests for Males vs. Females for Pooled Sample, Table 4.13: Univariate Levene's Tests for Males vs. Females for Provenienced Sample,** and **Table 4.14: Univariate Leven's Tests for Males vs. Females for Unprovenienced Sample.** Statistically significant differences in variance between the sexes are marked with an asterisk.

Table 4.12: Univariate Levene's Tests for Males vs. Females for Pooled Sample

	Levene's Test	P-Value
UFH	0.1550	0.694752
UFB	0.0087	0.925993
LOH	1.0741	0.302719
LOB	0.7199	0.398462
IOB	0.4649	0.497083
NAH	2.0432	0.156307
NAB	0.6984	0.405735
IPL	0.7219	0.397744
EPB	0.1663	0.684360
IPB	0.3824	0.537922
BOB	0.7615	0.385595
BZB	0.2220	0.638960
MaxL	0.0347	0.852675
MaxB	0.2314	0.631609
BaPr	1.0870	0.301328

Table 4.13: Univariate Levene's Tests Males vs. Females for Provenienced Sample

	Levene's Test	P-Value
UFH	0.1596	0.691127
UFB	2.1452	0.149279
LOH	1.3140	0.256631
LOB	0.6373	0.428380
IOB	2.0629	0.156798
NAH	0.3180	0.575182
NAB	0.0883	0.767601
IPL	0.1095	0.742026
EPB	0.3327	0.566593
IPB	0.0379	0.846345
BOB	0.0125	0.911557
BZB	0.0018	0.966632
MaxL	0.0081	0.928760
MaxB	1.8441	0.180229
BaPr	0.0808	0.778232

Table 4.14: Univariate Levene's Tests for Males vs. Females for Unprovenienced Sample

	Levene's Test	P-Value
UFH	3.5348	0.068206
UFB	3.0951	0.087028
LOH	0.0336	0.855508
LOB	4.9349	0.032697*
IOB	0.6677	0.419387
NAH	3.8540	0.057389
NAB	3.1924	0.083767
IPL	0.1943	0.662070
EPB	0.0345	0.853677
IPB	0.0885	0.767749
BOB	3.2022	0.082449
BZB	0.0940	0.761244
MaxL	0.2396	0.627551
MaxB	0.4056	0.528249
BaPr	3.7678	0.062377

Few of the tests display significant results at the $\alpha=0.05$ level. The only significant result was for left orbit breadth in the unprovenienced sample. However, some of the results are significant at the $\alpha=0.1$ level. In the unprovenienced sample, the results are significant at this level for upper facial height, upper facial breadth, nasal height, nasal breadth, biorbital breadth and basion-prosthion length. However, similar patterns are not observed for the provenienced or pooled populations. Furthermore, in general there is no pattern observed in the comparative sizes of standard deviations among males compared to females (i.e. roughly even numbers of variables display higher standard deviations for each sex). This does not suggest a consistent pattern of increased variation in one sex compared to the other.

Multivariate Variance Comparison Methods

The comparisons of the determinants of the male and female variance-covariance matrices were performed for the entire population, including both provenienced and unprovenienced individuals. The results of these analyses are presented in the tables below.

Table 4.15: Determinant Ratio Analysis for Whole Population

	Log of Determinant	Determinant	|M|/|F|	Ln(|M|/|F|)	p-value
F	23.49054	1.5915E+10			
M	25.17504	8.5779E+10	5.389755381	1.6845	0.17

95% Confidence Interval based on jackknife: 1.049169-1.534989

This analysis suggests a slight trend toward greater male within-group variance as compared to female within-group variance, although the results were not significant for the whole population analysis.

Table 4.16: Results of Van Valen's Test for Males vs. Females

Sex	d_{ij}
Female	25.28878129
Male	24.5577161

The results of the Van Valen's test, however, suggest the opposite pattern. In this test, females display slightly more variability, although the difference is not significant.

The reason for the difference between these two analyses is unclear. However, it appears that there is no clear trend toward either greater male or greater female variability. This suggests either a society with no firm rules of post-marital residence or an endogamous society with multiple unrelated descent groups (Kongisberg 1988, Stojanowski & Schillaci 2006: 407).

Despite this, however, the results of the determinant ratio analysis may still point to greater immigration to İkiztepe by males compared to females. Isotopic data may be used to further evaluate this hypothesis.

Matrix Decomposition and Finite Mixture Analysis

Both the matrix decomposition method and the finite mixture analysis suggest that the most likely number of groups in the cemetery is three.

Table 4.17: Results of Matrix Decomposition

Negative Residuals	Total Residuals	Proportion	m
656	1510	0.370621	2.698171

Table 4.18: Results of Finite Mixture Analysis

Variable	Suggested # Groups
UFH	3
UFB	4
LOH	2
LOB	3
IOB	4
NAH	2
NAB	2
IPL	3
EPB	1
IPB	3
MaxL	3
MaxB	5

K-Means Analysis

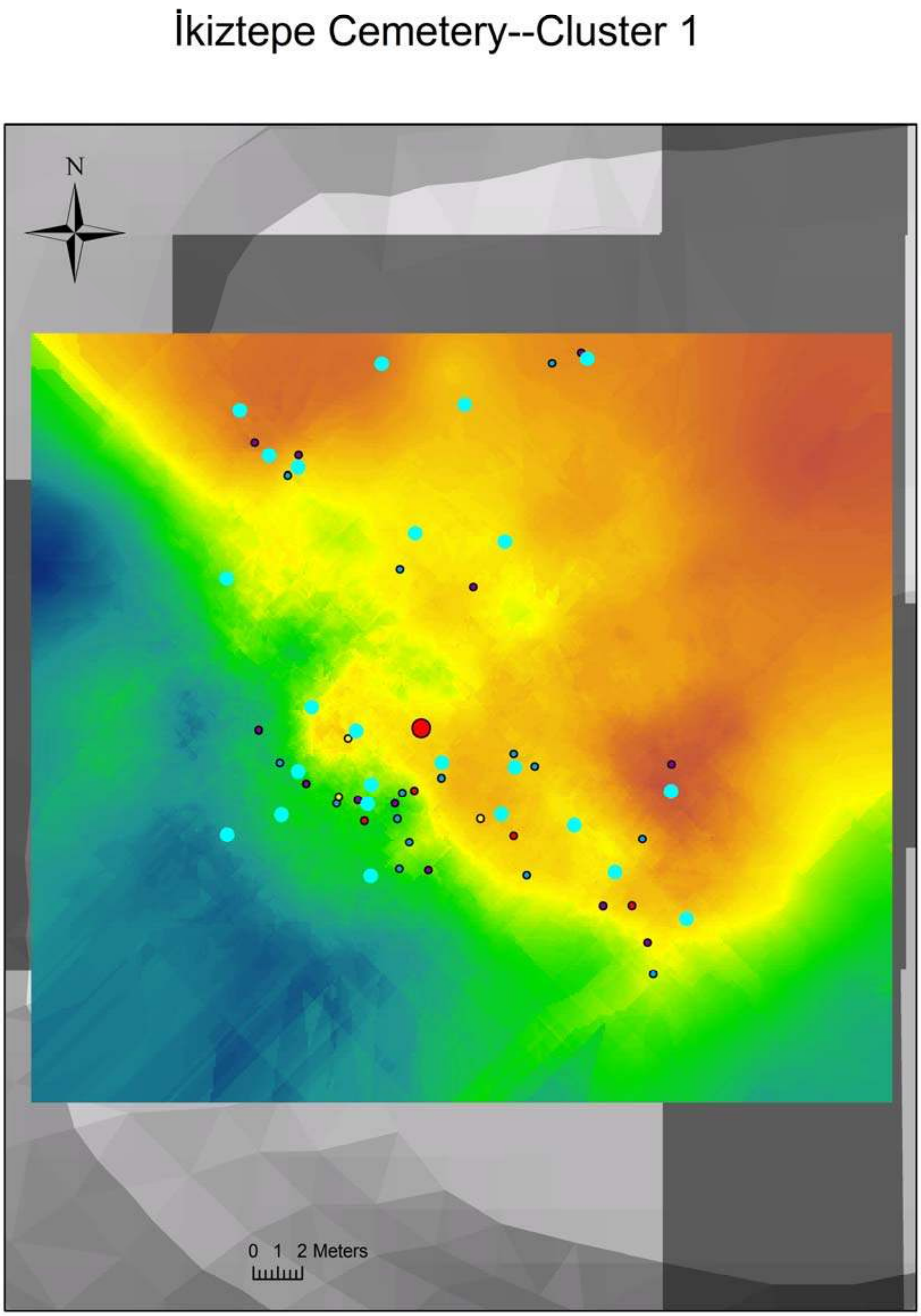
The results of the output where three clusters are presented in the table below, along with relevant information about each burial, including sex, time period, number of grave goods, non-local individuals, and the presence of particular types of grave goods.

Table 4.19: Results of K-Means Cluster Analysis with 3 Output Clusters

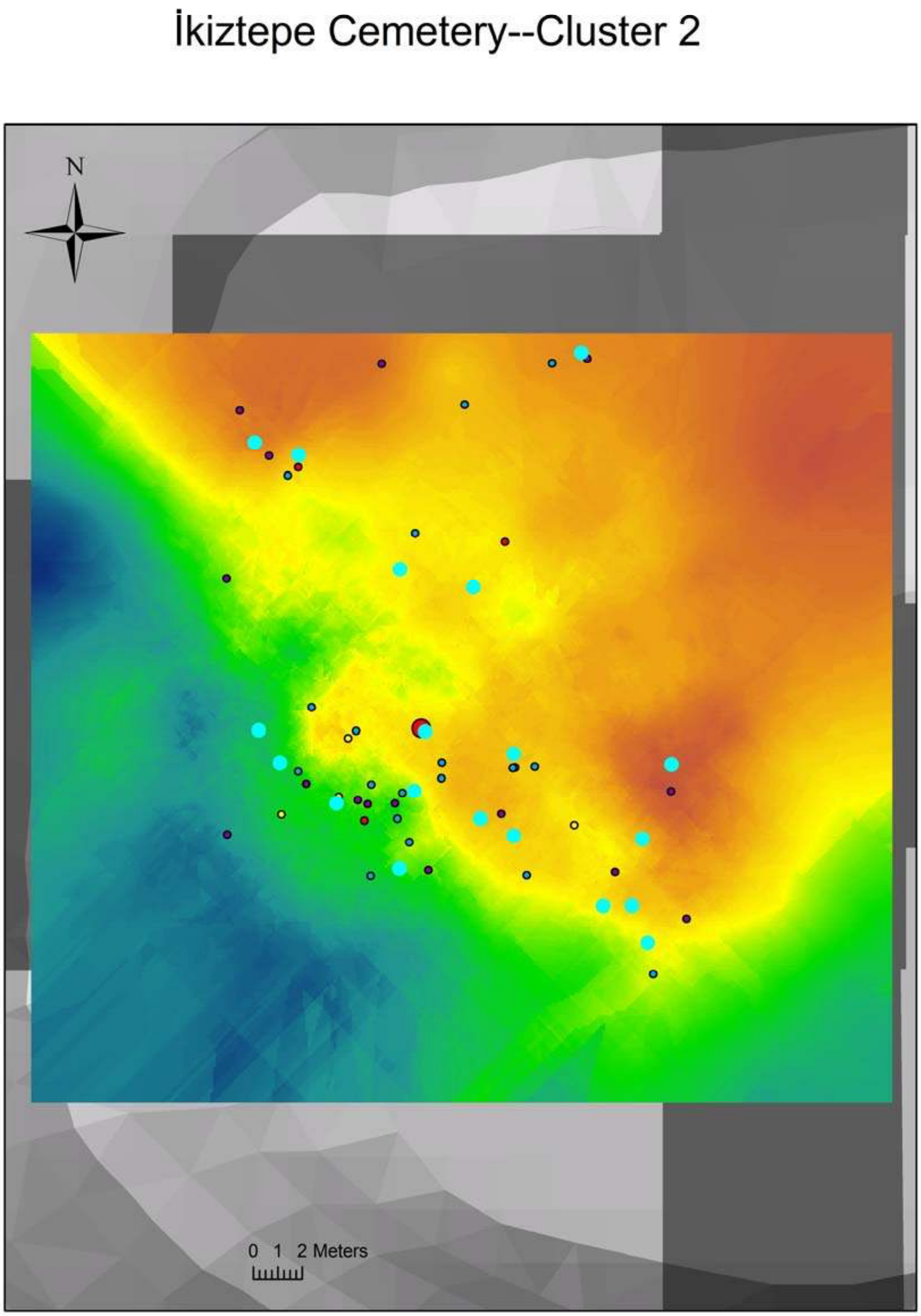
Cluster 1 (n=24)	**Cluster 2** (n=19)	**Cluster 3** (n=16)
ITSK251 (F, -, 0)	ITSK288 (F, L, 0) 🧍	ITSK295 (M?, L, 0)
ITSK266 (F?, M, 2)	ITSK296 (F, M, 2)	ITSK306 (F, - , 0) ★
ITSK268 (F, L, 0) ★	ITSK320 (M, M, 2)	ITSK315 (M?, L, 0)
ITSK270 (F, M, 2) 🧍	ITSK328 (M, M, 0)	ITSK340 (M, E, 2)
ITSK280 (F, M, 0)	ITSK348 (M?, M, 0) ⚡ 🧍	ITSK393 (F, M, 0)
ITSK297 (M? M, 5)	ITSK356 (U, -, 0)	ITSK413 (M, M, 7) $
ITSK316 (M, L, 2)	ITSK358 (F, M, 0)	ITSK444 (U, M, 2)
ITSK329 (M?, E, 0) 🧍	ITSK389 (M, L, 0) 🧍	ITSK462 (M, M, 4) ◎
ITSK337 (M?, L, 4) ⚡¢	ITSK433A (M?, - , 3)	ITSK471 (M, E, 5)
ITSK364 (M, E, 8) $	ITSK447 (F, L, 2)	ITSK473 (F, L, 3) ¢
ITSK395 (M, M, 9) ◎ $	ITSK465 (M, E, 7) $	ITSK545 (M, L, 1) ◎
ITSK414 (M, M, 0) 🧍	ITSK467 (F, E, 5) ♠	ITSK569 (M, M, 11) ◎⚡$
ITSK434 (M?, L, 0)	ITSK512 (F, M ,0)	ITSK602 (M, M, 3) ★
ITSK494 (U, M, 3)	ITSK552 (F, L, 3) ¢	ITSK621 (F, E, 1) ★
ITSK550 (M, L, 1)	ITSK553 (M, L, 1) ★	ITSK646 (M, M, 6) 🧍
ITSK567 (F, L, 1) ★	ITSK596 (M, -, 6)	ITSK678 (F?, M, -)
ITSK573 (M, M, 6) ★	ITSK643 (M, L, 1) ★ 🧍	
ITSK599 (M, L, 1)	ITSK652 (F?, L, -)	
ITSK642 (F?, - , 0) ★	ITSK677 (F, L, 0)	
ITSK644 (F, L, 0)		
ITSK654 (F?, M, -)		
ITSK664 (F, L, 1)		
ITSK668 (F, L, 2)		
ITSK675 (M, L, 2)		

Legend: First letter within brackets represents sex (M=Male, M?=Possible Male, U=Unknown, F?=Possible Female, F=Female); second letter within brackets indicates time period, using a three time period system (E=Early, M=Middle, L=Late); third and final number within brackets indicates number of grave goods; for any of these values, - indicates that data is not available. Additional symbols: ★= non-local individual as indicated by strontium isotopic analysis; ◎=occurrence of quadruple-spiral plaques in grave; ♠ = female individual buried with weaponry; $ = presence of 7 or more grave goods; ¢ = presence of 3 or more grave goods in the Late period of cemetery use;⚡=presence of healed or unhealed cranial trauma; 🧍 = unusual burial position (i.e. not dorsal). The relative significances of patterns in these clusters with regard to time period and non-local individuals are discussed in the fluoride dating and isotopic results chapters, respectively.

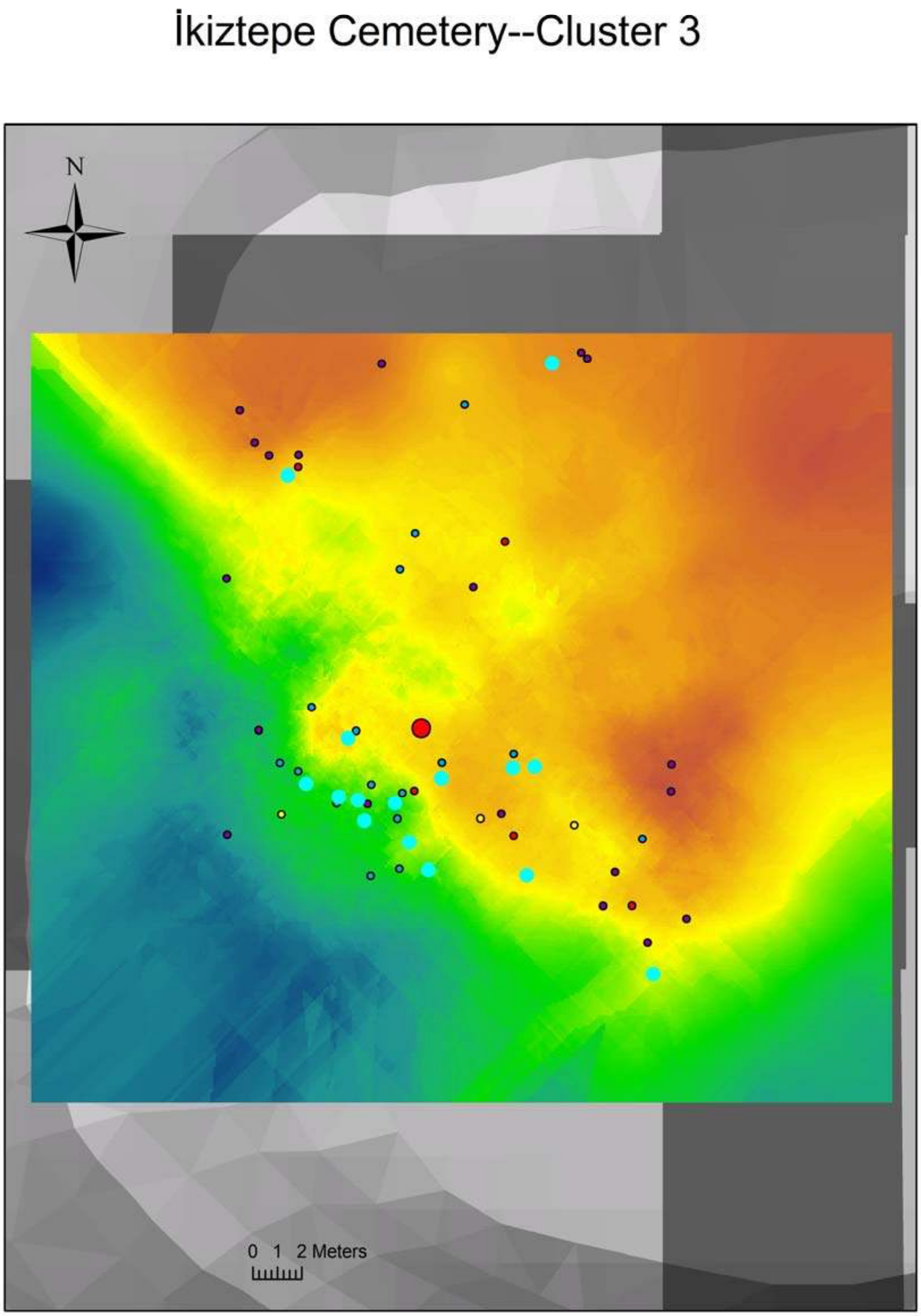
Map 4.2: İkiztepe Cemetery—Locations of Individuals in K-Means Cluster 1



Map 4.3: İkiztepe Cemetery— Locations of Individuals in K-Means Cluster 2



Map 4.4: İkiztepe Cemetery— Locations of Individuals in K-Means Cluster 3



Certain patterns are revealed in the results of the k-means analysis, if we interpret the results as being suggestive of potential lineage groups. First of all, individuals buried with high numbers of grave goods (i.e. 7+ items), are spread throughout all clusters (2 in Cluster 1, 1 in Cluster 2, 2 in Cluster 3). This would suggest that high numbers of grave goods do not appear to be directly linked to lineage affiliation. However, certain types of grave goods do appear to be potentially linked to certain lineage groups. For example, three of four graves containing quadruple or double spiral plaques identified by the excavators as idols were found in Cluster 3, the cluster with the fewest individuals (χ^2=5.268655, p=0.071767). The occurrence of cranial trauma among these groups displays no clear pattern, with one instance occurring in each group. The occurrence of non-standard burial positions among the groups was also examined. Given the extremely high frequency of dorsal burials, burials in other positions are quite rare and could be an intentional differentiation of individuals. Cluster 1 has 3 individuals buried in non-standard positions, Cluster 2 has 4 individuals in non-dorsal positions, and Cluster 3 has only 1 individual (χ^2 = 1.662515, p = 0.167864). There is thus a slight trend toward differential occurrence of non-standard burial practices in the various clusters, although it is not statistically significant; it should be noted, however, that there are high numbers of burials with unknown burial positions. There are no clear patterns in terms of which non-standard burial practices occur in which clusters.

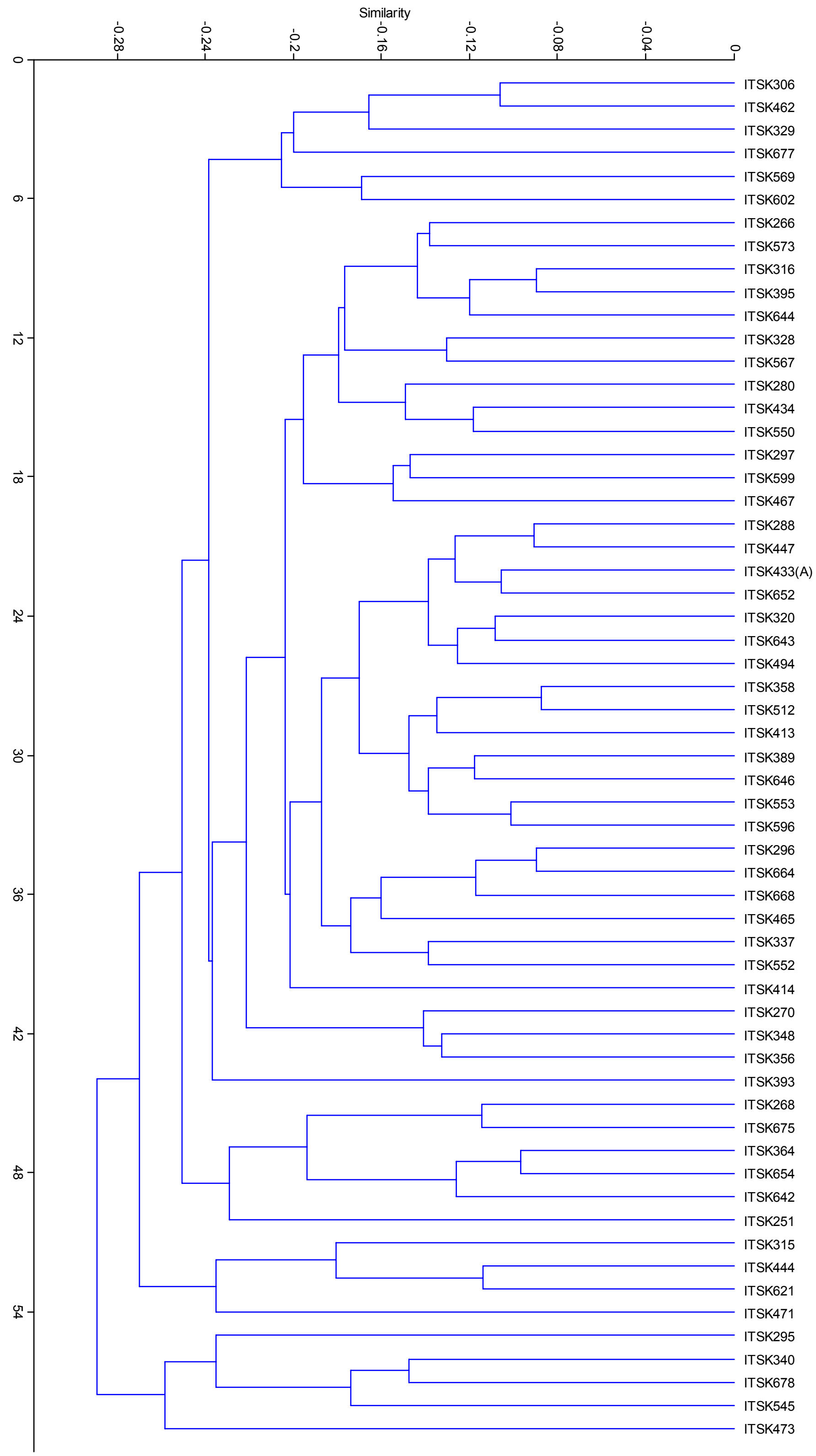
There appears to be minimal spatial patterning in the locations of the burials in each cluster. Both Cluster 1 and Cluster 2 have burials that are dispersed throughout the cemetery. However, they display different patterns. For Cluster 1, outliers from the general cluster formed by the lineage group are almost exclusively women who, it may be postulated, could have been interred with their husband's family. For Cluster 2, however, many of the outlying individuals are men.

Cluster 3, in contrast to the other two groups, displays a much greater degree of spatial clustering. Cluster 3 is highly clustered in the same area of the cemetery in which individuals with high numbers of grave goods are clustered. There are fewer spatial outliers in this cluster than observed in either of the other groups; however, as seen in Cluster 2, these are often men rather than predominantly women. It is clear from the maps of burial locations in each cluster that lineage groups are not placed in clearly segregated areas of the cemetery, as there is almost complete overlap in the spatial territories of burials associated with each group.

Cluster Analysis

The results of the cluster analysis are presented in **Figure 4.1: Dendrogram of Provenienced Craniometric Samples.** The first group of outliers that is separated from the remainder of the population includes 5 individuals (ITSK295, ITSK340, ITSK678, ITSK545, ITSK473). From this group, two of the individuals split off as outliers (ITSK 473 and ITSK295). The remainder form a small related group of individuals. Following this, a second small group of related individuals splits off from the main population (ITSK315, ITSK444, ITSK621 and ITSK471). Of this group, ITSK471 and ITSK315 split off as outliers, leaving the remaining two individuals as a closely related pair. These first two groups to split off from the main population form the majority of the individuals in Cluster 3 from the k-means analysis. A third related group then splits off from the main population (ITSK268, ITSK675, ITSK364, ITSK654, ITSK642 and ITSK251). From this group, a single individual splits off as an outlier (ITSK251), leaving two smaller groups of related individuals. All of the individuals in this group are from Cluster 1 in the k-means analysis. A fourth group that splits off from the main population includes 6 individuals (ITSK306, ITSK462, ITSK329, ITSK677, ITSK569, ITSK602). This group is then further broken down into smaller pairs of more closely related individuals. Most of the individuals in this group form part of Cluster 3 from the k-means analysis, although one individual in this group falls into each of Cluster 1 and Cluster 2. Following this, a small number of individuals split off as outliers (including ITSK393, a small group containing ITSK270, ITSK348 and ITSK356, and finally ITSK414). These individuals are split between the clusters provided by the k-means analysis.

Figure 4.1: Dendrogram of Provenienced Craniometric Samples



Once these groups have been split off from the population as a whole, the main part of the group is broken down into two basic sub-groups, both of which are broken down further into smaller related groups of individuals. The first and largest of these two groups is primarily composed of individuals who were part of Cluster 2 in the k-means analysis, although a couple of individuals from each of Clusters 1 and 3 are present. The second group is primarily composed of individuals from Cluster 1, although two individuals from Cluster 2 are present.

In general, the results of the cluster analysis suggest that quadruple and double spiral plaques may be less clustered within a particular family group than suggested by the k-means analysis. Three of the four individuals who had these plaques in their graves are found in the outlying groups who split off from the main population (these are the three individuals who were found in Cluster 3 in the k-means analysis). Non-local individuals are spread throughout all of the family groups suggested by the cluster analysis, rather than being clustered in one particular part of the dendrogram. The graves of women buried with weaponry are clustered within the main part of the population, rather than in the offshoot populations, but are spread throughout these two main groups forming the bulk of the main population at the site. The richest graves, as determined by taking into account the averages of the burial period (i.e. including individuals with 3-4 grave goods during the later part of the cemetery, where there are much fewer grave goods) are predominantly clustered in the main part of the population, although rich graves are not absent from the offshoot groups. Within the two main population groups, the richest graves tend to be highly clustered within particular branches of closely related individuals. This may suggest that displays of wealth in burial practices were limited to particular nuclear family groups, rather than to lineages as a whole. Non-standard burial positions (i.e. non-dorsal burials) were predominantly concentrated in one of the population groups within the main bulk of the population. However, it appears that these non-dorsal burials often occur in pairs of closely related individuals. The significance of this pattern, however, is not clear.

Principal Coordinates Analysis

The results of principal coordinates analysis performed on the biological distance matrix constructed from the z-transformed craniometric data are presented in the figures below.

Figure 4.2: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 2, Grouped by Sex
(red cross=female, blue square=male, black dot=unknown sex)

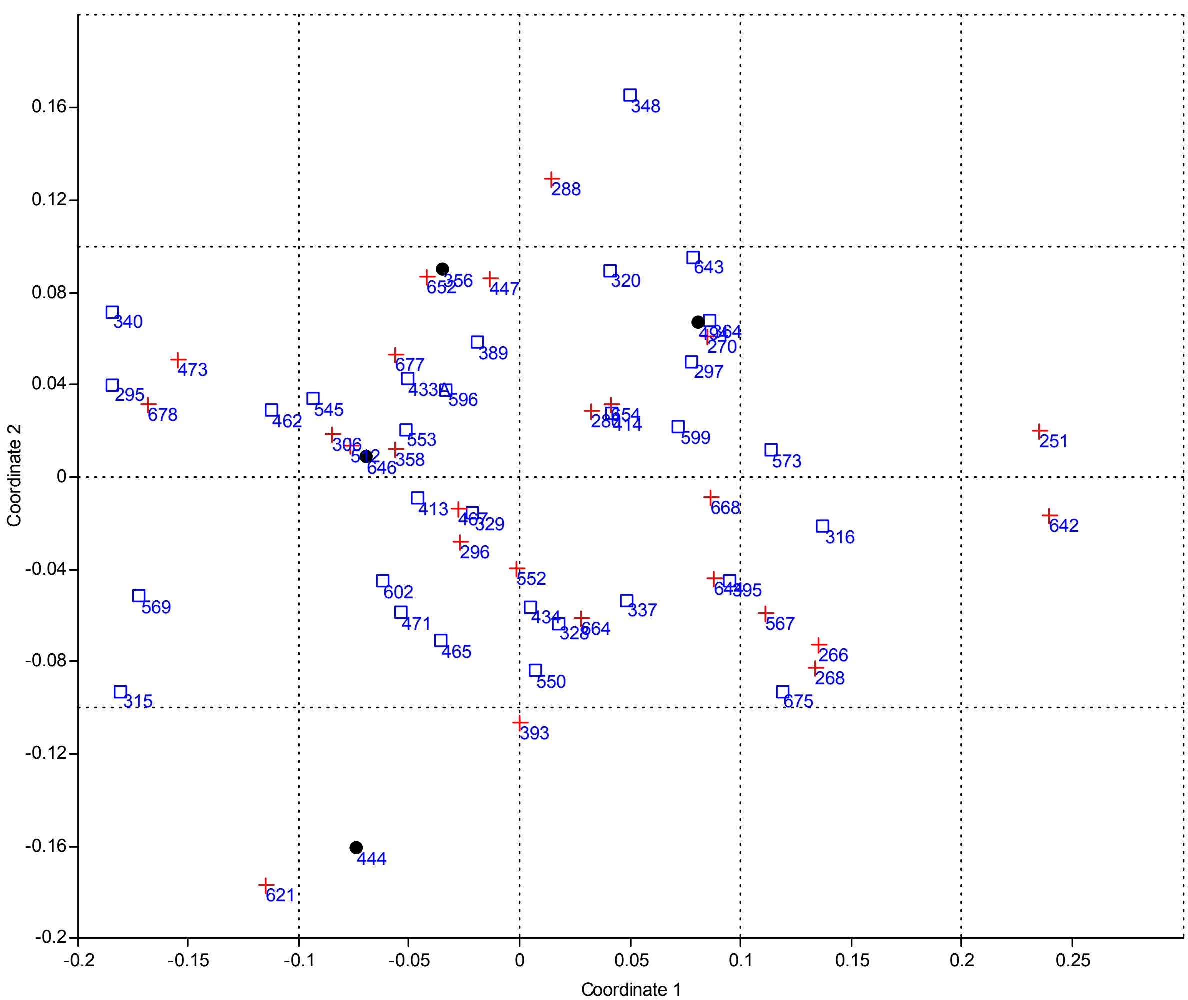


Figure 4.3: Principal Coordinates Analysis—Coordinate 2 vs. Coordinate 3, Grouped by Sex
(red cross=female, blue square=male, black dot=unknown sex)

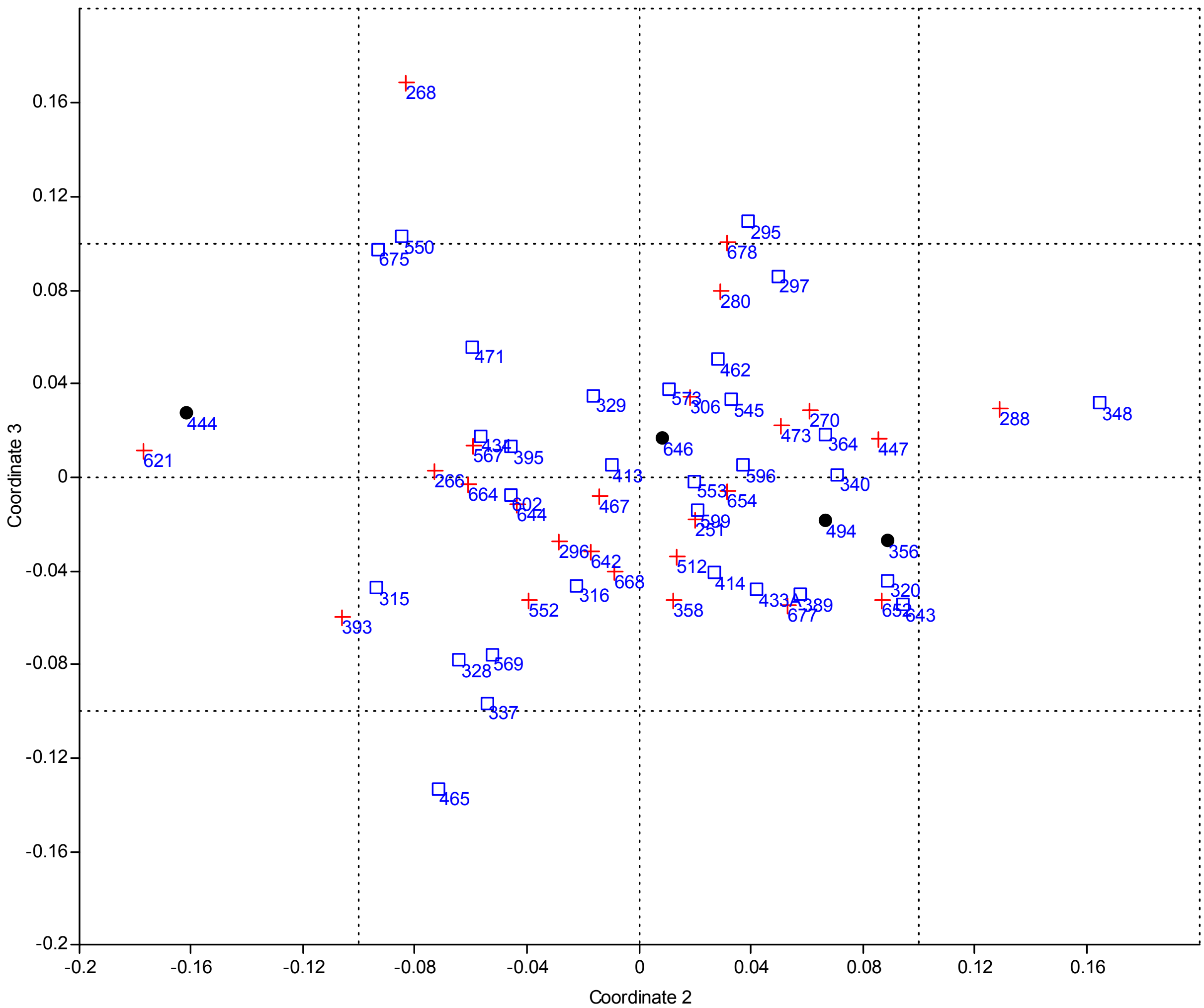
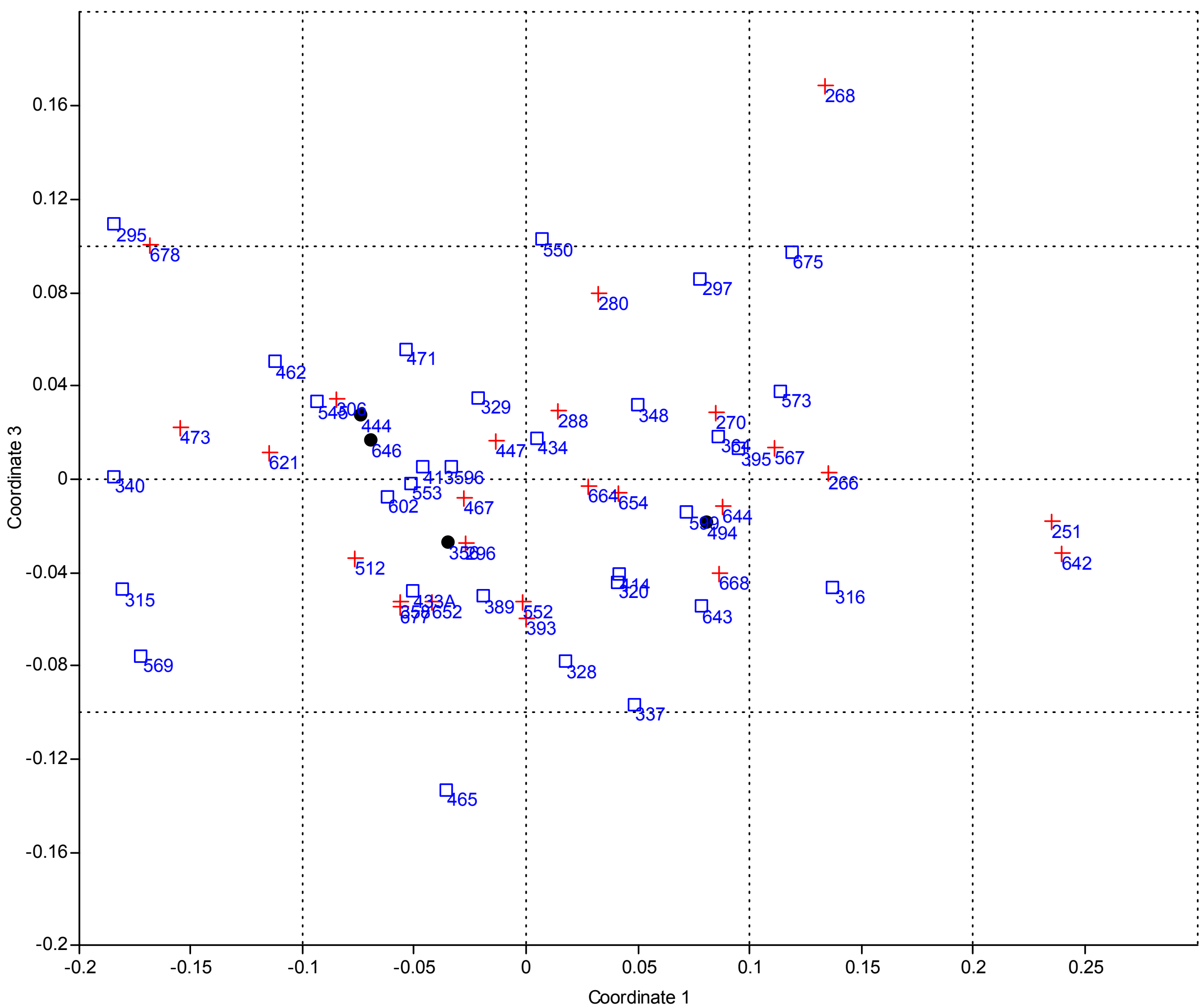


Figure 4.4: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 3, Grouped by Sex
(red cross=female, blue square=male, black dot=unknown sex)



These results suggest a reasonable degree of clustering for the majority of the population, along with a number of individuals who may be considered phenotypic, and thus potentially genotypic, outliers among the analyzed population. The characteristics of these outliers are displayed in the table below.

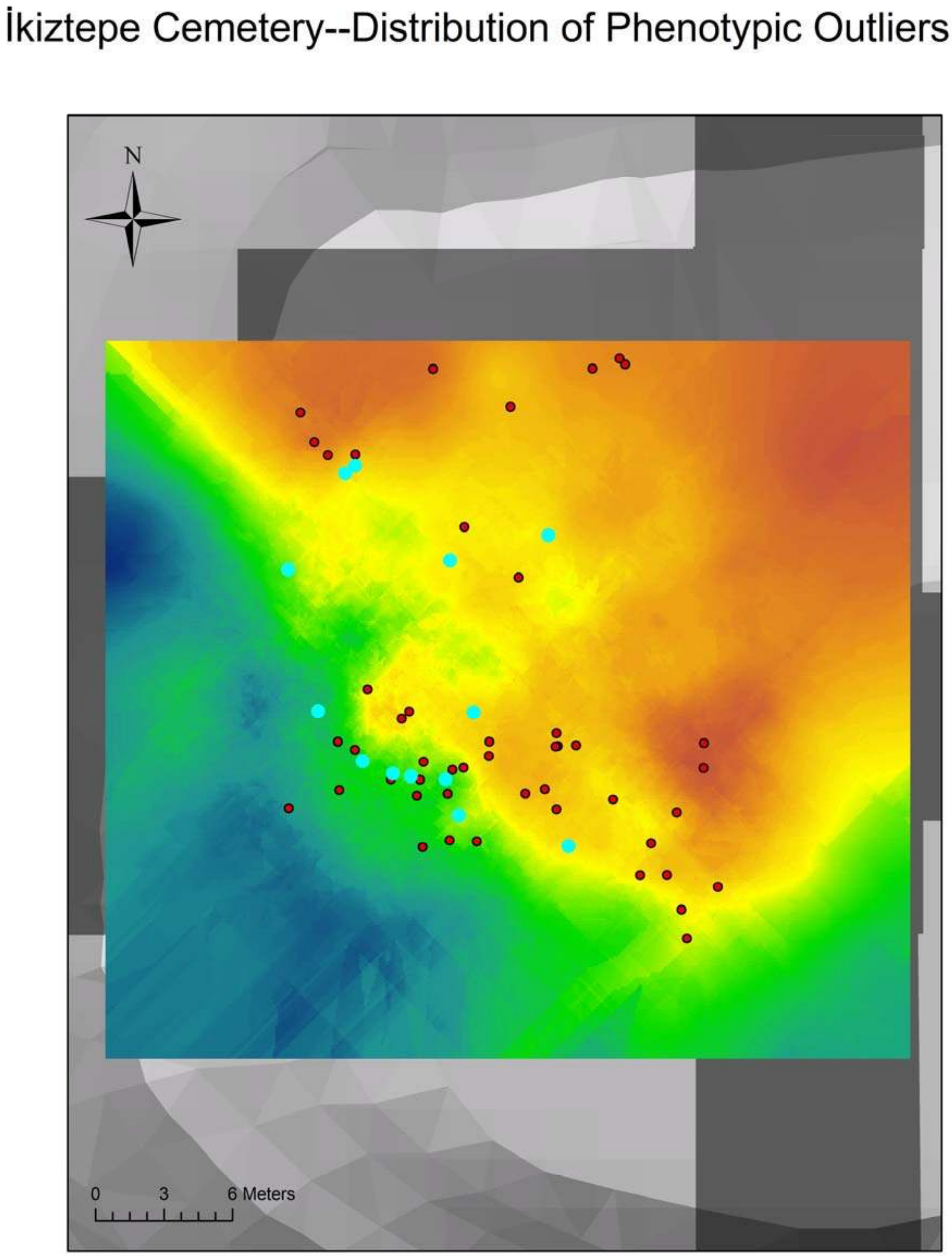
Table 4.20: Characteristics of Phenotypic Outliers

Sk No.	**Sex**	**Age**	**Head Direction**	**Body Position**	**Grave Goods**
ITSK251	Female	Older (UWB)/Middle (YSE) Adult	South	Dorsal	None
ITSK268	Female	Young (UWB)/Middle (YSE) Adult	North	Unknown	None
ITSK288	Female	Older (UWB)/ Middle (YSE) Adult	West	Left	None
ITSK295	Unknown/Male	Older (UWB)/Middle (YSE) Adult	Unknown	Unknown	None
ITSK315	Unknown/Male	Older (UWB)/Middle (YSE) Adult	Unknown	Unknown	None
ITSK340	Male	Older Adult	South	Dorsal	1 cutter, 1 stone pendant
ITSK348	Unknown/Male	Young Adult	South	Right	None
ITSK444	Female	Young Adult	East	Dorsal	2 earrings
ITSK465	Male	Older (UWB)/Middle (YSE) Adult	West	Dorsal	7 total: 1 spearhead, 1 frit necklace, 3 earrings, 2 bracelets
ITSK473	Female	Young (UWB)/Middle (YSE) Adult	Northwest	Dorsal	1 necklace, 2 earrings
ITSK569	Male	Older Adult **Note: unhealed trauma*	Southeast	Dorsal	11 total: 2 spearheads, 1 dagger, 1 spearhead, 1 harpoon, 1 earring, 2 bracelets, 1 silver pendant, 1 horned plaque
ITSK642	Female	Unknown (UWB)/Young (YSE) Adult	Unknown	Unknown	None

ITSK678	Unknown/Female	Unknown/Middle Adult	Unknown	Unknown	Unknown

There is no clear pattern in the sex of these outlying individuals, with seven females and six males identified as possible genetic outliers. This mirrors the patterns observed in the figures above, which demonstrate no clear patterns with regard to sex. Individuals from a variety of age groups at death are found in this group, from younger adults to older adults, with no pattern immediately observable. A variety of burial directions and burial positions are also represented. One individual was buried in a position turned to the right (ITSK348) and one turned to the left, (ITSK288), but the remainder of the group whose burial positions were known were buried dorsally. There is thus no evidence for differentiation in burial positions among individuals who can be considered to be genetic outliers in the population. Interestingly, seven of the individuals in this group were buried with no grave goods, a further two individuals have only two grave good items. This suggests a trend toward decreased grave goods among those who are genetic outliers, but this pattern is only tentative. Two individuals (ITSK465 and ITSK569), both males, were buried with high numbers of grave goods, including weaponry. One of these individuals (ITSK569) also displayed evidence for unhealed cranial trauma. There is a great deal of correlation between the individuals identified as outliers by the principal coordinates analysis and those identified by cluster analysis. The individuals in the chart above predominantly represent those in the first three clusters that split off from the majority of the population in the cluster analysis, although the correspondence is not perfect (ITSK364, ITSK471, ITSK545, ITSK654 and ITSK675 were identified by cluster analysis as outliers in one of these three clusters but not by principal coordinates analysis; ITSK288, ITSK348, ITSK465 and ITSK569 were identified as outliers by principal coordinates analysis but not by cluster analysis).

Map 4.5: İkiztepe Cemetery—Distribution of Individuals Identified as Phenotypic Outliers by Principal Coordinates Analysis



Map 4.5: İkiztepe Cemetery—Distribution of Individuals Identified as Phenotypic Outliers by Principal Coordinates Analysis displays the spatial distribution of these outlying individuals. There appears to be a concentration of these individuals in the central area of the cemetery, in the same location in which individuals with high numbers of grave goods were concentrated. A secondary group, however, is found further to the north; this group consists primarily of females (ITSK251, ITSK268, ITSK642, ITSK678, but also one unknown/male ITSK348). These individuals also include four of the seven individuals with no grave goods, and one individual whose grave goods are unknown. All of the outlying individuals who were buried with grave goods are buried in the central portion of the cemetery. Interestingly, of these individuals, both of the two males with high numbers of grave goods were buried at the lowest elevations, while individuals with lower numbers of grave goods were buried on the slope of the hill.

Matrix Correlation Results

The results of the MANTEL tests to look for correlations between the biological and spatial distance matrices are presented in the tables below.

Table 4.21: Results of MANTEL Test for All Individuals (using 2-dimensional spatial distance)

Observed Z	867097.24482
Correlation	0.01493
T	0.21687
Left-tailed p	0.58584
Right-tailed p	**0.41416**
Two-tailed p	0.82831

Table 4.22: Results of Permutations for MANTEL Test with 2-dimensional Spatial Distance (999 Permutations)

# of Permutations < Observed	598
# of Permutations > Observed	401
# of Permutations = Observed	1
Left-tailed p	0.59900

Right-tailed p	**0.40200**

Table 4.23: Results of MANTEL Test for All Individuals (using 3-dimensional spatial distance)

Observed Z	881758.58857
Correlation	0.01571
T	0.22860
Left-tailed p	0.59041
Right-tailed p	**0.40959**
Two-tailed p	0.81918

Table 4.24: Results of Permutations for MANTEL Test with 3-dimensional Spatial Distance (999 Permutations)

# of Permutations < Observed	596
# of Permutations > Observed	403
# of Permutations = Observed	1
Left-tailed p	0.59700
Right-tailed p	**0.40400**

Table 4.25: Results of Partial MANTEL Tests

	Partial with TimeRank and Phys2D	**Partial with TimeRank and Phys3D**	**Partial with TimeConc and Phys2D**	**Partial with TimeConc and Phys3D**
Observed Z	601.62388	811.16783	535.36080	743.19243
Correlation	0.00380	0.00521	0.00339	0.00480
T	0.05152	0.07107	0.04661	0.06628
Left-tailed p	0.52054	0.52833	0.51859	0.52642
Right-tailed p	0.47946	0.47167	0.48141	0.47358
Two-tailed p	0.95891	0.94334	0.96283	0.94716
# of Permutations < Observed	529	563	522	528
# of Permutations > Observed	470	436	477	471
# of Permutations = Observed	1	1	1	1
Left-tailed p	0.53000	0.56400	0.52300	0.52900

Right-tailed p	0.47100	0.43700	0.47800	0.47200

The results of these Mantel tests indicate that there is no evidence for a correlation between biological distance and spatial distance. This suggests one of two potential interpretations. The first possibility is that there is no evidence for kin-structured burial in the cemetery at İkiztepe. Alternatively, it may suggest that the presence of multiple lineages in the cemetery is obscuring the relationship between biological and spatial distance, leading to a non-significant p-value for the Mantel result. There is little difference between the results produced using two-dimensional and three-dimensional measures of spatial distance. The use of the time matrices as a means of controlling for the effects of time on the relationship between physical and biological distance did not have a significant effect on the results observed with the regular Mantel test. The partial Mantel tests, in these cases, tended to make the results of the original Mantel tests slightly less statistically significant, compared to those tests where time was not accounted for.

In order to look for differential burial practices in males and females in terms of correlations between biological and spatial distance matrices, males and females were divided into separate matrices and the Mantel tests were run again. The results of the Mantel tests for males and females are presented in the following tables.

Table 4.26: Results of MANTEL Tests for Males

	2D Physical Distance	**3D Physical Distance**	**Partial with TimeRank and Phys2D**	**Partial with TimeRank and Phys3D**	**Partial with TimeConc and Phys2D**	**Partial with TimeConc and Phys3D**
Observed Z	126796.10235	127789.63143	-382.93286	-368.47373	-385.61172	-368.83175
Correlation	-0.02983	-0.02879	-0.02805	-0.02711	-0.02827	-0.02717
T	-0.22330	-0.21398	-0.21001	-0.20150	-0.21364	-0.20388
Left-tailed p	0.41165	0.41528	0.41683	0.42015	0.41541	0.41922
Right-	0.58835	0.58472	0.58317	0.57985	0.58459	0.58078

tailed p						
Two-tailed p	0.82331	0.83056	0.83366	0.84031	0.83083	0.833845
# of Permutations < Observed	429	421	420	430	427	426
# of Permutations > Observed	570	578	579	569	572	573
# of Permutations = Observed	1	1	1	1	1	1
Left-tailed p	0.43000	0.42200	0.42100	0.43100	0.42800	0.42700
Right-tailed p	0.571000	0.57900	0.58000	0.57000	0.57300	0.57400

Table 4.27: Results of MANTEL Tests for Females

	2D Physical Distance	3D Physical Distance	Partial with TimeRank and Phys2D	Partial with TimeRank and Phys3D	Partial with TimeConc and Phys2D	Partial with TimeConc and Phys3D
Observed Z	98396.11946	100638.93999	475.69748	622.19595	444.51241	592.41250
Correlation	0.02792	0.03986	0.03553	0.04770	0.03327	0.04552
T	0.21179	0.30476	0.27751	0.37572	0.25838	0.35694
Left-tailed p	0.58386	0.61972	0.60931	0.64644	0.60194	0.63943
Right-tailed p	0.41614	0.38028	0.39069	0.35356	0.39806	0.36057
Two-tailed p	0.83227	0.76055	0.78139	0.70712	0.79611	0.72114
# of Permutations < Observed	588	617	608	640	594	648
# of Permutations > Observed	411	382	391	359	405	351
# of Permutations = Observed	1	1	1	1	1	1
Left-tailed	0.58900	0.61800	0.60900	0.64100	0.59500	0.64900

p						
Right-tailed p	0.41200	0.38300	0.39200	0.36000	0.40600	0.35200

The results of these tests indicate similar patterns to those observed for the population as a whole. There is no clear correlation between biological distance and spatial distance within the male or the female population. Females maintain a positive correlation between the two distance matrices, while males demonstrate a negative correlation between the matrices. Neither of these correlations are significant, however.

One possible interpretation of these results is that the Mantel test is not powerful enough to detect correlations between the distance matrices due to the presence of multiple lineage groups in the cemetery obscuring a pattern of kin-structured burial. As a result, the population was divided into three groups according to the results of the k-means analysis described above, and the MANTEL tests were run again.

Table 4.28: Results of MANTEL Tests for Cluster 1

	2D Physical Distance	**3D Physical Distance**
Observed Z	182865.55651	186047.67320
Correlation	0.12634	0.12582
T	1.33691	1.33897
Left-tailed p	0.90937	0.90971
Right-tailed p	**0.09063**	**0.09029**
Two-tailed p	0.18125	0.18058
# of Permutations < Observed	911	904
# of Permutations > Observed	88	95
# of Permutations = Observed	1	1
Left-tailed p	0.91200	0.90500

Right-tailed p	**0.08900**	**0.09600**

Table 4.29: Results of MANTEL Tests for Cluster 2

	2D Physical Distance	**3D Physical Distance**
Observed Z	92234.09406	93151.92453
Correlation	0.02320	0.02776
T	0.21091	0.25061
Left-tailed p	0.58352	0.59894
Right-tailed p	0.41648	0.40106
Two-tailed p	0.83296	0.80212
# of Permutations < Observed	542	566
# of Permutations > Observed	457	433
# of Permutations = Observed	1	1
Left-tailed p	0.54300	0.56700
Right-tailed p	0.45800	0.43400

Table 4.30: Results of MANTEL Tests for Cluster 3

	2D Physical Distance	**3D Physical Distance**
Observed Z	43944.82682	45603.62339
Correlation	0.03964	0.04043
T	0.25607	0.26125
Left-tailed p	0.60105	0.60305
Right-tailed p	0.39895	0.39695
Two-tailed p	0.79790	0.79390
# of Permutations < Observed	568	583
# of	431	416

Permutations > Observed		
# of Permutations = Observed	1	1
Left-tailed p	0.56900	0.58400
Right-tailed p	0.43200	0.41700

In general, once again, there is no clear trend toward a correlation in between biological and spatial distance that would indicate a trend toward kin-structured burial within the various lineage groups. Both Cluster 2 and Cluster 3 demonstrate similar matrix correlation values to those observed in the overall population. In contrast, Cluster 1 does demonstrate a trend toward kin-structured burial within the cluster; this result is not significant at the $\alpha=0.05$ level, but is significant at $\alpha=0.1$. This suggests that there *may* be different burial patterns within different lineage groups, although the majority of the lineage groups appear to demonstrate no clear kinship-related structuring of burial practices.

Conclusions

This chapter presents the results of intra-cemetery craniometric analysis on the İkiztepe cemetery. Craniometric data was collected for a total of 102 individuals on 15 variables. Of these 102 individuals, 64 were of known provenience and 38 were unprovenienced; there were 39 males, 46 females and 17 individuals of unknown sex. Three variables were removed from consideration due to high numbers of blank values, leaving only twelve variables that were included in the analysis. Tests of normality for these twelve variables suggest that many of them demonstrate significantly non-normal distributions.

Methods employed to examine differences in variability between males and females included univariate Levene's tests, as well as multivariate determinant ratio analysis and a Van Valen's test. These tests all demonstrated a very close relationship between the variability in males and females. None of the univariate tests indicate significant differences in variance between the sexes. The determinant ratio analysis suggested a slight trend toward increased variability in males compared to females, but this result was not statistically significant (p=0.17). The Van Valen's test, however, suggested the opposite, indicating very slightly higher variability in females. Neither of these results suggests a clear pattern of matrilocal or patrilocal post-marital residence with exogamous marriage. Instead, these results may suggest a pattern of endogamous marriage within the İkiztepe society or alternatively equal immigration of male and female individuals for the purposes of intermarriage.

Both matrix decomposition and finite mixture analyses suggest the existence of three lineage groups within the İkiztepe population. K-means analysis was thus conducted to identify three clusters within the population; these clusters were then interpreted in terms of the possibility that they may represent these lineage groups. This k-means analysis indicated that individuals with the highest numbers of grave goods were distributed among all lineage groups, suggesting that rich graves are not limited to particular lineages within the population. They also suggested that the occurrence of double and quadruple spiral idols *may* be linked to lineage affiliation (three of four individuals buried with these idols were found in one particularly cluster, p=0.07). There are few clear patterns in the distribution of these clusters within the cemetery. Only Cluster 3 demonstrates any clear spatial clustering, with its burials being found predominantly within the central part of the cemetery, with few outliers. This cluster is found in the same area of the cemetery in which individuals with high numbers of grave goods are concentrated. Clusters 1 and 2 are much more dispersed throughout the cemetery, but with slightly different patterns. The clearest spatial outliers among the burials in Cluster 1 belong to females, who could possibly have been buried with their husband's family, rather than with their own relatives. However, this pattern is not observed in Cluster 2, where many of the spatial outliers represent the burials of men.

Cluster analysis provided a slightly different point of view to that obtained by k-means analysis. The results of cluster analysis suggested a less significant relationship between individuals buried with double or quadruple spiral idols than observed in the k-means analysis. Furthermore, the results suggest that individuals buried in non-standard positions (i.e. positions other than dorsal) fall predominantly within the core portion of the population, rather than among the phenotypic (and thus presumably genetic) outliers. Similarly, the majority of the richest graves seem to fall within the same core portion of the population, rather than among the outlying individuals.

Principal coordinates analysis indicated a variety of phenotypic outliers to the remainder of the general population. These outliers tended to have low numbers of grave goods; the majority of these individuals were buried with no grave goods. Two males within this group, however, had high numbers of grave goods and were identified by Bilgi as "distinguished" burials (2005). Interestingly, the outliers identified by principal coordinates analysis were found to demonstrate a tendency toward burial in the centre of the cemetery; this included the two "distinguished" burials, as well as individuals buried with grave goods. Some individuals were found outside of this central area; these individuals were more likely to be those with no grave goods. In general, good correspondence was found between the phenotypic outliers identified by cluster analysis and those identified by principal coordinates analysis.

Mantel tests were conducted in order to test for matrix correlations between the biological distances between individuals and the physical distances between their graves. These tests are used to detect patterns of kin-structured burial within the cemetery. No significant correlations were found to indicate that the population as a whole practiced kin-structured burial, nor was there any evidence to suggest that kin-structured burial was practiced among either sex differentially. Stojanowski (2003) suggests that Mantel tests may not be robust enough to detect kin-structured burial where different lineages are utilizing the same burial ground, with overlapping spatial areas. Thus, Mantel tests were also performed on the potential lineage groups to look for kin structured patterns of burial within particular lineage groups. Of the three lineage groups, matrix correlations were only found to be significant for one group. For Clusters 2 and 3, no evidence was detected for kin-structured burial. For Cluster 1, there is evidence for kin-structure burial that is significant at a level of α=0.1. With the possible exception of this particular lineage group, there is no evidence to suggest that the İkiztepe population practiced kin-structured burial. Thus, it seems likely that the İkiztepe cemetery is organized around other principles and criteria.

Our understanding of biological relationships within the İkiztepe population would be greatly augmented by the study of non-metric traits and/or dental metric data to complement the cranial metric data already collected. Furthermore, the understanding of population structure, gene flow and migration practices could be increased by the continuation of such biodistance studies on other Anatolian populations. The need for such research stresses the importance of studies that examine biodistance from the point of view of intra-population variability, rather than focusing on population means as a method of describing and explaining population movements.

Chapter Five: Theory and Application of Oxygen and Strontium Isotope Analyses

Archaeological Applications of Isotope Analysis

The use of stable isotope analysis of bone and enamel samples has a relatively long history in archaeological research. Originally, this type of analysis was applied mainly to palaeodiet reconstruction, and focused primarily on the use of carbon, nitrogen and oxygen isotopes for this purpose (i.e. see Schwarcz & Schoeninger 1991). In these contexts, oxygen isotope analyses were applied particularly to questions about weaning practices (Wright & Schwarcz 1998, White *et al* 2004, Dupras & Tocheri 2007, Lösch *et al* 2006). Although not as commonly employed, sulphur isotopes have also been applied to palaeodiet studies (Privat *et al* 2007). More recently, other archaeological applications of stable isotope research have been examined more thoroughly. These include palaeoenvironmental, palaeoclimatic and seasonality studies (D'Angela & Longinelli 1993; Kennett & Voorhies 1996, Davis & Muehlenbachs 2001, Mannino *et al* 2003, Mannino *et al* 2007, Iacumin *et al* 2004, Stephens *et al* 2008; Jones *et al* 2008; Peacock & Seltzer 2008). Such research has not been limited to analysis of human and animal tissues; studies have also looked at oxygen isotopes in maize cellulose to examine seasonal sources of water for cultivation (Williams *et al* 2005). Various types of isotopes, including strontium and lead, have been applied to provenience studies of various types of archaeological materials, including metals, glass and stone (glass: Freestone *et al* 2003, Henderson *et al* 2004, Henderson *et al* 2005, Degryse *et al* 2006, Leslie *et al* 2006, Degryse & Schneider 2008, salt: Hosono *et al* 2006; marble: Brilli *et al* 2005; metal: Degryse *et al* 2007; maize: Benson *et al* 2008). Other research aims to study the provenience of biological tissues (shell: VanHaeren *et al* 2004, Eerkens *et al* 2005; animal: Killingley 1980; Jahren *et al* 1998; Hobson 1999; Benson *et al* 2008, Dufour *et al* 2007). In animal studies, examinations of intraand inter-tooth variations in isotopic composition have been used to reconstruct mobility and herd movements, among archaeological domesticated species, as well as among ancient wild animal populations (i.e. Balasse *et al* 2002, Weidemann *et al* 1999, Meiggs 2009). Recently, these kinds of studies have also been applied to the relatively new field of wildlife forensics for the purpose of managing and tracking animal movements (i.e. Bowen *et al* 2005).

These kinds of isotope studies have also contributed significantly to the study of residential mobility in ancient human populations. In particular, two elements have received the greatest amount of attention in terms of their ability to address questions of human mobility: strontium and oxygen. Strontium has been used for this purpose in various wide-reaching geographical areas, including Crete (Nafplioti 2008), Greece (Richards *et al* 2008), the Nile Valley (Buzon *et al* 2007), Libya (Tafuri *et al* 2006), South America (Knudson *et al* 2004, Knudson *et al* 2005, Slovak 2007, Knudson & Price 2007), Central Europe (Hoogewerff *et al* 2001, Price *et al* 2002, Bentley *et al* 2002, Chiaradia *et al* 2003, Schweissing & Grupe 2003, Bentley *et al* 2003, Bentley *et al* 2004b, Bentley & Knipper 2005), Iceland (Price & Gestsdottir 2006), southeast Asia (Bentley *et al* 2007, Bentley *et al* 2007b, Valentine *et al* 2008), the United States (Price *et al* 1994, Ezzo *et al* 1997, Ezzo & Price 2002, Quinn *et al* 2008), Mexico (Price *et al* 2000, Hodell *et al* 2004, Price *et al* 2006), Siberia (Havercort *et al* 2008), and England (Montgomery *et al* 2005, Evans *et al* 2006, Evans *et al* 2006b). Oxygen isotopes have been used less widely, but have been applied to human populations primarily in the Valley of Oaxaca and Teotihuacan (White *et al* 1998, White *et al* 2001, White *et al* 2002), the Dakhleh Oasis in Egypt (Dupras & Schwarcz 2001) and Southern Ontario (Schwarcz *et al* 1991). There have also been a number of studies that apply both types of analysis, providing a complementary approach to human mobility studies (Budd *et al* 2004; Bentley & Knipper 2005, Bentley *et al* 2005, Evans *et al*

2006, Evans *et al* 2006b, Knudson & Price 2007, Slovak 2007, Quinn *et al* 2008). Lead isotopes have also been used for the purpose of examining prehistoric migration, but their fairly low variation over moderately-sized geographical areas results in decreased sensitivity compared to oxygen and strontium isotope analyses (Bentley 2001). Nitrogen isotopes have also been used to examine human mobility patterns, as populations living in arid regions display elevated nitrogen isotope values (Dupras & Schwarcz 2001; based on: Ambrose & DeNiro 1986; Sealy *et al* 1987; Schwarcz *et al* 1999; Dupras *et al* 2001; Dupras & Schwarcz 2001).

Basic Principles of Mass Spectrometry

Isotope ratios are calculated using mass spectrometry, a process known as Isotope Ratio Mass Spectrometry (IRMS). The basic principle of mass spectrometry is that the movement of charged ions is governed by their mass (or, more accurately, based on their mass-to-charge ratio) (Pollard 2007). A mass spectrometer thus separates these charged ions based on mass-to-charge ratio in order to determine the composition of the substance undergoing analysis. A mass spectrometer essentially consists of three parts: the ion source, the mass analyzer and the detector/collector. The ion source generates a stream of charged particles and focuses them into a beam that travels into the mass analyzer. Various kinds of ionizing technologies may be used, such as inductively-coupled plasma (in ICP-MS), an accelerator (AMS) or thermal ionization (TIMS). The mass analyzer separates this single stream of particles on the basis of their mass-to charge ratios. In the most common type of mass spectrometer, the sector type, this is accomplished by bending the stream of particles differentially based on the mass-to-charge ratio, with the faster and lighter ions bending more. The detector/collector then measures the particles of each mass-to-charge group. Based on the type of methodology used, machines may be either solid source (samples are atomized or vaporized prior to ionization) or gas source (samples are reacted to produce a gas). Measurements of radiogenic and heavier isotopes are generally made using a solid source machine (i.e. Sr, Pb, often performed using TIMS) (Pollard 2007). Lighter stable isotopes are generally measured using a gas source machine (i.e. H, C, N, O, S) (Pollard 2007). Many machines that measure isotope ratios have a dual inlet, which allows rapid alternation between the sample and a reference substance, allowing calibration of the results. More discussion of various methods of IRMS, including their benefits and drawbacks for particular applications, will be discussed in the relevant sections below.

The Formation and Composition of Human Bone and Enamel

Archaeological applications of stable isotope analysis have focused on the analysis of bone, enamel and dentine. While these tissues display similarities in chemical composition, they vary according to differences in organic content and crystal structure. Both bone and dentine are relatively porous, and contain approximately 25-30% organic material by weight (Hillson 2005: 184). The inorganic portion of these tissues is composed of small, highly reactive crystals of hydroxyapatite (Hillson 2005: 184). In contrast, enamel is composed of larger crystals, and is much less porous with very little intercrystalline space (<= 2%) (Wang & Cerling 1994: 282; Hillson 2005: 155; Dufour *et al* 2007: 1229). It also contains a much higher relative proportion of inorganic material than bone or dentine, at around 96% (Hillson 2005: 155). This composition, however, depends somewhat on the maturity of the enamel. The process of the production of enamel is known as amelogenesis, and consists of two principal parts: matrix formation and maturation. During the matrix formation stage, enamel consists of an organic matrix with inorganic components known as crystallites; at this time enamel is approximately 1/3 protein, 1/3 mineral and 1/3 water (Hillson 2005: 155). During the maturation stage, water and protein are removed to increase the inorganic mineral portion, and crystal size becomes larger (Hillson 2005: 155).

Of major concern in the archaeological study of the chemical composition or other properties of these tissues is diagenesis, which involves chemical and/or structural changes that occur *post-mortem* in the depositional environment. The types of diagenetic changes that occur, as well as the resulting changes to human tissues such as bone and enamel, vary depending on soil type, temperature, moisture content, acidity and chemical composition, among a number of other factors (for an broad overview of changes associated with diagenetic processes and factors contributing to them, see Hedges 2002). A major trend in diagenetic change is toward dissolution and recrystallization of hydroxyapatite, which may introduce contamination through chemical exchange with ions originating from the surrounding matrix. Precipitation of secondary minerals and/or the adsorption of ions from the burial environment onto the surface of the hydroxyapatite crystals and subsequent diffusion into the matrix of the crystal may also occur (Dufour *et al* 2007: 1228-1229). Such changes are more frequently observed in tissues that have greater porosity and thus, permeability. Thus, the propensity for diagenetic changes is not only different in different tissues (i.e. enamel vs. bone), but also in different bone types (trabecular vs. cortical), different skeletal elements, and in bones of adults vs. juveniles, all of which display variation in levels of porosity (Robinson *et al* 2003). The low porosity of enamel causes much lower permeability in this tissue, and decreases its susceptibility to chemical changes relating to diagenetic fluids in the burial environment. Furthermore, tissues with small initial crystal size, such as bone and dentine, seem to be more susceptible to recrystallization of *post-mortem* hydroxyapatite than enamel due to their increased reactivity (Lee-Thorp 2002; Blake *et al* 2007). While enamel can by no means be assumed immune to diagenetic contamination, the effects of contamination are on an order of magnitude less than the predisposition of bone and dentine to post-mortem changes (Lee-Thorp 2002; Dufour *et al* 2007).

Stable isotope analysis of both oxygen and strontium in human tissues is generally conducted on biological apatite, similar in structure to hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) (Lee-Thorp 2002). The majority of the inorganic mineral portion of bones and teeth consists of hydroxyapatite, but it rarely occurs in a pure form (Hillson 2005: 146). Rather, biological apatites generally display a range of substitutions at a number of different loci within the molecule. The generic formula $Ca(Sr)_5(PO_4, CO_3, F)_3(OH, F, Cl, CO_3)$ can be used to describe biogenic apatite (Vennemann *et al* 2002: 322). While the calcium and phosphate portions may be replaced by the substitution of other elements, geologically, the most common substitution is of the hydroxide ion for fluorine (Hillson 2005: 146). In biogenic apatites, this substitution occurs most frequently *post-mortem* in the burial environment, with fluorine originating from the groundwater (although it can occur *in vivo* during tissue formation as well) (Hillson 2005: 147).

Carbonate (CO_3) occurs in two different forms within biogenic apatites: structural and labile. Labile carbonate does not occupy a well-defined position in the apatite crystal, but rather adheres to the surface of the apatite crystals; it is more easily dissolved and altered than structural carbonate (Lee-Thorp 2002: 436; Garvie-Lok *et al* 2004: 764). Structural carbonate is incorporated into the apatite crystal in two different positions, substituting for either the hydroxide (OH) or phosphate (PO_4) portions of apatite, locations known as the A and B lattice sites, respectively. (Garvie-Lok *et al* 2004: 764). Carbonates occurring in these positions behave differently both during life and during diagenesis (Sponheimer & Lee-Thorp 1999). Carbonate is most commonly found in the B lattice site (89%), substituting for phosphate, which means that the proportions of these two ions within biogenic apatites tend to vary inversely (Bryant *et al*

1996: 5146; Lee-Thorp 2002: 437). Their relative proportions vary depending on the type of tissue involved. In general, enamel apatite displays much fewer substitutions than observed in both bone and dentine (~3% substituted CO_3 compared to ~6% in bone) (Lee-Thorp 2002: 437).

Thus, oxygen is present in three different locations of the mineral (phosphate, carbonate and hydroxide), and of these, the phosphate (PO_4) and carbonate (CO_3) phases are those most often isolated for isotope analysis.

Oxygen

Oxygen Isotopic Chemistry

Oxygen has nine naturally occurring isotopes, with three isotopes of particular geological interest (^{16}O, ^{17}O, ^{18}O), whose relative frequencies are 99.759, 0.037 and 0.204 percent respectively (Faure & Mensing 2005). Oxygen isotope values are measured using the ratio of the two most abundant isotopes, and are expressed through comparison to a standard substance of known constant isotopic composition, using the following formula:

$$\delta^{18}O = (^{18}O/^{16}O_{sample} - {}^{18}O/^{16}O_{standard}) / {}^{18}O/^{16}O_{standard} \times 1000 ‰ \text{ VSMOW}$$

The standard used for this comparison is Vienna Standard Mean Ocean Water (VSMOW), which is a manufactured standard designed to be similar to the isotopic value of ocean water (Coplen 1996).

Geographical Patterns in Oxygen Isotopes

Most natural processes preferentially incorporate or affect one isotope of a particular element relative to another, a process known as fractionation. Fractionation occurs due to differences in the rates of reactions of different isotopes in relation to each other (Clark & Fritz 1997). In each step of the hydrological cycle (evaporation, condensation, precipitation, runoff, etc.), oxygen isotopes are partitioned due to fractionation. Fractionation causes patterns of geographic variation in the oxygen isotope values of meteoric water, variation that is governed primarily through the processes of evaporation and precipitation. Although ocean $\delta^{18}O$ values have been variable over geological time, the isotopic composition of modern ocean water is similar to the standard currently used in the expression of oxygen isotope values, VSMOW, which by definition has a $\delta^{18}O$ value of 0. In contrast, the average isotopic composition for global precipitation is estimated to be -4‰, and local precipitation composition varies significantly around this value in different geographical locations (Yurtsever & Gat 1981; Craig & Gordon 1965). The isotopic composition of local precipitation is controlled by geography and climate. In general, the local $^{18}O/^{16}O$ value of meteoric water decreases with distance from the sea, with elevation and with decreasing temperature (Yurtsever & Gat 1981, Luz *et al* 1984; Luz & Kolodny 1985; Clark & Fritz 1997; White *et al* 1998; Bowen & Wilkinson 2002; Bentley & Knipper 2005). The correlation between temperature and the $\delta^{18}O$ value of meteoric water is particularly strong (Yurtsever & Gat 1981, Rozanski *et al* 1993, Clark & Fritz 1997). As temperature decreases, local meteoric water becomes progressively more depleted in ^{18}O (Yurtsever & Gat 1981, Rozanski *et al* 1993; Clark & Fritz 1997). As a result of this relationship with temperature, there is a corresponding correlation between latitude and $\delta^{18}O$, as well as altitude and $\delta^{18}O$ (Clark & Fritz 1997). There are also continental effects on meteoric water isotopic composition, which result from relatively large seasonal variations in temperature in continental areas (Clark & Fritz 1997). In contrast, close proximity to maritime influences tends to moderate isotopic values (Clark & Fritz 1997). As a result, coastal precipitation tends to be more stable and more enriched in ^{18}O, while land-locked continental areas tend to be more ^{18}O-depleted, but show larger seasonal variations in isotopic composition of precipitation (Clark & Fritz 1997).

Biological tissues can act as a proxy for the recording of temperature and climatic information. Analysis of oxygen isotopes in collections of modern landsnail shells from locations throughout Europe shows that their isotopic compositions display similar geographic patterns to those observed in precipitation, and a high correlation with local precipitation $\delta^{18}O$ values in general (Lécolle 1985).

Oxygen Isotopes in the Human Body

The isotopic composition of the oxygen in phosphate (PO_4) and carbonate (CO_3) in biogenic apatites in the human body has been determined to be in equilibrium with the body's water pool (Luz *et al* 1984, Luz & Kolodny 1985, White *et al* 1998, Knudson & Price 2007). The average $\delta^{18}O$ value of the body's water pool is controlled by the various sources of oxygen entering and exiting the body. The primary sources of oxygen contributing to this average value are water imbibed, water contained within food consumed, water produced from the metabolism of food, and atmospheric oxygen (O_2) (Luz *et al* 1984; Luz & Kolodny 1985). Oxygen exits the body in the form of CO_2 and water vapour through exhalation, as well as through bodily waste products, such as sweat and urine. In general, the waste products that leave the body in the form of liquid are identical in isotopic composition to that of body water (Luz *et al* 1984; Luz & Kolodny 1985: 30; Luz & Kolodny 1989: 319; Kohn 1999: 4814; White *et al* 1998). In contrast, water vapour leaving the body is generally 8‰ depleted in ^{18}O with respect to body water, while oxygen in respiratory CO_2 is enriched by 38‰ (Luz & Kolodny 1985: 30; Luz & Kolodny 1989: 319; Kohn 1996: 4814).

Of the sources of oxygen entering the body, water consumed generally appears to have the most significant effect on the isotopic composition of the body's tissues. This may, however, vary according to species, particularly with species that are not obligate drinkers, or which derive the majority of their water intake from plant consumption (Kohn 1996: 4812-4813; Kohn *et al* 1996: 3895). Studies have shown that upon a change in the isotopic value of water consumed, the resulting change in the composition of the body's water pool occurs over a relatively short period of time, having completely shifted after 10-14 days (Sharp & Cerling 1998: 221).

Most studies that have examined the relationships between drinking water and tissue composition have focused specifically on the composition of bone phosphate. In animals that do not have a constant body temperature, the $^{18}O/^{16}O$ of bone phosphate is dependent upon both environmental water and ambient temperature (Luz & Kolodny 1985; 1989). However, for animals that do maintain a constant body temperature (i.e. mammals), bone phosphate composition is determined primarily by the composition of ingested water, with other environmental variables (i.e. temperature) having minimal or no effect on its values (Luz & Kolodny 1985; 1989). Environmental humidity, however, may also play a role in the composition of bone phosphate, where a change of 1.1-1.3‰ may be observed for a 10% change in relative humidity (Ayliffe & Chivas 1990; Kohn 1996: 4819).

As a result of its relationship with local drinking water sources, bone phosphate $\delta^{18}O$ values can be used to calculate the isotopic values of local water sources at the time the bone (or enamel) was formed. Problems, however, may be encountered when "foreign" water sources are consumed, such as distantly sourced rivers or glacial melt streams (White *et al* 1998). Furthermore, despite the existence of a relationship between water ingested and the isotopic composition of the body's tissues, their isotopic values are not equal. Fractionation also affects the incorporation of ingested water into the body's water pool, and from the body's water pool into the various tissues. In general, the isotopic composition of body water has been found to be more positive than local environmental water (Longinelli 1984). Research has demonstrated that within a particular species, the relationship between ingested water and body water isotopic composition is linear and approximately constant between individuals, although species may differ significantly in the fractionation processes that occur in their incorporation of oxygen from ingested water (Longinelli 1984). For example, the following equation demonstrates the relationship between local meteoric water and body water (measured through blood) for humans:

$$\delta^{18}O_{bw}=0.60(\delta^{18}O_{mw}) +0.68 \text{ (R=0.98, s(a)=±0.03) (Longinelli 1984: 386)}$$

A different relationship, however, was noted for domestic pigs:

$$\delta^{18}O_{bw} = 0.88(\delta^{18}O_{mw}) + 2.1 \text{ (R=0.98, s(a)=±0.03) (Longinelli 1984: 386)}$$

It should also be noted, however, that the latter relationship appears to be significantly different between domestic pigs and wild boars, to the level of an approximate difference of 5‰ (Longinelli 1984: 387). $\delta^{18}O$ values for domestic pigs were higher than those for wild boars, a difference presumably attributable to differences in diet, as the two groups are of the same species (Longinelli 1984: 387). Thus, it is clear that other variables besides species differentiation may lead to variation in the incorporation of oxygen isotopes from drinking water into the body.

In addition to the relationship between meteoric water and body water, the linear relationships between local meteoric water and bone phosphate have been determined for both humans and domestic pigs (Longinelli 1984):

Humans: $\delta^{18}O_{bp} = 0.64(\delta^{18}O_{mw}) + 22.37$ (R=0.98,s(a)=+/-0.03)
(Longinelli 1984: 388)

Pigs: $\delta^{18}O_{bp} = 0.86(\delta^{18}O_{mw}) + 22.71$ (R=0.98,s(a)=+/-0.05)
(Longinelli 1984: 388)

As a result, given a particular isotopic value for bone phosphate, it is possible to calculate the isotopic value for local meteoric water at the time the tissue was formed for these species (Longinelli 1984). Given these equations, the mean fractionation factor between body water and bone phosphate was determined to be 1.0214 for humans and 1.0209 for domestic pigs (Longinelli 1984: 389).

In addition to the equation given above, other studies of modern human populations have attempted to model the relationship between local sources of water consumed and the isotopic composition of bone or enamel phosphate. There have been three major studies which have calculated the relationship between the $\delta^{18}O$ values of drinking water and those of bone or enamel phosphate for humans (Longinelli 1984; Luz *et al* 1984; Levinson *et al* 1987). Of these, Levinson *et al* (1987) found a high correlation between human enamel phosphate isotopic compositions and local drinking water sources, based on 40 specially selected test subjects known to have lived the first 20 years of their life in a single location (i.e. the entire period of enamel formation), a linear relationship described by the following equation:

$$\delta O_P = 0.46\ \delta O_W + 19.4\ (R = 0.93)$$ (Levinson *et al* 1987: 369)

The slope of the regression line produced by this study, however, at a=0.46, was different from that observed in the other studies conducted by Luz *et al* (1984) and Longinelli (1984) in human populations:

$$\delta^{18}O_{bp} = 0.64(\delta^{18}O_{mw}) + 22.37\ (R=0.98, s(a)=+/-0.03)$$ (Longinelli 1984: 388)

$$\delta^{18}O_P = 0.78(\delta^{18}O_W) + 22.7\ (R=0.97)$$ (Luz *et al* 1984: 1690)

Both of these equations fit relatively well with the physiological model of oxygen isotope incorporation developed by Luz *et al*, which predicts a slope value of 0.7 based on average human physiological data (1984: 1692).

A number of differences in sample design could be cited as the source of the differences in the results produced. Firstly, Longinelli (1984) studied the composition of bone phosphate, while Levinson *et al* (1987) conducted their analyses on enamel phosphate. However, it should be noted that the regression line calculate by Luz *et al* (1984) was also based on enamel rather than bone phosphate. On a related note, Levinson *et al* (1987) were much more selective in terms of life history variables than Longinelli (1984) and Luz *et al* (1984) appear to have been, selecting only individuals who were known to have not been mobile during the full period of enamel formation. However, another factor may better explain the discrepancy in the slope values obtained by these studies to describe the relationship between the isotopic signatures of bone/enamel phosphate and those of local drinking water sources. Despite their selectivity, the study conducted by Levinson *et al* (1987) was conducted on modern populations from the 1970s-1980s. While the individuals selected for Luz *et al*'s study are not defined, Longinelli's study, in contrast, was conducted on bone phosphate from individuals that died between approximately 1900-1950 (Longinelli 1984: 388). Modern populations consume a much higher proportion of non-local water sources than did earlier populations (i.e. imported beverages, etc.) (Levinson *et al* 1987: 370; Luz & Kolodny 1989: 321). These non-local sources of drinking water are likely to have altered enamel phosphate isotopic signatures.

The relationship between $\delta^{18}O$ in meteoric water and enamel phosphate was reconsidered in 2008 by Daux *et al.* This study aimed to clarify the relationship between the two variables, as the previously determined equations had shown variation in their slope and intercept values. The authors of this study attribute the variation to the use of different analytical techniques, small sample datasets and individual variation in the timing and duration of crown mineralization (Daux *et al* 2008: 1139). This study analyzes tooth enamel from 38 molars derived from various individuals from populations located between 4ºN and 70ºN, and compares the results to isotopic values determined from tap water taken from these locations, estimated precipitation values and various types of locally grown food. The results showed a relatively high correlation between tap water and estimated precipitation values (R^2=0.89), and the resulting equation was developed from measured tap water values, which were determined to best represent the water ingested (Daux *et al* 2008: 1144). The resulting conversion equation was determined to be:

$\delta^{18}O_w$= 1.54 (±0.09) * $\delta^{18}O_p$ -33.72 (±1.51) (Daux *et al* 2008: 1143)

The study also examined the effects of dietary variation on $\delta^{18}O$ values, and determined that both dietary composition (i.e. relative amounts of meat, cereal or vegetable consumption), as well as differences in food preparation methods (i.e. cooking techniques) may have significant effects on interindividual variation in $\delta^{18}O$ values (Daux *et al* 2008: 1144-1145).

Biological and Behavioral Factors Affecting Isotopic Composition and Variation

In general, due to the fact that bone continually remodels during life, with new bone formation occurring constantly, the oxygen isotope ratio of bone should represent an approximate mean isotopic value for the last ten or more years of life (Parfitt 1983, Price *et al* 2002). As a result of this fact, bone phosphate (or carbonate) oxygen isotope ratios should not be affected significantly by seasonal variations in the isotopic composition of local water sources. Furthermore, the consumption of new water sources due to changes in residence during an individual's lifetime will be reflected in the averaging of the isotopic signatures of these water sources, eventually coming to reflect the isotopic signature of the new area of residence. In contrast to bone, enamel is not remodeled after its formation, and therefore its oxygen isotope composition in humans is reflective of the environment during childhood, at the time that the enamel was formed.

In animals (and in particular hypsodont mammals), enamel mineralization proceeds from the apex to the cervix of the tooth over a period of several months, during which time the animal is fully mobile and may undertake seasonal migration over a wide geographical area (Fricke &

O'Neil 1996; Wiedemann *et al* 1999). As a result, these animals may consume water sources that are different in their isotopic composition due to either seasonality or altitude changes occurring as a result of herd management practices. Sampling of hypsodont enamel in horizontal bands perpendicular to the tooth's growth axis at discrete intervals from the apex to the cervix has been used to glean information about changes in the isotopic composition in the enamel throughout the life span of the animal (Fricke & O'Neil 1996, Stuart-Williams & Schwarcz 1997; Wiedemann *et al* 1999, Balasse 2002, 2003). This variation is often used for determining seasonality and herding strategies, and is affected by such factors as season of birth, mobility, and time of weaning (Fricke & O'Neil 1996; Sharp & Cerling 1998). Lower isotopic values are observed for winter months, and higher values for summer months (Fricke & O'Neil 1996; Stuart-Williams & Schwarcz 1997). The range in isotopic composition between summer and winter values in Canadian beaver enamel phosphate (~4‰) was determined to be significantly smaller than between the seasonal values of meteoric water (~10‰) (Stuart-Williams & Schwarcz 1997). This is similar to the level of intra-tooth variation found in South African sheep, which displayed ranges between 2.2-4.3‰ (Balasse *et al* 2002: 921), and fossil horses from Texas, which varied in the range of 2-3‰ (Sharp & Cerling 1998: 221). This decreased amplitude of seasonal fluctuation in the isotopic composition of enamel relative to the variations in seasonal meteoric water values is due to the nature of the enamel formation. Despite the progression of enamel matrix formation from cusp to cervix, the mineralization of that enamel does not occur immediately upon the matrix formation, but occurs over a longer period (Hillson 2005: 155). It is during this mineralization process that the oxygen in the inorganic portion of the enamel is incorporated in to the tissue. As a result, enamel sampled from a spatially confined area of a tooth may in fact represent an average of isotopic values from several months of mineralization (Passey *et al* 2005). Passey *et al* therefore present methods of reconstructing the original amplitude of the seasonal variation in meteoric water isotope compositions from the attenuated amplitude of enamel variation from samples taken at intervals along the growth axis of the tooth (2005). For further information, Fricke & O'Neil provide a detailed discussion of the issues involved in the study of seasonal changes in isotopic composition in animal enamel phosphate (1996).

Levels of isotopic variation as well as in patterns of enamel formation and mineralization are species-specific (Wiedemann *et al* 1999, Balasse 2002, 2003). As described above, animal enamel mineralizes over the entire period of growth of the animal. In contrast, in humans, enamel formation occurs before the majority of the growth process has been completed, and over a relatively short period compared to the length of the lifespan as a whole (Fricke & O'Neil 1996; Stuart-Williams & Schwarcz 1997). As with bone, human enamel mineralizes over a long enough period that seasonal variations in the isotopic composition of local water sources should not affect the composition of the enamel, which should represent the annual average composition of the water sources. Furthermore, due to the use of substantial portions of the teeth, spanning the entire height of the crown, and their subsequent homogenization prior to analysis, any seasonal variation in isotopic values will be masked.

Another related potential issue leading to problems with comparability of analytical results is that variation both between and within skeletal elements is not well understood. Bone turnover rates are variable throughout the body, and may lead to differences in incorporating the isotopic signatures of new residence locations. Turnover rates may vary between 3% per year in cortical bone to 26% per year in trabecular bone, leading to bone replacement times varying between 2-20 years (Parfitt 1983: Table 7, see also Mulhern & Van Gerven 1997). As a result, the way that isotopes are incorporated into different parts of the skeleton may vary, and differences in isotopic residence times for different parts of the skeleton cause skeletal material to be heterogeneous in composition (Luz & Kolodny 1989; Price *et al* 2002: 130). Furthermore, it is not well understood to what degree there may be variations in isotopic composition between different portions of the same bone. For example, Luz & Kolodny (1985) demonstrate a variation of 1.1‰ within the same bone for laboratory rats. However, this intra-bone variation in oxygen isotopic composition has not been well examined, and is poorly understood (but see Balasse *et al* 1999 for discussion of the issue for C and N isotopes).

It is also unclear to what degree there may be systematic differences in isotopic composition between similar chemical phases in the hydroxyapatite of different types of skeletal tissues (i.e. phosphate in bone vs. dentine vs. enamel). Luz & Kolodny suggest that in rats, enamel may be more enriched in ^{18}O by 0.8‰, although they did not find these results to be statistically significant (1985: 32). Ayliffe *et al* demonstrate that in fossil elephants, enamel values are 1-3‰ higher than the other bone components of the skeleton (1994: 5293). There is also a tendency for dentine to have higher $\delta^{18}O$ values than bone and cementum (Ayliffe *et al* 1994: 5294). A statistically significant difference of approximately 0.5‰ was also discovered between enamel carbonate of deciduous and permanent dentition, with deciduous teeth being more enriched in ^{18}O (Dupras & Tocheri 2007: 68).

Beyond these biological factors that may cause intra-individual variations in isotopic values, there may also be a number of behavioral factors that may contribute to intra-population variation. Due to the complexities of human behavior, archaeological studies examining human populations may encounter additional source of variation that may not apply to other species. For example, variation in δO_p in human populations may be greater than for other species due to the higher likelihood of consuming a variety of water sources (Stuart-Williams *et al* 1996). However, this source of variation may be greater for modern human populations than for archaeological ones, as we consume a much greater variety in sources of drinking (and food-derived) water, due to practices such as the consumption of imported beverages or fruits and vegetables (Levinson *et al* 1987: 30). In the past, the consumption of imported food sources would have been much rarer, and would likely have been limited to elite populations (White *et al* 2000: 542). The question of how much variability to expect within a coherent population is a key issue in the identification of outliers as potential immigrants. Considering a series of isotopic studies on British archaeological populations, it was suggested that the amount of variation in human populations varies from ± 2.76‰ - ±2.9‰ (2σ) (Evans *et al* 2006). The authors of this article settle on ±2.8‰ as a reasonable amount of population diversity. This figure, however, is somewhat larger than the range suggested by other studies. Stuart-Williams *et al* (1996) show variation in reconstructed archaeological populations of between 1-2.5‰. Levinson *et al* analyzed teeth of known origin, and describe a range of 1.7‰-2.2‰ in three populations (1987: 368). Other studies suggest that archaeological human populations display variation within a range of 2‰ (White *et al* 2002: 219; White *et al* 1998, 2000a, 2000b). These authors, however, note that these figures were derived from populations to serve as control groups, and were chosen to represent a wide variety of time periods, social groups and statuses; these therefore might be expected to represent the larger end of the spectrum for variation (White *et al* 2002: 219). Others have suggested even lower amounts of variation, stating that in human populations that have a consistent water supply, variation on the order of 1‰ is normal (Budd *et al* 2004; Bentley *et al* 2007, 2007b).

One behavioral factor contributing to intra-individual, inter-tooth variation in isotopic signatures that is relatively well understood is the weaning process (White *et al* 2000a; Wright & Schwarcz 1998, 1999). Due to the fact that breast milk is elevated in ^{18}O compared to drinking water sources, enamel formed prior to weaning displays higher $\delta^{18}O$ than enamel formed post-weaning. This trophic effect due to breastfeeding is estimated to be approximately +0.7‰ in enamel phosphate (White *et al* 2002: 224; Wright & Schwarcz 1999: 1164). Accordingly, some studies have attempted to correct for this trophic effect by adjusting the observed values by this amount for teeth whose enamel is formed prior to weaning, in order to improve the comparability of values obtained from different teeth. For example, canines and first molars represent pre-weaning enamel production, and so these $\delta^{18}O$ are adjusted downward. In contrast, second and third molars are formed generally post-weaning, so they require no conversion. Pre-molars contain both pre- and post-weaning enamel, so they are adjusted by 0.35‰, rather than 0.7‰ (White *et al* 2002: 224). These adjustments were used in the study of a skeletal population from Teotihuacan, which has had significant prior study. Age at weaning had previously been determined for this sample by other methods, and had also been studied in depth in terms of its effect on oxygen isotope values. No such studies have been performed for the İkiztepe population, nor for that matter for any Anatolian or Near Eastern site. As a result, similar corrections for the isotopic effects of breastfeeding and weaning cannot be applied with similar confidence to this population.

Diagenetic Change in the Phosphate and Carbonate Portions of Hydroxyapatite

The two chemical phases of both bone and enamel to which oxygen isotope analysis is usually applied are phosphate (PO_4) and carbonate (CO_3). The advantages and disadvantages of measuring the isotopic composition of the carbonate vs. the phosphate portion of hydroxyapatite in bone and enamel have been extensively debated. Despite the increased risk of contamination in the carbonate portion of the enamel, many studies preferentially focus on this type of analysis because of greater difficulties in extracting the phosphate phase for analysis. In general, the procedure required to measure $\delta^{18}O$ in the carbonate component of these tissues is easier and faster than that required to do so in the phosphate component (Bryant *et al* 1996; Koch *et al* 1997; Vennemann *et al* 2002; Bentley *et al* 2005). The difficulty involved in the latter procedure is due to the strength of the chemical bonds within the phosphate component. Tudge (1960) demonstrated that isotopic exchange of oxygen between phosphates and water in the external environment is negligible under inorganic conditions, preventing isotopic contamination through processes of dissolution and reprecipitation of hydroxyapatite (Tudge 1960). This has led to the suggestion that oxygen in bone phosphate is more impervious to diagenetic contamination than oxygen from bone carbonate, providing a clear benefit for the analysis of phosphate despite the difficulty of sample preparation (Koch *et al* 1997; Stuart-Williams & Schwarcz 1997; Lee-Thorp & van der Merwe 1987, 1991; Sharp *et al* 2000; Bentley *et al* 2005).

In general, under abiotic conditions, there is almost no change in $\delta^{18}O_p$ values in phosphates over geological time scales due to oxygen exchange from external water or other sources (Lécuyer *et al* 1999; Blake *et al* 2007). However, where there are conditions with microbes (bacteria, algae, etc.) that utilize phosphorus, there may be some dissolution of P-O bonds, followed by microbially-mediated reprecipitation of secondary apatite (Blake *et al* 2007, Zazzo *et al* 2004). In cases of inorganic diagenesis, the isotope composition of carbonates is much more affected by oxygen exchange than is phosphate, which remains relatively pristine. However, under conditions of microbial diagenesis, the modification of both carbonate and phosphate composition is observed, and is associated with extensive recrystallization (Zazzo *et* *al* 2004). In the microbially-mediated modification of phosphates, the change in $\delta^{18}O_p$ occurs through an equilibrium rather than a kinetic reaction (Blake *et al* 2007). This reaction leads to the reprecipitation of hydroxyapatite with phosphate whose $\delta^{18}O_p$ value reflects neither the original phosphate, nor that of the diagenetic environment, but a value in equilibrium between the two.

In contrast to phosphate, both biotic and abiotic diagenetic processes may lead to alteration in the isotopic composition of bone carbonate. It has been suggested, however, that sample preparation procedures may be able to remove contaminated recrystallized hydroxyapatite, retaining the original isotopic signature of the carbonate component. Under certain conditions, there may be recrystallization of highly soluble diagenetic apatite with a high carbonate content, which can be dissolved through the use of acetic acid (Garvie-Lok *et al* 2004: 764). However, under different environmental conditions, much less soluble recrystallized material may also form that cannot be dissolved by acetic acid (Nielsen-Marsh & Hedges 2000: 1157; Garvie-Lok *et al* 2004: 764; Zazzo *et al* 2004).

In addition to contamination problems resulting from the failure of sample preparation treatments to remove recrystallized diagenetic material, there are also potential difficulties caused by the preparation procedures themselves. Experimental results have suggested that soaking in acetic acid that is too concentrated, or for too long a period, can lead to significant sample loss or may cause further recrystallization in the sample (Koch *et al* 1997; Garvie-Lok *et al* 2004). Research has suggested that sample treatment should avoid using acetic acid concentrations of greater than 1M, and should limit soaking time to 4 hours (Garvie-Lok *et al* 2004: 774). Furthermore, treatment of fresh bone samples that had not undergone any *post-mortem* diagenetic changes with acetic acid has been shown to produce changes in isotopic composition that cannot be attributed to the removal of diagenetic material. Koch *et al* (1997:

423) postulate that these changes may be due to systematic differences between the isotopic compositions of carbonate occurring in the A and B lattice sites of biogenic apatite, but while available data support this hypothesis, it has not been confirmed (Garvie-Lok *et al* 2004: 774-775). Available data also suggest that changes in isotopic composition relating to effects of sample preparation on structural carbonate may vary depending on the concentration of acetic acid used, suggesting that results from studies using different sample preparation techniques may not be directly comparable (Garvie-Lok *et al* 2004: 765*)*

Cynicism about the viability of conducting isotopic analyses on carbonate in bone and enamel led to a focus on phosphate in isotopic analyses for palaeoclimatic studies. This focus on phosphate was also related to the fact that there is a great deal more evidence to demonstrate a link between climatic factors and oxygen isotopic values in the phosphate in bone apatite than there is for the carbonate portion (Bryant *et al* 1996). While the connection between climate and bone apatite carbonate is often assumed, there have been few direct tests of this assumption. However, the ability of carbonate to provide information about both carbon and oxygen simultaneously provided an impetus for the continued use of carbonate in palaeodietary isotopic studies. Research in the latter field was conducted with the aim of determining the degree to which diagenetic changes truly obscured the original isotopic signature of carbonate in bone and enamel, by focusing on the relationship between $\delta^{18}O$ values in the carbonate and phosphate portions of these tissues. These studies showed a strong correlation (r^2=0.98) between the $\delta^{18}O$ values of the phosphate and carbonate components in modern uncontaminated bones and teeth, suggesting that the relationship between the two signatures could be used to monitor possible changes in carbonate during diagenesis (Iacumin *et al* 1996b). Furthermore, these studies have demonstrated a consistent relationship between the two phases, defined variously as:

$\delta^{18}O_{sc} = 1.02\ \delta O_p + 8.3$ (Bryant *et al* 1996: 5147)

$\delta^{18}O_{(PO4)} + 8.5 = 0{\cdot}998\ \delta^{18}O_{(CO3)} - 8{\cdot}5$ (Iacumin *et al* 1996b: 4)

The mean offset values between the $\delta^{18}O$ values of structural carbonate and phosphate in these two studies were found to be 8.7‰ and 9.1‰, respectively (Bryant *et al* 1996: 5147; Iacumin *et al* 1996b: 4). This known relationship between the composition of structural carbonate and phosphate provides the potential for direct comparison of the isotope ratios obtained from the different components of hydroxyapatite (Bryant *et al* 1996; Bentley *et al* 2005). Overall, research using these relationships to examine the viability of oxygen isotope studies on carbonate led to the conclusion that while digenesis may overpower the original isotopic signature of bone carbonate, the same problems may not be the case with enamel, as carbonate in enamel may be less susceptible to diagenesis due to its decreased porosity (Lee-Thorp & van der Merwe 1987; Wang & Cerling 1994; Kolodny *et al* 1996; Koch *et al* 1997; Sponheimer & Lee-Thorp 1999; Nielsen-Marsh & Hedges 2000: 1158; Sharp *et al* 2000).

However, even in the case of fossil enamel, diagenesis may still affect the isotopic signal and chemical treatment of samples prior to analysis may not successfully remove all diagenetic components (Zazzo *et al* 2004). Thus, studies of oxygen isotopic composition, particularly those conducted on carbonate, are often conducted in conjunction with methods designed to estimate the degree of diagenetic change in the samples under consideration. The methods used for this purpose vary. Some studies have employed Fourier Transform Infrared Spectra (FTIR) (Wright & Schwarcz 1996; Michel *et al* 1996; Stuart-Williams *et al* 1996; Hoppe *et al* 2003; White *et al* 2002) or X-Ray Diffraction (Person *et al* 1995; Michel *et al* 1996; Zazzo *et al* 2004: 2252;) to examine changes in the crystalline structure of archaeological teeth and bones. These studies have used a value known as the Crystallinity Index (CI) to estimate the degree of reprecipitation of crystalline apatite that has occurred post-depositionally. Studies have found, for instance, that there is a good correlation between the softness/friability of bone samples and their CI (Stuart-Williams *et al* 1996: 6). Modern fresh bone typically has an initial CI of between 2.8 and 3.0, while archaeological bone typically displays higher values, depending on the burial conditions (Stuart Williams *et al* 1996: 6; Wright & Schwarcz 1996: 939). Studies suggest that this increase in crystallinity occurs rather quickly *post-mortem* (Tuross *et al* 1989; Person *et al* 1995; Wright & Schwarcz 1996). An increase in the CI may indicate an increased possibility of diagenetic changes in isotopic compositions, although not always. In fact, while the CI may be useful as a general indicator of diagenetic change, there is no clear evidence that it reflects changes in isotopic composition. Stuart-Williams *et al* (1996: 6) found no evidence of a correlation between CI and δO_p in their studies of archaeological populations from Mexico, which they suggested indicated that diagenesis had not modified the original isotopic signature. Similar results were found by White *et al* (1998). Lee-Thorp & Sponheimer have suggested that increased crystallinity may in fact not be a good indicator of diagenetic changes in isotopic composition (2003: 214).

Comparison of Methods of Oxygen Isotope Analysis in Phosphates

Originally, phosphate for use in oxygen isotope analysis of hydroxyapatite was isolated as $BiPO_4$, using a method developed by Tudge (1960). However, $BiPO_4$ is extremely hygroscopic (i.e. easily absorbs moisture), and thus was susceptible to isotopic contamination from moisture originating from atmospheric sources during preparation and storage. Preparation of $BiPO_4$ for analysis was also a long and complicated process. Firsching (1961) developed a much simpler method of precipitating phosphate as Ag_3PO_4 (trisilver orthophosphate), through ammonia volitization. This method was less tedious and time-consuming than the $BiPO_4$ method, and

Ag_3PO_4 produced demonstrates no significant adsorption of water from atmospheric sources, even after being kept at ~70% humidity for 2 months (Crowson *et al* 1991: 2398). This method was subsequently adopted for use in many phosphate oxygen isotope analyses, and is now the method of choice for isolating phosphate from biogenic sources.

A number of variations are observed in the methods used to precipitate Ag_3PO_4. In general, these methods involve the dissolution of hydroxyapatite using hydrofluoric acid in order to precipitate CaF_2 (Crowson 1991; Stephan 2000). Some involve the use of nitric acid prior to hydrofluoric acid, in order to improve the speed and completeness of bone dissolution (O'Neil *et al* 1994: 205; Evans *et al* 2006a, 2006b). The method used by O'Neil *et al* produced 96-98% yields where relatively large samples were used (i.e. >30 mg) (1994: 204). A different method developed by Stuart-Williams involves the precipitation of Ag_3PO_4 using intermediary products of lead phosphate and lead sulphate, and avoids the use of hydrofluoric acid (1996). Yields produced by this method were ~70-90% (Stuart-Williams 1996: 25). Stuart-Williams and Schwarcz (1995: 3839; Stuart-Williams 1996) note fairly substantial variation in the Ag_3PO_4 crystals precipitated (i.e. on the order of ±1‰ around the mean), which they attribute to the ammonia volatilization method derived from Firsching (1961). The earliest crystals to form and the last crystals to form have a difference isotopically by 2-3‰, with the first crystals being isotopically lighter (Stuart-Williams and Schwartz 1995: 3839; Stuart-Williams 1996: 28). When standards are prepared in large batches, they note large amounts of inter-crystal variation; they propose that samples be prepared in small batches, which are precipitated over a much shorter period of time, may have less intra-crystal variation (Stuart-Williams & Schwartz 1995: 3838-3839). When small batches were prepared, variance between crystals was decreased to 0.15‰ (Stuart-Williams 1996: 29). In contrast, O'Neil *et al* noted inter-crystal differences of "several tenths of a permil", and suggest homogenization of the crystals produced prior to analysis (1994: 205).

A number of methods of performing oxygen isotope analysis on samples of silver phosphate have been used in the past. These include fluorination (using BrF_5, ClF_3, or F_2) (Crowson *et al* 1991, Lécuyer *et al* 1996), reaction with bromine Br_2 (Stuart Williams & Schwartz 1995), and high temperature reaction with a graphite mixture to produce CO_2 (O'Neil *et al* 1994). All of these methods analyze oxygen extracted from Ag_3PO_4 as CO_2. The conventional method is fluorination, and is the only one of these methods that extracts O_2 from the Ag_3PO_4 with 100% yield (Vennemann *et al* 2002: 322). However, it is difficult to perform because it involves the use of dangerously toxic and explosively volatile chemicals such as BrF_5. However, other methods (i.e. those mentioned above) have been developed that do not require the use of BrF_5. Stuart-Williams & Schwarcz (1995) present a method involving the reaction of the Ag_3PO_4 with Br_2 rather than BrF_5, which achieved 17.25% yields and a precision of ±0.07‰ (1995: 3839). This method, however, still requires the use of dangerous chemicals, and involves the construction of a complex furnace and extraction line dedicated to the analysis of phosphates (Vennemann *et al* 2002: 334). Furthermore, similar to other methods described here, it requires a fairly large amount of sample (~20mg). O'Neil *et al* developed a method that involves the reaction of Ag_3PO_4 with graphite at high temperatures (1200ºC) in silica tubes (1994). This method produced yields of 25% of O_2 with a precision of ±0.2‰, and required approximately 20-30 mg of Ag_3PO_4 (O'Neil *et al* 1994: 206-208). The production of this quantity of silver phosphate generally required approximately 20mg of hydroxyapatite, although samples as small as 10 mg were analyzed successfully using this method (O'Neil *et al* 1994: 209). Stephan, in a refinement of the method, provides more detailed descriptions of the procedure employed, which produced similar levels of precision (2000).

More recently, methods have been developed that involve the use of high temperature carbon reduction and continuous flow mass spectrographic analysis of CO, rather than CO_2 (Vennemann *et al* 2002). These methods are rapidly becoming the method of choice for oxygen isotope analysis of phosphates because of their requirement for smaller samples, the increased ease of handling and preparation compared to the conventional fluorination methods, and the precision of the results obtained (Vennemann *et al* 2002). The process generally uses a Finnigan MAT high temperature conversion elemental analyzer (TC/EA), which includes a glassy carbon tube filled with glassy carbon chips and a small graphite reaction cup encased within a ceramic tube (Vennemann *et al* 2002: 326). Samples are weighed into small silver cups, which are crushed and dropped into a reactor held at 1450ºC, while being continually flushed with helium (Vennemann *et al* 2002: 326). The measurement of $\delta^{18}O$ is made on the resulting CO produced by the reaction. Drift in $\delta^{18}O$ is monitored and corrected for by repeated analysis of standards of known composition. The oxygen yield for the high temperature reduction method is 100%, similar to the yield of the conventional fluorination reaction (Vennemann *et al* 2002: 333). However, the main advantage of this method is the speed and ease of analysis, and the very small sample size required (i.e. 2mg of Ag3PO4 is required for 3-4 measurements, compared to 20 mg for conventional fluorination) (Vennemann *et al* 2002: 333). A precision of ±0.3‰ can be achieved with frequent analysis of standards alongside sample measurements (Vennemann *et al* 2002: 333).

Most recently, greater attention has been paid to methods which eliminate the difficult sample preparation required to isolate the phosphate component of hydroxyapatite, as well as to reduce the amount of sample required to conduct the analysis. In this vein, research has focused on the use of *in-situ* laser ablation (Sharp & Cerling 1998) and laser fluorination (Kohn *et al* 1996). There are a number of advantages in the use of such techniques. Firstly, the sample size required is significantly smaller than with conventional solution-mode analyses (i.e. on the order of 0.5-2.0 mg compared to 20+ mg). Secondly, these techniques are significantly less destructive than conventional methods, a definite benefit for archaeological applications. Laser ablation, for example, can be performed in-situ, without grinding or dissolution of enamel, and instead produces tiny holes approximately 100µm in diameter with damage halos extending out 100-200µm (Sharp & Cerling 1998: 219). This spatial resolution also leads to another significant advantage of these methods, as it allows the characterization of high-resolution analyses within tooth enamel to examine intra-tooth variation in isotopic composition.

In most cases, there are no significant effects noted for reproducibility of the results obtained by these methods. The methods generally produce precisions of ±0.4‰ (Vennemann *et al* 2002: 333). In fact, the laser fluorination method has consistently achieved a reproducibility of ≤0.1‰ (Kohn *et al* 1996: 3890). This is substantially better than the reproducibility of 0.2-0.5‰ with sample sizes of 10-100mg for conventional solution-mode analyses (Kohn *et al* 1996: 3890). Kohn *et al* (1996) also developed another method for use with tooth enamel, which involved grinding the enamel to a fine powder and reacting it with BrF_5 with a high power diffuse CO_2 laser beam. This method produced results similar to those observed with laser fluorination (Kohn *et al* 1996: 3890). Samples which were pre-bleached with either NaOCl or H_2O_2 prior to analysis demonstrated a reproducibility of ≤0.1‰, while those that were not pre-treated had reproducibility values of ~0.2‰, but produced similar values (Kohn *et al* 1995: 3890).

The main drawback observed in these methods is the fact that these techniques do not extract a single chemical phase of the hydroxyapatite undergoing analysis, but rather represent the value of all oxygen in the sample (i.e. a combination of PO_4, structural CO_3 and hydroxyl portions) (Kohn *et al* 1996: 3890). The analysis of multiple chemical phases leads to interference between the different components, whose relative contributions to the overall value are not well understood. Furthermore, inclusion of the carbonate and hydroxyl portions of the hydroxyapatite may lead to increased contamination, as these portions may be more susceptible to diagenesis (Vennemann *et al* 2002: 322).

Strontium

Strontium Geochemistry

Strontium has four naturally occurring isotopes (^{88}Sr, ^{87}Sr, ^{86}Sr, ^{84}Sr), all of which are stable (of these, only ^{87}Sr is radiogenic). Their abundances in nature are 82.53, 7.04, 9.87, and 0.56 percent respectively (Faure 1986: 118; Faure & Mensing 2005). There is very slight variation in these abundance values, as they are affected by the formation of ^{87}Sr through the radioactive decay of ^{87}Rb (rubidium) (Faure & Mensing 2005). However, the half-life of ^{87}Rb is 48.8×10^9 years, which means that for archaeological purposes, the abundances of the various strontium isotopes can be considered to be approximately constant (Price *et al* 1994). The ^{87}Rb-^{87}Sr decay process has been extensively used in geochronological studies for dating geological formations (i.e. Faure 1986).

Unlike with light stable isotopes such as oxygen, strontium isotopes are not expressed via comparison to a standard; instead, strontium isotopes are expressed in terms of the relationship of ^{87}Sr to ^{86}Sr. The quantification of radiogenic isotopes is generally normalized by reference to a non-radiogenic isotope in order to control for variations in overall Sr concentration; ^{86}Sr is selected because it produces values nearest to unity, which are most analytically precise (Beard & Johnson 2000: 1049). The ionic radius of Sr^{2+} (1.13 Å) is slightly larger than Ca^{2+} (0.99 Å) (Faure 1986: 117). Sr often substitutes for Ca in minerals such as plagioclase, apatite, and calcium carbonate, but is limited in its ability to do so because of its slightly larger ionic radius (Faure 1986: 117).

The $^{87}Sr/^{86}Sr$ composition of any geological formation is determined not only by the relative abundances of rubidium and strontium, but also by its age (i.e. increasing in ^{87}Sr over time by the decay of ^{87}Rb) (Faure 1986: 118). For example, rock types with very high initial Rb/Sr ratios that are also very old (i.e. >100 million years) will have very high $^{87}Sr/^{86}Sr$ ratios, while younger formations with low initial Rb/Sr will have much lower strontium isotope ratios. Strontium isotope ratios generally vary between approximately 0.70 and 0.75 (Faure 1972; Price *et al* 2002; Bentley 2006). $^{87}Sr/^{86}Sr$ ratios in clay-rich rocks such as shale or in igneous rocks (i.e. granite) that have high silica contents can be as high as 0.730 (Faure 1972, Price *et al* 1994, 2000: 906; Bentley *et al* 2002: 799). In contrast, rocks relatively young geologically, such as basalt, can have ratios of less than 0.704 (Faure 1972; Price *et al* 1994, 2000: 906; Bentley *et al* 2002: 799). While the variation in these values may seem small, they are extremely large from a geological standpoint, as well as from the standpoint of standard analytical errors in analysis (generally around +/- 0.00001 to +/- 0.00003 for Sr analysis) (Price *et al* 1994, 2000: 906). Strontium isotope ratios are therefore best reported to 5 decimal points (Bentley 2006).

In order to facilitate comparisons between values that are numerically very small, a different notation for strontium isotope values is sometimes used:

$\varepsilon Sr = [(^{87}Sr/^{86}Sr_{SAMPLE} / ^{87}Sr/^{86}Sr_{BULK\ EARTH}) - 1] \times 10^4$ (Beard & Johnson 2000: 1050)

This equation functions similarly to the comparison with a standard value used for other isotopes; the value used for bulk earth is 0.7045 (Beard & Johnson 2000: 1050). This notation, however, does not seem to be commonly used (although see Price *et al* 1994: 322), and strontium isotope values are usually presented as $^{87}Sr/^{86}Sr$ values.

Strontium in the Environment

As strontium isotopic compositions vary according to local geological conditions, the identification and definition of patterns of local variability in isotopic signatures is an important issue in the use of this type of analysis. Firstly, it is important that there is sufficient variability in the strontium isotopic compositions of local geological formations over a wide enough area to make the identification of non-local signatures viable. The strontium isotopic signature in the soils, water and plants of any given region is determined primarily by the composition of the local bedrock, whose weathering creates a local signature. Depending on the amount of variation in local geology, isotopic signatures may be distinct in particular regions. In contrast to lighter isotopes (i.e. oxygen, see discussion above), fractionation of strontium in natural or biological processes is negligible due to the large mass of strontium and the very small relative mass differences between the various isotopes (Bentley 2006: 141). In any case, any fractionation in strontium isotopes that did occur would be corrected for by the mass spectrometry procedure, through the routine normalization procedure to a constant $^{88}Sr/^{86}Sr$ ratio (Beard and Johnson 2000; Bentley 2006; Capo *et al* 1998: 202).

In theory, the Rb-Sr decay system allows the construction of a rough strontium isotope map from a basic geological map of a region, based on the ages and rock types of geological formations (Bentley 2006). However, in practice, local strontium signatures are governed by a very complex set of factors. For example, strontium in a riverine environment originates from the weathering of bedrock within the entire catchment of the river in question, possibly resulting in the mixing of signatures from different geological formations along the river's length (Bentley 2006: 141; Dufour *et al* 2007: 1228). Rocks with a high $^{87}Sr/^{86}Sr$ value may have very low absolute concentrations of Sr, and thus contribute less significantly to local signatures than geological formations with lower $^{87}Sr/^{86}Sr$ signatures but higher overall Sr concentrations (Bentley 2006:142). Furthermore, erosion rates are greater at high elevations compared to lower elevations, and thus formations from higher elevations may contribute more significantly to local signatures (Bentley 2006: 142). Furthermore, chemical weathering of rocks tends to increase their Rb/Sr ratios, as well as enriching them in radiogenic ^{87}Sr (Faure 1986: 183). As a result of all of these sources of variation, it can be difficult to obtain an accurate picture of locally available strontium. This may be attempted by calculating weighted averages of local bedrock values for all geological formations (Bentley 2006: 143). However, it may be difficult or impossible to account for all relevant contributing factors. Comparatively, for areas in a riverine environment, river water may provide a more accurate picture of the composition of strontium that is locally available to plants and animals deriving from the river's entire catchment (Bentley 2006: 143).

In early archaeological strontium isotope studies, baselines for the interpretation of human strontium values were constructed based on geological maps, with the assumption that the lack of fractionation in strontium isotopes in biological processes meant that strontium isotopes could be reconstructed up the food chain based on local bedrock values. However, it is now clear that this is an oversimplification. In addition to the factors discussed above, there are a number of other complicating variables that preclude the direct application of local bedrock values to animals and humans. The first is the large degree of variation in $^{87}Sr/^{86}Sr$ that can be found within an individual rock (Price *et al* 2002: 119). In addition, there can be environmental or atmospherical contributions to soil strontium values that do not originate directly from local geology (Price *et al* 2002: 119). Alluvial deposits often display an average value of their input sources from upstream (Price *et al* 2002: 120). However, values in soil can display a range of $^{87}Sr/^{86}Sr$ values due to unequal weathering of particular rock types and uneven mixing of the various input sources (Price *et al* 2002: 120).

A study by Sillen *et al* (1998) examined strontium values across various parts of the local environment, and came to a number of important conclusions. They demonstrated that while soils are highly variable across a region, plants are significantly less variable. Available strontium in the soil is closely correlated with plant values, independent of geological substrate values (Sillen *et al* 1998: 2466). Furthermore, surface water generally displays a lower $^{87}Sr/^{86}Sr$ value than the surrounding plants and soils. They also noted a distinction in isotopic composition between plants growing immediately along the course of a stream traveling through their study area and those growing away from the water in grassland areas (Sillen *et al* 1998: 2466). Another study examined changes in $^{87}Sr/^{86}Sr$ at different trophic levels in two different forest ecosystems, and demonstrated that there is no discernible change in strontium isotope composition once it enters the food chain (Blum *et al* 2000: 95). The results of these studies show that it is important to consider biologically available strontium, which may differ in composition from local geology. These biologically available strontium values may be more productively used as a starting point when developing a baseline for local strontium values than local bedrock geology (Sillen *et al* 1998: 2466).

Strontium in Human and Animal Tissues

A number of elements can be substituted in the inorganic hydroxyapatite portion of bone and enamel in place of calcium, including strontium. Elements with a +2 valence state, such as strontium, iron, barium and lead are sometimes incorporated into bone in place of calcium. The amount of substitution of each is governed by the size of the ionic radius. Iron, for example, is incorporated into bone and enamel *in vivo* in levels extremely low in comparison to iron entering these tissues from the burial environment, and is thus obscured by post-burial diagenetic processes (Bentley 2006: 161). Strontium, due to the fact that it has the most similar ionic radius to calcium, is incorporated most often, and is thus of the greatest utility for isotopic studies. It is incorporated into bone in concentrations of approximately 10^2-10^3 ppm (Price *et al* 2000: 906).

Early archaeological research into strontium in human tissues focused on absolute concentrations of strontium and its relative abundance in relation to calcium, expressed in terms of Sr/Ca ratios. These ratios were used for the purpose of reconstructing dietary habits (Sillen 1992). Sr/Ca ratios are moderated by a trophic level effect, and the ratios decrease as one proceeds up the food chain. This is due to a process known as biopurification, which occurs in a fraction of about 1/5 at each trophic level (i.e. 20% of strontium available to plants is absorbed by them, 20% of strontium available to herbivores in plants they eat is absorbed, and so on) (Sillen 1986). Biopurification also decreases the variance in Sr/Ca ratios (Price *et al* 2002: 124; see Bentley 2006: 154 for further references on biopurification). While the decrease in the Sr/Ca ratio due to biopurification does not influence $^{87}Sr/^{86}Sr$ values, the decrease in variance extends to isotopic signatures (Bentley 2006:155).

As a result, there is a significant reduction in the variation in $^{87}Sr/^{86}Sr$ ratios seen in animal bone tissue compared to that in local plants and soils (Bentley 2006: 155). Price *et al* state that bone values of $^{87}Sr/^{86}Sr$ demonstrate variability several orders of magnitude smaller than soil values, and suggest that they form a representative sample of strontium from various local sources and likely represent a viable regional average (2002: 124). The reason for this seems to be the fact that the assimilation of environmental strontium over time acts as a powerful averaging force for isotopic values (Price *et al* 2002: 124). The coefficient of variation (CV) in animal tissues is consistently less than 0.6% for modern animals (Price *et al* 2002). The CV tends to be larger for animals that have larger habitat ranges, as well as for domestic animals that are herded over larger areas (Price *et al* 2002). Domestic pigs, which tend to have restricted movement, and are kept and fed locally, have smaller levels of variation in $^{87}Sr/^{86}Sr$ ratios (Bentley 2006: 155-6, Bentley 2004, Bentley *et al* 2004, Bentley & Knipper 2005a). Small mammals, particularly rodents, have the lowest levels of variation in isotopic composition, with standard deviations of 0.0003 at maximum (Bentley 2006: 155). Snails also have a highly restricted home range and display very low levels of variability (Price *et al* 2002: 125). However, these animals may have a natural range that is significantly smaller than the dietary catchment of human populations. Due to the similarities in diet and physiology between pigs and humans, domestic pigs may represent an ideal species for the comparison of strontium isotope values.

Identification of Immigrants: Definition of Local and Non-Local Signatures

The constant process of remodeling in bone means that isotopic composition in bone samples generally represent the average of local conditions during the last approximately ten or more years of life (Parfitt 1983, Price *et al* 2002). However, as tooth enamel is formed during childhood, and does not remodel, it reflects the local conditions at the time of its formation during childhood. As a result, it is possible to compare childhood and adult isotopic signatures and identify individuals who have moved between different areas during their lifetime. The following table demonstrates the possible interpretations of local and non-local isotopic signatures in bones and teeth from a given individual:

Table 5.1: Interpretation of Local and Non-Local Signatures in Bones and Teeth (from Bentley 2001: 111)

		Bone	
		Local	*Non-Local*
Teeth	*Local*	1. Lifelong local resident 2. Both bones and teeth are diagenetically changed 3. Too much geological homogeneity in region to detect movement of individuals	Uncommon 1. Locally born individual who lived elsewhere and returned to the area shortly before death, or who was buried in their place of birth 2. Diet change to imported foods (or seafood) in adulthood
	Non-Local	1. Individual moved to the local area after the formation of the teeth in question 2. Change in source of diet change from childhood to adulthood	1. Recent immigrant who died before significant bone remodeling 2. Diet of imported foods (or seafood) 3. Lifelong migrant throughout different geological areas; signal represents an average of these areas 4. Wide dietary catchment area in geologically heterogeneous region (Bentley *et al* 2003: 474)

The above table demonstrates that there may be a number of confounding factors that can mimic the expected pattern of isotopic signatures of bones and teeth in life long local residents and/or migrants. These factors include diagenesis (see discussion below), regional geological homogeneity (see discussion above) and systematic changes in diet, particularly with regard to the consumption of significant amounts of imported food. Consumption of seafood in inland areas may also contribute to the latter problem, but this is unlikely to be the case in coastal areas, where isotopic signatures will be heavily influenced by the proximity of the ocean. Problems of interpretation may also be encountered due to multiple residence locations of individuals (Price *et al* 2002: 130). While we often assume that a migrant moves from one place to another, and resettles, this may not always be the case; some individuals or groups may be nomadic or long-term migrants. Furthermore, some individuals may appear as "non-local" due to the consumption of food in a wide dietary catchment area where a region has a particularly heterogeneous isotopic composition (Bentley *et al* 2003: 474).

The issue of how to define what is considered to be a "local" vs. a "non-local" signature is important when trying to identify outliers as potential immigrants, and must be considered in relation to the variability of local strontium signatures. As discussed above, while baseline local strontium isotope signatures may be determined from the composition of geological formations, limitations in the availability of minerals to plants means that the isotopic composition of strontium in the food chain (biologically available strontium) may differ from that of exposed bedrock (Sillen *et al* 1998; Price *et al* 2002; Arnold 2006; Bentley 2006). As discussed above, studies of isotopic variation in human bone therefore often occur in conjunction with analyses of isotopic concentrations observed in local fauna, which are used as a baseline for comparison with human values as they display very low variation in values (Price *et al* 2002: 124). Strontium isotope values for small animals have been demonstrated to show high correlation with local human values (Price *et al* 2002: 125).

The selection of fauna to include in this baseline sample can be problematic. Samples of modern fauna have the advantage of having known patterns of mobility and behavior. However, modern animals are more likely to be fed with non-local or imported feed sources and fertilizers, causing them to have isotopic compositions that are not representative of their area of residence (Price *et al* 2002: 126; Bentley 2006). They may also be fed mineral supplements that may interfere with local dietary Sr isotope values (Wright 2005: 556). Archaeological faunal samples, however, are subject to the same problems of diagenetic contamination as human samples (see discussion below), and the range of mobility of ancient herds may be poorly understood. Rodents are often selected as species that have a limited geographical range, and thus are ideal for comparative analysis (Arnold 2006). Rodents have been used as control samples to aid in the reconstruction of local strontium signatures in archaeological or paleontological studies (Hoppe *et al* 1999, Ezzo *et al* 1997; Price *et al* 2002). They have also been demonstrated to display similar values and ranges compared to human samples (Beard & Johnson 2000; Price *et al* 2002: 125). The very limited home range of rodents, however, can be a detriment as well as an advantage, as they may not incorporate the full scope of the local variability available to human populations into their diet (Price *et al* 2002: 126). If using modern rodent samples (as opposed to archaeological ones), this can be compensated for by increasing the geographical range of sample collection from around the site in question (Price *et al* 2002: 126*).* However, due to their similarities to human populations in biology and dietary habits, pigs are increasingly often selected as proxies for local strontium signatures for human populations (Bentley & Knipper 2005; Bentley *et al* 2007b; Nafplioti 2008; Shaw *et al* 2009).

In addition to the use of animals in defining local variability in strontium isotope signatures, other methods are also used in tandem with this to confirm the expected range of variability in a population. Often, the expected local value in strontium isotope composition is reconstructed using the average value obtained from the human population under analysis. In calculating this average, bone values have often been preferentially used over enamel, as they represent the location of residence during the last years of life. Since the majority of the population would presumably have been resident locally at their time of death, bone values should represent the local signature (Bentley *et al* 2002, Grupe *et al* 1997, Price *et al* 1994). Individual isotopic signatures are then considered to be "non-local" if their values fall more than 2 standard deviations from the local average value (Price *et al* 2000, 2002).

However, the issue is significantly more complicated than this simple definition implies, due to the possibility of diagenetic contamination of human bone values. A number of studies have found substantially more variation in the strontium isotope values of teeth than in bone samples (Price *et al* 2000; Schweissing & Grupe 2003: Fig.3). This was interpreted in these cases as an indication that most of the individuals in their sample lived the final years of their life locally to where they were buried (Schweissing & Grupe 2003: 1377). Furthermore, it was interpreted as demonstrating that a large number of individuals in the population had been born elsewhere and immigrated to the location in question (Price *et al* 2000: 906; Schweissing & Grupe 2003: 1377). However, such a pattern could also, perhaps more convincingly, be attributed to diagenetic post-mortem adsorption of strontium from the burial environment. As it is generally accepted that bone is more heavily affected by diagenetic contamination, this would serve to preferentially decrease the variation in the bone isotopic values relative to enamel values. As a result, using bone values as a measure of the expected local range of isotopic variation would result in a substantial overestimate of the numbers of immigrating individuals (see Horn & Müller-Sohnius 1999). The use of bone samples can be a viable means of defining a local *average* isotopic value, particularly in region where isotopic compositions have not been well-studied, but should be used with extreme caution as a means of defining local variation. In order to control for the possibility of *post-mortem* contamination, the local range of isotopic variation should be defined using the data available from *both* bone and enamel values, as well as from archaeological faunal samples (Bentley *et al* 2004).

An approach that defines expected local variation as a range extending two standard deviations from the population mean of either bone or enamel values, however, necessitates the assumption that the strontium isotope values within a population can be reasonably modeled as a normal distribution (Montgomery *et al* 2007). There has been extensive discussion of this issue with respect to the modeling of population distributions for Pb isotopes, but relatively less attention has been paid to this issue for strontium isotopic values (Baxter 1999, 2000; Montgomery *et al* 2007). Wright in fact uses the assumption of normality as a means of identifying immigrant individuals (2005). She evaluates the strontium values obtained for normality, and eliminates outliers that contribute to non-normality of the data; these outliers are then suggested to represent potential immigrants (2005: 560-561). Such a method makes sense where there is good reason to believe that the majority of the population were born locally, and thus that their strontium isotope composition should approximate a normal distribution (Wright 2005: 561). Montgomery *et al*, however, suggest that a normal distribution of isotopic values in a population may be the exception rather than the rule (2007: 1503).

Instead, Montgomery *et al* advocate the use of isotope mixing models for identifying potential population groups (2007). Mixing models attempt to predict the likely range of isotopic variation based on calculations of weighted isotopic input sources (i.e. see Phillips and Koch 2002). Montgomery *et al* characterize local variation in strontium isotopes as being limited by two different end-members: local rock and rainwater. Thus, rather than possessing a normal distribution around a single local value, a human population will display a range of values between these two different input values (Montgomery *et al* 2007). Their model essentially requires that all food consumed is locally-grown on a single type of bedrock and that the population makes use of rainwater for agricultural production *(*Montgomery *et al* 2007:

1503). Furthermore, they assume that the strontium isotopic composition of rainwater has sea water as its ultimate source (δ^{87}Sr=0.7092), and that it falls without discernible fractionation from its original composition (Montgomery *et al* 2007: 1503). They do, however, recognize that while the isotopic composition of rainwater may be similar to seawater in coastal areas, in terrestrial areas, this value may be altered by the incorporation of terrestrial dust (Montgomery *et al* 2007: 1503). The amount of variation in a population, therefore, will be determined primarily by the magnitude of the difference between the isotopic values of the local geology and those of the local rainwater.

Essentially, however, what this mixing model accomplishes is a prediction of the local biologically available strontium signature. The mixing of the various local end-members considered by this model has already occurred when the strontium originally enters the food chain. As discussed above, plants show much less variation in their isotopic compositions than do the soils they are grown in, and the amount of variation in isotopic signatures decreases even further as trophic level increases. A human population's diet originates solely from either plants or animals (not from bedrock or soil), and assuming they are consuming local plants and/or animals, there is a much smaller range of variation in the strontium isotopes available from dietary sources than this model would suggest. The consumption of rainwater could potentially somewhat alter this value, but again, this input has already contributed to the biologically available strontium signature, as it is taken up by local plants and consumed by local animals. Furthermore, if we assume that individuals in a population consume water from similar sources, and have similar requirements in terms of the volume of water consumed, this should not alter individual values in radically different ways, but should directionally influence isotopic composition in a fairly consistent manner. Some variation in values may result from individual differences in dietary habits (Price *et al* 2002: 130), but the low overall levels of variation available in the diet means that this variation should not result in significantly different isotopic compositions. In fact, given the magnitude of variation that might be expected based on an omnivorous diet including both local plants and animals, it is perfectly plausible to model the distribution of bone and enamel compositions as a normal distribution around this relatively narrow range of potential dietary inputs.

Diagenesis

Diagenetic contamination of chemical signatures in bone from the local environment is an important concern in any chemical analysis of skeletal tissues. Contamination is of greater concern with bone samples than with enamel, as enamel has been demonstrated to be less susceptible to contamination by the burial environment (Sponheimer & Lee-Thorp 1999). Despite this, the introduction of some diagenetic strontium into enamel can still occur (Dufour *et al* 2007: 1229). Diagenetic changes to bone and enamel include the addition of environmental strontium from soil and groundwater in the burial environment in a variety of ways, which may eclipse the *in vivo* strontium isotope signature. The primary one is the in-filling of pores in the tissues with secondary minerals, as well as the diffusion of diagenetic strontium into microcracks (Koch *et al* 1992: 278, Bentley 2006: 164; Hoppe *et al* 2003: 25). However, accumulation of strontium in hydration layers on the surface of hydroxyapatite crystals can also occur, as can the recrystallization of hydroxyapatite and the direct exchange of environmental Sr with either Ca or Sr of the original hydroxyapatite (Koch *et al* 1992: 278; Hoppe *et al* 2003: 26). Diagenetic strontium diffuses into enamel from the burial environment into the surface of the tooth. Its concentrations are highest near the surface, decreasing significantly in the internal portion of the tooth (Little & Barrett 1986; Dufour *et al* 2007: 1229). A similar diffusion profile for diagenetic

Sr has been found in tooth-like microfossils known as conodonts (Holmden *et al* 1996: 425). Such a diffusion profile of environmental strontium, however, need not originate only from the burial environment, but may also be introduced during life from ingested water and food (Horn & Müller-Sohnius 1999: 263; Dufour *et al* 2007: 1229). While this diffusion of strontium into the surface of the tooth during life has been suggested, however, it has not been definitively demonstrated analytically (Price *et al* 2002: 127).

The effects of diagenesis on strontium isotope compositions are complex and difficult to separate from biogenic isotopic signatures. For example, Budd *et al* found that the effects of diagenesis on strontium isotope ratios were highly variable, with no apparent relationship evident with soil conditions (even for samples buried in the same conditions at the same site) (2000: 693). They found that anywhere between 34-79% of the Sr in their dentine samples could be attributed to the post-mortem burial environment (Budd *et al* 2000: 693). Nelson *et al* (1986) studied a sample of bones from marine animals that had been buried in terrestrial soils, with the intention of distinguishing between the original (marine) isotopic signal of the bones, and that caused by diagenesis (terrestrial). Their results demonstrated that the bones did not display an isotopic signature similar to one expected in a marine environment, and suggested that the effects of diagenetic strontium prevented the identification of the original isotopic composition of the bone (Nelson *et al* 1986: 1946-1947). This study represented a highly pessimistic view about the possibility of identifying biogenic strontium isotopic signatures in fossilized tissues. Sillen & Sealy, however, suggest that the problem may have actually been caused by the methodology used in Nelson *et al*'s study (1995). They suggest that the specific methodology used by Nelson *et al* (1986) may have resulted in the alteration of the isotopic signature of the bones being studied, rather than the changes observed being a result of diagenesis. In particular, they suggest that the ashing procedure employed resulted in significant changes to the crystal structures of the bone both before and during the chemical leaching process employed (Sillen & Sealy 1995: 318).

In contrast, it has been suggested that proper sample preparation procedures are sufficient to remove portions of the sample that may have been contaminated, as well as the chemical phases of the bone that are more likely to be affected by external contaminants (Sealy *et al* 1991; Price *et al* 1992, 1994; Sillen & Sealy 1995; Holmden *et al* 1996; Nielsen-Marsh & Hedges 2000a; Hoppe *et al* 2003; Bentley 2006; Dufour *et al* 2007). Typically, sample preparation procedures involve the soaking of samples in 5% acetic acid, which is thought to remove post-depositional strontium from pore spaces within the tissue, while retaining the original *in vivo* Sr (Koch *et al* 1992; Price *et al* 1992). This is due to the fact that post-depositional strontium is thought to be in a chemical phase that is more soluble than the original strontium contained within biological hydroxyapatite (Sillen 1986).

This method is known as "solubility profiling" and was developed by Sillen (1986, 1989). It is based on the principle that with increasing carbonate content, apatite becomes more soluble, while with increasing fluoride content, it becomes less soluble (Sillen 1986; Sillen & Sealy 1985; Trickett *et al* 2003: 654). In this method, the apatite is soaked in a series of weak acids, most commonly acetic acid. After each soaking event, the supernatant is removed and retained, each time isolating material with varying degrees of solubility. At each stage the Sr/Ca ratio is monitored. The first 6-7 washes remove the most soluble material, primarily diagenetic carbonates; in these washes, the Sr/Ca ratio decreases rapidly. Subsequent washes are considered to represent the biogenic apatite signal, while the Sr/Ca ratio remains stable. After these washes, the remaining residue is considered to represent an insoluble fluoride-rich diagenetic product of recrystallized hydroxyapatite (also Koch *et al* 1992: 278).

There has been a great deal of discussion about this method, and a number of varying opinions on its effectiveness at removing diagenetic strontium. Some studies have suggested that the solubility profiling method was not able to completely remove diagenetic strontium to allow the identification of the biogenic isotopic signature. Tuross *et al* studied changes in both crystallinity and strontium concentration in the remains of recently deceased exposed wildebeest, and found that the sequential leaching technique did not return the strontium levels and Sr/Ca ratios to their original levels (1989:670). Sealy *et al*, however, suggest that these problems were caused by the use of cancellous rather than cortical bone by Tuross *et al* (1991: 408). Similar to the experiment designed by Nelson *et al* (1986), Sealy *et al* then studied the remains of terrestrial animals that had been buried in marine-derived matrices and marine animals that were buried in terrestrial soils. Using these remains, they were able to determine that their solubility profile method was successful in removing the diagenetic signals introduced by the burial environment (Sealy *et al* 1991).

Further support for the method has come from other studies. For example, Price *et al* (1992, 1994) demonstrated that as the progressive leaching method progressed, Ca/P ratios (often used as a method of detecting diagenesis) decreased from very high values to values approaching 2.1. They argued that because a Ca/P ratio of approximately 2.1 is observed in biogenic hydroxyapatite, as the observed Ca/P ratios approached this value, this represented the removal of diagenetic materials, leaving only the original biogenic hydroxyapatite signature (Price *et al* 1994; Price *et al* 1992: 518, 520). Koch *et al*, however, found that the sequential leaching method was *not* able to remove the diagenetic strontium signature from fossil fish teeth, despite the fact that the elemental ratios (i.e. Sr/Ca and Ca/P) suggested that the removal of diagenetic material. However, despite the fact that the strontium signature did not represent the signature of the contemporary water of the fish's lifetime environment, the teeth still did display evidence of migratory movement from freshwater to ocean water, suggesting that this method can still be used to identify migration patterns (1992: 285).

In contrast to those who have criticized its utility, Hoppe *et al* found general support for the utility of the method, particularly with enamel (2003). They suggest, however, that the presence of material bearing the original biogenic strontium signature in the later stage leachates may in fact depend on the amount of fluoroapatite in the sample; if these levels are low, the most insoluble material will belong to the original biogenic hydroxyapatite, and this signal will be found in the residual powder left after the leaching procedure is completed (Hoppe *et al* 2003: 26). Others have pointed out, however, that diagenetic changes in bone tissue may take other forms besides the infilling of pore spaces (Hoppe *et al* 2003: 25). Recrystallization processes in particular are likely to contribute to the *post-mortem* uptake of diagenetic Sr (Hedges 2002: 324). Furthermore, diagenetic change does not simply result in the addition of Sr from the soil, but also in the partial exchange of Sr from the original biogenic apatite (Trickett *et al* 2003: 657). In these cases, the weak acid leaching method would be ineffective in removing diagenetic chemical signatures, as the original strontium signature could potentially have been completely replaced by recrystallization of hydroxyapatite or by direct exchange (Nelson *et al* 1986; Tuross *et al* 1989; Budd *et al* 2000:688; Hoppe *et al* 2003: 26). It has also been argued that the acid leaching technique may actually cause the recrystallization of hydroxyapatite, particularly when more concentrated acids are used (Hoppe *et al* 2003: 22, Nielsen & Hedges 1997, Sillen & Sealy 1995). In general, however, the solubility profiling method has been found to be effective for treating enamel, if not for bone. Hoppe *et al*, for example, found that ≥95% of diagenetic Sr in enamel was removed, compared to only 15-80% in bone (2003: 26).

While the results of discussions about diagenetic strontium in bone (and similarly dentine) are not encouraging, consideration of diagenetic changes in tooth enamel is more positive. This is due to the density, low porosity, and small pore size in enamel, as well as its general inertness (see discussion in oxygen section). Archaeological tooth enamel is generally found to have lower absolute concentrations of strontium than bone and dentine (Ezzo *et al* 1997, Price *et al* 1994, Beard & Johnson 2000: 1051, Chiaradia *et al* 2003: 366-367). The concentrations of Sr in enamel and dentine are similar in life, and thus the additional strontium found in archaeological dentine (and similarly, bone) is considered to have originated from diagenetic sources (Budd *et al* 2000). Studies have shown that while dentine strontium isotopic values tend to be close to soil values, enamel values are consistently different from both, as well as showing more variation (Budd *et al* 2000, Chiaradia *et al* 2003: 368). Similarly, while it has been shown that secondary minerals occur in concentrations of 5% in dentine, in enamel this value is only approximately 0.3% (Kohn *et al* 1999). Furthermore, in contrast to bone, which experiences a variety of diagenetic changes, the majority of the diagenetic strontium entering tooth enamel from the burial environment would appear to be secondary minerals that accumulate in the pore spaces of the tissue (Hoppe *et al* 2003: 25). As a result, these are the types of diagenetic strontium that can be removed with the sequential leaching technique, explaining its effectiveness at cleaning enamel (Hoppe *et al* 2003). In general, therefore, strontium isotopic values found in enamel are considered to be more reliable and less prone to contamination than both bone and dentine (Trickett *et al* 2003: 657).

Strontium concentrations in enamel have been shown to demonstrate inter-tooth variations, with incisors showing the highest levels of strontium, canines an intermediate amount, and molars the least (Beard & Johnson 2000: 1056). Beard & Johnson explain this variation as being the result in changes in diet during the formation of the various enamel tissues (2000: 1056). Due to the trophic level effect on strontium concentrations (see discussion of biopurification), lower strontium levels in teeth that form later in development (i.e. molars) might be expected as a result of the weaning process.

In-Situ vs. Solution Mode Analyses of Strontium Isotopes

Traditionally, strontium isotope analysis has been performed using Thermal Ionization Mass Spectrometry (TIMS), which can be done even with very low Sr concentrations (50-300 ppm), but which requires the digestion of 10-50mg of enamel for analysis (Horstwood *et al* 2008: 5660). The TIMS process is also extremely time-consuming, and therefore expensive; running a single sample may take 1-2 hours to complete (Simonetti *et al* 2008: 2). The use of Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) for Sr analysis has recently become more common, and has decreased analytical time to approximately 15 minutes per sample. Processes that require the digestion of the sample for analysis are known as solution-mode analyses, and for Sr analysis, their precision is generally between 0.01-0.001% (Latkoczy *et al* 1998: 561).

In recent years, there has been a strong trend toward the application of laser ablation in isotope and other chemical analyses. The use of laser ablation analysis has a number of advantages. It brings the analytical time per sample down to ~2 minutes, significantly decreasing the cost of analysis (Simonetti *et al* 2008: 2). Furthermore, it can be performed *in-situ*, obviating the need for the digestion and destruction of samples for analysis. It also allows high spatial resolution in sampling, so that specific features can be targeted. Laser ablation has been successfully demonstrated to yield similar values to solution-mode analyses for elemental analysis (Dolphin *et al* 2005; Simonetti *et al* 2008).

Originally, it was also suggested that LA-ICP-MS produced highly accurate results for strontium isotope ratios (Prohaska *et al* 2002). Richards *et al* also used laser ablation with a plasma ionization multi-collector mass spectrometer (PIMMS) to perform high spatial resolution analysis on Neanderthal enamel (2008). They used ablation pits rather than line rasters to minimize damage and to target particular incremental growth features, and used in-house standards and other archaeological samples that had also been analyzed in solution-mode to check the accuracy of the laser ablated measurements (Richards *et al* 2008: 1252). While they combined all of the laser ablated measurements taken on the tooth in question in order to compare it to the solution mode-results, it was difficult to confirm the accuracy of the laser ablation results, because they represent one small area of the tooth while the solution mode-analyses represent a bulk characterization.

However, there are a number of known difficulties when performing $^{87}Sr/^{86}Sr$ on samples where Sr concentrations are low, such as in the 100's of ppm range. Laser ablation involves the use of very small samples, and concentrations of strontium in bone and enamel are often low. The difficulties involved with low Sr concentrations include isobaric interference with ^{87}Rb, doubly-charged rare earth elements (REE), and Ca dimers (Horstwood *et al* 2008: 5660). However, while the correction factors for these interferences are known, recent analyses have also demonstrated the existence of isobaric interference with ^{87}Sr from a Ca-P-O polyatomic compound (Horstwood *et al* 2008, Simonetti *et al* 2008). This polyatomic compound does not lead to a constant offset in the isotopic values, and causes inaccuracies varying from 0.03-0.4%

in the $^{87}Sr/^{86}Sr$ values obtained (Horstwood *et al* 2008: 5659). It was determined that the Ca-P-O polyatomic interference varied according to the strontium concentration of the ablated material. Thus, its effect cannot be eliminated, and LA-MC-ICP-MS measurement of strontium ratios requires intensive calibration by comparing the values obtained against material also analyzed with TIMS (Horstwood *et al* 2008). In future studies, synthetic materials could potentially be used for this calibration. After these corrections, total uncertainty was determined to be between 0.04-0.15% on samples ranging from 13-24µg of enamel, which contained 100-500 ppm of Sr (Horstwood *et al* 2008: 5659). Uncertainties were greater when Sr concentrations were lower (i.e. in the range of 100-200 ppm). However, where strontium levels were greater than 300 ppm, they were able to achieve uncertainties of ~0.05% with as little as 7-12 ng of Sr (Horstwood *et al* 2008:5659). Thus, laser ablation can be used to provide relatively accurate results for strontium isotope analysis, but only after intensive calibration and correction for compounds interfering with the analysis.

Summary

This chapter has provided a review of the vast body of literature that exists addressing the application of isotopic studies to archaeological problems. It focuses in particular on the importance of isotopic studies for characterizing human population movements, through the in-depth examination of the two elements most commonly used for such studies: strontium and oxygen. In addition to a general introduction that focuses on basic principles of mass spectrometry and the fundamental issues associated with the formation and composition of bone and enamel, this chapter provides a detailed review of the main concerns regarding the application of isotopic studies of these two elements to issues of the residential mobility of ancient human populations. These issues include the basic isotopic geochemistry of each element, geographical patterns that affect the distribution of isotopic signatures and the incorporation of these elements in to the human body. The chapter also addresses biological and behavioral factors that influence variation in isotopic signatures within a population and thus affect the local range of variation for a given community, diagenetic contamination that may obscure *in vivo* patterns of isotopic variation, and basic issues of methodology affecting each of the different elements in question. The review of these issues provides fundamental background information required to inform the sample selection and methodology described in the following chapter.

Chapter Six: Isotope Analysis Methodology and Results

Sample Selection

Human Sample Selection

Sample selection procedures are particularly important for studying the cemetery at İkiztepe. Due to the large size of the cemetery, it is not possible to analyze material from all individuals buried within the cemetery; in addition, the condition of the skeletal sample means that not all individuals have all dental and skeletal elements available for analysis. All samples chosen for analysis were selected so as to maximize the number of available lines of evidence about the individuals under consideration. Thus, all samples analyzed were taken from provenienced individuals, to ensure that spatial information about the individuals was available. Furthermore, all provenienced individuals for whom complete or almost complete craniometric information was available were selected for isotopic analysis. Individuals with craniometric data for which enamel samples were available included 59 provenienced individuals. These individuals were selected because craniometric data would provide information about biological relationships which could be used in connection with isotopic data. Eight further individuals were selected due to the fact that they were described by Önder Bilgi as "distinguished burials" on the basis of their grave inclusions (2005); seven other individuals already selected due to the presence of craniometric information were also considered "distinguished" burials. Thus, a total of 15 individuals from "distinguished" burials were included for analysis, in order to examine the relationship between grave inclusions and isotopic signatures. Finally, a further five individuals were selected for analysis who exhibited signs of either healed or unhealed cranial trauma; three individuals among those previously selected for the craniometric and "distinguished" samples also exhibited similar signs. These individuals were selected as a means of determining if there was any relationship between isotopic signatures and evidence for participation in warfare or other violent activities. This brought the total number of individuals selected for analysis of enamel to 72.

It was also important to ensure that the selected individuals would adequately represent the range of age groups and sexes represented in the cemetery. Using sex estimates with a high degree of confidence, the 72 individuals selected for analysis of enamel included 30 females, 26 males, and 16 individuals of unknown sex. If sex estimates with a lower level of confidence are used, the sample is composed of 35 females, 36 males, and 1 individual of unknown sex. Using either set of estimates, both sexes are well represented. Using UWB age estimates, the individuals selected for enamel analysis include 20 younger adults (aged 15-30 years of age at death), 17 middle adults (aged 30-45 years of age at death), 28 older adults (age >45 years of age at death) and 7 adults of unknown age. Using YSE age estimates, the sample is composed of 25 younger adults, 41 middle adults and 6 older adults, with no adults of unknown age. No children were selected for analysis in this study because the isotopic composition of deciduous dentition in comparison to adult dentition with regard to isotopic composition has not been well documented.

Enamel samples for analysis were selected preferentially from 2nd and 3rd molars to avoid the complicating effects of weaning behaviour on $\delta^{18}O$ values. However, in some cases, these teeth were not available for sampling. In these cases, samples were taken from first molars, first or second premolars or canines. Teeth sampled for analysis therefore included 31 third molars, 26 second molars, eight first molars, three second premolars, one first premolar and three canines.

Of the three canines, one individual did not produce enough enamel to conduct both strontium and oxygen analysis; thus, this individual had only strontium analysis completed.

18 of the 72 individuals were selected upon which to conduct isotopic analysis of bone samples in addition to the enamel samples. These individuals were all selected from the group of individuals for whom craniometric data was available, in order to facilitate comparison between biological relationships and the isotopic signatures in both bone and enamel. An equal number of males and females (nine males and nine females) were selected from amongst available samples in order to prevent sex-related bias in bone isotopic signatures.

Some bias may have been introduced into the results of this study by the choice of only provenienced individuals for analysis. It is possible that isotopic signatures may be spatially related due to the preferential placement of locals vs. non-locals within the cemetery. The provenienced skeletal sample is preferentially located in the northern and southern portions of the cemetery. Due to the fact that early seasons of excavation focused on the centre of the cemetery, the unprovenienced sample (i.e. those that were reburied) was concentrated at the centre of the cemetery. However, sampling from the unprovenienced individuals in order to achieve an unbiased spatial distribution of samples would have actually decreased the amount of information available about the samples under consideration. Future studies may be required to further examine individuals from the central portion of the cemetery, although detailed spatial information may be lacking.

There is no reason to believe that there would be any significant bias in the results due to the selection of individuals for whom craniometric data was available, as there is no significant reason to believe that there would be any relationship between skeletal preservation and isotopic values. Individuals who were excavated in early seasons and who had particularly well preserved crania may not have been reburied, which may offset the spatial bias in the isotopic results somewhat.

The selection of individuals from "distinguished" burials may introduce some bias into the results of the analysis. However, these individuals were chosen purposely as a means of determining whether there was any observable connection between grave richness and isotopic signatures. Thus, these individuals should not be considered to represent a random or representative sample of isotopic signatures for the general population. The same principle applies to those individuals selected due to the presence of healed or unhealed cranial trauma.

Animal Sample Selection

Archaeological faunal samples taken for the purposes of determining a local isotopic baseline were selected from a limited available sample of faunal material from the site of İkiztepe, originating from the 2003-2006 excavation seasons at the site and consisting primarily, if not exclusively, of domestic species (sheep, goat, cow, and pig). Samples were selected by the faunal analyst, Evangelia Ioannido-Pişkin, with pig samples being preferentially selected. Pigs were selected for analysis because the size of their home range is narrower than most other species that were available from the faunal collection at the site, like sheep, goats and cattle, which are generally herded over a wider area. Where features were identifiable that might result in the identification of samples as wild or domestic pig, these samples were identified as such (E. Ioannido-Pişkin, personal communication). Eight enamel samples were selected from this material for analysis, of which four were identified originally as being possible wild specimens. While the wild individuals may have had a slightly larger range than the domestic individuals, even the wild species probably had a fairly restricted range around the settlement, as they likely fed on human garbage and by-products (Greenfield 1988). Studies of archaeological faunal material have shown that standard deviations in $^{87}Sr/^{86}Sr$ for pigs are less than half of those observed for the other species that were available from the İkiztepe excavations (i.e. cattle, sheep and goat), as well as having lower standard deviations than the values observed in human populations (Bentley *et al* 2004). Standard deviations in $^{87}Sr/^{86}Sr$ in pig samples have been demonstrated to be as low as 0.00017 (Vaihingen, Germany, Bentley *et al* 2004) or even 0.00003 (Khok Phanom Di, Thailand, Bentley 2004). $^{87}Sr/^{86}Sr$ values from pig enamel samples have been used in southern Germany to map regional strontium isotope signatures (Bentley & Knipper 2005a).

Sample Preparation and Analytical Methodology

Preliminary Sample Preparation

Samples of enamel were taken from the lingual surface of the teeth to retain the buccal surface intact for later observation of other phenomena (i.e. enamel hypoplasias, etc.). Enamel pieces were cut using a Dremel MultiPro tool with a diamond disc saw attachment. No samples were cut or taken from pathological teeth, as the İkiztepe sample has not yet been fully studied for evidence of dental pathologies. When cutting was required, and intact or partially intact crania were involved, teeth were often sampled preferentially from the mandible as opposed to the maxilla, due to the greater ease of sampling from the mandible, and due to the fragility of the crania under consideration. It was mechanically simpler to sample mandibular teeth, and I wished to prevent the vibration from the saw from damaging the crania. Where loose teeth were used, wherever possible teeth were sampled that could be refit into the mandible or maxilla in order to confirm their position and that they came from the individual in question; this was done in order to prevent potential problems due to mixing of teeth from secondary individuals. Teeth were mechanically cleaned with a dental pick prior to cutting or sampling to remove adhering dirt and dental calculus.

Additional external calculus and other contaminants were removed by abrasion with a tungsten carbide burr attached to a Dremel tool. Following this, adhering dentine was removed from the enamel using a diamond disc saw and diamond engraving bit attached to the Dremel tool. Samples were examined using 10x magnification to ensure that all adhering dentine was successfully removed. All tools were cleaned between the preparations of individual samples to prevent cross-contamination.

Bone samples were taken preferentially from rib shafts, and secondarily from cranial fragments. Previously broken rib fragments were preferentially selected over cutting intact ribs, and every effort was made to take rib shafts where there was no cracking to reveal the interior of the rib shaft, which could lead to greater contamination of the bone samples. Small, non-restorable cranial fragments were sampled in cases where ribs were not available. For some individuals, only cranial material was available. Where both types of bone samples were available, samples were taken from each (see fluoride dating methodology for more detail). When sampling for analysis, small slices of bone were removed using a Dremel MultiPro tool with a diamond disc saw attachment. These slices were removed from previously cut ends of bone, rather than from broken ends, to minimize contamination from the burial environment. The exterior surface of the bone samples were abraded using a tungsten carbide burr attached to the Dremel tool to remove dirt and potential contaminants from the bone surface. All tools were cleaned between samples to prevent cross-contamination.

Samples were then weighed prior to crushing. Both enamel and bones samples were then crushed to a fine powder prior to analysis using an agate mortar and pestle. Enamel and bone powder were immersed in acetone prior to crushing to prevent sample loss during the process. Samples were then weighed post-crushing, and divided into two portions. One portion was designated for oxygen isotope analysis, and one portion was sent to the University of Alberta for solution-mode strontium isotope analysis. Where enough sample was available, approximately 40 mg of sample was weighed out for each type of analysis. Where enough sample was not available for this, samples were divided so as to allow as close as possible to 40 mg for oxygen analysis; less material was required for strontium analysis. Sample amounts used for oxygen isotope analysis ranged from 18.0-49.4 mg, while those sent for strontium isotope analysis ranged from 12.1-47.0 mg. In general, the available volume of enamel samples extracted was much smaller than the available volume of bone samples. In cases where the enamel samples were too small to ensure that a large enough sample existed for both analyses, samples were sent preferentially for strontium analysis. This was the case for only one sample (SK643).

Oxygen Isotope Analysis Sample Preparation

For the purposes of this study, analysis of oxygen isotope ratios has been performed on the phosphate portion of the enamel samples. A step by step procedure for the production of silver phosphate from bone or enamel is provided in **Figure 6.1: Conversion Procedure from Bone/Enamel to Ag_3PO_4.**

Figure 6.1: Conversion Procedure from Bone/Enamel to Ag_3PO_4

40 mg powdered bone or enamel

↓

Soak 24 h in 2 mL 2.5% NaOCl at room temp
Rinse 5x with DIW to neutrality
Soak 48 h in 2 mL 0.125M NaOH at room temp
Rinse 5x with DIW to neutrality
Soak 24-48 h in 2 mL conc. H_2O_2 at room temp
Rinse 5x with DIW to neutrality

Dry sample

↓

Dissolve in 2 mL 2M (enamel) or 4M (bone) HNO_3
at room temp for 48 h or until completely dissolved

Solution

↓

Add 2 mL 2M HF at room temp, wait for
precipitation of CaF_2 (ca. 15-30 min)

Solution plus CaF_2 precipitate

↓

Neutralize by adding 3 mL 2M KOH (enamel) or
4.5 mL 4M KOH (bone)

Solution plus CaF2 precipitate

↓

Centrifuge and pipette solution into glass beaker
Add ca. 3 mL DIW to remaining solution and precipitate;
centrifuge again and pipette remaining solution into beaker
Repeat preceding step 2 more times

Solution of H^+, $H_2PO_4^-$, NO_3^-

↓

Add 15 mL of buffered silver ammine solution
(0.2M Ag_3PO_4, 1.16M NH_4NO_3)
Add 0.75 mL conc. NH_4OH
Heat beaker at 65-70°C for 3 hours

Ag_3PO_4 crystals + solution

↓

Collect on 0.2μ membrane
Dry overnight on membrane at 50°C

Ag3PO4 crystals

Samples were prepared according to a method modified from Stephan (2000) and Evans *et al* (2006), and from O'Neil *et al* (1994) and Vennemann *et al* (2002). Weighed samples were placed in 15 mL polypropylene centrifuge tubes and soaked in 2mL 2.5% NaOCl (sodium hypochlorite) for 24 hours, and then rinsed 5 times with deionized water to neutrality, in order to remove organic contaminants. Following this, the samples were soaked in 2mL 0.125M NaOH (sodium hydroxide) for 48 hours to remove further contamination from humic substances and again rinsed 5 times with deionized water to neutrality. Due to dissatisfaction with the utility of the NaOCl at removing organic contaminants, the samples were then further cleaned for approximately 64 hours in 2 mL of concentrated H_2O_2 (hydrogen peroxide).

Originally, we intended to use a quantity of modern human bone from India as an in-house standard (UTUHB-1) to judge the consistency of the chemical preparation procedures, as well as the internal reproducibility of the isotopic measurements. We also originally intended to directly dissolve the bone and enamel samples using 2M HF, without any prior dissolution in HNO_3. However, upon the addition of the HF to the in-house standard, we encountered problems with the dissolution of the bone. Ultrasonification improved the bone dissolution in HF, but still did not achieve full dissolution. In response, we modified our preparation procedure to involve prior dissolution in HNO_3, followed by the addition of HF to induce precipitation of CaF_2. However, some problems with dissolution were still encountered despite the use of HNO_3. The enamel samples dissolved successfully in 2M HNO_3, but the bone samples still failed to completely dissolve. Concentrated HNO_3 was successful at dissolving the bone completely, but also caused some degradation of the polypropylene tubes. Thus, it was determined that enamel would be dissolved in 2M HNO_3, while bone would be dissolved in 4M HNO_3 to ensure complete dissolution.

Even the fresh bone samples were successfully dissolved in 4M HNO_3 after 48 hours. Archaeological bone samples successfully dissolved in 4M HNO_3 over 24 hours. It seems likely that the problems with the dissolution of the modern bone sample were likely due to the freshness of the bone sample, and that organic material and fatty deposits interfered with the dissolution process. As a result, it was determined that the modern bone standard UTUHB-1 would not be appropriate for use as an in-house standard for this procedure. Instead, synthetic hydroxylapatite was used as a standard (HA).

Additional experimentation was conducted with the method outlined in Chenery (2005). This method involved the heating of the samples in 20mL of concentrated H_2O_2, followed by the addition of a few mL of concentrated nitric acid and additional hydrogen peroxide. The sample was then dissolved in 2 mL of 2M HNO_3. This sample was extremely effective at facilitating the fast and easy dissolution of both bone and enamel samples. However, the calcium fluoride precipitate produced by this method was gelatinous and was difficult to separate from the phosphate solution. Furthermore, the silver phosphate yields produced by this method for were significantly lower than those for standards processed using simple cleaning in hydrogen peroxide. In addition, the oxygen isotope values were neither internally consistent, nor consistent with other results obtained. As a result, this cleaning method was abandoned in favour of simple cleaning with hydrogen peroxide.

Following the experimentation with various strengths of acid to determine their utility in dissolving the samples, the cleaned enamel samples were then dissolved in 2mL of 2 M HNO_3 (nitric acid), while bone samples were dissolved in 4M HNO_3. Following complete dissolution (which generally took place after approximately 4 hours for enamel, and 24-48 hours for bone), 2mL 2M HF (hydrofluoric acid) was added to cause the precipitation of CaF_2 (calcium fluoride).

The formation of calcium fluoride occurred almost immediately, and precipitation to the bottom of the centrifuge tube was generally complete after about half an hour. This reaction was conducted at room temperature. Samples were then neutralized with KOH (potassium hydroxide); enamel samples, which had been dissolved in 2M HNO_3, were neutralized with 6mL of 2M KOH (3mL to neutralize the HNO_3, and 3mL to neutralize the HF). Bone samples, which had been dissolved in 4M HNO_3, were neutralized with 4.5 mL of 4M KOH (3mL to neutralize the HNO_3 and 1.5 mL to neutralize the HF). The resulting solution was then centrifuged, and the phosphate solution was pipetted into a 250 mL glass beaker. These beakers had previously been cleaned with a solution of 30% HNO_3 to remove any organic contaminants. Deionized water (approximately 3 mL) was added to the remaining solution, and centrifuged again. The remaining solution was then pipetted into the phosphate solution in the beaker. This rinsing procedure was then repeated. The resulting CaF_2 precipitate residue was retained in the original polypropylene centrifuge tube.

15 mL of a buffered silver ammine solution formed from 0.2M $AgNO_3$ (silver nitrate) and 1.16M NH_4NO_3 (ammonium nitrate) was added to the phosphate solution in the glass beaker, followed by the addition of 0.75mL of concentrated NH_4OH (ammonium hydroxide). 15 mL of deionized water was then added to the solution to prevent it from boiling away while the ensuing heating step was conducted. The resulting solution was then heated over a period of 3 hours using a hot plate at a temperature of between 65-70ºC. This resulted in the precipitation over of Ag_3PO_4 (trisilver orthophosphate) crystals, which began to appear after approximately 1 hour. After three hours had elapsed, the beakers were removed from the hot plate and allowed to cool. Once cooling was completed, the remaining solution was filtered and the silver phosphate

crystals collected using a 0.2µ Pall Nylaflo (nylon) membrane disc filter and dried at 50ºC overnight. Following drying, the silver phosphate crystals were collected and weighed.

The crystals resulting from this procedure varied from light yellowish green to almost black. In general, synthetic hydroxyapatite samples tended to produce very small bright yellow crystals, while enamel samples produced light yellowish green to medium green crystals; generally, the crystal size for enamel samples was also small. Bone samples also occasionally produced samples of light yellowish to medium green, but more commonly produced darker crystals varying from dark green to black. Bone samples also tended to produce much larger crystals than those observed with enamel samples. There was no apparent pattern between crystal appearance and the resulting oxygen isotope values.

Yields of Ag_3PO_4 crystals were calculated against predicted crystal weights given input sample weights. Yields produced by this method varied between 11% and 116% (mean yield 58%). Generally, bone samples produced much lower yields than enamel samples. Bone sample yields varied between 21% and 64% (mean yield 39%), while enamel samples varied between 21% and 103% (mean yield 66%). Yields for the synthetic hydroxylapatite standards varied between 11% and 88% (mean yield 56%), while those for the NIST120C standards varied between 56% and 116% (mean yield 74%).

Analytical Methodology for Oxygen Isotope Analysis

All Ag_3PO_4 samples were analyzed in the Geobiology Stable Isotope Laboratory of the Department of Geology, University of Toronto. Analysis was conducted using a Hekatech high temperature pyrolysis furnace and a Eurovector Elemental Analyzer attached to a Finnigan MAT 253 mass spectrometer with Finnigan Conflo-III and Finnigan Gas Bench.

Samples are weighed into small silver cups along with nickelized carbon, which are placed in an autosampler and fed into the pyrolysis furnace. The P-O bond in the Ag_3PO_4 crystals is broken using pyrolysis in a glassy carbon tube inside a ceramic insulator, which is held at a high temperature (which can vary between 1300-1450°C). The carbon tube is filled with glassy carbon fragments, which react with liberated oxygen from the phosphate to create CO gas. The CO gas is then carried in a helium stream, and is purified to ensure the absence of any other contaminating elements before entering the mass spectrometer.

Between 250 and 300 µg of Ag_3PO_4 were weighed into a small silver cup (minimum 268 µg, maximum 343 µg), along with approximately 400-500 µg of nickelized carbon (minimum 398 µg, maximum 669 µg). The silver cups were then closed and placed into an autosampler. All samples were burned at 1350°C, after experimentation with temperatures between 1300 and 1400 °C determined that 1350°C produced optimal results. Based on the predicted amount of oxygen available in the weighed samples, the yield of the measurement process was calculated. The samples had a minimum yield of 47.8% and a maximum yield of 111.7%. Only two samples run had yields of less than 60% (actually less than 50%), six between 60 and 70%, 19 between 70 and 80%, 21 between 80 and 90%, 70 between 90-100%, 28 between 100-110% and 3 over 110% (total 149 due to reruns of samples).

One particular sample provided repeated problems in terms of the yield it provided upon analysis. While other samples with low yields were re-run and provided better yields, and thus more reliable data, the yields obtained for the enamel sample of ITSK545 were consistently low. The results obtained for this individual were also abnormally low, an issue likely related to the low yields obtained for the sample. As a result, analysis of the oxygen isotopic results generally excluded this sample from consideration, viewing it to be an outlier resulting from methodological issues and potential contamination, rather than from a true difference in the observed isotopic value.

Calibration of results was performed using three international standards: IAEA-SO-6 (barium sulphate, reference value -11.3‰), NBS 127 (barium sulphate, reference value 8.6 ‰) and USGS 32 (potassium nitrate, reference value 25.7 ‰). These standards were included in each run of samples to allow the creation of a calibration curve for correcting observed results against substances of known isotopic composition. All observed values for samples fell within the range presented by these standards, allowing the creation of an appropriate calibration curve.

Two additional international standards were run and checked against known values to confirm the accuracy of the measurements: USGS 35 (sodium nitrate, observed average 57.83±0.24‰, n=3, reference value: 57.5‰) and IAEA-SO-5 (barium sulphate, observed average: 12.35± 0.03‰, n=2, reference value: 12.0‰).

Furthermore, two internal standards were used for measuring internal reproducibility of the results. The first was an internal barium sulphate standard, which had a value of 11.74 ± 0.23‰ (n=69). The second was an internal silver phosphate standard, which had a value of 20.31 ± 0.28 (n=34).

Values were also checked against international standard NIST 120c (Florida phosphate rock); this standard underwent the entire sample preparation process, including the precipitation of Ag_3PO_4 crystals. The observed average value of standard NIST-120c was 22.53 ± 0.53 ‰ (n=30). Where measurements with yields of <90% were removed, the observed average value was 22.60 ± 0.35 ‰ (n=26). The reported reference value for NIST 120c is 22.4‰ (LaPorte *et al* 2008).

Similarly, an in-house standard was developed from a sample of synthetic hydroxylapatite (henceforth HA). The complete sample preparation procedure developed for bone and enamel was also performed on this synthetic material to produce Ag_3PO_4 for analysis. This standard, along with NIST120c was used to test the reproducibility of the entire procedure. The value for the HA standard was 18.61 ± 0.44‰ (n=23); where yields were greater than 90%, the reproducibility improved, with a value of 18.77± 0.37‰ (n=16).

Strontium Isotope Sample Preparation and Analytical Methodology

Strontium sample preparation methodology was performed as described in Buzon *et al* 2007 and Simonetti *et al* 2008. "Samples were sonicated for 15 min in Millipore water (MQ) and then in 5% acetic acid for 15 min. After overnight leaching in 5% acetic acid, the acid was removed and samples were rinsed with MQ prior to transfer to vials. After adding a Rb–Sr spike, the samples were digested in a microwave oven in 4 mL 16N HNO_3 and 1 mL ~10N HCl. Digested samples were dried overnight on a hot plate (80°C). All dried samples were dissolved in 3 mL of 0.75N HCl and then loaded onto 10 cm ion exchange columns containing 1.42 mL of 200–400 mesh AG50W-X8 resin. Samples of 5 mL of 2.5N HCl each were collected into Teflon vials with an added drop of H_3PO_4 and then left to dry overnight on a hot plate (80°C). Subsequent to ion chromatographic treatment of the samples, the Sr-bearing aliquots were diluted in a 2% HNO_3 solution and aspirated into the ICP torch using a desolvating nebulizing system (DSN-100 from Nu Instruments Inc., Wrexham, UK). Strontium isotope values were determined using a NuPlasma MC-ICP-MS instrument" (Simonetti et al 2008: 6-8).

Expected Isotopic Values

Expected Oxygen Isotope Values from the Black Sea and Anatolia Region

The most comprehensive database of oxygen isotope data has been accumulated by the International Atomic Energy Agency—World Meteorological Organization (IAEA-WMO) as part of the Global Network for Isotopes in Precipitation (GNIP) project. This data includes readings from 550 stations, distributed worldwide in 82 countries, collected since the project's inception in 1961 (IAEA, 2002; Birks *et al* 2002). Much fewer of these stations (i.e. 386), however, have multiple $\delta^{18}O$ readings for precipitation (Bowen & Wilkinson 2002: 315; Birks *et al* 2002). The database is accessible online through the WISER application at http://nds121.iaea.org/wiser/ (last accessed: February 24, 2009).

Unfortunately, compared to some other parts of the world, GNIP stations recording $\delta^{18}O$ in the Black Sea region are rather sparse. Stations of interest are located at Sinop (Turkey), Batumi (Georgia), Odessa (Ukraine) and Rostov-Na-Donu (Russia), while stations in Ankara and Erzurum provide comparative data for the Central Anatolian Plateau. The station located at Sinop provides the most obvious source of comparative data for İkiztepe. The mean annual $\delta^{18}O$ value for the station is provided as -11.44‰.

Table 6.1: Isotope Data for Sinop, Turkey (IAEA, 2002)
Latitude: 42.025, Longitude: 35.1583, Elevation: 32

Sample Date	**H2**	**H3**	**O18**	**Precipitation**
12/15/1966	-74.5	160	-12.59	115
1/15/1968	-61.8	134	-10.29	111
Average	**-68.15**	**147**	**-11.44**	**113**

However, investigation of the dataset available for this station reveals that only two $\delta^{18}O$ readings are available. As a result, the mean annual $\delta^{18}O$ value for Sinop is based on inadequate data. Furthermore, both of the samples upon which these values are based were collected in the winter months (December/January), at the low end of seasonal fluctuations in $\delta^{18}O$. This may be causing the $\delta^{18}O$ value for Sinop to be artificially depleted in ^{18}O.

As a result, additional isotopic data for the southern coast of the Black Sea was sought. Unfortunately, it is rather hard to come by. An article studying the lakes district in the Konya region provides a mean annual $\delta^{18}O$ value for precipitation in Samsun of approximately -10 to -10.5 ‰ in graphic form only, and without citation of the source of the data (Gunyakti *et al* 1993). Furthermore, little or no archaeological work has been done regarding oxygen isotopic values in Turkey. An article studying the geographic origin of archaeological fish specimens from the site of Sagalassos on the western coast of Turkey provides a database of oxygen and strontium isotopic ratios for a number of riverine locations, but all of these are located within Western Anatolia (see Dufour *et al* 2007).

Fortunately, a great deal of work has been done on the topic of mapping known isotopic values in meteoric water and extrapolating to areas where no data is available (Bowen & Wilkinson 2002; Bowen & Revenaugh 2003; Bowen *et al* 2005). This process involves resampling available data for locations with known $\delta^{18}O$ values to interpolate values in intermediate locations, and generating a smoothed trend surface of predicted global $\delta^{18}O$ values. The maps produced by this research, as well as relevant GIS data are available online at www.waterisotopes.org (last accessed: February 24, 2009). This data provides monthly mean $\delta^{18}O$ values to capture the variability required for seasonality-based studies, as well as annual mean values. For the purposes of this study, annual mean values will be used as predicted for the area around Samsun/Bafra by the model developed by Bowen *et al* (2005). Also available online is the Online Isotopes in Precipitation Calculator (OIPC), which was developed based on this model, and is available online at www.es.ucsc.edu/~gbowen/OIPC_Main.html (last accessed:

February 24, 2009). It calculates the predicted values of δ^2H and $\delta^{18}O$ for a particular location based on latitude, longitude and elevation. The following data is presented for series of selected sites using the OIPC:

Table 6.2: $\delta^{18}O$ Values for Selected Sites

Location	Latitude	Longitude	Elevation (m)	$\delta^{18}O$ (‰, V-SMOW)	$\delta^{18}O$ 95% CI (‰)
Bafra, Turkey	41.566667	35.9	115	-7.3	0.5
Varna, Bulgaria	43.2167	27.9167	80	-7.0	0.6
Batumi, Georgia	41.65	41.65	0	-7.7	0.8
Ankara, Turkey	39.866667	32.866667	850	-8.1	0.3
Tokat, Turkey	40.31667	36.55	623	-8.0	0.3
Amasya, Turkey	40.65	35.833	409	-7.6	0.4
Trabzon, Turkey	41.0	39.733	0	-7.3	0.6
Erzurum, Turkey	39.9	41.27	1913	-10.6	0.4
Kastamonu, Turkey	41.372	33.7711	904	-8.6	0.4
Yozgat, Turkey	39.816667	34.8	1,406	-9.3	0.3
Karanovo, Bulgaria	42.65	27.2	147	-6.9	0.5

The following table represents the monthly range of $\delta^{18}O$ values in meteoric water for the city of Bafra, the closest city in the vicinity of İkiztepe.

Table 6.3: Monthly $\delta^{18}O$ Values for Bafra, Turkey

Month	$\delta^{18}O$ (‰, V-SMOW)
January	-10.4
February	-9.2
March	-7.6
April	-6.8
May	-5.6
June	-5.1
July	-4.5
August	-4.0

September	-5.3
October	-6.5
November	-8.0
December	-9.4

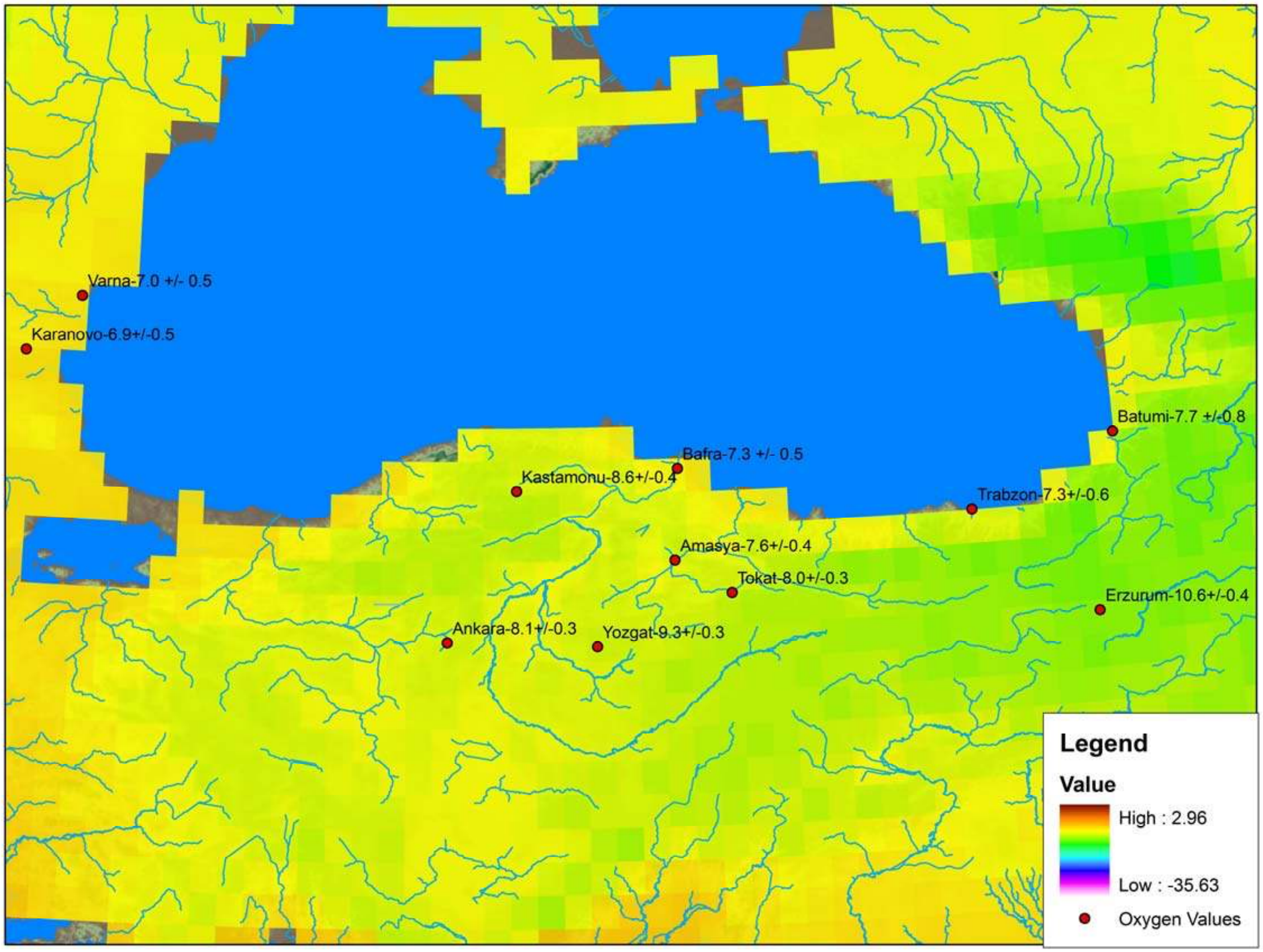
It is evident from the preceding tables that despite relatively significant changes in elevation throughout northern Anatolia, there does not appear to be a great variation in the range of $\delta^{18}O$ values for meteoric water. Furthermore, the range of monthly variation in $\delta^{18}O$ values in precipitation for the modern city of Bafra is greater than the variation observed between Bafra and other modern cities, including those at substantial distances and at significantly different elevations. This suggests the possibility that the variation in $\delta^{18}O$ values in the Black Sea region may not be adequately sensitive for distinguishing movements of individuals between the Bafra Plain and other nearby Anatolian or Black Sea locations.

The following table represents the calculated predicted bone phosphate values based on the three main available conversion equations and the predicted meteoric water values for various cities throughout the Black Sea region and northern Anatolia.

Table 6.4: Predicted $\delta^{18}O$ Values for Bone Phosphate in Various Cities

City	**$\delta^{18}O_{MW}$**	**$\delta^{18}O_{BP}$ (Longinelli 1984)**	**$\delta^{18}O_{BP}$ (Luz *et al* 1984)**	**$\delta^{18}O_{BP}$ (Levinson *et al* 1987)**
Bafra, Turkey	-7.3±0.5	17.70	17.01	16.04
Varna, Bulgaria	-7.0±0.6	17.89	17.24	16.18
Batumi, Georgia	-7.7±0.8	17.44	16.69	15.86
Ankara, Turkey	-8.1±0.3	17.18	17.52	15.67
Karanovo, Bulgaria	-6.8±0.5	18.02	16.38	16.27
Tokat, Turkey	-8.0±0.3	17.25	16.46	15.72
Amasya, Turkey	-7.6±0.4	17.51	16.77	15.90
Trabzon, Turkey	-7.3±0.6	17.70	17.01	16.04
Erzurum, Turkey	-10.6±0.4	15.58	14.43	14.52
Yozgat, Turkey	-9.3±0.3	16.42	15.45	15.12
Kastamonu, Turkey	-8.6±0.4	16.87	15.99	15.44

Map 6.1: Map of Predicted Oxygen Isotope ($\delta^{18}O$) Values for Precipitation in the Region of Northern Anatolia



Expected Strontium Isotopic Values

Geology of the İkiztepe Region

The understanding of the local strontium isotopic signatures for the region around the site of İkiztepe is highly dependent on the overall geological history of Northern Anatolia. Until a decade ago, the majority of the geological literature examining the geological history of Turkey, and especially the Pontides, was written in Turkish. However, more recently, a number of geological overviews of the region have been published (i.e. Yılmaz *et al* 1997, Robertson 1997, Ustaömer & Robertson 1997, Okay & Şahintürk 1997, Okay 2008).

Modern Turkey consists of three major geological zones, including the Pontides, the Tauride-Anatolide Platform, and the Arabian Platform (Yılmaz *et al* 1997: Fig. 1). The present geological makeup of northern Turkey has been heavily influenced by the closure of the Neotethys Ocean, which caused the collision of the Pontide orogenic zone and the Tauride-Anatolide Platform (Yılmaz *et al* 1997: 184). The southern margin of the Black Sea consists of the Pontides, an orogenic belt of compressional deformation extending from Thrace (the Bulgarian Rhodope Mountains) in the west to Georgia in the east. The southern margin of the Pontides is defined by a subduction-accretion complex resulting from the subduction of the Neotethyan Ocean beneath the remains of the Cimmerian Continent to the north. The modern Pontic Mountains, which run in a west-east direction along the southern border of the Black Sea, rose to their present height during the Late Miocene (Yılmaz *et al* 1997: 184). The Pontides are generally divided into three different geological regions, which are distinct from one another: the Western, Central and Eastern Pontides. Each of these generalized areas represents a mosaic of oceanic, continental and island-arc deposits (Yılmaz *et al* 1997: 217).

The geological history of the Western Pontides is quite complex, and geological formations in the Western Pontides include the İstranca Massif, the İstanbul-Zonguldak zone, the Armutlu-Almacık Zone, and the Sakarya continent (Yılmaz et al 1997: 183). The İstanbul-Zonguldak Zone was originally part of the Scythian Platform of the Laurasian Continent, and is separated from the Sakarya Continent to the south by the Intra-Pontide Suture (Yılmaz *et al* 1997: 192, 219; Okay & Tüysüz 1999: 476). Although to the east these areas collided during the Liassian to Early Cretaceous, a remnant basin of the Paleotethys Ocean remained in the west until the Late Cretaceous (Yılmaz *et al* 1997: 217). The Intra-Pontide Suture thus represents the remnants of the Paleotethys Ocean floor (Yılmaz *et al* 1997: 219). The Sakarya Continent to the south represents a portion of the Cimmerian Continent, which was rifted from the Eastern Pontide portion of the Cimmerian Continent during the Late Cretaceous (Yılmaz *et al* 1997: 219). The Sakarya Continent collided with the Tauride Anatolide Platform during the Oligocene to form the İzmir-Ankara Suture, which is equivalent to the Ankara-Erzincan Suture to the east (Yılmaz *et al* 1997: 188, Okay & Tüysüz 1999: 479-481). The İzmir-Ankara Suture thus represents the remnants of the Neo-Tethys Ocean Floor (Yılmaz *et al* 1997: 219). The Armutlu-Almacık Zone represents the metamorphosed northern edge of the Sakarya Continent, which underwent metamorphic changes during the subduction of the Sakarya Continent under the İstanbul-Zonguldak Zone (Yılmaz *et al* 1997: 191, 219). The equivalent of the Armutlu-Almacık Zone as it extends to the west is the İstranca Massif (Yılmaz *et al* 1997: 219). The İstranca Massif is also known as the Strandja (or Strandja Rhodope) Massif, and extends into the Balkans and Eastern & Central Europe (Okay & Tüysüz 1999: 479-480, Okay *et al* 1996: 424, Okay 2008). The Rhodope Massif is dominated by gneisses and extrusive granite plutons (Okay & Tüysüz 1999, Okay *et al* 1996, Marchev *et al* 2005). To the north of the Rhodope Massif lies the Srednogorie Zone, which has been interpreted as an island arc formation (Zagortchev 1994: 9).

The geological history of the Central Pontides is complicated by the fact the region represents a "tectonic knot" where the Western and Eastern Pontides meet, and which formed an important "hinge point" between west and east during the formation of Northern Anatolia and the Pontides (Yılmaz *et al* 1997: 183). A number of geological zones can be identified in the Central Pontides, including the Northern Zone, which represents a magmatic belt that formed above the passive continental margin during the Late Cretaceous as the Neotethys Ocean subducted beneath the Pontides (Yılmaz *et al* 1997: 218). The Kastamonu-Boyabat Basin fill was deposited within a fore-arc basin formed in association with the volcanic belt (Yılmaz *et al* 1997: 198, 219; Ustaömer & Robertson 1997: 265). To the south of the Kastamonu-Boyabat Basin lies the Ophiolite Belt, which includes both ophiolites (such as the Kızılırmak Group) and an ophiolitic mélange (such as the Kirazbaşı mélange), and which developed through the subduction of the Neotethyan Ocean Floor beneath the Cimmerian Continent (Yılmaz *et al* 1997: 199, 217, Ustaömer & Robertson 1997: 265). The Araç-Daday Shear Zone represents basin fill of deep-sea sediments that was deposited in the remains of the Paleotethys Ocean (Yılmaz *et al* 1997: 197, 218-219). Finally, the Kargı Massif represents a mosaic of Paleotethyan oceanic material that was trapped between the two continental plates (the İstanbul-Zonguldak Zone and the Cimmerian Continent). It contains a number of formations, including the Devrekani Massif (the easterly equivalent of the İstanbul-Zonguldak Zone), the remains of the Paleotethyan Ocean floor (including the Küre Ophiolite), and portions of the Cimmerian continental margin (such as the Gümüşoğulu and Aktaş metamorphic formations) (Yılmaz *et al* 1997: 198, 219; Ustaömer & Robertson 1994: 291, Ustaömer & Robertson 1997: 267-280, Okay *et al* 2006: 1248).

A large area to the south of İkiztepe is dominated by the Kirşehir Massif, which forms the majority of Central Anatolia (i.e. the Central Anatolian Crystalline Complex) (Yılmaz *et al* 1997: Fig. 1). This area is represented by a large area of metamorphic and plutonic rocks of predominantly Cretaceous age (Boztuğ & Arehart 2007: 3, Okay 2008: 35). Interspersed throughout the area, which primarily consists of ophiolitic and metasedimentary deposits, are extrusions of post-collisional granitoids (Göncüoğlu 1986, Göncüoğlu & Türeli 1994, Erler & Göncüoğlu 1996, Floyd *et al* 1998, Kadioğlu & Güleç 1999, Kadioğlu *et al* 2003, İlbeyli *et al* 2004, İlbeyli 2005, Boztuğ & Arehart 2007, Boztuğ *et al* 2007, Boztuğ *et al* 2007b, Köksal & Göncüoğlu 2008, Boztuğ *et al* 2009). These granitoids show high levels of variety in composition, ranging between I-, S- and A-type granitoids, based on trace element analysis (Göncüoğlu 1986, Göncüoğlu & Türeli 1994, Erler & Göncüoğlu 1996, Floyd *et al* 1998, Kadioğlu & Güleç 1999, Kadioğlu *et al 2003,* İlbeyli *et al* 2004, İlbeyli 2005 Boztuğ & Arehart 2007, Boztuğ *et al* 2007, Boztuğ *et al* 2007b, Köksal & Göncüoğlu 2008, Boztuğ *et al* 2009: Table 1).

The eastern portion of the Black Sea is generally viewed as younger than the western Black Sea (Robinson 1997: 4). The Eastern Pontides represent part of the Cimmerian Continent, which was sheared off from its western equivalent, the Sakarya Continent during the Late Cretaceous (Yılmaz *et al* 1997: 219). It eventually joined with the Tauride Anatolide Platform during the Oligocene through the subduction of the Neotethyan Ocean to form the Ankara-Erzincan Suture, which represents the eastern extension of the İzmir-Ankara Suture and the remains of the Neotethyan Ocean Floor (Yılmaz *et al* 1997: 219; Robinson *et al* 1995: 868-869). The Eastern Pontides contain a number of formations that are equivalent to the formations described above for the Central Pontides region. The Magmatic Belt represents the equivalent of the Northern

Zone, described above, which formed above the passive continental margin as a result of the consumption of the Neotethys Oceanic floor (Robinson *et al* 1995: 868; Yılmaz *et al* 1997: 204, 219; Okay & Tüysüz 1999: 498, Şen 2007; Kırmacı 2008; Altherr *et al* 2008). Sedimentary deposits, including flysch, were also common throughout the area as the ocean floor continued to be subsumed (Robinson *et al* 1995: 861, Okay & Tüysüz 1999: 501, Kırmacı 2008). The Tokat Massif represents the metamorphic basement of the Eastern Pontide region, and relates to the Karakaya marginal basin (Yılmaz *et al* 1997: 219). It is formed from three different formations: the Yeşılırmak metamorphic unit, the Turhal metaophiolite and the Devecidağ ophiolitic mélange, and the Amasya metamorphic unit (Yılmaz *et al* 1997: 199). The Beldağ Group represents the infill of a fore-arc basin formed in the Late Cretaceous during the subduction of the Neotethys Ocean, similar to the Kastamonu-Boyabat Basin described above (Yılmaz *et al* 1997: 218-219).

The Black Sea itself was created when a back-arc basin formed behind the subducting Neotethyan Ocean, which led to widespread collapse in the area to the north (Yılmaz *et al* 1997: 218; Okay *et al* 2006: 1248). The Black Sea is the world's largest meromictic basic, and is characterized by a permanent halocline and permanent stratification of water layers within it. Beginning between 120-170 m in depth, the lower layers of the Black Sea are filled with stagnant anoxic water containing hydrogen sulphide (Sorokin 2002: 130). However, at the surface, there is a constant inflow of saline Mediterranean water from the Sea of Marmara through the Bosporus Strait (Sorokin 2002). These waters spread within the deeper strata, while the upper layer is also freshened by influxes of fresh water from river outputs and from the Sea of Azov (Sorokin 2002). The majority of the rivers emptying into the Black Sea are located in the northern part of the sea, including the Danube, Dnepr, Southern Bug, Dnestr, and Ingulec

Rivers. Two principal rivers, the Danube and the Dnepr, contribute about 75% of the fresh river water discharged into the sea annually (Sorokin 2002: 74). Thus, the majority of the Black Sea's catchment area lies to its north and northwest.

The site of İkiztepe is located on the alluvial plain of the Kızılırmak River (the Bafra Plain), and in ancient times was on the former coastline of the Black Sea. The alluvial plain of the Kızılırmak River has since expanded due to the high sediment load of the river to its current extent. The site of İkiztepe is located in the boundary region between the Central Pontides (located in the Sinop region) and the Eastern Pontides, which extend from the Samsun region to the Georgian Black Sea coast.

The Pontic Mountains in some places extend 150-200m from the coast of the Black Sea, and reach elevations of 1000 or more (Yakar 2000: 9). While to the east, the northern ridge reaches altitudes of 2600-3000m, the hills and mountains to the south of the Bafra Plain are slightly lower, averaging 1000-1700m (Yakar 2000: 283). There are two main mountain chains that form the Pontic Mountains, which are separated by the Kelkit and Çoruh river valleys into the Northern Pontus ridge, and the Southern Pontus ridge (Yakar 2000: 283). The plains lying between the mountains and the coast are very narrow, with the exception of the Bafra and Çarsamba plains, which are formed by alluviation at the outlets of their respective rivers. The majority of the Bafra Plain has been formed from alluviation that has been deposited since the occupation of İkiztepe. İkiztepe is located at the very edge of the ancient alluvial plain of the Kızılırmak, which was located significantly closer to the mountainous highlands to the south in earlier periods than in modern times (Akkan 1970: Fig. 2). The Kızılırmak River flows from its source in the Anatolian highlands in the region of Şivas for 1 150 km to its outlet in the Bafra Plain. It first travels south and southwest, where it joins with its other major tributary, the Delice

River, and then curves to the north and northeast. The strontium isotopic composition of its water output and the composition of the alluvium it deposits at its delta are comprised of a series of contributions from the geological formations encountered along its course. Immediately prior to the entry of the Kızılrmak River into the Bafra Plain, it passes through the geological formations found directly to the south of İkiztepe, in the Pontic Mountains. These formations consist of a series of flysch deposits, which are sedimentary rocks formed from marine deposits in the foreland of a developing orogen (i.e. deposited as part of mountain formation). Flysch is generally formed in deep marine locations during the early phases of mountain formation, and is generally located at convergent plate boundaries. Such formations are expected, as the area under consideration is situated along the Northern Anatolian Fault, which marks the tectonic boundary between the Eurasian and the Anatolian Plates. Those deposits located nearest the coast have been formed most recently, and were deposited in the Neogene period, with increasingly older formations from the Eocene and Upper Cretaceous appearing with progressive movement toward the south into the Pontic Mountains. Immediately to the south of these deposits is the Magmatic Zone, described above for the Central and Eastern Pontides. These deposits likely make the greatest contribution to the isotopic composition of the water and sediment load of the Kızılrmak River. Upriver, the Kızılırmak River passes through geological deposits composed of generalized metamorphic rocks, serpentine, Mesozoic ophiolites, Eocene volcanic facies, and Oligo-Miocene gypsum deposits.

Expected Strontium Isotopic Values

Although predictions of strontium isotopic values from local geology can be problematic, as these values may not directly reflect biologically available values, knowledge of local geology can provide a useful broad view of expected potential values, if an imprecise one. Predicting likely isotopic values for the geological formations of Northern Anatolia is challenging because of the complicated geological history of the region, as well as the fact that in many cases there is no clear consensus among scholars as to the timing or date of certain events. Studies that have measured the strontium isotopic composition of geological formations in Turkey are patchy at best, and have often focused on particular geological formations due to their ability to answer nagging questions about Turkey's geological history. A selection of available measured strontium isotopic compositions of various geological formations throughout Northern Anatolia are presented in **Table 6.5: Tabulated Measured $^{87}Sr/^{86}Sr$ Value for Northern Anatolian Geological Formations,** including the region, geological formation, rock type and the range of measured strontium isotopic values.

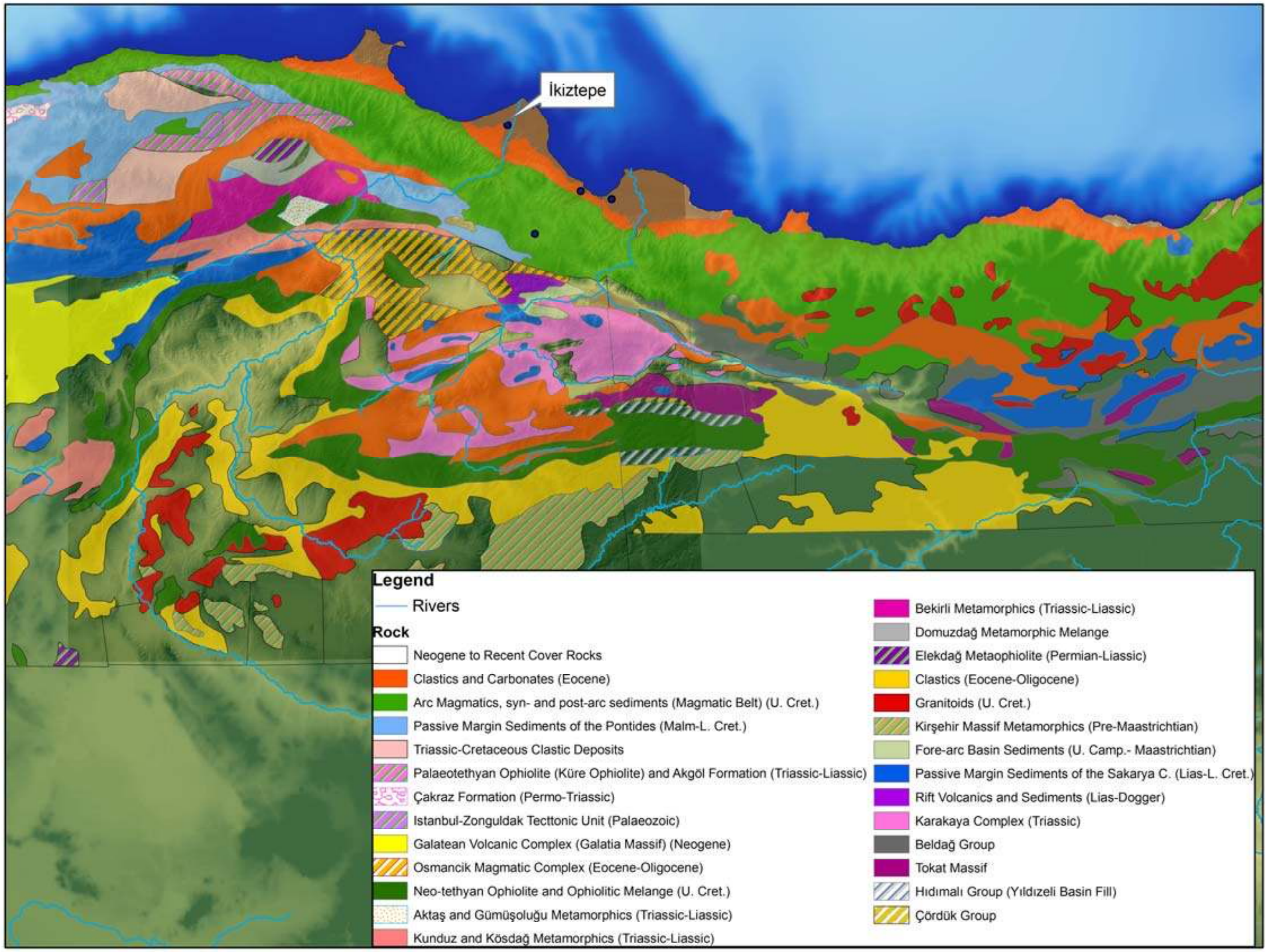
Table 6.5: Tabulated Measured $^{87}Sr/^{86}Sr$ Value for Northern Anatolian Geological Formations

Area/Formation	Rock Type	87Sr/86Sr	References	Region
Kirikkale-Baranadağ	Granitoids (I)	0.70873	İlbeyli *et al* 2004	CACC
Kirikkale-Behrekdağ	Granitoids (I)	0.71004	İlbeyli *et al* 2004	CACC
Kirikkale-Çelebi	Granitoids (I)	0.71028	İlbeyli *et al* 2004	CACC
Kirikkale-Cefalıkdağ	Granitoids (I)	0.70972-0.71087	İlbeyli *et al* 2004	CACC
Kirikkale-Hamit	Granitoids (A)	0.70875-0.71275	İlbeyli *et al* 2004	CACC
Kirikkale-Borucu	Granitoids (I)	0.715459-0.715723	Gönüoğlu & Türeli 1994	CACC
Kirikkale-Hisarkaya	Granitoids (I)	0.722029	Gönüoğlu & Türeli 1994	CACC
Kirikkale-Yenişabanlı (Ağaçören)	Granitoids (I)	0.711245-0.712702	Güleç 1994	CACC
Kirikkale-Borucu	Granitoids (I)	0.715323	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Hisarkaya	Granitoids (I)	0.716245-0.735422	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Sinandı	Granitoids (S)	0.714717	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Terlemez	Granitoids (I)	0.709462	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Namlıkışla	Granitoids (S)	0.717904	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Baranadağ	Granitoids (I)	0.709029	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Çamsarı	Granitoids (A)	0.711517	Köksal & Gönçüoğlu 2008	CACC
Kirikkale-Cefalıkdağ	Granitoids (I)	0.7093-0.7107	Ataman 1972	CACC
Niğde	Gneiss	0.71544-0.72464	Göncüoğlu 1986	CACC
Üçkapılı	Granodiorites (S)	0.71336-0.72212	Göncüoğlu 1986	CACC
Ulukışla Basin, between Kayseri & Adana	Sodic Alkaline Volcanics	0.707242-0.707712	Alpaslan *et al* 2004	CACC??
Ulukışla Basin, between Kayseri & Adana	Ultrapotassic Volcanics	0.708264-0.709514	Alpaslan *et al* 2006	CACC??
Eskişehir Region	Alkaline Lavas (Phonolite, Trachyte)	0.706358-0.708052	Sarıfakıoğlu *et al* 2009	Sakarya?
Murmano Pluton, Sivas	Granitoid (A)	0.70625-0.71113	Zeck & Ünlü 1988	Eastern
Murmana Pluton, Sivas	Granitoid (A)	0.70627 (mafic), 0.712666 (felsic)	Boztuğ *et al* 2007b	Eastern
Dumluca Granitoid, Sivas	Granitoid (A)	0.70456 (mafic), 0.70963 (felsic)	Boztuğ *et al* 2007b	Eastern
Domuzdağ Complex (Saraycık)	Chloritoid-mica schist (rock)	0.723913	Okay *et al* 2006	Central
Domuzdağ Complex (Eclogite outcrop)	Eclogite	0.705640-0.707620	Okay *et al* 2006	Central
Deliktaş, Kastamonu Granitoid Belt	Granites	0.73261-0.74825	Nzegge *et al* 2006	Sakarya

Sivrikaya, Kastamonu Granitoid Belt	Granites	0.70840-0.73246	Nzegge *et al* 2006	Sakarya
Karadere Basement Complex, near Bolu, İstanbul-Zonguldak Zone	Metasediments and Metagranitoids	0.70781-0.74698	Chen *et al* 2002	IZZ
Everek Hanları Plagioleucites, SE of Bayburt	Volcanics	0.70537-0.70568	Altherr *et al* 2008	Eastern
Galatia Massif	Volcanics (Basalts)	0.703421-0.705729	Wilson *et al* 1997	Sakarya?
Doğankavak Unit, Pulur Complex	Amphibolite	0.704126	Topuz *et al* 2004	Eastern
Intra-Pontide Suture, near Bolu	Basalts	0.7074-0.709	Göncüoğlu *et al* 2008	IZZ/Sakarya
S of Sea of Marmara	Granitoids	0.7043-0.7073	Kavacik *et al* 2008	IZZ/Sakarya
S of Sea of Marmara, Gönen	Volcanics	0.7070-0.7078	Kavacik *et al* 2008	IZZ/Sakarya
Biga Peninsula, NW Pontides, Aegean	Basaltic and Andesitie Volcanics?	0.702986-0.708806	Altunkaynak & Genc 2008	Sakarya?
Armutlu Region, Sea of Marmara	Basalts	0.704382-0.705463	Kurkcuoğlu *et al 2008*	AAZ
Kirmir Formation, Beypazari	Glauberite	0.707565-0.707760	Ortı *et al* 2002	Sakarya
Kirmir Formation, Beypazari	Secondary Gypsum	0.707694-0.707722	Ortı *et al* 2002	Sakarya
Saraycik Pluton, Pulur Area, E Pontides	Granodiorites	0.70491-0.70526	Topuz *et al* 2005	Eastern
Torul Pluton, N of Erzincan	Granitoids	0.707073-0.711885	Kaygusuz *et al* 2007	Eastern?
Sivas Region	Gypsum	0.707413-0.707819	Tekin 2001	Eastern
Bakırçay, Merzifon Region	Granodiorites	0.7043-0.7047	Taylor 1981	Central
Galatia Massif		0.703-0.706	Adiyaman *et al* 2001	Kargi?
Niksar-Resadiye		0.7043-0.7048	Adiyaman *et al* 2001	
Erzincan		0.7043-0.7053	Adiyaman *et al* 2001	
Kılıclar	Basaltic Pillow Lavas in Ophiolitic Melange	0.7039-0.7046	Gökten & Floyd 2007	Sakarya/CACC?
Çağlayan Formation, Trabzon area, E Pontides	Dolomite within Turbidites	0.707719-0.707772	Kırmacı & Akdağ 2005	Eastern
Çağlayan Formation, Trabzon area, E Pontides	Dolomite within Turbidites	0.707104-0.707458	Kırmacı 2008	Eastern
South Marmara	Granitoids	0.70431-0.70703	Karacık *et al* 2008	Sakarya
South Marmara, Gönen	Volcanics	0.70709-0.70784	Karacık *et al* 2008	Sakarya
Yerköy (Yozgat)	Gypsum	0.707743	Palmer *et al* 2004	Central
Çankiri-Çorum	Gypsum	0.707392-0.707962	Palmer *et al* 2004	Central
Beypazari	Gypsum	0.707656-0.707706	Palmer *et al* 2004	Central?
Sivas Region	Gypsum	0.707428-0.707760	Palmer *et al* 2004	Eastern?
S of Trabzon, interspersed with granitoids	Basalts/Andesites	0.705702-0.704868	Şen 2007	Eastern
Güvem, Galatia Province	Basalts	0.704-0.706	Tankut *et al* 1998	Sakarya?

Southeastern Europe				
Rhodope Massif	Igneous Rocks	0.7077-0.70977	Marchev & Moritz 2006	S Bulgaria
Rhodope Massif	Metamorphic Rocks	0.70883-0.71977	Marchev & Moritz 2006	S Bulgaria
Drocea Mountains	Ultramafics	0.7044-0.7063	Herz *et al* 1974	Romania
Drocea Mountains	Gabbros	0.7022-0.7048	Herz *et al* 1974	Romania
Drocea Mountains	Basalts	0.7029-0.7037	Herz *et al* 1974	Romania
Drocea Mountains	Banatites	0.7056-0.7092	Herz *et al* 1974	Romania
Rhodope Massif, SE Bulgaria	Oligocene Volcanics	0.7079290.709413	Marchev *et al* 2002	Bulgaria
Rhodope Massif, SE Bulgaria	Pre-Mesozoic Metamorphic Rocks	0.71170-0.73173	Marchev *et al* 2002	Bulgaria
Eastern Rhodopes	Igneous Rocks	0.70323-0.71199	Marchev *et al* 2004	Bulgaria
Central Rhodopes-Mesta (Serbo-Macedonian Massif)	Igneous Rocks	0.71292-0.71296	Harkovska *et al* 1998	Bulgaria
Central Rhodopes-Bratsigovo Dostat	Igneous Rocks	0.70931	Harkovska *et al* 1998	Greece/Bulgaria
Central Rhodopes-Perelic	Igneous Rocks	0.70929	Eleftheriadis 1995	Greece/Bulgaria
Central Rhodopes-Levochevo	Igneous Rocks	0.70900-0.70977	Harkovska *et al* 1998	Greece/Bulgaria
Central Rhodopes-Kotili Vitinia	Igneous Rocks	0.7077-0.70852	Eleftheriadis 1995	Greece/Bulgaria
Central Rhodopes-Central Pirin (Serbo-Macedonian Massif)	Igneous Rocks	0.71303-0.71521	Harkovska *et al* 1998	Greece/Bulgaria
Central Rhodopes-Teshovo (Serbo-Macedonian Massif)	Igneous Rocks	0.71246-0.71263	Harkovska *et al* 1998	Greece/Bulgaria
Central Rhodopes-Vrondou	Igneous Rocks	0.70520-0.70717	Christofides *et al* 1998	Greece/Bulgaria
Central Rhodopes-Xanti	Igneous Rocks	0.70452-0.70783	Christofides *et al* 1998	Greece/Bulgaria
Kirklareli Metagranite, Strandja Massif	Metagranite	0.72935	Okay *et al* 2001	Thrace
Sakar Granitoid Pluton	Granitoid	0.7028	Zagortchev 1994	S Bulgaria
South Bulgarian Granitoids, Sredna Gora Mountains	Granitoid	0.7057-0.7096	Zagortchev 1994	S Bulgaria
North-Pirin Pluton	Granitoid	0.7121	Zagortchev 1994	S Bulgaria
Bezbog Pluton, Pirin	Granitoid	0.7099	Zagortchev 1994	S Bulgaria
Vitosha Pluton	Granitoid	0.7042-0.7043	Zagortchev 1994	S Bulgaria
Central Pirin Pluton	Granite	0.713	Zagortchev 1994	S Bulgaria

Map 6.2: Geological Map of Northern Anatolia (Adapted from Yılmaz *et al* 1997)



In general, mafic volcanic rocks formed from the upper mantle, such as gabbros and basalts tend to have low Rb/Sr ratios and resulting low $^{87}Sr/^{86}Sr$ values, usually in the range of 0.702-0.706 (Faure & Powell 1972: 24). Intermediate rocks such as andesites, and ultramafic rocks also tent to have relatively low strontium isotopic values, in the range of 0.700-0.709 (Faure & Powell 1972: 29). Sedimentary rocks from oceanic sources, such as carbonates and limestones have very low Rb/Sr values, and have strontium isotopic values determined primarily by the isotopic composition of seawater at the time of their formation. Seawater values currently have isotopic values around 0.7092, but since the Phanerozoic have ranged between approximately 0.707 and 0.709 (Faure & Powell 1972: 81-82). All of these trends are consistent with the observed values presented in **Table 6.5** for Northern Anatolia.

As described above, the carbonate and flysch deposits immediately to the south of İkiztepe, as well as the Magmatic Zone, likely contributed most heavily to the strontium isotopic signature of the Kızılırmak River entering the Bafra Plain. The Carbonate deposits, of Tethyan origin, likely have isotopic values similar to those of Tethyan seawater (i.e. 0.7090). The magmatics immediately to the south likely have values in the range of 0.7045. Some mixture of these two signatures likely represents the largest part of the terrestrial inputs to the İkiztepe area. The majority of observed values for other local geological formations in the mountainous region to the south of İkiztepe likely have relatively low strontium isotopic values, in the vicinity of 0.703-0.708 (see **Table 6.5: Tabulated Measured $^{87}Sr/^{86}Sr$ Value for Northern Anatolian Geological Formations**).

The other major input to the isotopic signatures in the area around İkiztepe would have been Black Sea Water. Sea water has a worldwide average strontium isotope value that remains constant around 0.7092, which has been demonstrate to remain applicable throughout the

Holocene (Bentley *et al* 2007b: 304; McArthur *et al* 2001). After about 8400 bp, with the flooding of the Black Sea basin, $^{87}Sr/^{86}Sr$ values for Black Sea water **increase** to 0.7092, similar to the modern values for ocean water (Ryan *et al* 2003: 538). Prior to this increase, the values had been sitting around 0.7088-0.7090 since about 20 kya (Ryan *et al* 2003: 538).

Strontium isotopes in coastal areas are often dominated by inputs from sea spray and from rain derived from evaporated seawater (Bentley 2006: 152). Studies of plants on the Hawaiian coast have showed that they demonstrate signatures characteristic of seawater inputs, rather than the underlying basalt geology (Bentley 2006: 152). Furthermore, at a Thai coastal archaeological site, Bentley *et al* postulated that the predominant signature at the site would be dominated by marine sources, while discharging rivers in the vicinity would only cause very slight variations (i.e. <0.0001) (2007b: 304). Their results confirmed that the enamel values of the population were very close to those of the ocean values (0.70933 ± 0.00005) (Bentley *et al* 2007b: 305). An earlier study by Sealy *et al* on South African populations produced similar results, where human populations living in coastal locations displayed strontium isotope values very close to the marine average, while those from inland areas displayed higher values (Sealy et al 1991: 403).

Isotopic values derived of geological formations derived from the continental crust, and particularly felsic volcanics such as granites, tend to have higher isotopic values than observed in other volcanic rocks. However, such formations are also much more variable, due to their variable origins (Faure & Powell 1972: 43-44). Faure & Powell suggest a likely average value of approximately 0.719 for the isotopic composition of the continental crust, but observed values in granitic formations have ranged from 0.700-0.737 (1972: 26, 54). Many studies have focused on measuring strontium isotope granitic rocks in Central and Northern Anatolia, and confirm the variability of granitoids, as well as their tendency toward higher isotopic values (see **Table 6.5**). Also displaying higher isotopic values are outcrops of the metamorphic basement of the area, such as the Karadere Basement Complex of the İstanbul-Zonguldak Zone (see **Table 6.5**). Other metamorphic rocks of continental origin (i.e. the Aktaş and Gümüşoğlu metarmorphic formations, as well as possibly the Kösdağ and Bekirli metamorphics, in the Central Pontides; the Uludağ Group in the west and the Tokat-Gümüşhane-Bayburt metamorphic basement in the East) may have also displayed higher strontium isotopic signatures (Yılmaz et al 1997: 217).

High strontium isotopic signatures (i.e. above those of Black Sea water) would be expected from outcrops of granite, few of which are found throughout the Central Anatolian Crystalline Complex (CACC). Granite outcrops that do exist in this area are generally small, but could have high enough signatures to explain the outlying human results. To the southwest of Sinop, two small outcrops of granitoids of Jurassic age (i.e. older than many other post-collisional granitoids found in Central Anatolia) are found at Deliktaş and Sivrikaya (Nzegge *et al* 2006). The Deliktaş outcrop has signatures in the range of 0.73-0.74; Sivrikaya, on the other hand, has produced signatures that range from 0.70840-0.73246 (Nzegge *et al* 2006). Also found in the region, further into the highlands of the Kızılırmak River, are granite outcrops in the area around Yozgat and Kirikkale. These granitoids represent a mix of S-type and I-type granitoids, and have strontium signatures varying between 0.712 and 0.716 (Göncüoğlu 1986, Göncüoğlu & Türeli 1994, Erler & Göncüoğlu 1996, Floyd *et al* 1998, Kadioğlu & Güleç 1999, Kadioğlu *et al 2003,* İlbeyli *et al* 2004, İlbeyli 2005 Boztuğ & Arehart 2007, Boztuğ *et al* 2007, Boztuğ *et al* 2007b, Köksal & Göncüoğlu 2008, Boztuğ *et al* 2009: Table 1). Studies in the western portion of the Yozgat batholith have revealed S-type granitoids in the northwest (Sarıhacılı outcrop) (Erler & Göncüoğlu 1996, Boztuğ *et al* 2007, Köksal & Göncüoğlu 2008, Boztuğ *et al* 2009) and

I-type granitoids in the southwest (composite Yozgat batholith) (Erler & Göncüoğlu 1996, Boztuğ *et al* 2007, Köksal & Göncüoğlu 2008, Boztuğ *et al* 2009). In contrast, the eastern portion is comparatively poorly studied, and exact isotopic values are not available.

Although the Strandja and Rhodope Massifs are poorly understood, and few isotopic studies have been conducted on geological formations within it, high strontium isotopic signatures may also be found in this region, which has high numbers of granitoid extrusions (Okay & Tüysüz 1999: 479-480, Okay *et al* 1996: 424, Okay 2008). Plutons in the Pirin area, in the Central Rhodopes in Southern Bulgaria/Northern Greece also produce measured strontium isotopic values in the range of 0.712-0.715 (see **Table 6.5**) (Zagortchev 1994, Harkovska *et al* 1998).

Results of Oxygen Isotopic Analysis ($\delta^{18}O$)

The average $\delta^{18}O$ value for the enamel samples analyzed was 16.024±0.808 (n=71), with a range of 11.3 to 17.46. A Shapiro Wilk test of normality determined that the isotopic values of the enamel samples were not normally distributed (W Value= 0.7912468, p=1.189032E-08). See **Figure 6.2: Histogram of Human Enamel Oxygen Isotope Values.** One significant outlier is noticeable among the values of the human enamel samples, which may result from problems with the measurement (see below); with this individual value removed, the distribution was determined to be normally distributed (W Value=0.9895767, p=0.8327676).

The average $\delta^{18}O$ value for the bone samples analyzed was 15.863±0.366 (n=18), with a range of 15.21 to 16.52. A Shapiro Wilk test of normality determined that unlike the enamel samples, the isotopic values for the bone samples were normally distributed (W Value= 0.9797869, p=0.9477862**).** See **Figure 6.3: Histogram of Human Bone Oxygen Isotope Values.**

Figure 6.2: Histogram of Human Enamel Oxygen Isotope Values

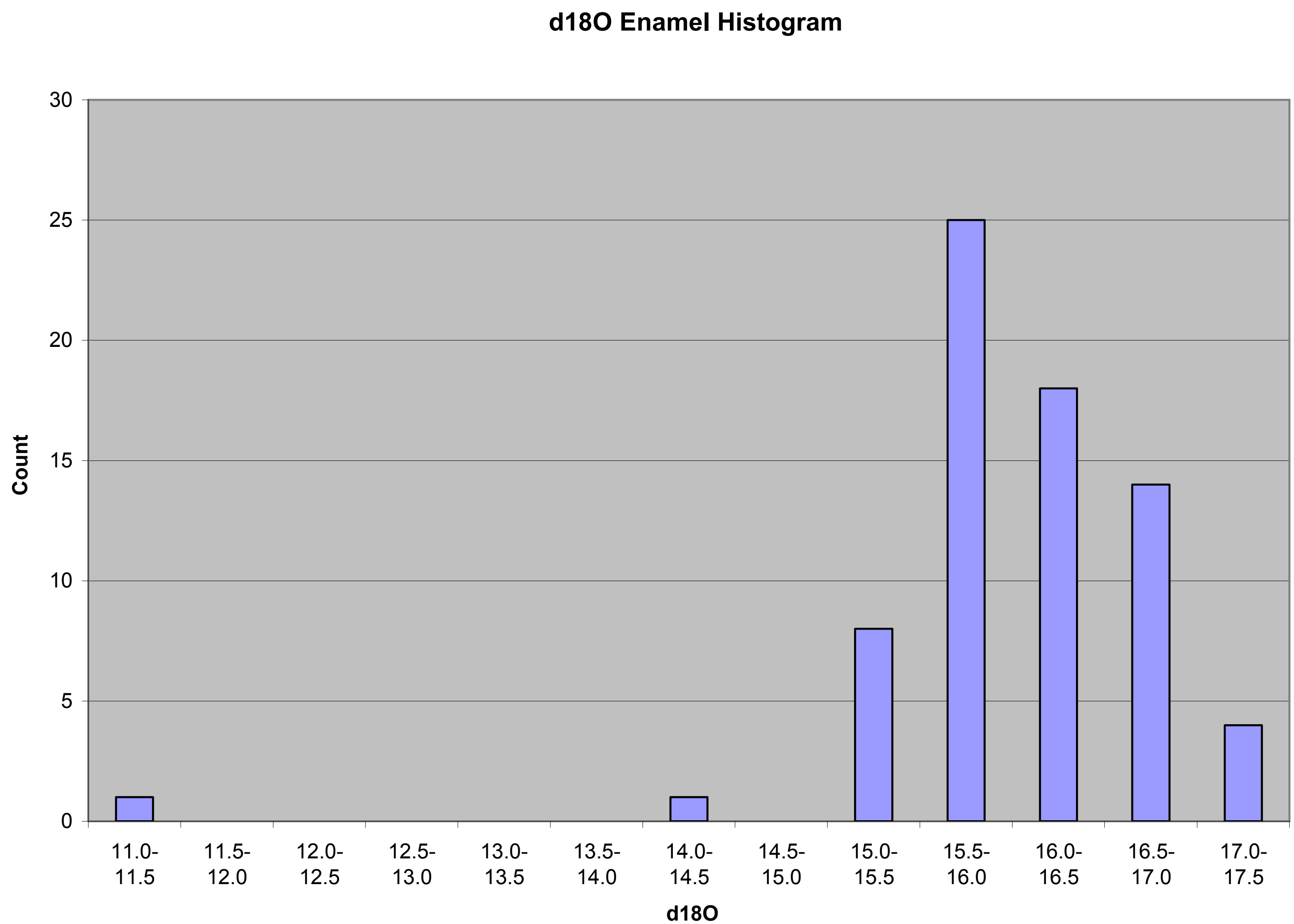


Figure 6.3: Histogram of Human Bone Oxygen Isotope Values

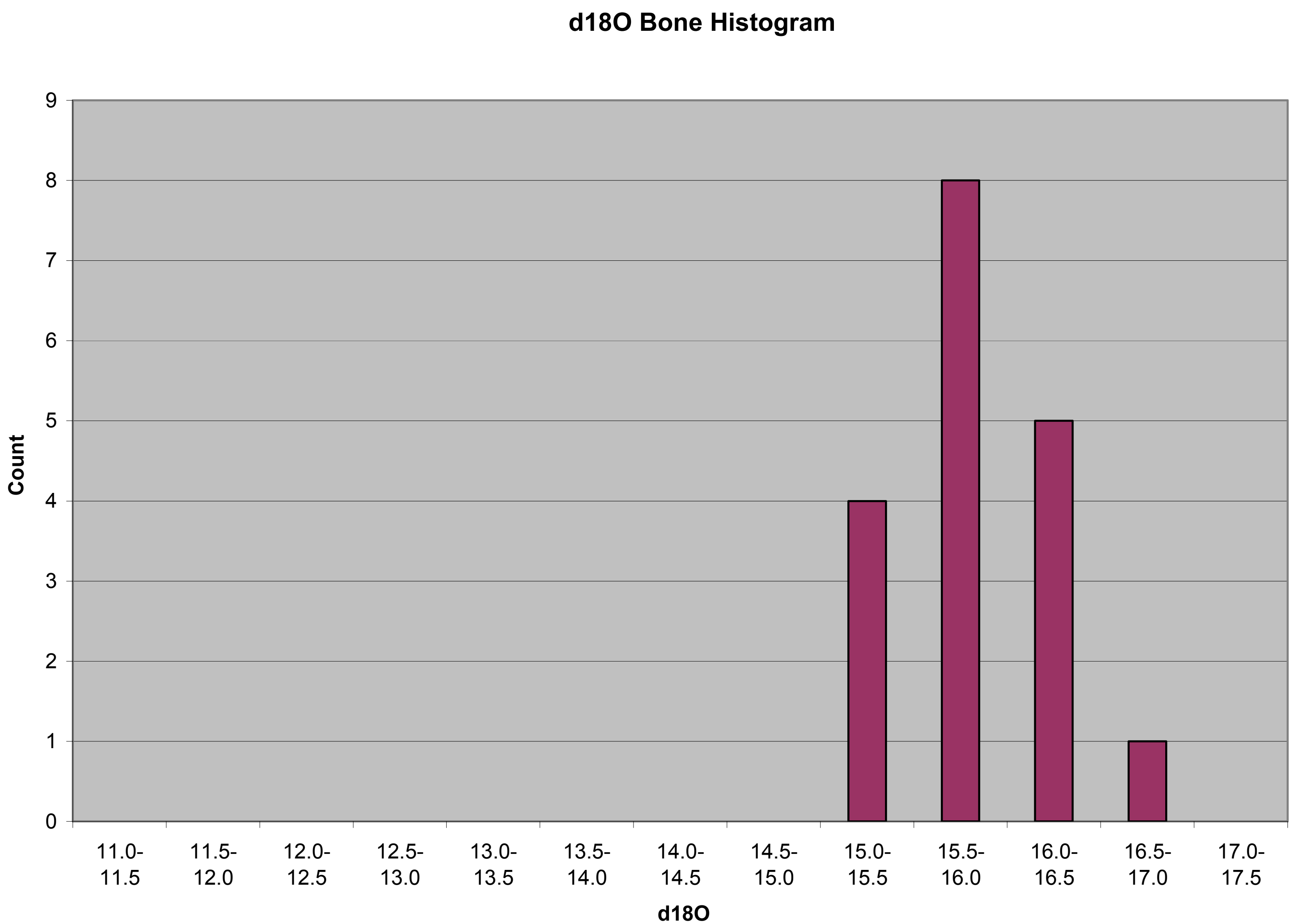
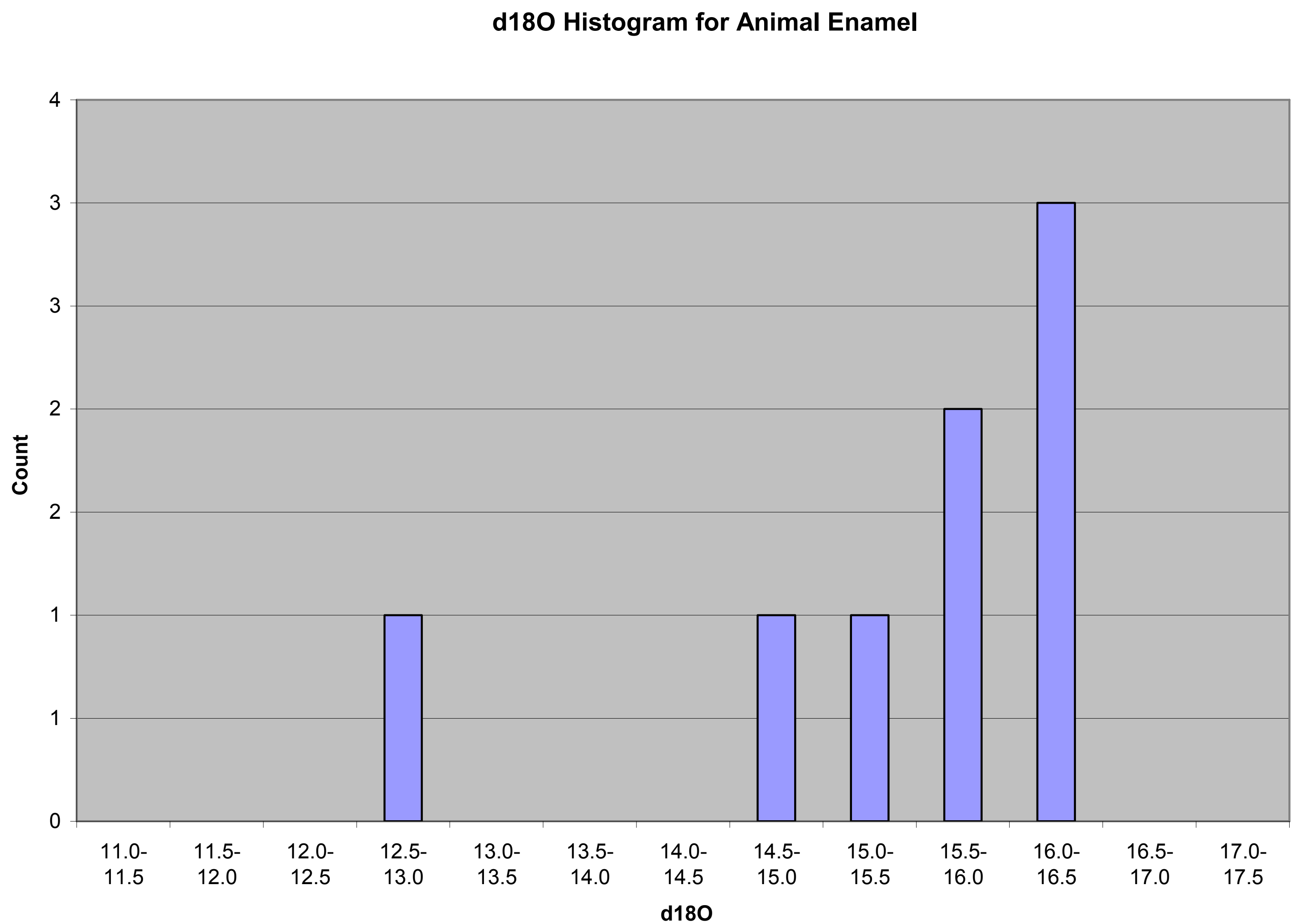


Figure 6.4: Histogram of Animal Enamel Oxygen Isotope Values



Finally, the average $\delta^{18}O$ value for the animal samples analyzed was 15.298±1.202 (n=8), with a range of 12.61 to 16.2. A Shapiro Wilk test of normality determined that, like the human enamel samples, the animal enamel samples were not normally distributed (W Value= 0.7634252, p= 0.0114826). Amongst the animal enamel samples analyzed, there was one obvious outlier, which had both a significantly lower value than the remainder of the enamel samples, and was located outside of the range of 2 standard deviations from the mean among the animal samples. As a result, this individual was removed from the analysis, and the average values for the animal enamel samples were then recalculated. With this individual removed as an outlier, the average for the animal samples analyzed becomes 15.681±0.556 (n=7), with a range of 14.61 to 16.2. Furthermore, with this individual removed, a Shapiro Wilk test of normality determined that the remainder of the isotopic values for the animal enamel samples were normally distributed (W Value= 0.8769755, p= 0.2133578). See **Figure 6.4: Histogram of Animal Enamel Oxygen Isotope Values.**

This outlying individual animal (3624AP1.II) was identified by the site's faunal analyst at the time of selection as a possible wild boar, as opposed to the other samples, which were identified as likely to be domesticated pigs (Evangelia Ioannidou-Pişkin, personal communication). The same individual was also identified as an outlier amongst the results of $^{87}Sr/^{86}Sr$ isotopic analyses (see above), further strengthening the possibility that this animal should be considered significantly different from the rest of the animal sample.

The two groups of samples, human bone and animal enamel samples, are used together to provide a sense of a baseline of local values for oxygen isotopic signatures, as well as an idea of natural levels of variation in isotopic values. Human bone samples provide a good idea of the values and variation in water sources in the years prior to death of the human population.

However, in order to determine whether the bone samples oxygen isotope signatures have been affected by post-mortem exchange of oxygen from the burial environment, samples of animal enamel provide a secondary source about the likely local range of oxygen isotope signatures. Enamel has been shown to be less affected by post-mortem contamination than bone, so it should permit the identification of possible contamination in human bone values, the averages deviate significantly between the two groups.

There was no significant difference determined between the human bone samples and the animal enamel samples, intended to function as a baseline for the human enamel samples (t-test, t= -1.3040, p=0.230409). Furthermore, a t-test revealed no significant difference between the two groups of human samples, bone and enamel (t-test, t= -1.2524, p=0.215127). When the outlying enamel value is removed, however, the difference between the averages of human bone and human enamel become significant (t-test, t= -2.4355, p=0.019320). However, no significant difference was detected between animal enamel and human enamel (t-test, t= -1.6690, p=0.134982). Even with the outlying animal and human individuals removed, the result (t-test, t= -1.8568, p=0.103624) remains statistically insignificant.

Using the bone samples as an estimation of the local range, and defining the local range as 2 standard deviations from the mean of the bone samples, the local range may be estimated as between 15.13 and 16.60. Using all of the animal samples as an estimation of the local range, and defining the local range in the same manner as described above, the local range is estimated as being between 12.89 and 17.70. However, with the outlier animal value removed, the local range is then estimated as being between 14.57 and 16.79. The range provided by the human bone samples is thus significantly narrower than the range provided by the animal enamel samples.

Using the bone samples as an estimation of the local range, 16 of 71 (~23%) human enamel samples analyzed fall outside of this range The local range provided by the animal samples is larger; using all samples, only one human enamel value of the 71 (~1.4%) falls outside this range. Using the animal enamel range calculated with the outlying animal individual removed, 9 of the 71 (~13%) human enamel samples fall outside this range. Using these ranges, it suggests that between 13% and 23% of the individuals analyzed could be considered to represent non-local individuals.

$\delta^{18}O$ Values by Sex

The following tables display the differences in isotopic signatures in bone and enamel for males and females. Tests were performed to determine if there were any significant differences between the sexes in terms of oxygen isotopic signatures. These tests were performed for both the most secure sexual designations (i.e. greater certainty in assigned sexes, with greater numbers of individuals of unknown sex) and less secure sexual designations (i.e. a lower degree of certainty in assigned sexes, with lower numbers of individuals of unknown sex).

Table 6.6: Average $\delta^{18}O$ Values for Adult Males vs. Females (Less Certain and More Certain Sex Estimates)

	More Certain			Less Certain		
	Females	**Males**	**Unknown**	**Females**	**Males**	**Unknown**
N	30	26	16	35	36	1
Enamel Average	16.13214	15.75360	16.31188	16.19485	15.93925	17.46000
Enamel Standard Deviation	0.49475	1.08662	0.68194	0.51495	0.96990	--
Enamel Min	15.24000	11.30000	15.19000	15.24000	11.30000	17.46000
Enamel Max	17.18000	16.99000	17.46000	17.23000	17.46000	17.46000
Enamel Range	1.94000	5.69000	2.27000	1.99000	6.16000	0
Bone Average	15.79556	15.93000	--			
Bone StDev	0.24623	0.46279	--			

T-tests were conducted to test for differences in means between adult males and females in both enamel and bone samples. When dealing with both the more certain sex estimates (i.e.

greater degree of certainty), and the less certain sex estimates (i.e. lesser degree of certainty), no difference was detected between in the isotopic values between the sexes (more certain estimates, $t=1.0666$, $p=0.291798$; less certain estimates, $t= 1.3607$, $p=0.178291$). The difference between the means of male and female bone values was also determined to be not statistically significant ($t= -0.7694$, $p=0.456301$).

Prior to conducting a Levene's test to test for differences in variance between the sexes, a Shapiro Wilk test of normality was conducted for both sexes. Both males and females were determined to demonstrate a normal distribution in enamel values (females: more certain estimates, $W= 0.9752958$, $p=0.6914465$; less certain estimates, $W=0.9799663$, $p=0.7580775$; males: more certain estimates, $W= 0.9742619$, $p=0.7715689$; less certain estimates, $W= 0.9746746$, $p=0.6011137$). For bone isotopic values, both females ($W=0.9277093$, $p=0.4598447$) and males ($W=0.9490032$, $p=0.6791202$) demonstrated a normal distribution.

In addition to testing for significant differences in the mean isotopic values between adult males and females, a univariate Levene's test was conducted to test for differences in variance. This test suggested that there was trend toward a difference in variance, but that this difference was not statistically significant (more certain estimates, test statistic= 2.0154, $p= 0.141906$; less certain estimates, test statistic=1.2689, $p=0.263992$). Furthermore, there was evidence for a trend toward a difference in variance in bone isotopic values between males and females, but this difference was only statistically significant at $\alpha=0.1$ (test statistic=3.6022, $p=0.075895$).

Thus, there is no evidence for any difference between males and females in terms of either average oxygen isotopic values. There is a slight trend toward greater variation in oxygen isotope values in bone and enamel for males compared to females, but this trend is not statistically significant in enamel values.

Figure 6.5: Box Plot of $\delta^{18}O$ Enamel Values by Sex (More Certain Estimates)

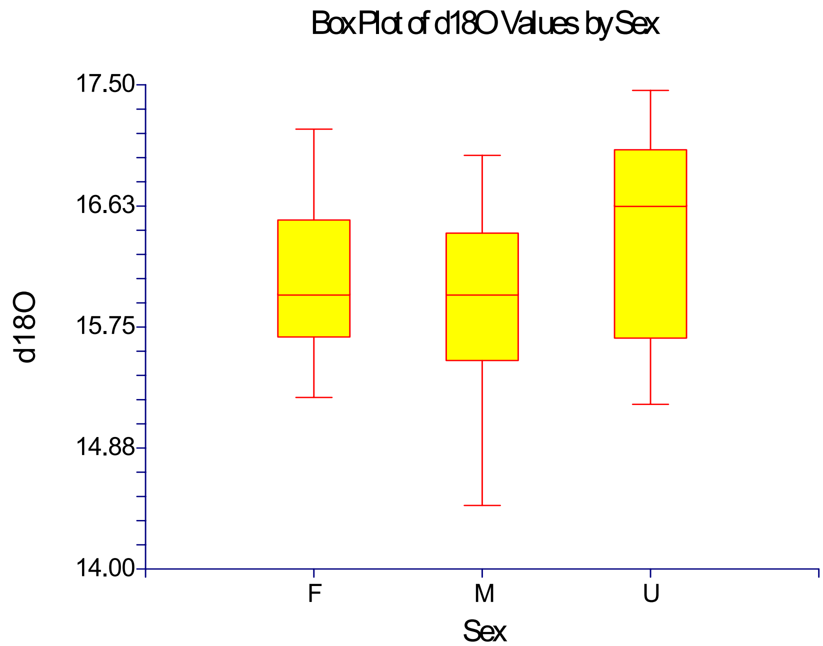


Figure 6.6: Box Plot of $\delta^{18}O$ Enamel Values by Sex (Less Certain Estimates)

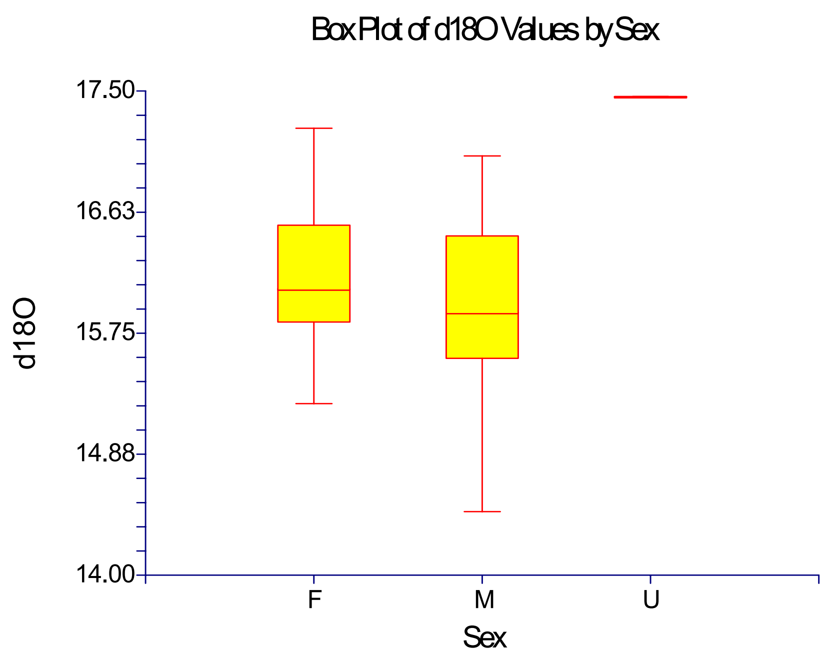
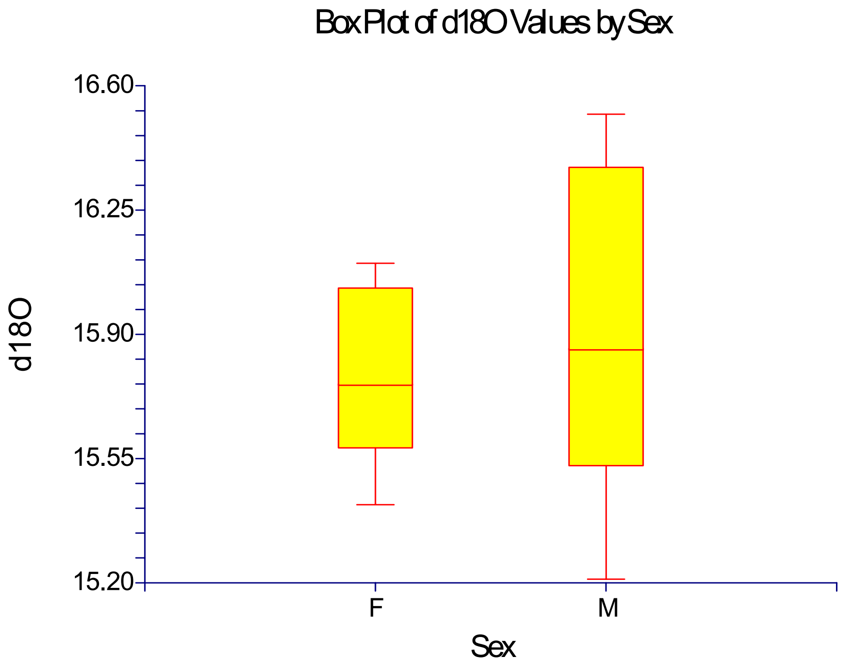


Figure 6.7: Box Plot of δ¹⁸O Bone Values by Sex



δ¹⁸O Isotopic Values by Age Groups

The following tables display the differences in isotopic signatures in enamel for different adult age groups based on estimated age at death. Tests were then performed to determine if there were any significant differences between the age groups in terms of oxygen isotopic signatures. These tests were performed for both sets of available ages estimates (those by Ursula Wittwer-Backofen, henceforth UWB, and those by Yılmaz Selim Erdal, henceforth YSE). Age groups were defined as young adults (15-30 years), middle adults (30-45 years) and older adults (45+ years).

Table 6.7: Average $\delta^{18}O$ Values for Adult Age Groups (UWB and YSE Age Estimates)

	UWB				YSE		
	Young	**Medium**	**Old**	**Unknown**	**Young**	**Medium**	**Old**
N	20	17	28	7	25	41	6
Average	15.87050	16.23938	15.94429	16.29286	16.01720	16.07825	15.69500
Standard Deviation	1.22313	0.59830	0.57056	0.45176	0.70483	0.90354	0.48492
Min	11.30000	15.20000	14.46000	15.81000	14.46000	11.30000	15.24000
Max	17.23000	17.46000	17.18000	16.98000	17.23000	17.46000	16.44000
Range	5.93000	2.26000	2.72000	1.17000	2.77000	6.16000	1.20000

T-tests were conducted to test for differences in mean between adult age groups for enamel samples. For UWB age estimates, none of the t-tests demonstrated a significant difference between any of the different pairs of age groups.

Table 6.8: Results of Paired T-Tests for $\delta^{18}O$ Values Based on Age Groups (UWB)

	Young	**Middle**	**Old**
Young		t=0.6323 p=0.531708	t= -0.9558 p=0.345304
Middle			t=1.6004 p=0.119956

For YSE age estimates, the majority of the t-tests demonstrated no significant difference between the different pairs of age groups. The exception was observed in the test between middle adults and older adults, where a significant difference between the two groups was detected at the $\alpha=0.1$ level (t=2.3876, p= 0.050821).

Table 6.9: Results of Paired T-Tests for $\delta^{18}O$ Values Based on Age Groups (YSE)

	Young	**Middle**	**Old**
Young		t=1.1483 p=0.258058	t=1.3258 p=0.212328
Middle			t=2.3876 p=0.050821

Prior to conducting Levene's tests to look for differences in variance between the various age groups, Shapiro Wilk tests of normality were conducted. In all cases, for both UWB and for YSE age estimates, the various age groups were determined to be normally distributed (UWB

Middle Adults: W= 0.9809935, p=0.9709736; UWB Older Adults: W= 0.9731863, p=0.6680613; UWB Younger Adults: W=0.9494424, p=0.3866536; YSE Middle Adults: W= 0.9831439, p=0.8143604; YSE Older Adults: W= 0.8898261, p=0.3172774; YSE Younger Adult: 0.9499167, p=0.2496442).

Due to the fact that the data is normally distributed, a univariate Levene's test was also conducted to test for differences in variance between the different age groups. This test detected no difference in variance between the age categories for either the UWB or YSE age estimates, (UWB: test statistic = 0.2773, p=0.841563; YSE test statistic= 1.9631, p=0.148419).

Thus, there is little evidence for any significant difference between different categories of adult age at death in terms of either average oxygen isotopic value, or in the degree of variation in the samples. The only exception to this statement is seen in the comparison between the average oxygen isotopic values for middle adults and older adults. Although these groups were not determined to be significantly different when using UWB age estimates, the difference was significant at a level of $\alpha=0.1$ when using YSE age estimates.

Figure 6.8: Box Plot of $\delta^{18}O$ Values by Age Group (UWB Age Estimates)

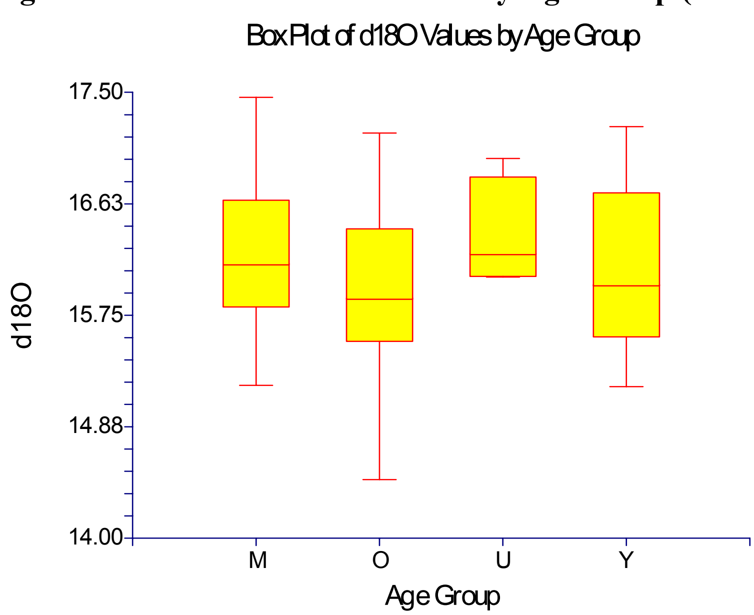
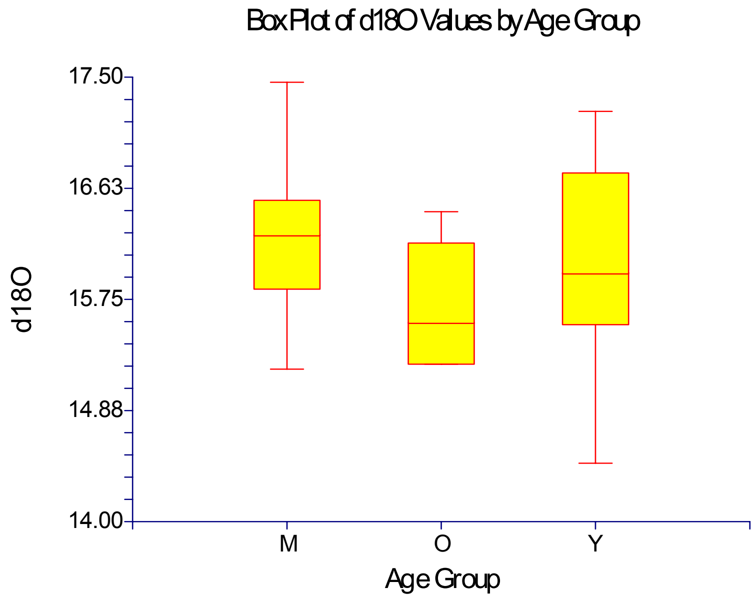


Figure 6.9: Box Plot of δ18O Values by Age Group (YSE Age Estimates)



δ18O Values by Tooth Type

Due to the fact that enamel samples analyzed were taken from a variety of available teeth, it was necessary to determine whether there were any significant differences in isotopic values that could be attributed to the tooth type sampled. Differences in $\delta^{18}O$ values between teeth formed at different times have been linked to fractionation from a trophic effect due to weaning practices (i.e. Wright & Schwarcz 1998). Thus, it was particularly important to test for differences in oxygen isotopic values between different tooth types to determine whether weaning effects could be having an impact on the values obtained for the human enamel samples.

The following table demonstrates the average $\delta^{18}O$ isotopic values for each tooth type sampled.

Table 6.10: $\delta^{18}O$ Isotopic Values by Tooth Type

	C	P3	P4	M1	M2	M3
N	2	1	3	8	26	31
Average	15.76000	15.93000	15.93000	16.39500	15.97444	16.00226
Standard Deviation	0.28284	0.00000	0.42579	0.43785	1.13209	0.55507
Min	15.56000	15.93000	15.52000	15.61000	11.30000	14.46000
Max	15.96000	15.93000	16.37000	16.81000	17.46000	16.98000
Range	0.40000	0	0.85000	1.20000	6.16000	2.52000

T-tests were conducted to determine if any differences between the values for different tooth types were statistically significant. In the case of canines, first premolars and second premolars, sample sizes were too small to allow for t-tests to be conducted. Thus, 95% confidence intervals were calculated for the two most common tooth types (second and third molars) and these intervals were compared to the values obtained for the tooth types with smaller sample sizes. The results of paired t-tests between the tooth types with larger samples sizes are presented in the table below. Italicized values represent results that were determined to be statistically significant at the level of α=0.1.

Table 6.11: Results of Paired T-Tests for $\delta^{18}O$ Values Based on Tooth Type

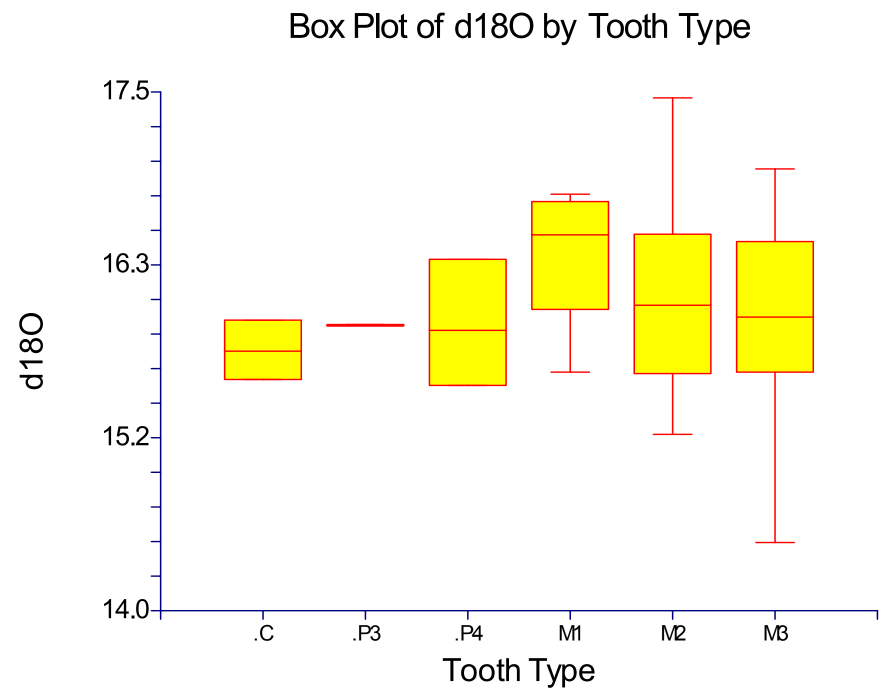
	C	P3	P4	M1	M2	M3
C		Small sample size	Small sample size	Small sample size	Small sample size	Small sample size
P3			Small sample size	Small sample size	Small sample size	Small sample size
P4				Small sample size	Small sample size	Small sample size
M1					t=1.1591 p=0.261341	*t= 2.1330 p=0.051853*
M2						t=0.9392 p=0.352455

Of the t-tests conducted, only the difference between first molars and second molars was determined to be significant, and only at a level of α=0.1, with first molars having elevated $\delta^{18}O$ levels. The 95% confidence interval calculated for second molars was 15.88-16.43‰, and the interval for third molars was 15.80-16.21‰. While the average values of both first and second premolars fall within both of these ranges, the average isotopic value for canines falls below the lower 95% confidence limit for both molar types. However, when individual values are considered, only one of the two values obtained for canine teeth actually falls outside of these ranges. Thus, it would appear that only the values of first molars appear to display elevated values that could be attributed to a trophic effect as a result of their pre-weaning formation time.

Prior to conducting an F-test to examine differences in variance between the different tooth types, Shapiro Wilk tests of normality were conducted to determine if the distributions of isotope values could be considered normal. For both canines, and second premolars, Shapiro Wilk tests could not be conducted due to the small sample size, and thus non-parametric Kolmogorov Smirnov tests were conducted instead. In both of these cases, the existence of a normal distribution in isotope values could not be rejected (canines, K-S test statistic: 0.2602499; second premolars, K-S test statistic: 0.1947516). Due to the fact that only one sample of first premolar was analyzed, neither a Shapiro Wilk nor a Kolmogorov Smirnov test could be conducted. Of the Shapiro Wilk tests conducted, the distribution of both all molar isotope values was determined to be normal (first molars, W= 0.8818355, p=0.1960758; second molars, W= 0.9545182, p=0.3161127; third molars, W= 0.9694076, p=0.5029106).

A univariate Levene's test was conducted to determine if significant differences in variance were present between different tooth types in terms of $\delta^{18}O$ isotopic values. The result of this test suggested that there was no significant difference in variance between the various tooth types (test statistic= 1.1613, p=0.331596).

Figure 6.10: Box Plot of δ[18]O Isotopic Values by Tooth Type



δ[18]O Isotope Values by Disposition of the Body

Compared to other roughly contemporary Anatolian cemeteries, there is surprisingly little variation in the methods used for deposition of the bodies within the cemetery at İkiztepe. The main source of variation in depositional practices is in the direction of the placement of the body, which shows little patterning. Thus, tests were conducted to determine if there was any difference in isotopic signatures based on the direction in which the body's head was pointing.

The following table demonstrates the average isotopic values found for groups based on the head direction of the individual burial.

Table 6.12: Average δ[18]O Values for Groups Based on Head Direction of Burial

	N	NW	W	SW	S	SE	E	NE	U
N	1	7	9	0	16	21	2	0	15
Avg	15.960	16.28571	16.14500		16.09750	15.61905	16.0450		16.33133
Std Dev	0.000	0.66935	0.62228		0.69658	1.09892	0.74246		0.44526
Min	15.960	15.58000	15.24000		14.46000	11.30000	15.5200		15.56000

Max	15.960	17.23000	17.18000		17.46000	16.99000	16.5700		16.98000
Range	0.00	1.65000	1.94000		3.00000	5.69000	1.05000		1.42000

T-tests were then conducted to determine if there were any significant differences between these groups. In the cases of head directions oriented toward the north and the east, the sample sizes were too small to allow t-tests to be conducted. In order to evaluate these categories, a 95% confidence interval was calculated for the most common burial orientation (head oriented to the southeast), which was then compared to the average isotopic values obtained for the smaller groups. The table below shows the results of paired t-tests for different burial groups based on head direction.

Table 6.13: Results of Paired T-Tests for $\delta^{18}O$ Values Based on Head Direction

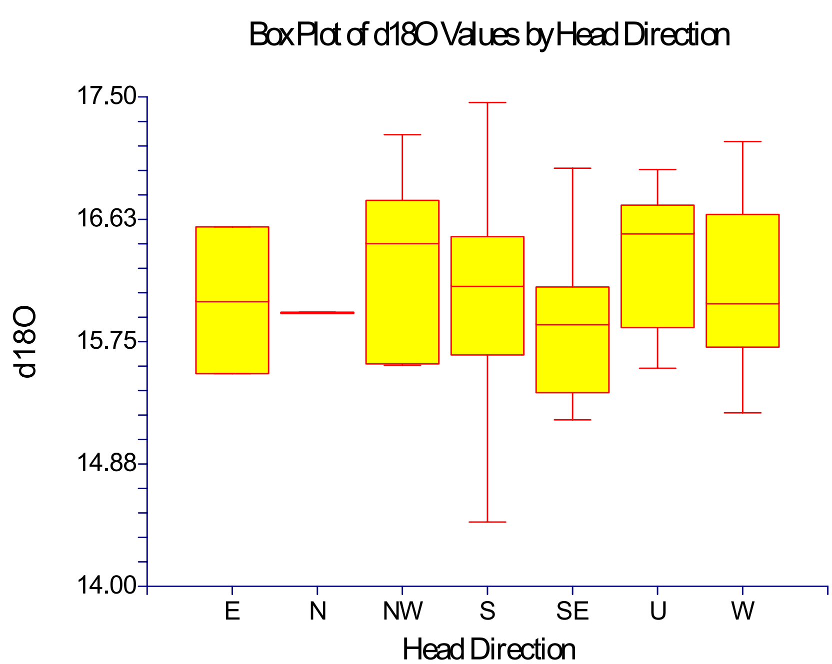
	N	**NW**	**W**	**S**	**SE**	**E**
N		Small sample size	Small sample size	Small sample size	Small sample size	Small sample size
NW			t= 0.4197 p=0.681873	t=0.6128 p=0.551477	t= 1.6347 p=0.139074	Small sample size
W				t= -0.1693 p=0.867739	t= -1.2612 p=0.234134	Small sample size
S					t= 1.2757 p=0.213333	Small sample size
SE						Small sample size

None of the results of these t-tests were determined to be statistically significant. The 95% confidence interval calculated for the southeast orientation group was 15.61-16.06‰. The average values for both smaller groups (those with the head oriented to the north and the east) fall within this range, suggesting that these groups are also not significantly different from burials with the head oriented to the southeast.

Prior to conducting Levene's tests to look for differences in variance between these burial groups, the isotopic values for these groups were subjected to Shapiro Wilk tests of normality to determine if they represented a normal distribution. For burials with heads oriented in an easterly direction, the sample size was too small (n=2) to conduct a Shapiro Wilk test, and thus a non-parametric Kolmogorov Smirnov test was performed. This test suggested that a normal distribution could not be rejected for this group (K-S statistic: 0.2602499). For burials with the head oriented in a northerly direction, the sample size was too small (n=1) to conduct either a Shapiro Wilk or a Kolmogorov Smirnov test. However, for the remaining four groups, Shapiro Wilk tests were conducted. Of these, all four groups demonstrated a normal distribution (head oriented northwest, W= 0.8701689, p=0.1862601; head oriented south, W= 0.9717209, p=0.8656561; head oriented west, W= 0.9830208, p=0.976283; head oriented southeast, W= 0.9485142, p=0.345099).

A univariate Levene's test was conducted to look for significant differences in variance between the different groups based on head orientation, which demonstrated that no significant difference exists between the various groups (test statistic= 0.6092, p=0.657639).

Figure 6.11: Box Plot of δ^{18}O Isotopic Values by Head Direction



Average isotopic values were also calculated based on the position of the body. The vast majority of the burials in the İkiztepe cemetery were placed dorsally, with the arms at the sides. However, a small number of burials were placed in unusual positions, and the individuals were examined to see if unusual burial positions were an indicator of a "non-local" individual, as identifiable through the oxygen isotopic signatures. Unusual burial positions included: individuals with legs or the entire body turned to the left or to the right, one individual buried face down, those buried in "unknown" positions and one individual who was buried in a more complex position. This individual had their trunk and head turned to the left, the legs turned to the right (the knees were probably originally placed above the body), with the arms placed under the body (SK389).

The table below demonstrates the values calculated for the various groups based on body position. These values were calculated for both specific burial positions (i.e. turned to the left, turned to the right, etc.), as well as for non-typical burial practices as a group. Thus, the "Not Dorsal" category in the table below can be divided into "Left", "Right" and "Other" categories; the "Left" and "Right" categories are also shown separately.

Table 6.14: Average $\delta^{18}O$ Isotopic Values Based on Body Position

	Dorsal	**Not Dorsal**	**Left**	**Right**	**Unknown**
N	45	9	4	2	18
Average	15.91955	15.98250	15.86333	16.05000	16.33389
Standard Deviation	0.90399	0.86432	1.50932	0.62225	0.40041
Min	11.30000	14.46000	14.46000	15.61000	15.56000
Max	17.23000	17.46000	17.46000	16.49000	16.98000
Range	5.93000	3.00000	3.00000	0.88000	1.42000

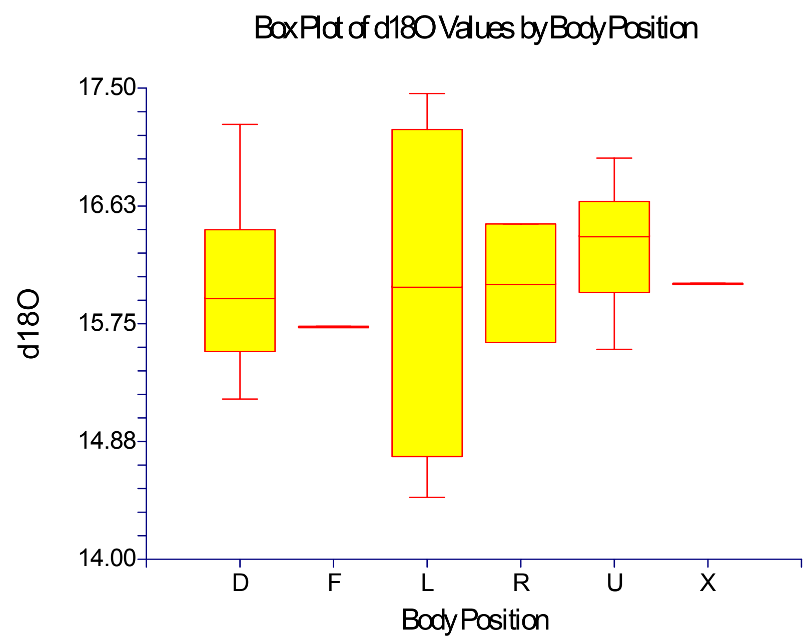
Because all of the specific body positon categories that differ from the standard dorsal body position display very small sample sizes, t-tests comparing the $\delta^{18}O$ values between different body positions could not be conducted. Instead, a 95% confidence interval was calculated for the $\delta^{18}O$ values of the dorsal burials, and this interval was then compared to the values obtained for non-dorsal burial positions.

The 95% confidence interval calculated for the $\delta^{18}O$ values of the dorsal burial group is 15.84-16.18‰. The average values obtained for burials placed on the right and the left side both fall within this range, suggesting that they cannot be considered to demonstrate significantly different values from the dominant dorsal burial position group. Interestingly, however, both individuals whose bodies were placed on their right side fall outside the 95% confidence interval provided by the dorsal burial group, with one value falling below this range and one falling above. A similar pattern is observed in burials placed on their left side. Although the average for the group falls within the confidence interval range observed for the dorsal burial group, two of the individuals in this group have values that fall above this range and two have values that lie below the range. The value obtained for the individual buried face down falls below the dorsal burial range, while the individual buried in an atypical position falls within the 95% confidence interval. Thus, the majority of individuals placed in non-dorsal burial positions display $\delta^{18}O$ values outside the 95% confidence interval obtained for the dorsal group, although the average values obtained for the non-dorsal groups fall within this range. This discrepancy is to the fact that the individual values are widely distributed both above and below the range of values obtained for the dorsal burials. These tests suggest that there may be some differences in oxygen isotopic signatures based on body position, with individuals buried in non-standard positions displaying greater variation in $\delta^{18}O$ values compared to the remainder of the population.

Prior to conducting a Levene's test to look for significant differences in variance between the body position groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. These tests were not possible for the "Face Down" and "Atypical" categories, which had a sample size of one each. Furthermore, the sample size for the "Right" category was too small to allow a Shapiro-Wilk test to be conducted; thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.2602499). Thus, Shapiro Wilk tests could be conducted only for the "Dorsal" and "Left" categories, neither of which was found to significantly deviate from normality (dorsal, W= 0.9567241, p=9.812509E-02; left, W=0.9989678, p=0.9969983).

A univariate Levene's test was conducted to test for significant differences in variance between the different body position groups, and this test found a trend toward a difference in variance that was statistically significant at a level of α=0.1 (test statistic= 2.9474, p=0.059754).

Figure 6.12: Box Plot of $\delta^{18}O$ Isotopic Values by Specific Body Positions



Spatial Patterns in $\delta^{18}O$ Isotopic Values

In order to determine if there were any spatial patterns in the $\delta^{18}O$ values, tests were conducted to look for correlations between spatial variables and isotopic values. The results of these tests are displayed in the table below.

Table 6.15: Correlations between Spatial Variables and $\delta^{18}O$ Isotopic Values

$\delta^{18}O$ vs. :	R^2 value	P-value
X Coordinate	0.0048	0.5688
Y Coordinate	0.0490	0.0654
Distance from Centre-X Coordinate	0.0002	0.8988
Distance from Centre-Y Coordinate	0.0080	0.4605
Absolute Distance from Centre	0.0012	0.7790
Absolute Elevation	0.0098	0.4220
Depth Below Surface	0.0013	0.7723

As demonstrated by the p-values in the table above, none of the correlations between isotopic values and spatial variables are significant. There is, however, a slight correlation between the isotopic values and the absolute location of the burial on the Y coordinate. However, this trend does not play out in the distance from the centre of the cemetery on the Y coordinate or in the absolute distance from the centre of the cemetery. Thus, there is no evidence for a spatial pattern in the oxygen isotopic values.

Relationship between Grave Goods and $\delta^{18}O$ Values

In order to determine whether there was a relationship between the number of grave goods included in the burials and the strontium isotopic values, tests were conducted to look for correlations between these two variables.

This test suggests that there is no significant trend towards a relationship between the number of grave goods and the $\delta^{18}O$ values (r^2= 0.0333, p= 0.1392; Spearman Rank Coefficient= -0.1996, p= 0.1054).

Figure 6.13: Total Number of Grave Goods vs. Oxygen Isotopic Values

The table below displays the differences in oxygen isotopic signatures in enamel for Bilgi's "distinguished" burials compared to the other "non-distinguished" burials.

Table 6.16: Average $\delta^{18}O$ Values for "Distinguished" vs. "Non-Distinguished" Burials

	Distinguished	Non-Distinguished
N	14	56
Enamel Average	15.86	16.15
Enamel Std Dev	0.5933	0.5653
Enamel Min	15.2	14.46
Enamel Max	16.99	17.46
Enamel Range	1.79	3.0

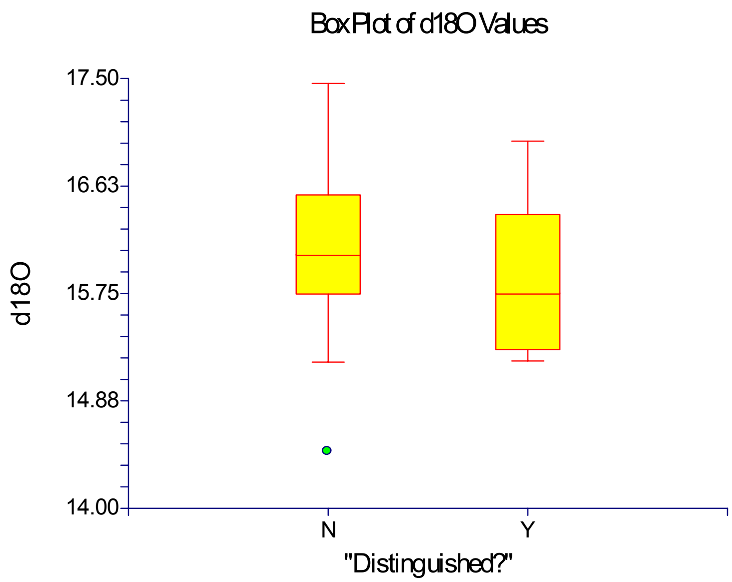
A t-test was conducted to determine whether any significant difference could be distinguished between individuals in these two groups based on grave richness. The results of this t-test suggest that the difference in oxygen isotopic signatures between these two groups is not significant (t= 1.6297, p=0.119354).

Prior to conducting a Levene's test to test for differences in variance between the two groups, a Shapiro Wilk test of normality was conducted for both groups. Both non-distinguished and distinguished burials were determined to be normally distributed (non-distinguished, W=0.9859031, p=0.7548391; distinguished, W=0.9138789, p=0.1793887).

In addition to testing for significant differences in the mean isotopic values between "distinguished" and "non-distinguished" burials, a univariate Levene's test was conducted to test for differences in variance. This test detected no significant difference in variance between the two groups (test statistic=0.1653, p=0.685627).

Thus, there is no evidence to suggest a difference between "distinguished" and "non-distinguished" burial groups, in terms of both average oxygen isotopic value, and in the degree of variation in the samples for each group.

Figure 6.14: Box Plot of $\delta^{18}O$ Isotopic Values by Grave Good Groups



δ^{18}O Isotope Values by Presence of Cranial Trauma

Tests were also conducted to determine if there was any difference in isotopic signatures based on the presence of healed or unhealed cranial trauma.

The following table demonstrates the average isotopic values found for groups based on the presence or absence of healed or unhealed cranial trauma.

Table 6.17: Average δ^{18}O Isotopic Values Based Presence/Absence of Cranial Trauma

	None	**Healed**	**Unhealed**
N	**63**	**3**	**6**
Average	16.03032	15.56000	16.19500
Standard Deviation	0.83135	0.14177	0.73241
Min	11.30000	15.40000	15.40000
Max	17.23000	15.67000	17.46000
Range	5.93000	0.27000	2.06000

T-tests were conducted to determine whether any significant differences could be distinguished between individuals with healed or unhealed cranial trauma and those who had none. Due to the small sample size of individuals with healed cranial trauma, however, t-tests could not be conducted to compare this group to others. As a result, 95% confidence intervals were calculated for both the group with no cranial trauma and those with unhealed cranial trauma, and these ranges were then compared to the values obtained for the healed trauma group. The results of paired t-tests are shown in the table below.

Table 6.18: Results of Paired T-tests Based on Presence/Absence of Cranial Trauma

	None	**Healed**	**Unhealed**
None		Small sample size	t= -0.2831 p=0.787238
Healed			Small sample size

A t-test could only be conducuted to compare those with unhealed cranial trauma to those with none, and this test did not demonstrate any significant difference in oxygen isotopic signature. The 95% confidence interval calculated for those with no cranial trauma was 15.96-

16.25‰, while that for those with unhealed cranial trauma was 15.42-16.96‰. The average isotopic value obtained for the group with healed cranial trauma lies outside the confidence interval produced for those with no trauma, but within the range produced for unhealed cranial trauma. This suggests that those with healed cranial trauma have $\delta^{18}O$ values somewhat different from those with no cranial trauma, but similar to those with unhealed trauma.

Prior to conducting a Levene's test to look for significant differences in variance between the cranial trauma groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. The sample size for the "Healed" category was too small to allow a Shapiro-Wilk test to be conducted (n=3); thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.2189099). Thus, Shapiro Wilk tests could be conducted only for the "Unhealed" and "No Cranial Trauma" categories. Of these, neither the "No Cranial Trauma" nor the "Unhealed Cranial Trauma" was found to significantly deviate from normality (no cranial trauma, W= 0.9851477, p=0.6675556; unhealed cranial trauma, W= 0.9333665, p=0.606339).

A univariate Levene's test was conducted to test for significant differences in variance between the different cranial trauma groups, and this test found no significant differences in variation (test statistic= 1.9057, p=0.156700).

Figure 6.15: Box Plot of $\delta^{18}O$ Isotopic Values by Cranial Trauma Groups

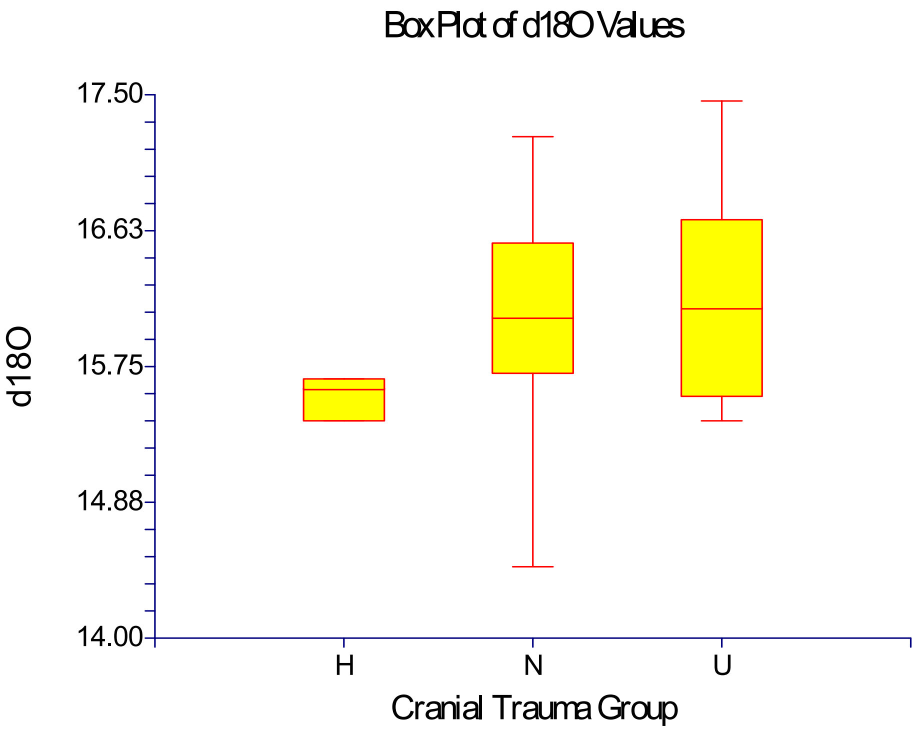


Figure 6.16: Histogram of Human Enamel Strontium Isotope Values

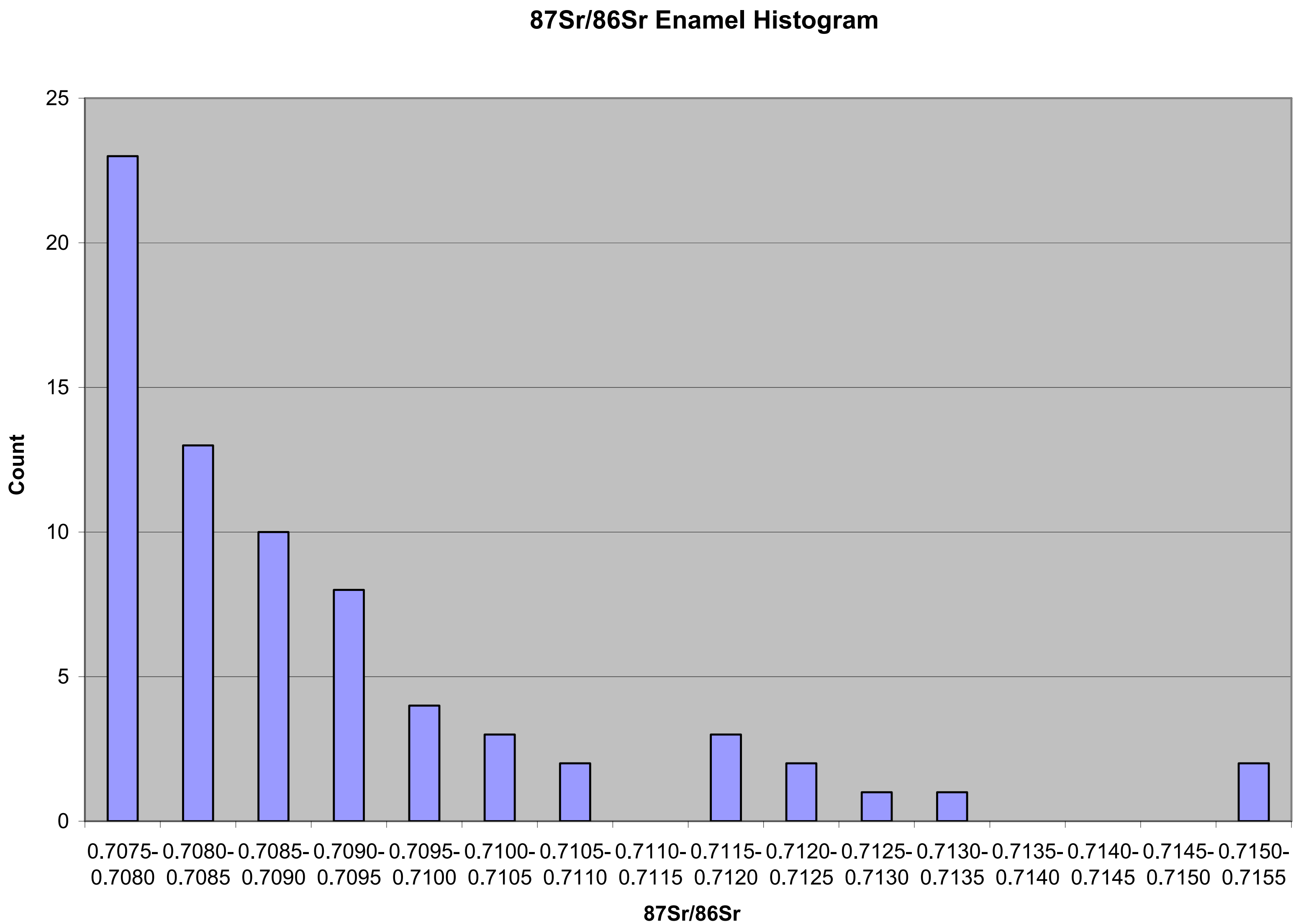


Figure 6.17: Histogram of Human Bone Strontium Isotope Values

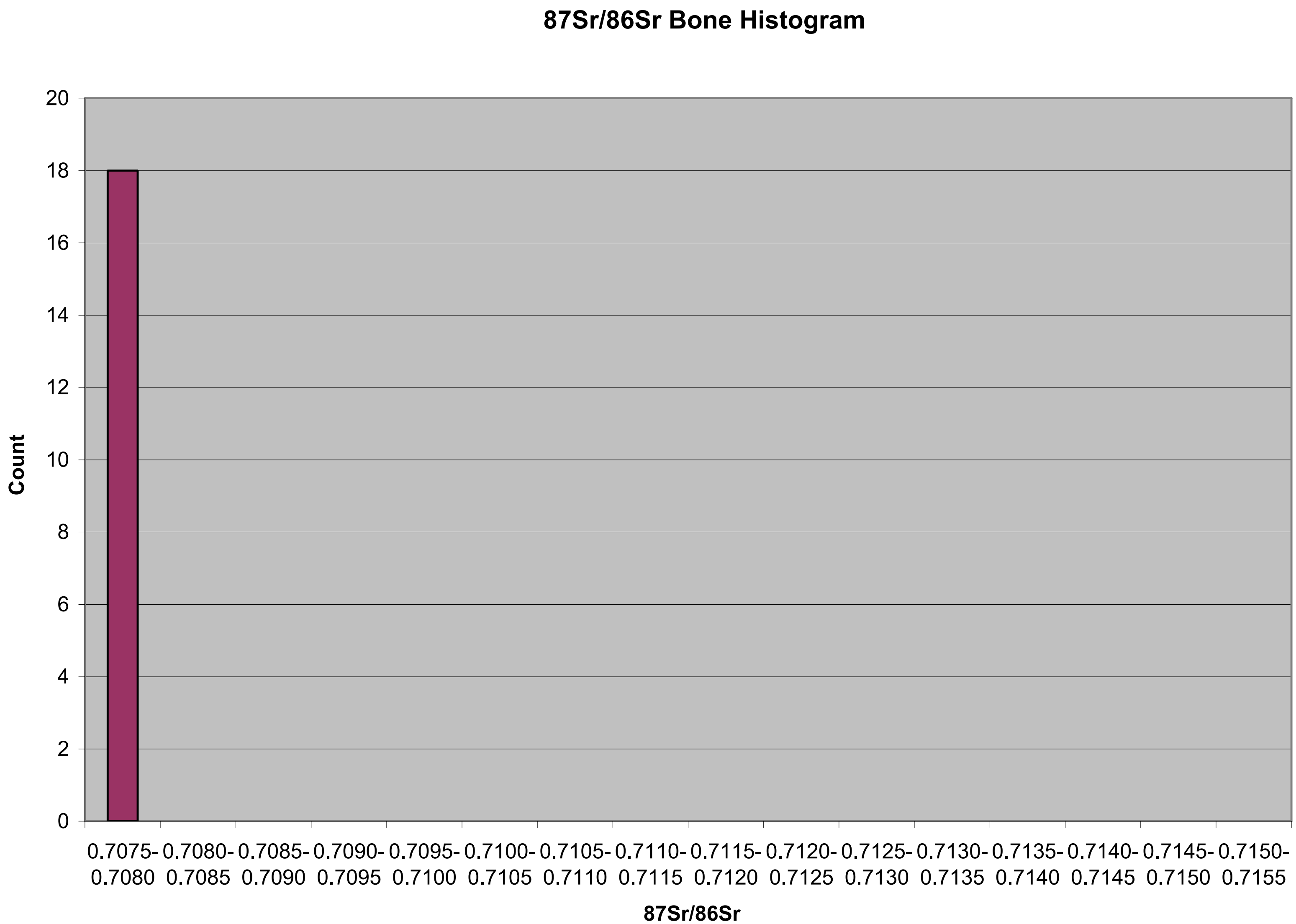
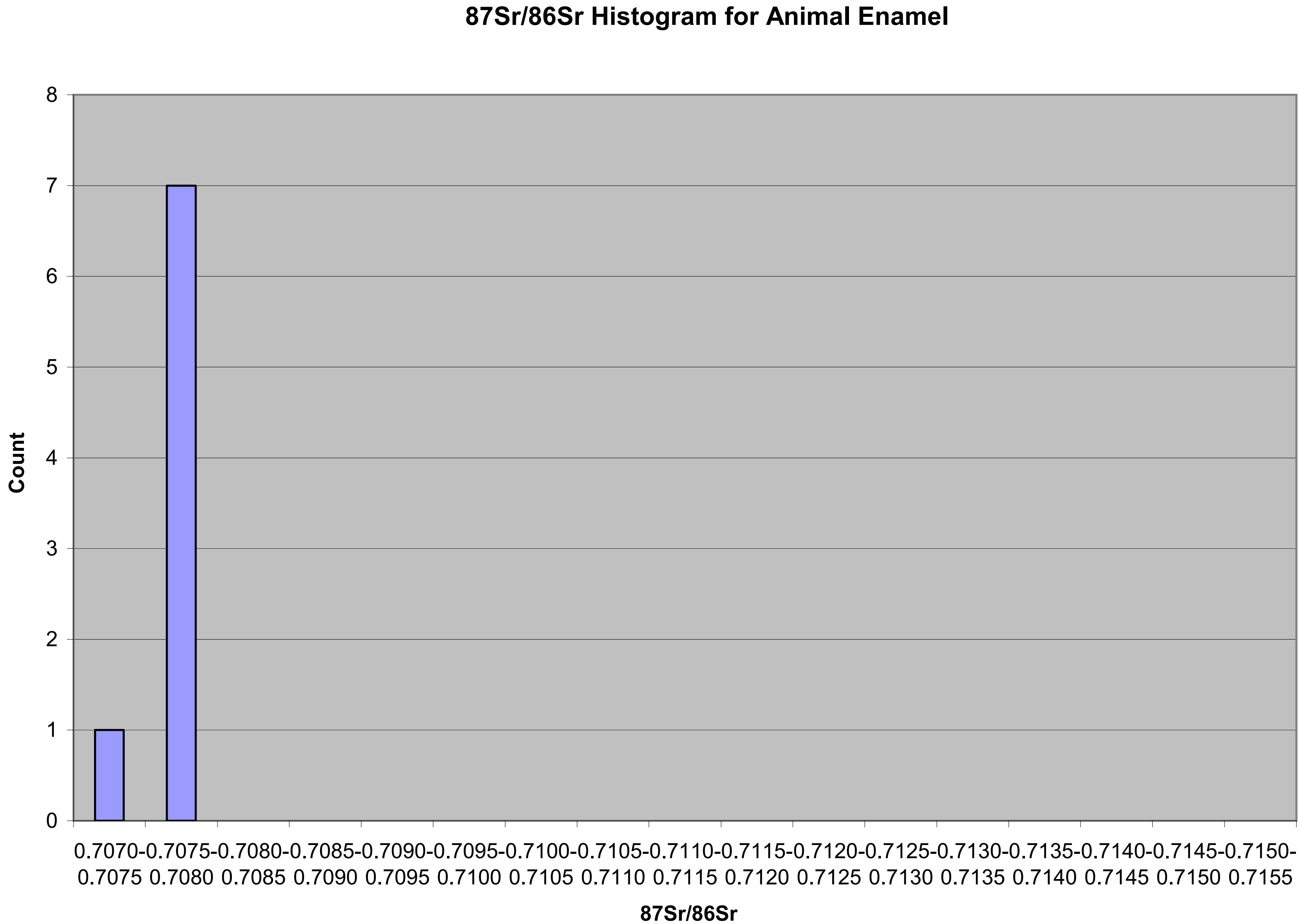


Figure 6.18: Histogram of Animal Enamel Strontium Isotope Values



Results of Strontium Isotopic Analysis

The average $^{87}Sr/^{86}Sr$ value for the enamel samples analyzed was 0.7091±0.00172 (n=72), with a range of 0.70766 to 0.71548. A Shapiro-Wilk test for normality determined that the isotopic values of the enamel samples were not normally distributed (W value=0.7644241, p=2.120981E-09). See **Figure 6.16: Histogram of Human Enamel Strontium Isotope Values.**

In contrast, the average $^{87}Sr/^{86}Sr$ value for the bone samples analyzed was 0.70777±0.00007 (n=18), with a range of 0.70767 to 0.70799. A Shapiro-Wilk test for normality determine that unlike the enamel samples, the isotopic values for the bone samples were normally distributed (W Value=0.9688236, p=0.8402645). See **Figure 6.17: Histogram of Human Bone Strontium Isotope Values.**

Finally, the average $^{87}Sr/^{86}Sr$ value for the animal samples analyzed was 0.70759±0.00023 (n=8), with a range of 0.70704 to 0.70773. A Shapiro-Wilk test for normality demonstrated that, like the enamel samples, the isotopic values for the animal samples were not normally distributed (W Value=0.7634252, p=0.0114826). Amongst the animal enamel samples analyzed, there was one obvious outlier, which had both a significantly lower value than the remainder of the enamel samples, and was located outside of the range of 2 standard deviations from the mean among the animal samples. As a result, this individual was removed from the analysis, and the average values for the animal group were recalculated. With this individual removed as an outlier, the average for the animal samples analyzed becomes 0.70767±0.00007 (n=7), with a range of 0.70755 to 0.70773. Furthermore, with this individual removed, a Shapiro-Wilk test for normality determined that the remainder of the isotopic values for the animal samples were normally distributed (W Value=0.8600947, p=0.1516861). See **Figure 6.18: Histogram of Animal Enamel Strontium Isotope Values.**

This outlying individual animal (sample 3624AP1.II) had been identified by the site's faunal analyst at the time of selection as a possible wild boar, as opposed to the other samples analyzed, which were identified as likely to be domesticated pigs (personal communication, Evangelia Iannidou-Pişkin). The same individual was also determined to be an outlier by oxygen isotope analysis.

The two groups of samples, human bone and animal enamel samples, are used together to provide a sense of a baseline of local values for strontium isotopic signatures, as well as an idea of natural levels of variation in isotopic values. Human bone samples provide a good idea of the values and variation in the diet and water sources in the years prior to death of the human population. However, in order to determine whether the bone samples strontium signatures have been affected by post-mortem addition of strontium (i.e. through modern fertilizers or ground water), samples of animal enamel provide a secondary source about the likely local range of strontium signatures. Enamel has been shown to be less affected by post-mortem contamination than bone, so it should permit the identification of possible contamination in human bone values, the averages deviate significantly between the two groups.

Interestingly, there is a significant difference between the averages calculated for the human bone and animal enamel samples, which are both intended to represent a local baseline (t= -3.0376, p=0.005674). Even with the outlier among the animal values removed, the difference between the two groups is still statistically significant (t= -3.1196, p= 0.004818). However, in comparison to the difference between the human enamel samples and both the human bone and animal enamel samples, this difference is relatively small (animal enamel vs. human enamel t-test: t= -6.9536, p=0.000000; same test with outlier removed: t= -7.0496, p=0.000000; human enamel vs. human bone t-test: t= -6.5844, p=0.000000). Indeed, the order of magnitude of the difference between the human bone and animal enamel values is 0.0001, while the order of magnitude of the variation in the human enamel samples is close to 0.01 (i.e. two orders of magnitude greater). This suggests that despite the statistically significant difference between the two baseline groups, they represent a narrow enough range of variation to use as a baseline for comparison with the highly variable human enamel samples.

Using the bone samples as an estimation of the local range, and defining the local range as 2 standard deviations from the mean of the bone samples, the local range may be estimated as between 0.70762 and 0.70791. Using all of the animal samples as an estimation of the local range, and defining the local range in the same manner as described above, the local range is estimated as being between 0.70713 and 0.70805. However, with the outlier animal value removed, the local range is slightly narrower, and is estimated as being between 0.70752 and 0.70781. The range provided by the animals is thus of a similar magnitude to but slightly lower than the range provided by the human bone samples.

Using the bone samples as an estimation of the local range, only 17 of 72 (~24%) human enamel samples analyzed fall within this range. The local range provided by the animal samples is slightly larger (with all animal samples?), and 25 of the 72 (~35%) human enamel samples fall within this range. Using these ranges, it suggests that between 65% and 75% of the individuals analyzed could be considered to represent non-local individuals.

However, examination of the distribution of the strontium values for the population suggests that there may in fact be a bimodal distribution of values (see **Figure 6.16: Histogram of Human Enamel Values**). The observed number of individuals decreases as isotopic values increase towards 0.7110, and there are no individuals whose isotopic values fall between 0.7110 and 0.7115. There are 7 individuals whose enamel isotopic values form a secondary, smaller peak between 0.7115 and 0.7135; a further two individuals form a third "peak" between 0.7150 and 0.7155.

As discussed above, Wilk-Shapiro tests were conducted to assess the isotope distributions for the three tissue types for normality. The bone strontium isotope values were determined to be normally distributed, but the enamel values were determined to deviate significantly from normality, due to the existence of this trimodal distribution.

$^{87}Sr/^{86}Sr$ Isotope Values by Sex

The following tables display the differences in isotopic signatures in bone and enamel for males and females. Tests were performed to determine if there were any significant differences between the sexes in terms of strontium isotopic signatures. These tests were performed for the most secure sexual designations (i.e. greater certainty in assigned sexes, with greater numbers of individuals of unknown sex) and less secure sexual designations (i.e. a lower degree of certainty in assigned sexes, with lower numbers of individuals of unknown sex).

Table 6.19: Average $^{87}Sr/^{86}Sr$ Values for Adult Males vs. Females

	Females	Males	Unknown
N	30	26	16
Enamel Average	0.70910	0.70911	0.70930
Enamel Std Dev	0.00178	0.00189	0.00162
Enamel Min	0.70770	0.70766	0.70768
Enamel Max	0.71548	0.71520	0.71245
Enamel Range	0.00778	0.00754	0.00478
Bone Average	0.70777	0.70776	--
Bone Std Dev	0.00004	0.00010	--

Table 6.20: Average $^{87}Sr/^{86}Sr$ Values for Adult Males vs. Females (with Less Certain and More Certain Sex Estimates)

	More Certain			Less Certain		
	Females	**Males**	**Unknown**	**Females**	**Males**	**Unknown**
N	30	26	16	35	36	1
Average	0.70910	0.70911	0.70930	0.70908	0.70911	0.70868
Standard	0.00178	0.00189	0.00162	0.00178	0.00172	--

Deviation						
Min	0.70770	0.70766	0.70768	0.70770	0.70766	0.70868
Max	0.71548	0.71520	0.71245	0.71548	0.71520	0.70868
Range	0.00778	0.00754	0.00478	0.00778	0.00754	0
Bone Average	0.70777	0.70776	--			
Bone StDev	0.00004	0.00010	--			

T-tests were conducted to test for differences in mean between adult males and females in both enamel and bone samples. When dealing with the both the more certain sex estimates (i.e. greater degree of certainty), and the less certain sex estimates (i.e. lesser degree of certainty), no difference was detected in the isotopic values between the sexes (more certain estimates, t= -0.0321, p=0.974524; less certain estimates, t= -0.1418, p=0.887667). The difference between the means of the male and female bone values was also determined to be statistically insignificant (t= 0.3414, p= 0.737258).

Prior to conducting a Levene's test to test for differences in variance between the sexes, a Shapiro Wilk test of normality was conducted for both sexes. Both males (more certain estimates, W=0.7391279, p=1.910224E-05; less certain estimates, W=0.7994242, p=1.586336E-05) and females (more certain estimates, *W*=0.712385, p=2.374766E-06; less certain estimates, W=0.7236524, p=8.860178E-07) were determined to not be normally distributed. For bone isotopic values, females demonstrated a normal distribution (W=0.9794635, p=0.961457), while males did not (W=0.8291183, p=4.364898E-02).

In addition to testing for significant differences in the mean isotopic values between adult males and females, a univariate Levene's test was conducted to test for differences in variance. This test detected no difference in variance (more certain estimates, test statistic=0.2204, p=0.802791; less certain estimates, test statistic=0.3713, p=0.544300). Furthermore, no difference in variance was detected between isotopic bone values for females and males (test statistic=1.6505, p=0.217181).

Thus, there is no evidence for any difference between males and females in terms of either average strontium isotopic value, or in the degree of variation in the samples for each sex.

Figure 6.19: Box Plot of $^{87}Sr/^{86}Sr$ Values by Sex (More Certain Estimates)

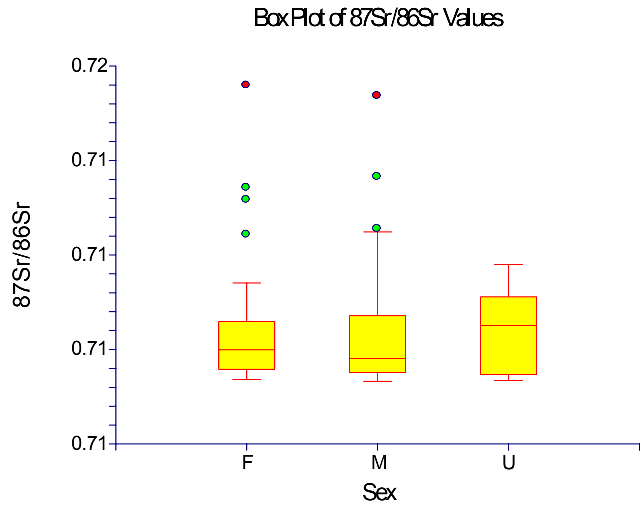
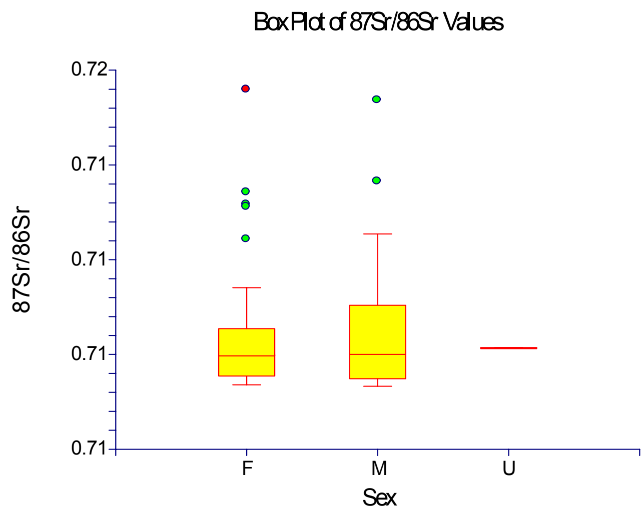


Figure 6.20: Box Plot of $^{87}Sr/^{86}Sr$ Values by Sex (Less Certain Estimates)



$^{87}Sr/^{86}Sr$ Isotopic Values by Age Groups

The following tables display the differences in isotopic signatures in enamel for different adult age groups based on estimated age at death. Tests were then performed to determine if there were any significant differences between the various age groups in terms of strontium isotopic signatures. These tests were performed for both sets of available ages estimates (those by Ursula Wittwer-Backofen (UWB), and those by Yılmaz Selim Erdal (YSE)). Age groups were defined as young adults (15-30 years), middle adults (30-45 years) and older adults (45+ years).

Table 6.21: Average $^{87}Sr/^{86}Sr$ Values for Adult Age Groups (UWB and YSE Age Estimates)

	UWB				YSE			
	Young	**Medium**	**Old**	**Unknown**	**Young**	**Medium**	**Old**	**Unk**
N	20	17	28	7	25	41	6	0
Average	0.70932	0.70926	0.70872	0.70965	0.70877	0.70944	0.70823	
Standard Deviation	0.00193	0.00163	0.00142	0.00238	0.00131	0.00196	0.00066	
Min	0.70770	0.70766	0.70768	0.70774	0.70768	0.70766	0.70774	
Max	0.71548	0.71245	0.71520	0.71306	0.71239	0.71548	0.70933	
Range	0.00778	0.00479	0.00753	0.00531	0.00471	0.00782	0.00159	

T-tests were conducted to test for differences in mean between adult age groups for enamel samples. For UWB age estimates, none of the t-tests demonstrated any significant differences between the different pairs of age groups.

Table 6.22: Results of Paired T-Tests for $^{87}Sr/^{86}Sr$ Values Based on Age Groups (UWB)

	Young	**Middle**	**Old**
Young		t= -0.1078 p=0.914770	t= -1.2345 p=0.223289
Middle			t=1.1545 p=0.254668

For YSE age estimates, once again, none of the t-tests demonstrated any significant difference between the different pairs of age groups.

Table 6.23: Results of Paired T-Tests for $^{87}Sr/^{86}Sr$ Values Based on Age Groups (YSE)

	Young	**Middle**	**Old**
Young		t= 1.4919 p=0.140634	t= -0.9793 p= 0.335547
Middle			t= 1.4777 p=0.146460

Prior to conducting Levene's tests to look for differences in variance between the various age groups, Shapiro Wilk tests of normality were conducted. In all cases, for both UWB and YSE age estimates, all age groups were determined to not be normally distributed (UWB Young Adults: W= 0.7452781, p=2.029936E-04; UWB Middle Adults: W=0.7682025, p=3.009451E-

04; UWB Older Adults: W=0.586162, p=1.066515E-07; YSE Young Adults: W=0.7950279, p=1.880362E-04; YSE Middle Adults: W=0.78376, p=2.531108E-06; YSE Older Adults: W=0.7777866, p=3.675418E-02).

A univariate Levene's test was also conducted to test for differences in variance between the different age groups. This test detected no difference in variance between the age categories for either the UWB or YSE sex estimates (UWB: test statistic=0.6350, p=0.595130; YSE: test statistic= 1.2506, p= 0.292754).

Thus, there is no evidence for any significant difference between different categories of adult age at death in terms of either average strontium isotopic value, or in the degree of variation in the samples.

Figure 6.21: Box Plot of $^{87}Sr/^{86}Sr$ by Age Group (UWB Age Estimates)

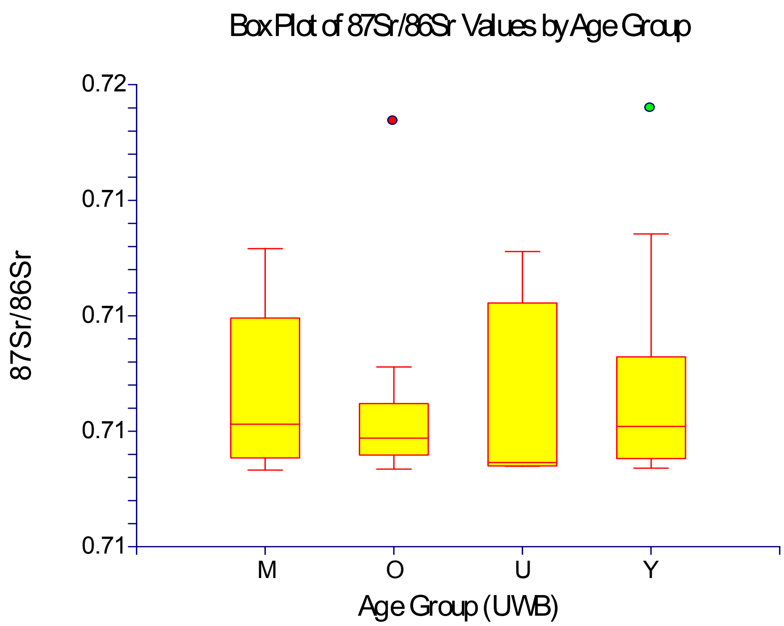
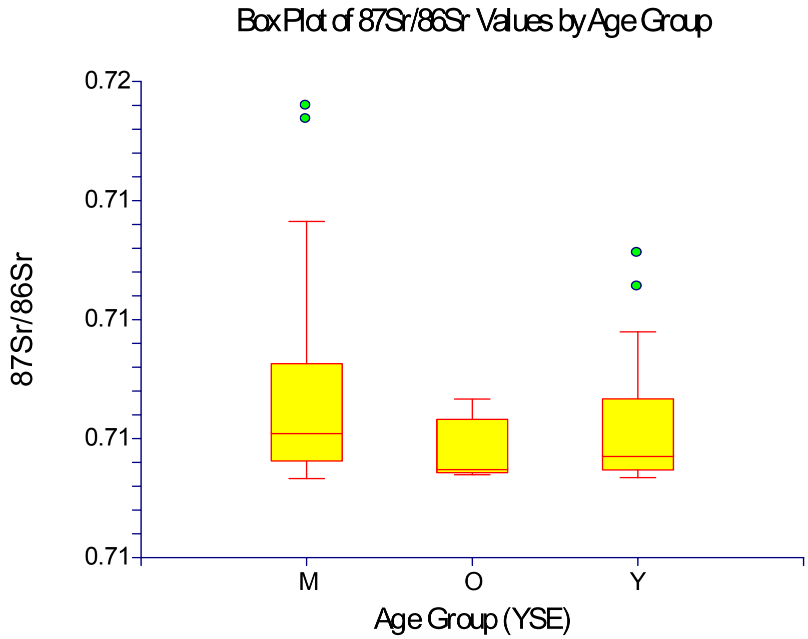


Figure 6.22: Box Plot of $^{87}Sr/^{86}Sr$ by Age Group (YSE Age Estimates)



$^{87}Sr/^{86}Sr$ Isotope Values by Tooth Type

Due to the fact that enamel samples analyzed were taken from a variety of available teeth, it was necessary to determine whether there were any significant differences in isotopic values that could be attributed to the tooth type sampled.

The following table demonstrates the average $^{87}Sr/^{86}Sr$ isotopic values for each tooth type sampled.

Table 6.24: $^{87}Sr/^{86}Sr$ Isotopic Values by Tooth Type

	C	P3	P4	M1	M2	M3
N	3	1	3	8	26	31
Average	0.71245	0.71306	0.71029	0.70963	0.70850	0.70888
Standard Deviation	0.00271	0.00000	0.00425	0.00194	0.00097	0.00119
Min	0.71026	0.71306	0.70770	0.70784	0.70766	0.70768
Max	0.71548	0.71306	0.71520	0.71277	0.71168	0.71239
Range	0.00522	0	0.00750	0.00493	0.00401	0.00471

T-tests were also conducted to determine if any differences between the values for different tooth types were statistically significant. For canines, first premolars and second premolars, the sample sizes were too small to allow t-tests to be conducted. In order to examine the relationship of the $^{87}Sr/^{86}Sr$ values for these groups with other tooth types groups, a 95% confidence interval was calculated for the the two tooth types with the largest sample sizes (second and third molars). These intervals were then compared to the average values obtained for the tooth types with smaller sample sizes. The results of paired t-tests between the different tooth types are presented in the table below. Bold values represent statistically significant results.

Table 6.25: Results of Paired T-Tests for $^{87}Sr/^{86}Sr$ Values Based on Tooth Type

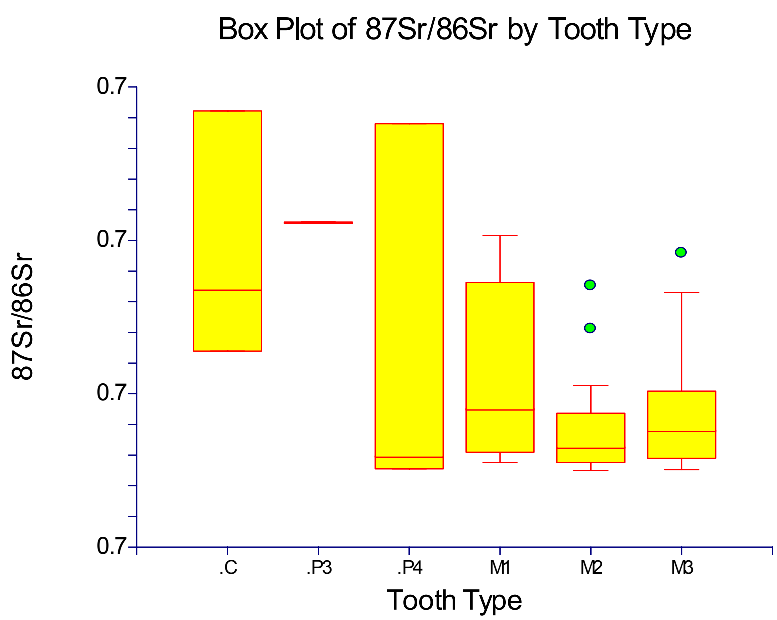
	C	**P3**	**P4**	**M1**	**M2**	**M3**
C		Small sample size	Small sample size	Small sample size	Small sample size	Small sample size
P3			Small sample size	Small sample size	Small sample size	Small sample size
P4				Small sample size	Small sample size	Small sample size
M1					**t=2.1768 p=0.036987**	t=1.3812 p=0.175496
M2						t= -1.2063 p=0.232855

These t-tests determined that the difference in $^{87}Sr/^{86}Sr$ between first molars and second molars was significant, but no significant differences were observed between other molar types. The 95% confidence interval obtained for second molars was 0.70784-0.70863, while the interval calculated for third molars was 0.70806-0.70933. Interestingly, the average values obtained for all tooth types with small sample sizes (canines, first premolars and second premolars) fall outside both of these ranges. All three values obtained for canine teeth were elevated compared to second and third molars, falling above both confidence intervals. In contast, among second premolars only one elevated value above the confidence interval was observed, while the other two values fell below the molar confidence intervals.

Prior to conducting a Levene's test to examine differences in variance between the different tooth types, Shapiro Wilk tests of normality were conducted to determine if the distributions of isotope values could be considered normal. For both canines, and second premolars, Shapiro Wilk tests could not be conducted due to the small sample size, and thus non-parametric Kolmogorov Smirnov tests were conducted instead. In both of these cases, the existence of a normal distribution in isotope values could not be rejected (canines, K-S test statistic: 0.2883946; second premolars, K-S test statistic: 0.3734832). Due to the fact that only one sample of first premolar was analyzed, neither a Shapiro Wilk nor a Kolmogorov Smirnov test could be conducted. Of the Shapiro Wilk tests conducted, the distribution of first molar isotope values was determined to be normal (W= 0.8231279, p= 0.0503278); in contrast, both second and third molars were not normally distributed (second molars, W=0.7906333, p=1.225398E-04; third molars, W=0.8538261, p=6.118896E-04).

A univariate Levene's test was conducted to determine if significant differences in variance were present between different tooth types in terms of $^{87}Sr/^{86}Sr$ isotopic values. The result of this test suggested that there was no statistically significant difference in variance between the different tooth types (test statistic=1.9268, p=0.116283).

Figure 6.23: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Tooth Type



$^{87}Sr/^{86}Sr$ Isotope Values by Disposition of the Body

Compared to other roughly contemporary Anatolian cemeteries, there is surprisingly little variation in the methods used for deposition of the bodies within the cemetery at İkiztepe. The main source of variation in depositional practices is in the direction of the placement of the body, which shows little obvious patterning. Thus, tests were conducted to determine if there was any difference in isotopic signatures based on the direction in which the body's head was pointing.

The following table demonstrates the average isotopic values found for groups based on the head direction of the individual burial.

Table 6.26: Average $^{87}Sr/^{86}Sr$ Values for Groups Based on Head Direction of Burial

	N	NW	W	SW	S	SE	E	NE	U
N	1	7	9	0	16	21	2	0	15
Avg	0.71548	0.70856	0.70905		0.70854	0.70900	0.70962		0.70962
Std Dev	0.00000	0.00096	0.00110		0.00142	0.00168	0.00271		0.00184
Min	0.71548	0.70784	0.70780		0.70766	0.70774	0.70770		0.70774
Max	0.71548	0.71047	0.71161		0.71306	0.71520	0.71153		0.71277
Range	0.00	0.00262	0.00381		0.00539	0.00747	0.00383		0.00502

T-tests were then conducted to determine if there were any significant differences between these groups. For burials oriented with the head toward the north and the east, the sample sizes were too small to conduct t-tests. To examine these cases, a 95% confidence interval was calculated for the burial orientation with the largest sample size (head oriented toward the southeast). This interval was then compared to the average strontium isotope values obtained for the groups with small sample sizes. The table below shows the results of paired t-tests for different burial groups based on head direction.

Table 6.27: Results of Paired T-Tests for $^{87}Sr/^{86}Sr$ Values Based on Head Direction

	N	NW	W	S	SE	E
N		Small sample size	Small sample size	Small sample size	Small sample size	Small sample size
NW			$t= -0.9326$ $p=0.366836$	$t=0.0369$ $p=0.970884$	$t= -0.6460$ $p=0.523947$	Small sample size

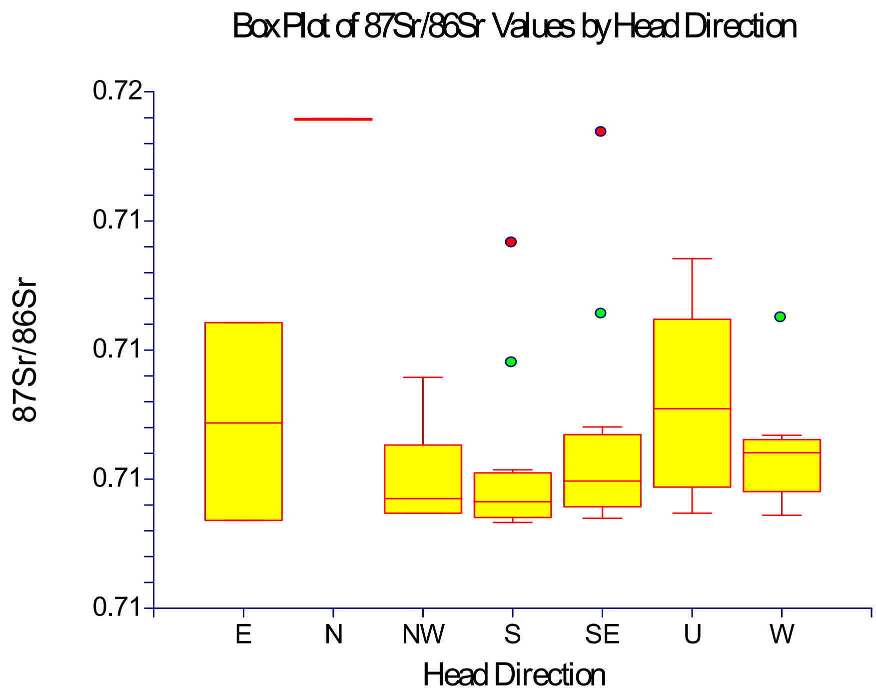
W				t= -0.9314 p=0.361301	t= -0.0903 p=0.928672	Small sample size
S					t= -0.8747 p=0.387694	Small sample size
SE						Small sample size

None of these t-tests revealed any significant differences between the isotopic values observed in burials with different orientations. The 95% confidence interval calculated for burials with a southeastern orientation was 0.7080-0.70933. The average strontium isotope values obtained for burials with both northerly and easterly orientations lie above this range. However, only one of the individuals with an easterly orientation lies above this range, while the other in fact lies below this range. These results suggest that burials with northerly and easterly orientations may display slightly different strontium isotope values from other burial orientations.

Prior to conducting Levene's tests to look for differences in variance between these burial groups, the isotopic values for these groups were subjected to Shapiro Wilk tests of normality to determine if they represented a normal distribution. For burials with heads oriented in an easterly direction, the sample size was too small (n=2) to conduct a Shapiro Wilk test, and thus a non-parametric Kolmogorov Smirnov test was performed. This test suggested that a normal distribution could not be rejected for this group (K-S statistic: 0.2602499). For burials with the head oriented in a northerly direction, the sample size was too small (n=1) to conduct either a Shapiro Wilk or a Kolmogorov Smirnov test. However, for the remaining four groups, Shapiro Wilk tests were conducted. For all groups, a normal distribution was rejected (head oriented west, W=0.8339753, p=0.0494755, head oriented northwest, W=0.7993085, p= 4.032382E-02; head oriented south, W=0.6207322, p=2.556849E-05; head oriented southeast, W=0.6479127, p=6.602126E-06).

A univariate Levene's test was conducted to look for significant differences in variance between the different groups based on head orientation, which demonstrated that a significant difference did not exist between the various groups (test statistic=0.7602, p= 0.555243).

Figure 6.24: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Head Direction



Average isotopic values were also calculated based on the position of the body. The vast majority of the burials in the İkiztepe cemetery were placed dorsally, with the arms at the sides. However, a small number of burials were placed in unusual positions, and the individuals were examined to see if unusual burial positions were an indicator of a "non-local" individual, as identifiable through the strontium isotopic signatures. Unusual burial positions included: individuals with legs or the entire body turned to the left or to the right, one individual buried face down, those buried in "unknown" positions and one individual who was buried in a more complex position. This individual had their trunk and head turned to the left, the legs turned to the right (the knees were probably originally placed above the body), with the arms placed under the body (SK389).

The table below demonstrates the values calculated for the various groups based on body position. These values were calculated for both specific burial positions (i.e. turned to the left, turned to the right, etc.), as well as for non-typical burial practices as a group. Thus, the "Not Dorsal" category in the table below can be divided into "Left", "Right" and "Other" categories; the "Left" and "Right" categories are also shown separately.

Table 6.28: Average $^{87}Sr/^{86}Sr$ Isotopic Values Based on Body Position

	Dorsal	Not Dorsal	Left	Right	Unknown
N	45	9	5	2	18
Average	0.70889	0.70903	0.70900	0.70888	0.70970
Standard Deviation	0.00153	0.00123	0.00160	0.00072	0.00227
Min	0.70768	0.70808	0.70811	0.70837	0.70766
Max	0.71520	0.71161	0.71161	0.70939	0.71548
Range	0.00753	0.00353	0.00350	0.00102	0.00782

Due to the small sample sizes for all non-dorsal burial positions, including those placed on their right and left sides, t-tests could not be conducted to determine whether any significant differences could be distinguished between individuals of different body position groups. Instead, a 95% confidence interval was calculated for the mean strontium isotopic value obtained for burials placed in a dorsal position. This interval was then compared to the average values obtained for the various non-dorsal burial positions.

The 95% confidence interval for the isotopic values of dorsal burials was 0.7080-0.70884. The average isotopic values obtained for burials placed on the left and right sides both lie above this range. However, only one of the two individuals placed on their right side actually displays a strontium isotopic signature lying outside of this confidence interval. Furthermore, only one of the five burials placed on their right side falls outside this range, despite the high average isotopic value obtained for the group. The individual buried face down produced an isotopic value that fell outside of the confidence interval obtained for dorsal burials, while the value of the individual buried in an atypical position did not. Overall, these results suggest that there is no significant difference between the strontium isotopic signatures of burials placed in non-dorsal positions and those placed dorsally.

Prior to conducting a Levene's test to look for significant differences in variance between the body position groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. These tests were not possible for the "Face Down" and "Atypical" categories, which had a sample size of one each. Furthermore, the sample size for the "Right" category was too small to allow a Shapiro-Wilk test to be conducted; thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.2602499). Thus, Shapiro Wilk tests could be conducted only for the "Dorsal" and "Left" categories, both of which were found to significantly deviate from normality (dorsal, W=0.7209615, p=6.421793E-08; left, W=0.7038632, p=1.050578E-02)

A univariate Levene's test was conducted to test for significant differences in variance between the different body position groups, and this test found no significant differences in variation (test statistic=1.4190, p=0.249342). When unusual body positions were grouped together and compared to dorsal burials, a significant difference in variation was detected at the $\alpha=0.1$ level (test statistic=2.8787, p=0.062980). When burials of unknown burial position were removed, however, this difference in variation disappeared (test statistic=0.0619, p=0.804514).

Figure 6.25: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Specific Body Positions

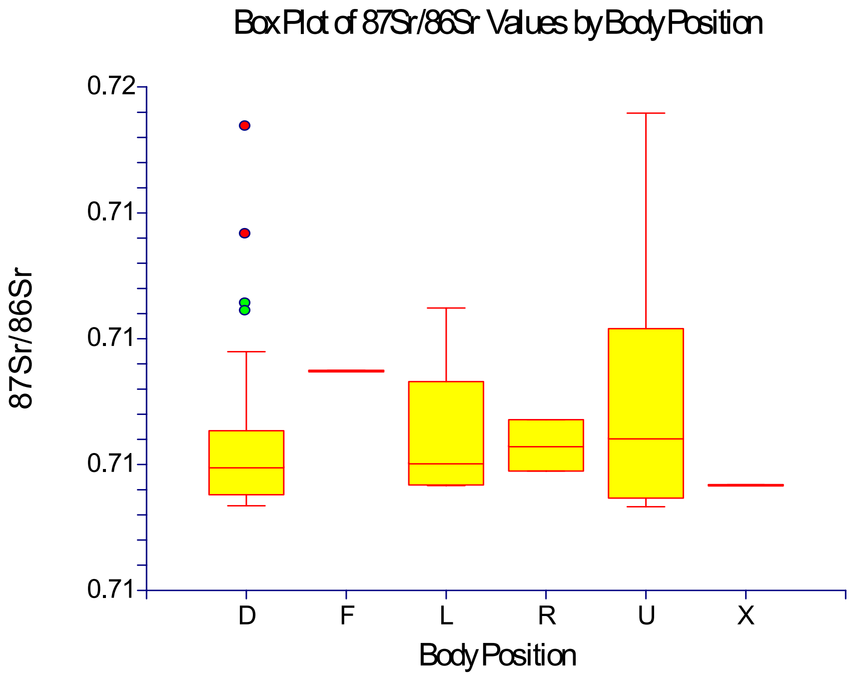
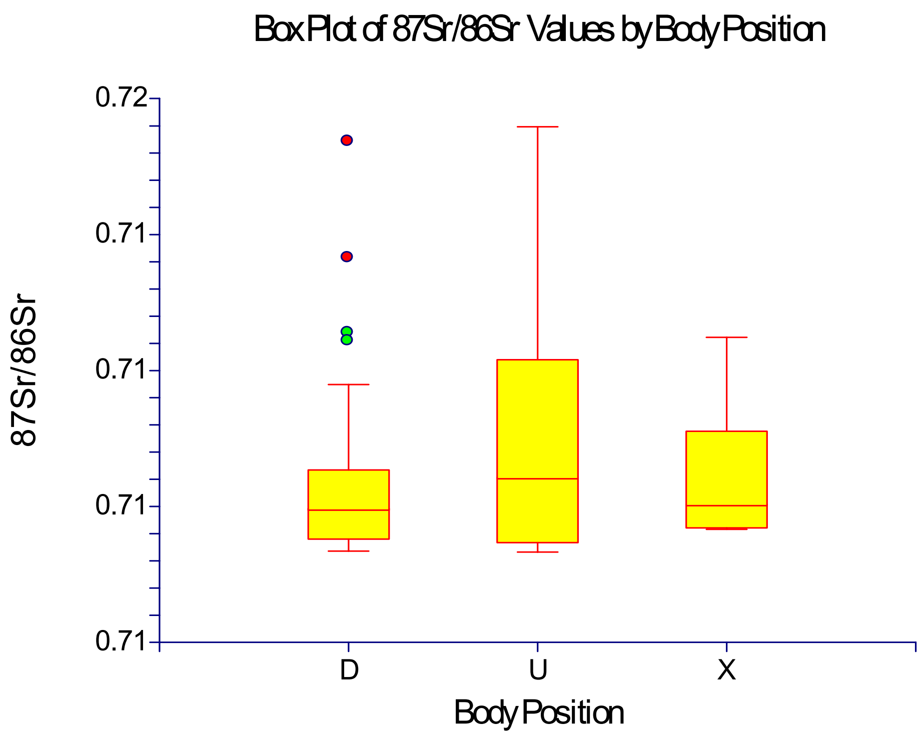


Figure 6.26: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Grouped Body Positions



Spatial Patterns in Sr Concentrations (ppm) and $^{87}Sr/^{86}Sr$ Isotopic Values

In order to determine if there were any spatial patterns in the $^{87}Sr/^{86}Sr$ values, tests were conducted to look for correlations between spatial variables and isotopic values. The results of these tests are displayed in the table below.

Table 6.29: Correlations between Spatial Variables and $^{87}Sr/^{86}Sr$ Isotopic Values

$^{87}Sr/^{86}Sr$ vs. :	R^2 value	P-value
X Coordinate	0.0011	0.7877
Y Coordinate	0.0161	0.2922
Distance from Centre-X Coordinate	0.0368	0.1090
Distance from Centre-Y Coordinate	0.0006	0.8425
Absolute Distance from Centre	0.0093	0.4239
Absolute Elevation	0.0840	0.0157
Depth Below Surface	0.0155	0.3005

As demonstrated by the p-values in the table above, none of the correlations between isotopic values and horizontal spatial variables are significant. There is, however, a slight correlation between the isotopic values and the distance of the burial from the centre of the cemetery on the X coordinate. However, this trend does not play out in the absolute distance from the centre of the cemetery. Furthermore, while there is no significant correlation between absolute elevation and strontium isotopic values, when the ancient slope is accounted for and depth below the ancient slope is considered, there is a significant relationship detected.

Similar tests were performed for correlations between strontium concentrations (in ppm) and the same spatial variables described above. The results of these tests are displayed in the table below.

Table 6.30: Correlations between Spatial Variables and Sr Concentrations

Sr (ppm) vs. :	R^2 value	P-value
X Coordinate	0.0014	0.7560
Y Coordinate	0.0003	0.8932
Distance from Centre-X Coordinate	0.0016	0.7432
Distance from Centre-Y Coordinate	0.0022	0.6976
Absolute Distance from Centre	0.0047	0.5691
Absolute Elevation	0.0059	0.5313
Depth Below Surface	0.0005	0.8543

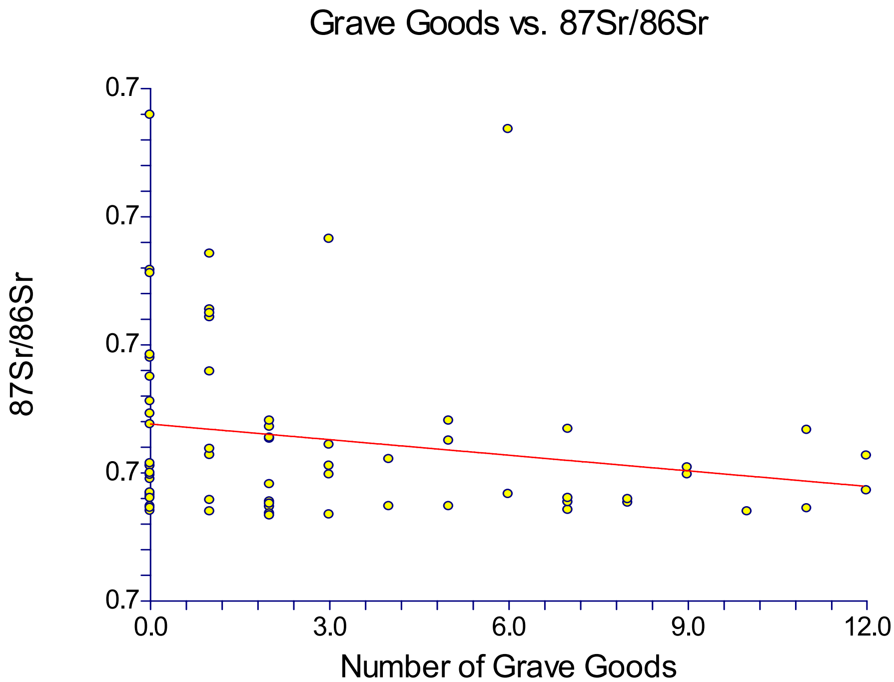
As demonstrated by the p-values in the above table, none of these correlations between strontium concentrations and these spatial variables can be considered significant. These results suggest that there is no spatial patterning in strontium concentrations, which suggests that there is unlikely to be any spatially patterned contamination in strontium isotopic values.

Relationship between Grave Goods and $^{87}Sr/^{86}Sr$ Values

In order to determine whether there was a relationship between the number of grave goods included in the burials and the strontium isotopic values obtained, tests were conducted to look for correlations between these two variables.

This test did suggest a trend towards a positive correlation between the number of grave goods and the $^{87}Sr/^{86}Sr$ values (r^2=0.0413, p=0.0939; Spearman Rank Coefficient= -0.2361, p= 0.0508). The correlation between the two variables was only statistically significant at α=0.1, but it does suggest a trend toward increased grave goods in the burials of individuals in elevated strontium isotopic signatures.

Figure 6.27: Total Number of Grave Goods vs. $^{87}Sr/^{86}Sr$ Values



As a result, the link between grave goods and strontium isotopic values was examined further. The table below displays the differences in strontium isotopic signatures in enamel for Bilgi's "distinguished" burials compared to the other "non-distinguished" burials.

Table 6.31: Average $^{87}Sr/^{86}Sr$ Values for "Distinguished" vs. "Non-Distinguished" Burials

	Distinguished	**Non-Distinguished**
N	15	57
Enamel Average	0.70911	0.70910
Enamel Std Dev	2.130975E-03	1.613347E-03
Enamel Min	0.70774	0.70766
Enamel Max	0.7152	0.71548
Enamel Range	0.00746	0.00782

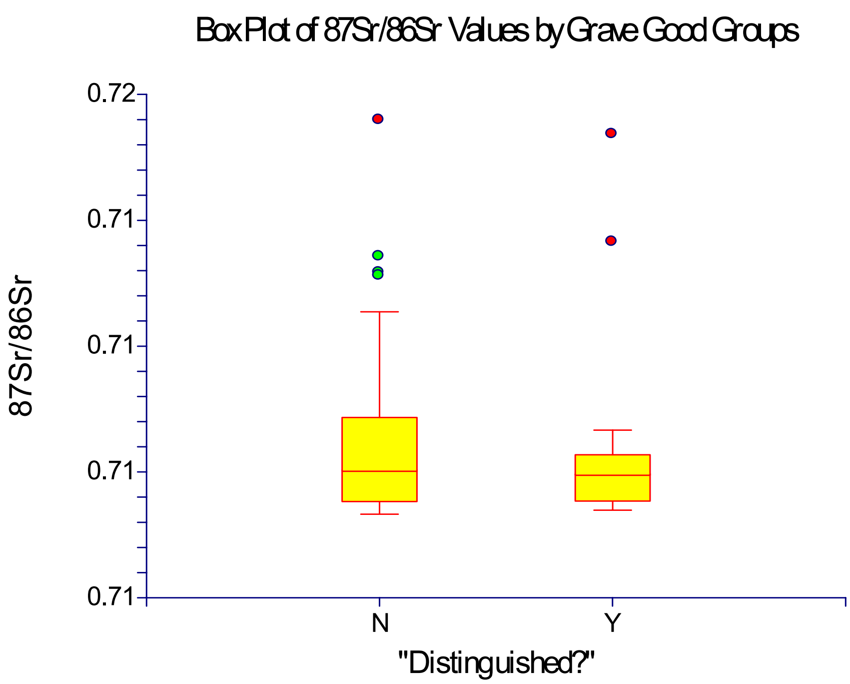
T-tests were conducted to determine whether any significant differences could be distinguished between individuals in these two groups based on grave richness. The results of this t-test suggest that there is no significant difference in strontium isotopic signatures between these two groups (t= -0.0019, p=0.998499).

Prior to conducting a Levene's test to test for differences in variance between the two groups, a Shapiro Wilk test of normality was conducted for both groups. Both "non-distinguished" and "distinguished" burials were determined to be not normally distributed ("non-distinguished": W= 0.8053219, p=3.14782E-07; distinguished: W=0.6263726, p=4.493509E-05).

In addition to testing for significant differences in the mean isotopic values between "distinguished" and "non-distinguished" burials, a univariate Levene's test was conducted to test for differences in variance. This test detected no significant difference in variance between the two groups (test statistic=0.0012, p=0.972113).

Thus, there is no evidence to suggest a difference between "distinguished" and "non-distinguished" burial groups, in terms of either average oxygen isotopic value, or in the degree of variation in the samples for each group.

Figure 6.28: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Grave Good Groups



$^{87}Sr/^{86}Sr$ Isotope Values by Presence of Cranial Trauma

Tests were conducted to determine if there was any difference in isotopic signatures based on the presence of healed or unhealed cranial trauma.

The following table demonstrates the average isotopic values found for groups based on the presence or absence of healed or unhealed cranial trauma.

Table 6.32: Average $^{87}Sr/^{86}Sr$ Isotopic Values Based Presence/Absence of Cranial Trauma

	None	Healed	Unhealed
N	63	3	6
Average	0.70919	0.70827	0.70865
Standard Deviation	0.00181	0.00039	0.00074
Min	0.70766	0.70784	0.70774
Max	0.71548	0.70860	0.70965
Range	0.00782	0.00076	0.00191

T-tests were conducted to determine whether any significant differences could be distinguished between individuals with healed or unhealed cranial trauma and those who had none. However, due to the small sample size observed for individuals with healed trauma, t-tests could not be conducted to compare this group to the other trauma groups. Thus, 95% confidence intervals were calculated for both of these groups, and the average value for the group with healed trauma was compared to this range. The results of paired t-tests are shown in the table below.

Table 6.33: Results of Paired T-tests Based on Presence/Absence of Cranial Trauma

	None	Healed	Unhealed
None		Small sample size	t= 0.7214 p=0.473195
Healed			Small sample size

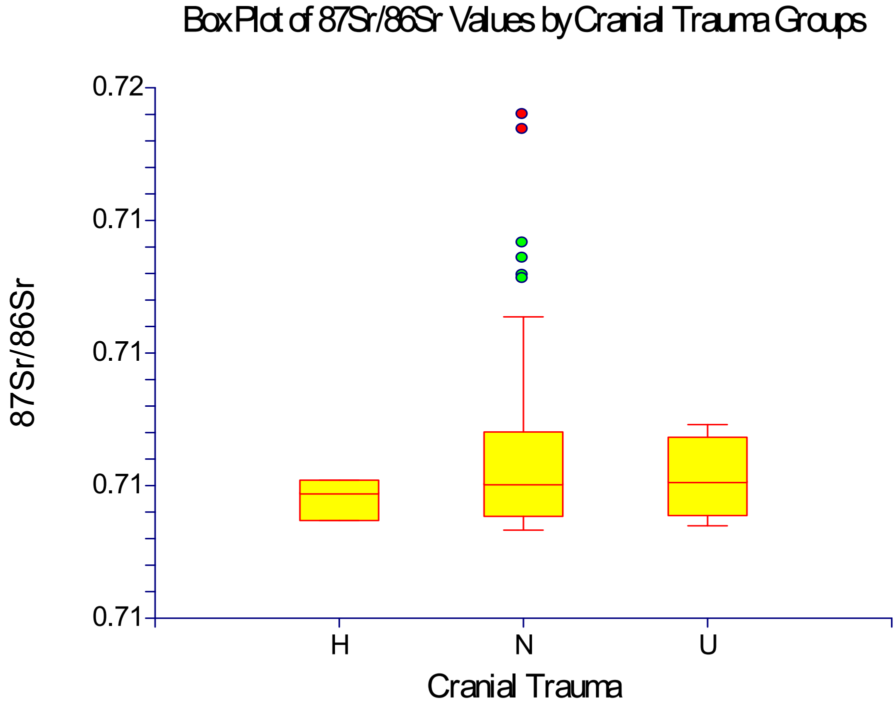
Only the t-test comparing those with no cranial trauma to those with unhealed trauma could be completed, but it did not demonstrate any significant difference in strontium isotopic signatures between these two groups. The 95% confidence interval for those with no trauma was

0.70808-0.70904, while that for individuals with unhealed cranial trauma was 0.70774-0.70965. The average value for individuals with healed cranial trauma falls within both of these ranges, suggesting that there was no significant difference in strontium isotopic signatures between individuals based on the presence or absence of healed or unhealed cranial trauma.

Prior to conducting a Levene's test to look for significant differences in variance between the cranial trauma groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. The sample size for the "Healed" category was too small to allow a Shapiro-Wilk test to be conducted (n=3); thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.1985782). Thus, Shapiro Wilk tests could be conducted only for the "Unhealed" and "No Cranial Trauma" categories. Of these, the "No Cranial Trauma" was found to significantly deviate from normality (W=0.776629, p=2.1111205E-08), while the unhealed cranial trauma was found to have a normal distribution (W=0.9558521, p=0.7872712).

A univariate Levene's test was conducted to test for significant differences in variance between the different cranial trauma groups, and this test found no significant differences in variation (test statistic= 1.2019, p=0.306825).

Figure 6.29: Box Plot of $^{87}Sr/^{86}Sr$ Isotopic Values by Cranial Trauma Groups



Discussion of Oxygen Isotopic Results

The vast majority of the values obtained for both bone and enamel phosphate for $\delta^{18}O$ fall within a 2‰ range, between approximately 15 and 17‰. If the enamel value of individual ITSK545 is excluded from consideration due to its low yield and anomalous isotopic value, then the absolute range of values observed is between 14.46‰ and 17.46‰, a range of 3‰. A range of approximately 2‰ represents a relatively normal range of variation for a population consuming a consistent water source (Evans *et al* 2006, 2007, White *et al* 1998, White *et al* 2001; White *et al* 2004). A range of 3‰ is not unreasonably different from such an expectation, particularly given the large amount of variability observed in the strontium isotopic results. The majority of the population, falling within a range of 2‰, likely represents a normal range of variation for a stationary population. However, the observed low levels of variation in meteoric water values for the Black Sea and Central Anatolian regions (see section on Expected Oxygen

Isotopic Values, above) mean that this narrow range of enamel oxygen isotopic values could potentially mask the consumption of a variety of different water sources with similar $\delta^{18}O$ values. It is possible that in the Black Sea and Central Anatolian region, $\delta^{18}O$ analysis may not be sensitive enough to distinguish differences in water consumption, due to overlapping oxygen isotope values across water sources.

If the enamel value of individual ITSK545 is excluded from consideration, due to its low yield and anomalous isotopic value, then no individuals lie outside of the possible range of local values suggested by a range of two standard deviations from the mean of the enamel values. If, instead, the range of bone values observed is used for the definition of a local range of variation, the local values obtained lie between 15.21‰ and 16.52‰ (i.e. a range of 1.31‰). In this case, three individuals have values that lie below 15.21‰ (ITSK414, ITSK297, ITSK364), and 17 individuals have values above 16.52‰ (ITSK266, ITSK277, ITSK295, ITSK306, ITSK315, ITSK343, ITSK395, ITSK434, ITSK467, ITSK471, ITSK473, ITSK512, ITSK567, ITSK574, ITSK621, ITSK642, ITS675). A slightly different local range is provided by using a measure of two standard deviations from the average of the human bone values, creating a range of 15.13‰ to 16.60‰ (i.e. 1.47‰). Using this range removes two of the individuals with values at the lower end of the range, leaving only ITSK414 with a value below 15.13‰. Furthermore, three of the individuals with values above the range discussed above are removed when the latter range is used (ITSK512, ITSK567, ITSK675), leaving the remaining 14 individuals as outliers. These individuals may not necessarily have been born non-locally, but may have consumed different water sources during the process of enamel formation.

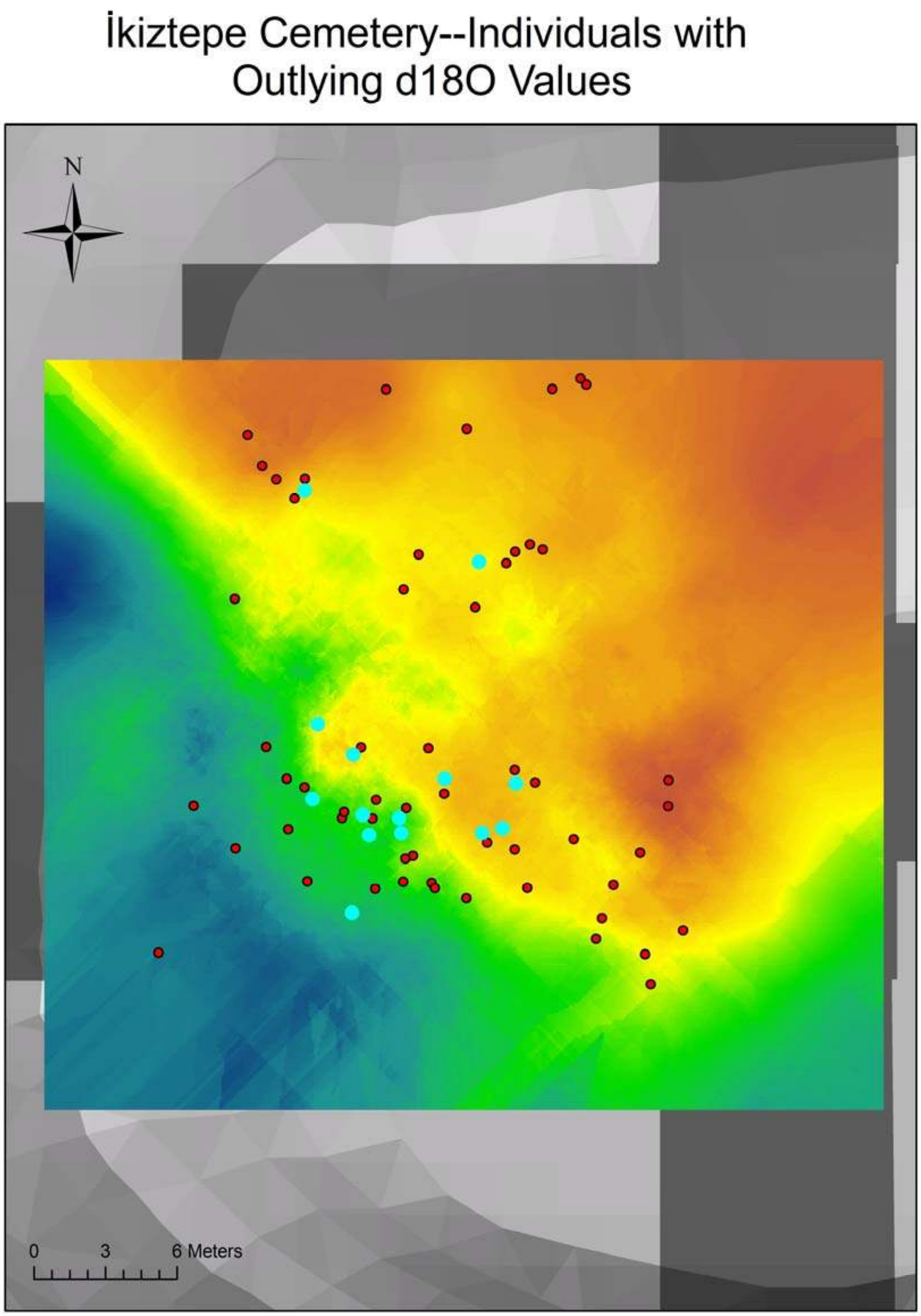
The characteristics of these outlying individuals are outlined in the chart below, **Table 6.36: Characteristics of Outlying $\delta^{18}O$ Individuals.** Italicized individuals represent individuals who lie within the larger range provided by a measure of two standard deviations from the average of the bone values, and are therefore not considered outliers using this measure.

Table 6.34: Characteristics of Outlying $\delta^{18}O$ Individuals

Sk No.	Sex	Age	Head Direction	Body Position	Grave Goods	Tooth	Fluoride Date
Group 1 (>16.52)							
ITSK 266	Unknown/ Female	Young Adult	Northwest	Dorsal	1 needle, 1 bead	LLM2	0.35 (Middle Period)
ITSK 277	Unknown/ Male	Young Adult	South	Dorsal	None	ULM2	0.31 (Middle Period)
ITSK 295	Unknown/ Male	Older (UWB)/Middle (YSE) Adult	Unknown	Unknown	None	LLM3	0.29 (Late Period)
ITSK 306	Female	Middle Adult	Unknown	Unknown	None	LLM1	--
ITSK 343	Unknown	Middle Adult	South	Left	None	URM2	--
ITSK 315	Unknown/ Male	Older (UWB)/ Middle (YSE) Adult	Unknown	Unknown	None	URM3	0.20 (Late Period)
ITSK 395	Male	Middle Adult	Southeast	Dorsal	9 total: 4 spearheads, 2 harpoons, 1 spatula, 1 bone object, 1 four-spiral plaque	LLM2	0.46 (Middle Period)
ITSK 434	Unknown/ Male	Young Adult (YSE)	Unknown	Unknown	None	LRM1	0.25 (Late Period)
ITSK 467	Female	Older (UWB)/ Young (YSE) Adult	West	Dorsal	5 total: 1 spearhead, 1 cutter, 1 harpoon, 2 earrings	LLM2	0.87 (Early Period)
ITSK 471	Male	Young Adult	Northwest	Dorsal	5 total: 1 dagger, 1 spearhead, 1 harpoon, 1 frit necklace, 1 spiral ring	LRM3	0.61 (Early Period)

ITSK 473	Female	Young (UWB)/ Middle (YSE) Adult	Northwest	Dorsal	3 total: 1 necklace, 2 earrings	LLM3	0.17 (Late Period)
ITSK 512	*Female*	*Young (UWB) /Middle (YSE) Adult*	*Unknown*	*Unknown*	*None*	*URM3*	*0.37 (Middle Period)*
ITSK 567	*Female*	*Middle Adult (both)*	*East*	*Dorsal*	*1 harpoon*	*LRM3*	*0.19 (Late Period)*
ITSK 574	Female	Middle (UWB)/ Young (YSE) Adult	West	Dorsal	12 total: 1 spearhead, 1 harpoon, 1 pot, 6 earrings, 1 frit necklace	LRM1	0.50 (Middle Period)
ITSK 621	Female	Young(UWB) /Middle (YSE) Adult	Unknown	Unknown	1 earring	LLM1	0.91 (Early Period)
ITSK 642	Female	Unknown (UWB) / Young (YSE) Adult	Unknown	Unknown	None	URM3	--
ITSK 675	*Male*	*Middle Adult*	*South*	*Unknown*	*1 harpoon, 1 frit necklace*	*LLM2*	*0.28 (Late Period)*
Group 2 (<15.21)							
ITSK 297	*Unknown/ Male*	*Young Adult*	*Southeast*	*Dorsal*	*5 total: 1 spearhead, 1 harpoon, 1 needle, 1 hook, 1 frit necklace*	*ULM2*	*0.39 (Middle Period)*
ITSK 364	*Male*	*Middle Adult*	*Southeast*	*Dorsal*	*2 spearheads, 1 harpoon, 1 ring, 3 earrings, 1 stone object*	*LLM3*	*0.72 (Early Period)*
ITSK 414	Male	Older (UWB)/ Young (YSE) Adult	South	Left	None	URM3	0.40 (Middle Period)

Map 6.3: İkiztepe Cemetery—Individuals with Outlying $\delta^{18}O$ Values



There are few observable patterns among these individuals. Ten of the 20 individuals are male, while nine are female. These individuals also represent highly variable ages at death, from young adulthood to older adulthood. They also represent a variety of burial directions and positions; like the remainder of the cemetery, the majority of the burial positions were dorsal. However, one individual (ITSK414) was buried on his left side, and a large number of individuals' burial positions were unknown. While a number of individuals in this group were buried with no grave goods, quite a few had high numbers of grave goods, including weaponry, tools and jewelry, and were identified as "distinguished" burials by Bilgi (2005). These individuals included two women who were buried with weaponry (ITSK467 and ITSK574).

Interestingly, a spatial pattern amongst these individuals is observable, but it is difficult to discern its significance. The individuals in this group are concentrated in the central portion of the cemetery, in the same area in which the individuals with the highest numbers of grave goods were concentrated. This pattern is more pronounced when individuals whose isotopic values lie within the larger range of variations (two standard deviations from the enamel mean value) are removed (see **Map 6.3: İkiztepe Cemetery—Individuals with Outlying δ^{18}O Values).**

White *et al* (2000: 540) suggest that due to enriched levels of ^{18}O that are observed in teeth formed prior to weaning, it is appropriate to adjust δ^{18}O values obtained for pre-weaning teeth in order to eliminate the trophic effect of breastfeeding. Teeth whose enamel is primarily formed prior to the weaning period include incisors, canines and first molars. For this study, there were no incisors analyzed. However, enamel from canine teeth was analyzed for δ^{18}O in two cases, while first molars were analyzed for δ^{18}O in eight cases. Analysis of the δ^{18}O values obtained for the different tooth types supports the idea that first molars may have higher δ^{18}O values than some other tooth types. While the difference between first molars and second molars was not found to be significant, the difference between first and third molars was significant, with first molar values being elevated. However, the average obtained for canines fell below the 95% confidence intervals calculated for both second and third molars, despite the fact that both of these tooth types are formed pre-weaning. In order to examine the effect that weaning may have had on $\delta^{18}O$ values, the values of first molars were adjusted downward by 0.7‰, the average trophic effect suggested by White *et al* (2000: 543; White *et al* 2002: 224; Wright & Schwarcz 1999: 1164). The results observed after this adjustment can be seen in **Figure 6.30: Adjusted $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ Values.** This adjustment did little to affect the variability in $\delta^{18}O$ values observed in the sample, although it did affect the relationships observed between individuals or groups.

For 18 individuals, paired bone and enamel samples were analyzed; of these individuals, one was ITSK545, whose enamel sample had a particularly low yield and a resulting anomalous value. When this individual is eliminated, the remaining 17 pairs of bone and enamel values are displayed in **Figure 6.31: Bone vs. Enamel $\delta^{18}O$ Values.** Eight of these 17 pairs displayed a higher $\delta^{18}O$ value for the bone sample, while the remaining nine pairs had a higher enamel $\delta^{18}O$ value. There is also no consistent pattern with regard to the size of the difference between the $\delta^{18}O$ values obtained for the bone and enamel samples of the same individuals. However, the values obtained for the paired samples of bone and enamel all range between 15.2‰ and 16.6‰, and thus vary by less than 1.4‰. This very narrow range of variation likely means that the lack of a noticeable pattern in the differences between the bone and enamel samples is due to random variation.

The $\delta^{18}O$ values obtained by isotopic analysis of bone and enamel are valuable in their ability to allow the reconstruction of the isotopic values of the water consumed. The following represent conversion equations between human bone phosphate and meteoric water (literally, water consumed) $\delta^{18}O$ values.

$\delta^{18}O_{bp} = 0.64(\delta^{18}O_{mw}) + 22.37$ (R=0.98,s(a)=+/-0.03) (Longinelli 1984: 388)

Rearranged, this equation becomes:

$\delta^{18}O_{mw} = (\delta^{18}O_{bp} -22.37) / 0.64$

Based on the $\delta^{18}O$ averages from the human enamel phosphate, and using these equations, the $\delta^{18}O$ value of the meteoric water consumed was -9.97 ‰ based on the average human enamel isotopic value. In contrast, based on the average isotopic value observed in the human bone samples, the $\delta^{18}O$ of the meteoric water consumed was -10.16 ‰. After eliminating the value obtained for the enamel of ITSK545, the most negative value is -12.36‰, while the least negative value is -7.67‰. These values represent the outlying values, for the individuals discussed above. The range between the lowest and highest calculated $\delta^{18}O$ values for consumed water sources is 4.69‰.

The following represents the conversion equation between the $\delta^{18}O$ values of domestic pig bone phosphate and meteoric water consumed.

$\delta^{18}O_{bp} = 0.86(\delta^{18}O_{mw}) + 22.71$ (R=0.98,s(a)=+/-0.05) (Longinelli 1984: 388)

Rearranged, this equation becomes:

$\delta^{18}O_{mw} = (\delta^{18}O_{bp} -22.71) / 0.86$

Based on the average $\delta^{18}O$ value obtained from the animal enamel samples, and using these equations, the $\delta^{18}O$ value of the meteoric water consumed by the sampled pigs is -8.62‰. If the outlying animal individual is removed from the group, the average $\delta^{18}O$ value for the remainder of the animal population is -8.17‰. The outlying individual possessed a more negative $\delta^{18}O$ value of -11.74‰.

Figure 6.30: Adjusted $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ Values

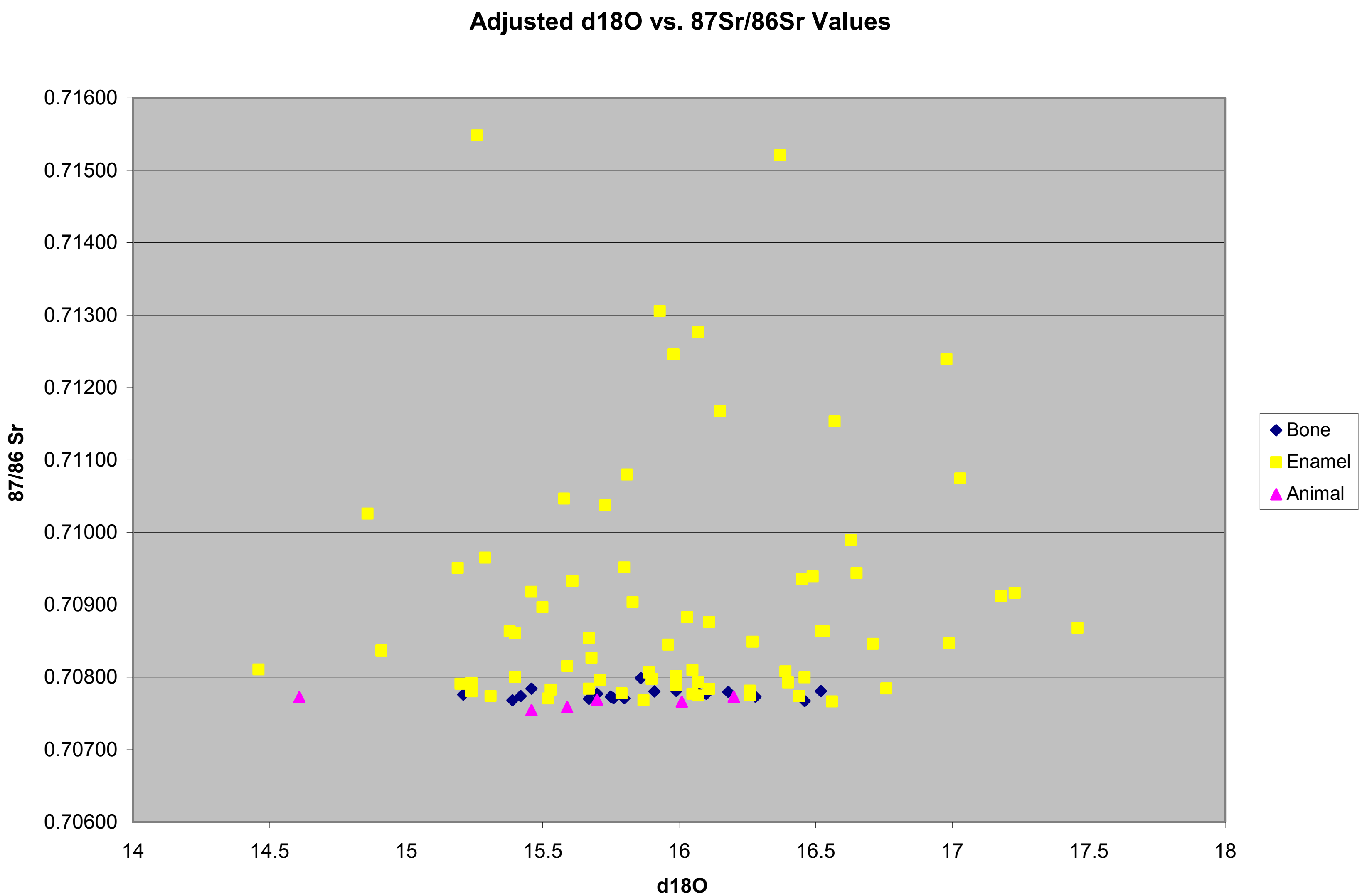


Figure 6.31: Bone vs. Enamel $\delta^{18}O$ Values

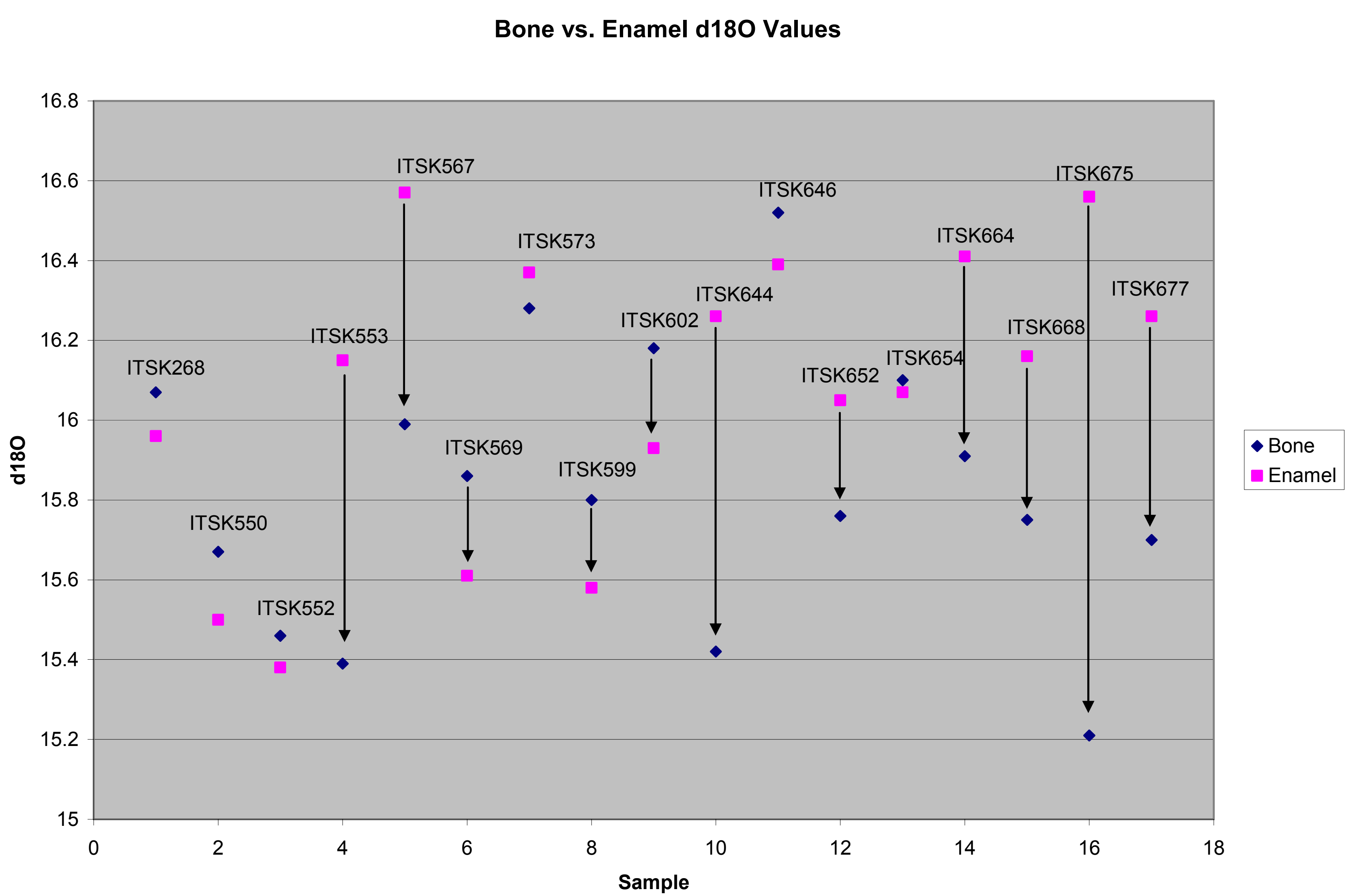
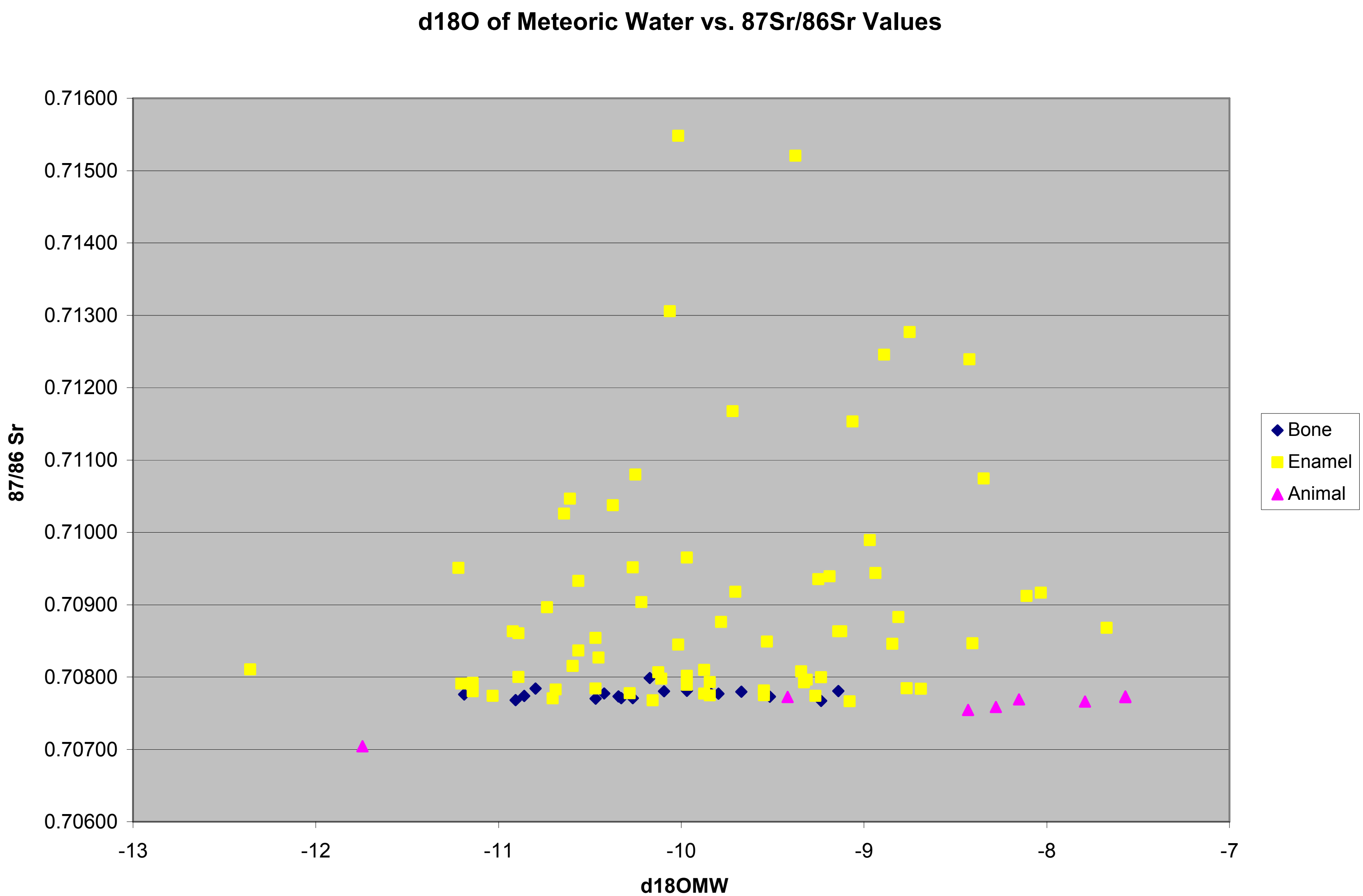


Figure 6.32: $\delta^{18}O$ of Meteoric Water and $^{87}Sr/^{86}Sr$ Values



The meteoric water $\delta^{18}O$ values calculated from the averages of human bone and enamel samples tend to be more negative than the values calculated for the majority of the animal population, with the exception of the outlying animal individual. The values obtained by calculating the $\delta^{18}O$ values for water sources consumed are displayed in **Figure 6.32: $\delta^{18}O$ of Meteoric Water and $^{87}Sr/^{86}Sr$ Values.** This figure makes clear the shift in the animal enamel values upward in comparison to the human enamel and human bone samples.

The most negative values observed among the human bone and enamel samples (i.e. values below -10.4‰) are outside of the seasonal range of variation in meteoric water isotopic values observed for the Bafra Plain (see Expected Oxygen Isotope Values section). In fact, a significant proportion of the population have enamel phosphate values that suggest they were consuming water sources with $\delta^{18}O$ values outside of the range observed for the modern Bafra Plain (20 of the 72 enamel samples analyzed produced water values less than -10.4‰). These lower $\delta^{18}O$ values could be the result of a number of factors. First, it is possible that environmental changes in the last 5000 years may have had an affect on $\delta^{18}O$ values in meteoric water, so that modern values from precipitation are not applicable to the study of ancient water values. It is also possible that the values of the population were shifted downward by the consumption water source originating outside of the Bafra Plain, which had more negative $\delta^{18}O$ values. Water from the Kızılırmak River could potentially have lower $\delta^{18}O$ values, due to the fact that much of its catchment area lies at significantly higher elevations than the Bafra Plain, where slightly (although not significantly—see Expected Oxygen Isotope Values) lower values in $\delta^{18}O$ might be expected. The other possibility is the direct consumption by the population of water sources at higher elevations, perhaps during the herding of animals in mountainous pasture areas. These animals were likely to have been sheep and goats, as well as cattle; domestic pigs would not have been herded and would have remained closer to the settlement. The absence of water inputs from higher elevations could potentially explain the higher average $\delta^{18}O$ values observed in the pig samples. The outlying animal individual on the other hand, which likely represents a wild boar, has a more negative value than the remainder of the domestic pig samples. This individual may thus have originally resided in an area with drinking water that had a lower $\delta^{18}O$ value, such as the forested mountainous area to the south of the Bafra Plain.

Discussion of Strontium Isotopic Values

The animal enamel and human bone samples, which are intended to provide a local baseline, demonstrate a very narrow range of variation, with similar absolute values to each other. Bone samples were observed to have an average of 0.70777±0.00007 (n=18), and animal enamel samples to have an average of 0.70759±0.00023 (n=8) (with outlier removed, 0.70767±0.00007 (n=7)). Despite the fact that a statistically significant difference was detected between human bone and animal enamel samples (t= -3.0376, p=0.005674), these values display a very small absolute difference in values. Many of the human enamel samples cluster in this region as well, although the average enamel value is slightly higher (0.7091±0.00172 (n=72)). These baseline values are consistent with values that might be anticipated in the region of İkiztepe, primarily representing mixing of values originating from the two inputs most likely to affect the Kızılırmak River (i.e. carbonates and flysch with values in the region of 0.7090-0.7092, and island arc magmatics from the Magmatic Zone with values in the vicinity of 0.7045) and Black Sea water values (0.7093). There is no reason to necessarily assume equal mixing of these inputs, but the observed values clustering around 0.7075 represent a perfectly acceptable value for the mixing of these end members. The values of the majority of the İkiztepe population can likely be explained by the consumption of a combination of a terrestrial diet with rather low strontium isotopic signatures, and a marine diet with a high proportion of fish, with a higher strontium isotopic signature similar to that of modern ocean water. However, many of the enamel samples display higher results, and in some cases, significantly higher results. The degree of variation in human enamel values is significantly higher than the degree of variation observed in both human bone and animal enamel values.

Turner *et al*, in studying strontium isotope variation at Macchu Picchu found a similarly high level of variability in the strontium isotope values from the site, where very few individuals could be considered to be of local origin based on the local isotopic range (2009: 326). They suggest that one possible explanation for this increased variability could be the consumption of imported food sources (Turner *et al* 2009: 326). However, they argue against this being the case through the results of concurrent analysis of nitrogen isotopes (Turner *et al* 2009: 327). The greatest dietary sources of strontium are calcium-rich foods, including small fish bones, leafy green produce, legumes and dairy products (Burton 1996, Burton & Wright 1995; Knudson 2004). They suggest that the results of nitrogen isotopic analysis suggest no significant consumption of marine products, and furthermore state that dairying practices were not commonly conducted in the Andes (Turner *et al* 2009: 327).

Given the coastal location of İkiztepe, it is likely that marine products comprised a relatively significant portion of the population's diet. While documenting faunal evidence for fish consumption is often relatively difficult, sieving of soil samples taken from the site has produced evidence for some fish consumption (Alkım *et al* 2003: 175-177). Furthermore, given the likelihood of pastoral practices involving sheep and goats and perhaps cows during this period, it seems quite likely that dairy consumption by the İkiztepe population was quite high. These two food sources likely represent the most significant inputs of strontium into the diet of this population. However, fish consumption only provides an explanation for values ranging as high as the isotopic values of Black Sea water, and not for values ranging higher than this. The importation of fresh water fish with non-local isotopic signatures seems unlikely given the proximity of an abundant source of seafood, the Black Sea. Thus, the primary explanation for high values may be the consumption of dairy products from animals herded in areas outside of the coastal plain. The animals in question must have been herded by groups of people, and the most likely explanation is not that these animals were imported, but that they were herded by members of the İkiztepe population. Carbon and nitrogen isotopic analysis for evidence of diet might provide additional evidence for the overall dietary composition of the İkiztepe population, and for the relative inputs of sources that might significantly affect the strontium isotopic values obtained by this study.

Turner *et al* also point out that to accept a completely dietary explanation for the variation in strontium isotopic values "is to assume *extreme*, idiosyncratic and long-term variation in diet among all individuals in the study population" (2009: 327). Such a possibility is countered by a large amount of ethnographic evidence, which suggests pooling of dietary resources based on kin and community ties (Turner *et al* 2009: 327). Similar evidence can be found ethnographically in Anatolia, predominantly occurring within extended groups of affinal kin (Yakar 2000: 128-129). Turner *et al* thus characterize the variability in their strontium isotopic values as being the result of actual differences in the residence locations of these individuals during childhood (2009: 329).

Based on the variety of strontium isotopic signatures observed in the İkiztepe population, it is likely that we are dealing with a number of individuals who were born non-locally. The more significant problem, however, is what proportion of the population should in fact be considered to be non-local. As previously discussed, the method traditionally used in isotopic studies for identifying non-local individuals is through the definition of a local range of variation based on two standard deviations from the mean of human bone or animal remains. For İkiztepe, these methods yielded ranges of 0.70762-0.70791 and 0.70752 and 0.70781, respectively. When we compare these ranges to the observed range of variation in human enamel for the İkiztepe population, we find that 55 of 72 (or 76%) and 47 of 72 (65%), respectively, fall outside of these "local" ranges. This is a remarkably high percentage of non-local individuals. Indeed, the standard deviation in human enamel strontium isotope values observed for the İkiztepe population is extremely high compared to most estimates for populations where this type of study has been previously completed (i.e. Bentley *et al* 2003, Bentley *et al* 2004b, Bentley & Knipper 2005, Bentley *et al* 2005, Bentley *et al* 2007b, Nafplioti 2008; more similar to Price *et al* 2002).

The histogram of $^{87}Sr/^{86}Sr$ isotopic values (see **Figure 6.16: Histogram of Human Enamel Strontium Isotope Values)** suggests that the distribution is actually tri-modal. The majority of the population displays values of less than 0.710, but with secondary peaks occurring around 0.712 and 0.715. The second peak, located around 0.712, includes 7 individuals, while the third peak at around 0.715 includes 2 individuals. This suggests that 9 out of 72, or 12.5%, of the individuals analyzed demonstrate enamel signatures that are almost certain to be non-local. These individuals represent relatively clear outliers to the general population. In most previous studies, outliers were defined by the methods described above. Populations most often demonstrated relatively normal or slightly skewed distributions, and non-local individuals were identified as those located in the tails of these distributions. Rarely, however, did these distributions indicate bimodal or trimodal distributions, as observed at İkiztepe (but see Montgomery *et al* 2005). This suggests, perhaps, that this portion of the İkiztepe population were long-distance migrants, and clearly distinguishable from individuals from the surrounding region.

In general, previous isotopic analyses of mobility have tended to be performed on societies known or supposed to be primarily sedentary, rather than nomadic (i.e. Teotihuacan, Tiwanaku, European agriculturalists, Grasshopper Pueblo, Thai agriculturalists, etc). The population at İkiztepe, of course, is also generally believed to be sedentary. However, traditional practices in mountainous regions of Turkey, which still persist today, involve seasonal movements of groups or portions of the society into highland areas in association with the herding of animals. These practices are often known as *yayla*, and were described in **Chapter One: Introduction**. Such practices could potentially have added to the variability of the İkiztepe population's isotopic signatures, as individuals or groups moved between areas with slightly different strontium isotopic signatures. Given the local geology, and the fact that most of these *yayla* tended to move over relatively short distances, these movements are not likely to have produced extremely "non-local" signatures (i.e. like the outliers in the secondary and tertiary peaks in the histogram above), but may have contributed to increased variability in the population.

However, the variability observed in the human enamel values was not observed in corresponding strontium isotopic values for bone samples from the İkiztepe individuals. The reason why the human bone samples did not display similar levels of variability is not immediately clear. It is possible that this pattern is the result of a number of factors, the most likely of which is some form of diagenetic contamination which reduced the variability of isotopic signatures in the bone samples from the site (Budd *et al* 2000).

However, the animal enamel samples, which were also intended to act as an isotopic baseline, displayed similar absolute values to those of the human bone, and a similarly small range of variation. This fact initially argues against contamination of the bone values. While the human bone samples could easily be diagenetically contaminated, it is less likely that the animal enamel samples would be contaminated due to the more stable chemical nature of enamel. It is still less likely that the animal enamel would be contaminated while the human enamel did not display evidence for contamination such as reduced variability. Studies have found that groups of enamel and bone samples from animals often display narrower ranges of variation than human bone and enamel values (Price *et al* 2002; Bentley & Knipper 2005). This observation naturally depends on the animal species under analysis, and more particularly on how mobile the species under consideration is, and over what size of an area the species is likely to move. Animals that are relatively sedentary, and only move within a restricted geographical area have the smallest standard deviations in strontium values, particularly rodents (Price *et al* 2002). However, domestic pigs are also quite sedentary, and have been shown to have similarly small standard deviations to rodents (Price *et al* 2002; Bentley & Knipper 2005).

Thus, the narrow range of variation observed in the animal enamel samples, all originating from pigs, is not unexpected given previous analyses of groups of archaeological pig remains. Because bone is significantly more permeable than enamel, it often absorbs strontium from the soil and ground water. This may alter the absolute values of the strontium isotopic signatures observed in bone, but it also significantly decreases the amount of variation observed in bone values (i.e. see Horn & Müller-Sohnius 1999, Budd *et al* 2000). In this case, contamination may have artificially reduced the amount of variation in the isotopic values observed in the bone samples from this study, resulting in significantly lower levels of variation compared to the values observed in enamel samples from the same population. Interestingly, however, the similarity in absolute values between the contaminated bone isotopic values and those from animal enamel samples (which are not likely to be contaminated) suggests that the isotopic values of the local soil at and around the site of İkiztepe may not have changed significantly over the last 5000 years. Thus, the effect of diagenesis on the bone isotopic values, while apparently not having a significant effect on the absolute average value observed in the samples, simply decreased the amount of variation observed in the bone samples.

Non-Local Individuals

The trimodal distribution of strontium isotopic composition in the İkiztepe population suggests that there are two clear groups of non-local individuals. The first group of non-locals includes seven individuals who have strontium isotopic values between 0.7115 and 0.7135, and includes the individuals listed in **Table 6.37: Characteristics of Non-Local Individuals**. The demographic and archaeological characteristics of these burials are also outlined in the table below.

Table 6.35: Characteristics of Non-Local Individuals

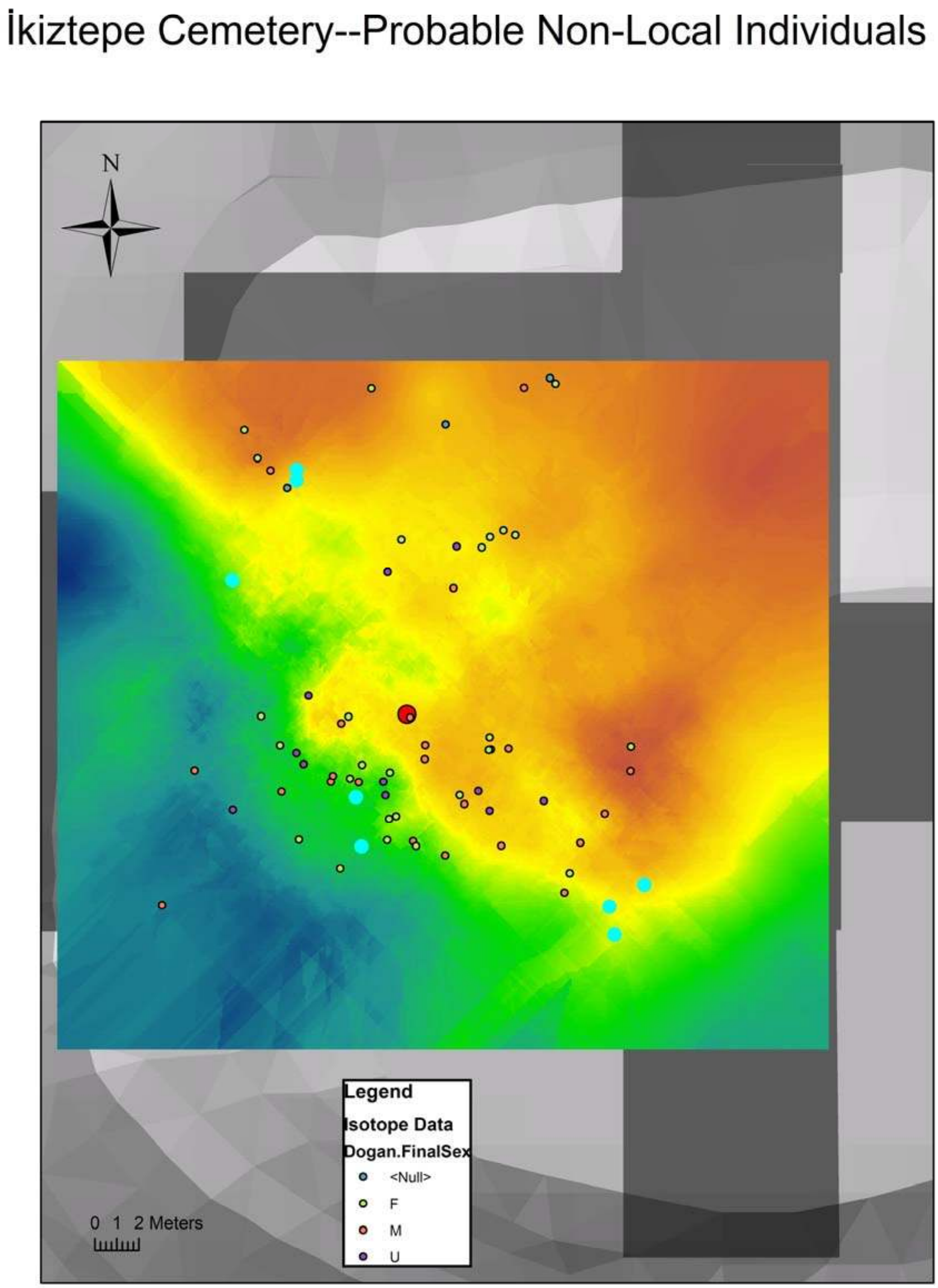
Sk No.	Sex	Age	Head Direction	Body Position	Grave Goods	Tooth	Fluoride Date
Group 1 (0.7115-0.7135)							
ITSK306	Female	Middle Adult (both)	Unknown	Unknown	None	LLM1	--
ITSK553	Male	Middle (UWB)/Young (YSE) Adult	Southeast	Dorsal	1 spearhead	LLM2	0.201 (Late Period)
ITSK567	Female	Middle Adult (both)	East	Dorsal	1 harpoon	LRM3	0.19 (Late Period)
ITSK602	Male	Middle Adult	South	Dorsal	3 total: 1 spearhead, 1 dagger, 1 earring	URP1	0.36 (Middle Period)
ITSK621	Female	Young (UWB)/Middle (YSE) Adult	Unknown	Unknown	1 earring	LLM1	0.91 (Early Period)
ITSK642	Female	Unknown (UWB)/Young (YSE) Adult	Unknown	Unknown	None	URM3	--

ITSK643	Male	Middle Adult (both)	West	Left	1 needle	LRC	0.26 (Late Period)
Group 2 (0.715+)							
ITSK268	Female	Young (UWB)/Middle (YSE) Adult	North	Unknown	None	ULC	0.12 (Late Period)
ITSK573	Male	Older (UWB)/Middle (YSE) Adult	Southeast	Dorsal	6 total: 2 spearheads, 1 dagger, 1 knife, 1 harpoon, 1 whetstone	ULP2	0.34 (Middle Period)

Among the individuals in this group of non-local individuals, there is no clear pattern with regard to sex; four of the seven individuals were females, and three males. In general, these individuals were predominantly middle aged at the time of their death (i.e. 30-45 years old). Some of these individuals were poorly preserved, and thus their body positions are unknown; among those whose positions are known, however, there is no clear pattern, and a lot of variation is observed. The head may be oriented to the east, south, southeast or west. While the body positions of these individuals were predominantly dorsal, in one case the body was turned to the left.

Two of the seven individuals were buried with no grave goods. Both of these individuals were poorly preserved, however, which may have affected the identification of associated grave goods. The majority of the other members of this group (four of the seven) were buried with one grave object. The types of grave goods observed in these cases were not consistent with regard to type (spearhead, harpoon, needle, earring). Only one individual (ITSK602) in this group of non-locals was buried with more than one grave good. This individual was buried with three objects, including a spearhead, a dagger and an earring.

Map 6.4: İkiztepe Cemetery—Distribution of Non-Local Individuals Identified by Strontium Isotopic Analysis



The spatial distribution of the first group of non-local individuals displays an interesting pattern. Only six of the seven individuals in this group have known spatial locations; the location of SK621 is unknown. Of the remaining burials, whose locations are known, five of the six burials are located in peripheral areas of the cemetery. These burials occur in two groups, one located in the northwestern portion of the cemetery and one on its southeastern border. Burials SK642 and SK643 (one male and one female) are buried in extremely close proximity to each other in the northwest. Burials SK553, SK567 and SK602 are located in the southeast, and consist of two males and one female. Both of these males were buried with weaponry, including spearheads and a dagger. Only one individual from this group, SK306, was buried in the central portion of the cemetery, which seems to show a higher concentration of burials with high numbers of grave goods. Interestingly, however, this individual was not buried with any grave goods.

The second group is smaller than the first, and includes two individuals (SK268 and SK573) whose strontium isotopic values are greater than 0.715. This group represents the most extreme outliers with regard to the strontium isotopic values observed. Again, as with Group 1, there is no clear pattern among the non-locals with regard to sex (one female and one male). The ages were identified as a young-middle aged female, and a middle-aged to older adult male. They were not buried with a consistent orientation (i.e. one’s head to the north, and one to the southeast). Furthermore, there was no consistent pattern in orientation in comparison to the other group of non-locals described above. While the body position for the male was dorsal, the position of the female was unknown. Once again, no clear pattern in grave good occurrence is noticeable. The female’s grave includes no grave goods, while the male was buried with six objects, and was identified by Bilgi as a “distinguished” burial. The grave goods buried with this male include a number of weapons (two spearheads, a dagger and a knife), as well as a harpoon and a whetstone.

The second group of non-local individuals, which represent the most extreme outliers in terms of their strontium isotopic values, displays a slightly different spatial pattern to that observed among the first group of non-locals. Neither of these burials is located in the peripheral areas of the cemetery. One of the two individuals (SK573, the male) is located in the central portion of the cemetery, which is not surprising given the number of grave goods associated with this burial. The second individual (SK268, the female) was buried on the middle part of the slope of the cemetery to the north of the cemetery's central area.

If these individuals are considered to represent long-distance migrants, then it seems that there is no clear pattern with regard to which sex tends to be more migratory over long distances. Furthermore, there is no clear pattern with regard to how non-locals are treated in the mortuary record in comparison to locally born individuals. These individuals do not display any clear trend toward a particular orientation or burial position. Furthermore, there is no apparent tendency for these individuals to be buried with different numbers of grave goods, or different types of objects than local individuals. While a few individuals were buried with no grave goods, the majority of the non-locals had at least one grave good. Furthermore, at least one individual was buried with a large number of grave goods and was identified by Bilgi as a "distinguished" burial. This suggests that non-locals were well-integrated into the İkiztepe community, and were not distinguished in any archaeologically identifiable way from local individuals in terms of the way they appear in the archaeological record.

Overall, there is no clear pattern of spatial location that applies to both of these two groups of non-local individuals. While the first group of non-locals displays a distinct tendency to be buried toward the peripheral areas of the cemetery, this was not observed with the second group of non-locals. These individuals, along with one of the individuals from the first non-local group displayed a tendency to be buried closer to the cemetery's centre.

The values observed among the enamel samples in both of these groups of outliers are difficult to explain with the values derived from local geology, which range between 0.712-0.715. Geological outcrops with strontium isotopic signatures high enough to explain the outliers are rare in the area of İkiztepe. Granite outcrops to the southwest of Sinop, previously described, in general have signatures much higher than observed in the İkiztepe non-local individual (Nzegge *et al* 2006). The Deliktaş outcrop has signatures in the range of 0.73-0.74; Sivrikaya, on the other hand, has produced signatures that range from 0.70840-0.73246 (Nzegge *et al* 2006); some intermediate values could potentially be appropriate but must be highly localized. More promising are the granitoid outcrops to the south of İkiztepe, further into the highlands of the Kızılırmak River, in the area around Yozgat and Kirikkale. One possible interpretation is that the İkiztepe non-local individuals could originate from the vicinity of these outcrops. Contemporary archaeological sites, such as Alişar Höyük and Çadır Höyük are located in the eastern portion of one of the largest of these granite outcrops, the Yozgat batholith (Boztuğ *et al* 2007: 192-194). While studies have not provided a clear picture of the range of values observed within the Yozgat batholith itself, and particularly in its eastern portion, observed values in related granite outcrops to the west have produced values in the range of 0.712-0.715, as observed among the non-locals from İkiztepe. One plausible scenario is thus that some immigrants to İkiztepe with very high observed strontium isotopic signatures could have been born in the vicinity of Central Anatolian granite outcrops, such as those found around Alişar Höyük and Çadır Höyük, providing a potential place of origin for the non-local migrants.

However, other potential locations of origin with similar high strontium isotopic signatures are not ruled out. Based on observed values from the Strandja and Rhodope Massifs, it is possible that other potential sources of isotopic values for non-local individuals may be found in this region, which has high numbers of granitoid extrusions (Okay & Tüysüz 1999: 479-480, Okay *et al* 1996: 424, Okay 2008). Furthermore, studies suggest that formations with strontium isotopic signatures consistent with the non-local individuals at İkiztepe can be found in this area, particular in plutons in the Pirin area, in the Central Rhodopes in Southern Bulgaria/Northern Greece (Zagortchev 1994, Harkovska *et al* 1998). However, an origin for these individuals in areas on the western Black Sea coast, previously suggested as an area with close connections to İkiztepe, is unlikely.

Variability in the "Local" Population

If we remove these nine non-local individuals from consideration, and consider the rest of the population, whose strontium isotopic values exist within the primary peak of the histogram (see **Figure 6.16: Histogram of Human Enamel Strontium Isotope Values),** the results are displayed in **Table 6.38: Average ^{87}Sr/^{86}Sr Values by Sex (More Certain and Less Certain Sex Estimates) After Removal of Non-Local Individuals.**

Table 6.36: Average ^{87}Sr/^{86}Sr Values by Sex (More Certain and Less Certain Sex Estimates) After Removal of Non-Local Individuals

	More Certain			**Less Certain**		
	Females	**Males**	**Unknown**	**Females**	**Males**	**Unknown**
N	26	22	15	30	32	1
Average	0.708485	0.7084236	0.7088953	0.7084403	0.7086709	0.70868
Standard Deviation	6.495737E-04	7.84957E-04	1.113257E-03	6.517535E-04	9.824963E-04	--
Min	0.70770	0.70766	0.70768	0.70770	0.70766	0.70868
Max	0.71026	0.7108	0.71074	0.71026	0.7108	0.70868
Range	0.00256	0.00314	0.00306	0.00256	0.00314	0

T-tests were conducted to determine whether any difference in the isotopic values could be observed between the sexes for this local population. These tests were conducted for both the more certain and less certain sex estimates. Neither of these tests detected any significant difference in values between males and females (more certain sex estimates, t=0.2964, p=0.768224; less certain sex estimates, t= -1.0814, p=0.278220).

Shapiro Wilk tests of normality were conducted to determine if the remaining local population could be determined to display a normal distribution of isotopic values, as suggested by the original histogram conducted for the entire population (see **Figure 6.16: Histogram of Human Enamel Strontium Isotope Values).** In fact, these tests demonstrated that for both the more certain and the less certain sex estimates, the values for both sexes were still determined to deviate from normality, even after non-local individuals had been removed (more certain sex estimates: female, W=0.9156196, p=3.553425E-02; male, W=0.8307254, p=1.577971E-03; less certain sex estimates: female: W=0.9027586, p=9.816865E-03; male, W=0.8581341, p=6.256117E-04). In each case, when histograms of the remaining population were plotted, the distribution looked remarkably similar, consisting of a single large peak with a fairly narrow range of variation and a smaller, wider peak partially overlapping with the first peak, but ranging higher than this primary peak.

In order to test for differences in variance between the sexes, a Levene's test was conducted, due to the deviation of the distributions from normality. For the more certain sex estimates, no significant difference in variance between the sexes was detected (test statistic= 0.1405, p=0.709497). However, for the less certain sex estimates, the difference in variance was determined to be significant at α=0.1 (test statistic= 3.3168, p=0.073561), with males displaying greater variance than females.

Finite mixture analysis, as described in Chapter Four, was conducted on the distribution of strontium values in the "local" population, and determined the distribution to display a mixture of two distinct groups, as displayed in the figure below.

Figure 6.33: Finite Mixture Analysis of Strontium Values After Non-Locals Removed
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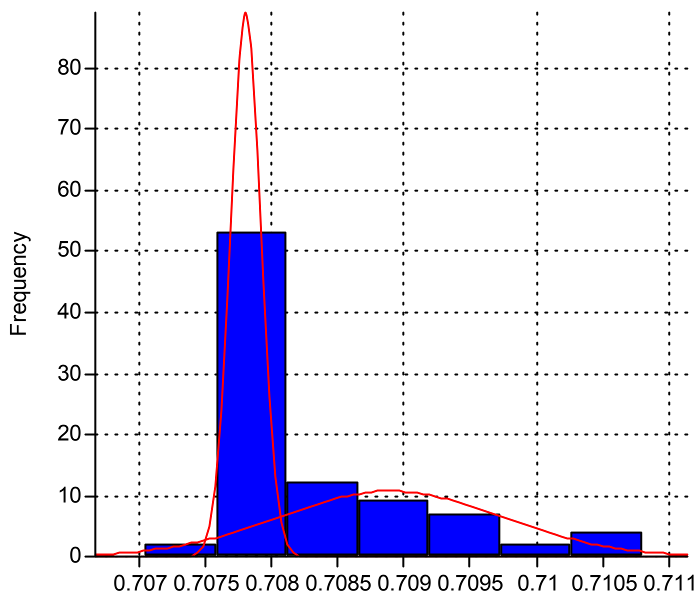


The results of the finite mixture analysis suggest that there are two distinct groups within the local İkiztepe population, one larger group of individuals displaying a fairly narrow range of variation, and a smaller group displaying much more variation. These groups are not mutually exclusive, but rather overlap with each other.

The existence of a small group of individuals within the general population that displays an increased level of variability may be explained, as suggested above, by the use of seasonal transhumance practices. Such practices, still observed in the Black Sea region today, may have involved the seasonal movement of selected groups of individuals into mountainous areas for the purpose of pasturing animals. The segmentation of individuals between those remaining in the primary settlement, and those involved in animal herding may have occurred either within or between households.

Due to the overlap of isotopic values between these two groups, as observed in **Figure 6.33: Finite Mixture Analysis of Strontium Values After Non-Locals Removed**, it is difficult to assign certain particular individuals to one group or another. Individuals with isotopic signatures higher than those of Black Sea water (i.e. higher than 0.7093) must have had inputs from other areas than the immediate Bafra Plain area, and thus may be suggested to represent part of this more "mobile" group. In order to gain a better understanding of the characteristics of these more mobile individuals, this was the criteria used for defining a possible transhumant segment of the population. Other individuals, with values lower than Black Seas water are more difficult to assign, but may still represent part of this group.

Table 6.37: Characteristics of "Mobile" Local Individuals

Sk No.	**Sex**	**Age**	**Head Direction**	**Body Position**	**Grave Goods**	**Tooth**	**Fluoride Date**
Group 3 (0.710-0.7110)							
ITSK 277	Unknown/ Male	Young Adult	South	Dorsal	None	ULM2	0.31 (Middle Period)
ITSK 280	Female	Young(UWB) /Middle(YSE) Adult	Unknown	Unknown	None	ULC	0.30 (Middle Period)
ITSK 328	Male	Middle Adult (YSE)	Unknown	Unknown	None	URM3	0.42 (Middle Period)
ITSK 329	Unknown/ Male	Middle Adult	Unknown	Face Down	None	URM3	0.69 (Early Period)
ITSK 599	Male	Young Adult	Northwest	Dorsal	1 harpoon	ULM3	0.26 (Late Period)
Group 4 (0.7093-0.710)							
ITSK 257	Female	Young Adult **Note:*	Unknown	Unknown	None	UM1	0.41 (Middle

		unhealed cranial trauma					Period)
ITSK 270	Female	Middle Adult	Southeast	Right	1 pot, 1 harpoon	LLM3	0.32 (Middle Period)
ITSK 295	Unknown/ Male	Older(UWB)/ Middle (YSE) Adult	Unknown	Unknown	None	LLM3	0.29 (Late Period)
ITSK 297	Unknown/ Male	Young Adult	Southeast	Dorsal	5 total: 1 spearhead, 1 harpoon, 1 needle, 1 hook, 1 frit necklace	ULM2	0.39 (Middle Period)
ITSK 315	Unknown/ Male	Older(UWB)/ Middle (YSE) Adult	Unknown	Unknown	None	URM3	0.20 (Late Period)
ITSK 320	Male	Older(UWB)/ Middle (YSE) Adult	Southeast	Dorsal	1 spearhead, 1 bone hook	LLM2	0.4 (Middle Period)
ITSK 465	Male	Older(UWB)/ Middle (YSE) Adult	West	Dorsal	7 total: 1 spearhead, 1 frit necklace, 3 earrings, 2 bracelets	LLM3	0.72 (Early Period)
ITSK 569	Male	Older Adult **Note: unhealed trauma*	Southeast	Dorsal	11 total: 2 spearheads, 1 dagger, 1 spearhead, 1 harpoon, 1 earring, 2 bracelets, 1 silver pendant, 1 horned plaque	LRM3	0.4 (Middle Period)

Interestingly, this group presents a much clearer pattern with regard to sex. The "mobile" individuals are predominantly men. Many of these sex assignments are based on the less certain sex estimates but the pattern is still observable through the more certain estimates. The also reflects the significantly greater variability observed in the less certain sex estimates, as described above. This suggests that mobile individuals, possibly practicing transhumant animal herding, were significantly biased toward the inclusion of males. This is in contrast to modern practices, where the responsibilities of *yayla* transhumant movements are predominantly performed by women and female children (Yakar 2000: 289). It is, however, consistent with ethnographic observations that herding practices are often performed by children and adolescents (i.e. these signatures represent movement prior to adolescence). Another important observation is the occurrence of very few grave goods, particularly among individuals with strontium isotopic values between 0.710 and 0.7110. Amongst individuals with signatures between Black Sea water (0.7093) and 0.710, there were more individuals with higher numbers of grave goods, including individuals designated as "distinguished" burials.

The exact routes taken by these mobile, and possibly transhumant, individuals are difficult to determine based on the available strontium isotope signatures. The variability observed in this mobile group suggests that the same routes and locations may not have been used by all individuals or families, or that these routes may have varied over time. However, the areas exploited by these individuals must include local signatures that would create dietary inputs higher than the value of Black Sea water. Mixing with such inputs would create overall dietary averages as high as those observed in the mobile group of individuals. It seems likely that groups herding animals may have passed into the mountains through the Kızılırmak River valley, following the river up into alluvial pastureland higher in the mountains. Areas of the river or its tributaries that pass through zones consisting of metamorphic geological formations of continental origin could provide isotopic signatures high enough to explain the observed values.

Comparison of these isotope results to the craniometric data discussed in **Chapter Four** also provides interesting information. Four of the nine non-local individuals were found in Cluster 1, with 2 non-locals found in Cluster 2 and 3 non-locals in Cluster 3. This pattern, however, was not determined to be statistically significant (χ^2 =0.516825, p=0.772277). Of the thirteen mobile, possible transhumant individuals, identified by the strontium isotopic analysis, two were not included in the k-means analysis. Of the remaining eleven individuals, five were located in Cluster 1, three in Cluster 2 and three in Cluster 3. This distribution was, once again, not considered significant (χ^2=0.178, p=0.915). The distribution of non-local and mobile individuals according to their phenotypic similarity to the remainder of the population are shown in the results of principal coordinates analysis in the figures below, where non-local individuals are indicated with a red cross, "mobile" individuals with a blue square, and the remainder of the population with a black dot.

Figure 6.34: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 2, Grouped By Locals and Non-Locals

(red cross=non-local individuals, blue square = "mobile" individuals, black dot=local and non=mobile population)

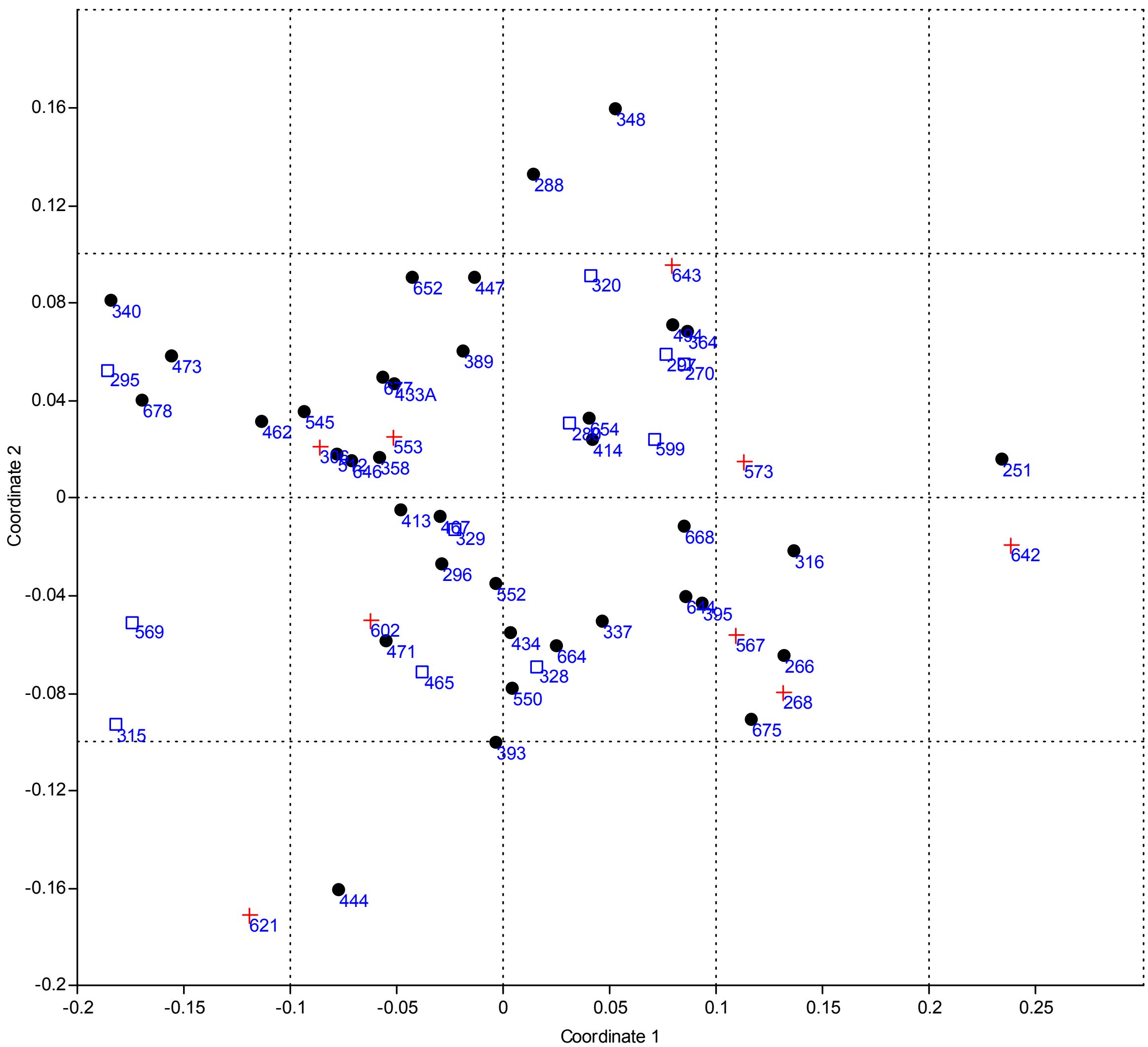


Figure 6.35: Principal Coordinates Analysis—Coordinate 2 vs. Coordinate 3, Grouped By Locals and Non-Locals
(red cross=non-local individuals, blue square = "mobile" individuals, black dot=local and non=mobile population)

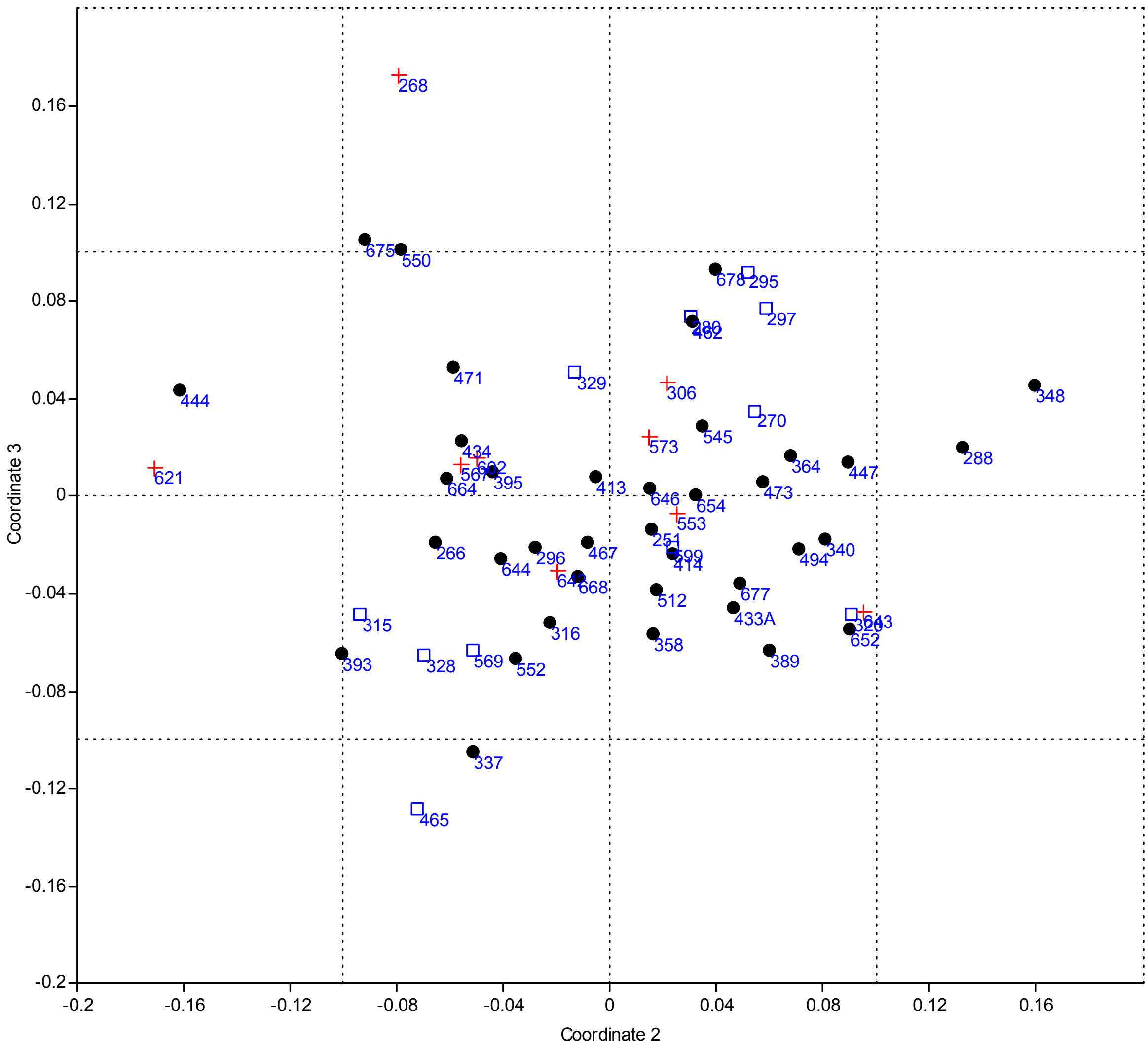
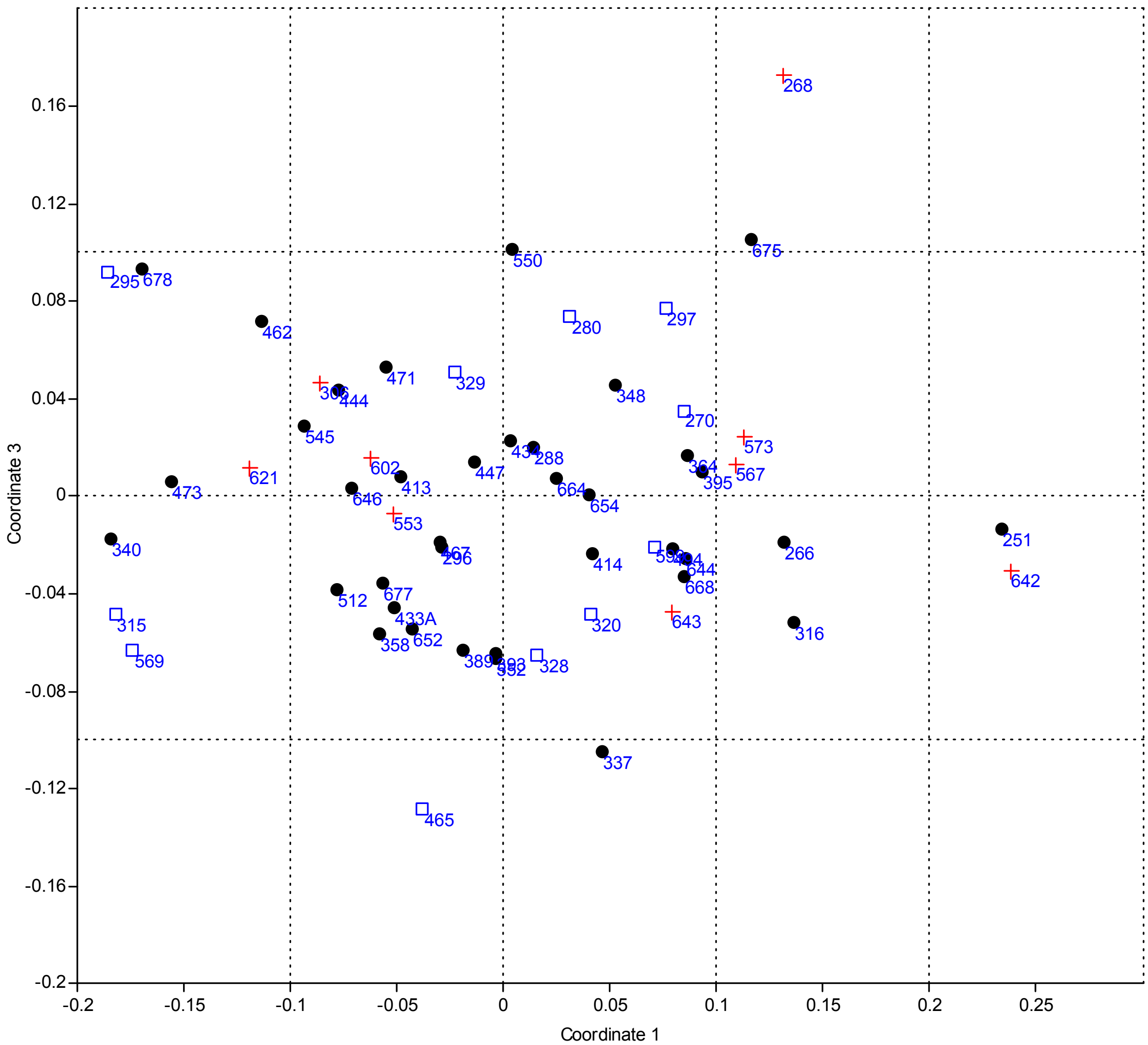
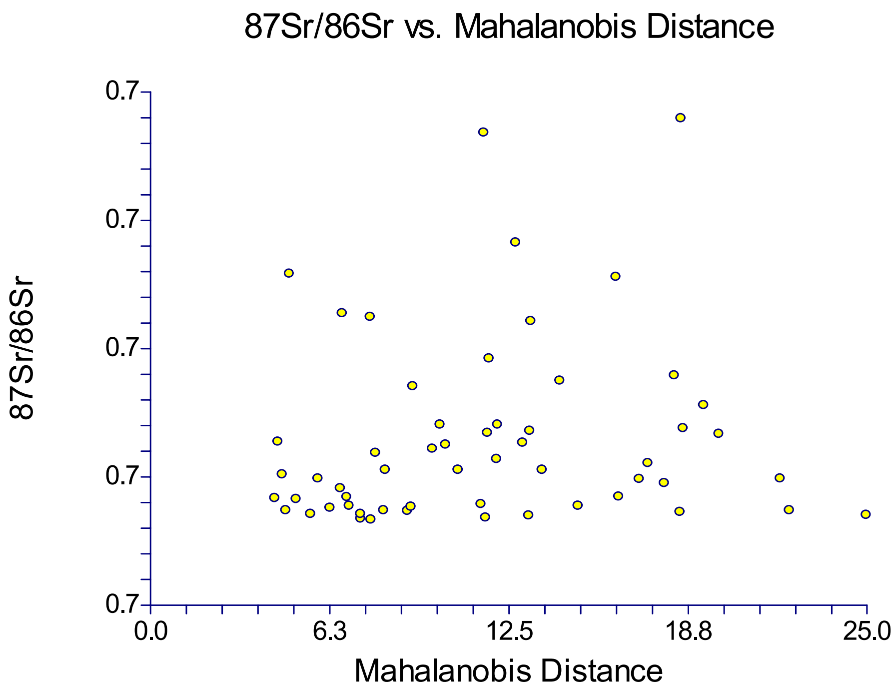


Figure 6.36: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 3, Grouped by Locals and Non-Locals
(red cross=non-local individuals, blue square = “mobile” individuals, black dot=local and non=mobile population)



The following figure compares the strontium isotope values obtained for the population to the Mahalanobis distance values for these individuals to the population centroid. In other words, it looks at the relationship between isotopic outliers and phenotypic outliers.

Figure 6.37: $^{87}Sr/^{86}Sr$ vs. Mahalanobis Distance from Population Centroid



No clear pattern in the occurrence of non-local individuals is immediately clear in these figures, as isotopic outliers do not appear to match well with phenotypic outliers. The non-locals and mobile individuals identified by strontium isotopic analysis are predominantly found at low to moderate Mahalanobis distances from the population centroid, compared to other members of the population. Two groups of these individuals can be observed along coordinate one in the principal coordinates figures, the first containing three individuals (ITSK306, ITSK553 and ITSK602) and the second five individuals (ITSK268, ITSK567, ITSK573, ITSK642, and ITSK643). Few of the clear outliers of in these figures consist of non-local individuals. In fact, only two non-local individuals appear to represent phenotypic outliers according to the principal coordinates analysis (ITSK268 and ITSK642). The figure which compares Coordinates 2 and 3 demonstrates a noticeably greater degree of clustering among non-local individuals within the core group of the population. These results suggest that non-locals remain genetically related to other individuals within the İkiztepe population, which indicates that they did not remain genetically isolated but interbred with the local population and contributed to the local gene pool. Similar patterns can be observed among the "mobile" groups of individuals identified by the strontium isotopic analysis. Two groups of these individuals can be observed along Coordinate 1, the first consisting of three individuals (ITSK295, ITSK315 and ITSK569) and the second of eight individuals (ITSK270, ITSK280, ITSK297, ITSK320, ITSK328, ITSK329, ITSK465 and ITSK599). More of the clear phenotypic outliers evident in these figures consist of "mobile" individuals; this includes four individuals (ITSK295, ITSK315, ITSK465 and ITSK569). These individuals, however, are not clearly related to each other. Overall, it appears that, similar to the pattern observed among non-local individuals, this more mobile group of individuals appears to have contributed to the local gene pool by largely interbreeding with the local population

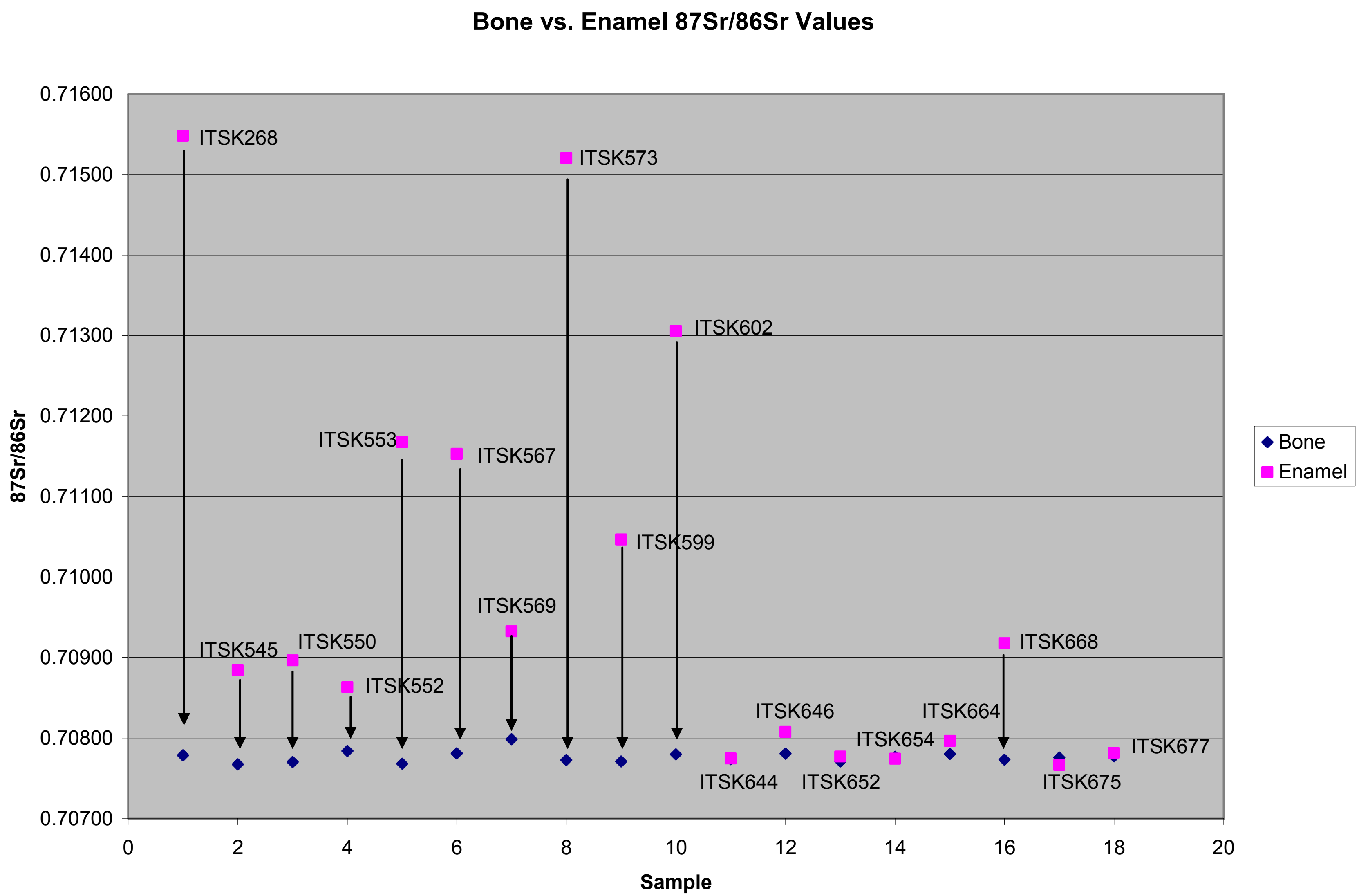
Synthetic Discussion of Strontium and Oxygen Isotopic Values

There is no clear correlation between the non-local individuals as identified by the strontium analysis, and the values obtained for the oxygen isotope analysis. Two measures could be used as indicators of more mobile individuals for the results of the oxygen isotopic analysis. One of these is the group of outlying individuals who lie outside of a local range as suggested by the range of values obtained for the bone samples analyzed. The second is the group of individuals for whom $\delta^{18}O$ of enamel phosphate produced values low enough to suggest that the isotopic value of the water they consumed was outside of the modern range of values observed for the Bafra Plain. Of the 20 individuals identified as being part of the latter group, not a single one of these represented the non-local individuals as identified by strontium isotopic analysis. Furthermore, this group showed few individuals in common with the group of "mobile" individuals suggested to represent animal herders, as identified by strontium analysis. The individuals with outlying $\delta^{18}O$ enamel values, as defined by the range of values observed in bone samples also had few individuals in common with the non-local or mobile groups, as defined by the strontium analysis.

Overall, a relatively small range of variation was observed in the $\delta^{18}O$ values obtained for the İkiztepe population. Both groups of potential outliers may thus not be truly indicative of population movement. The oxygen isotopic values observed for the bone samples may represent a sample whose variability may have been affected by diagenesis, as suggested for the strontium isotopic values obtained for the bone samples. Such a diagenetic decrease in the range of bone oxygen isotopic values observed might negate the identification of outlying enamel values using this bone range. Furthermore, the bone and enamel values that suggest the consumption of water sources outside the modern range of isotopic values for meteoric water observed in the Bafra Plain could be the result of environmental changes, or of the consumption of distantly sourced water from the Kızılırmak River. It is quite possible that the more mobile individuals in the İkiztepe population, as identified by strontium isotopic analysis, moved along herding routes that followed the Kızılırmak River upstream, as this would have been the easiest route into the mountains for herds and people to traverse. In this case, these individuals might have been consuming water from the same river, and thus from the same distant source, masking the observation of mobility-related changes through the measurement of bone and enamel oxygen isotopic values. Furthermore, as noted by Knudson, there is no reason to believe that strontium and oxygen isotopic zones should be isomorphic (2009: 181). Movement of an individual within a single geological zone could still involve movement through a variety of environmental zones, and vice versa (Knudson 2009: 181). She also found that the variability within each site, as determined by oxygen isotope analysis, was often more significant than the variation observed between different sites or regions (Knudson 2009: 185)

There is also no clear pattern visible in the comparison of paired bone and enamel isotopic values between strontium and oxygen. The two individuals representing the most extreme outliers among the strontium values, and which thus also displayed the greatest differences between bone and enamel in these values, both have oxygen isotopic results that are very similar in bone and enamel (see **Figure 6.38: Bone vs. Enamel $^{87}Sr/^{86}Sr$ Values** and **Figure 6.31: Bone vs. Enamel $\delta^{18}O$ Values).** Nor is there a pattern in these two individuals in terms of which tissue displays a higher oxygen isotope value. Of the other, larger group of non-locals, only three of the seven individuals had both bone and enamel samples analyzed. Of these three individuals, two of the three demonstrated moderate to large differences between bone and enamel values. These same two individuals displayed higher oxygen isotopic values for enamel compared to bone. The third individual displayed relatively similar values for bone and enamel, although the value obtained from the bone sample was slightly higher than that of the enamel. Among the seven presumed sedentary individuals whose paired strontium isotopic values for bone and enamel were virtually identical, however, there is a great deal of variety in the patterns observed for the comparative oxygen values. Only two of these seven individuals display correspondingly small differences between bone and enamel in $\delta^{18}O$ values. The remainder have moderate to large differences in oxygen isotopic values between the two tissues, despite the very small differences observed between bone and enamel samples for strontium isotopic analysis of these same individuals. In the majority of these seven cases, however, $\delta^{18}O$ values in enamel were higher than those in bone (five of seven cases).

Figure 6.38: Bone vs. Enamel $^{87}Sr/^{86}Sr$ Values



The adjustment of the $\delta^{18}O$ values of first molars and canine teeth downward by 0.7‰ had little affect on the variability of $\delta^{18}O$ values observed overall in the population, but it did affect the relationships of individuals to each other (see **Figure 6.30: Adjusted $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ Values)**. This was particularly visible among individuals determined as likely to be non-local by strontium isotopic analysis. Among the group of individuals representing the most clear outlying non-locals according to their strontium values, the adjustment of the $\delta^{18}O$ values created a much more distinct separation between these two individuals. This raises the question of whether these two individuals can be considered to originate from the same location. They may in fact originate from two distinct areas with similar strontium isotopic values, but with slightly different oxygen values. Alternatively, it is quite possible that they could still originate from the same location, as they represent a reasonable range of variation in $\delta^{18}O$ within the same population, with a difference in $\delta^{18}O$ values of only 1.11‰.

The adjustment of the $\delta^{18}O$ also altered the relationships between the individuals in the second group of non-locals identified by strontium analysis, creating a clear cluster of three individuals (ITSK306, ITSK602, ITSK621). This group includes two females and one male, and does not exhibit any clear patterns in other variables. Furthermore, the spatial patterning in this group is difficult to determine, as the burial location of ITSK621 is not known.

Figure 6.39: $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ Values with Phenotypic Outliers

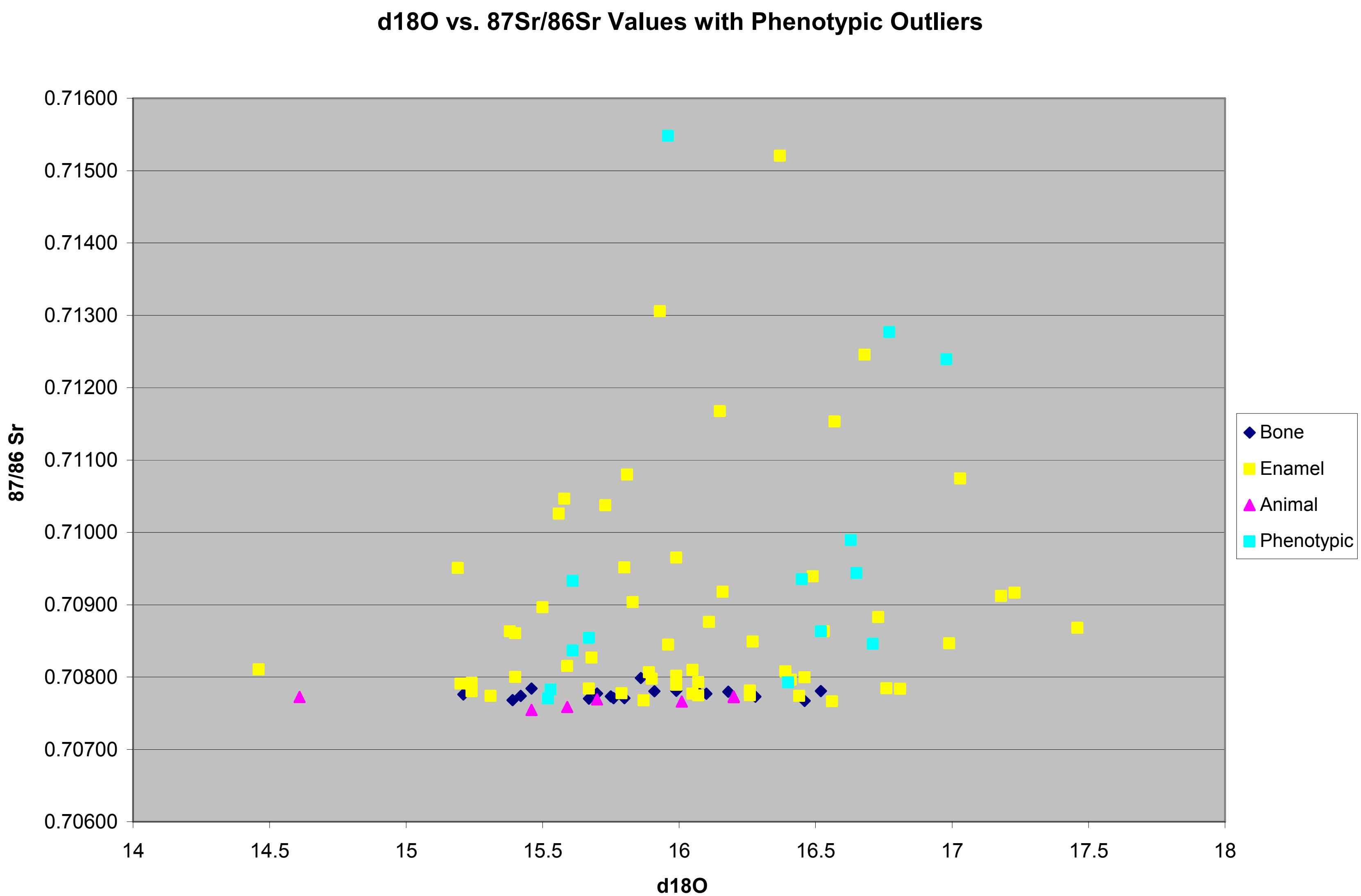


Figure 6.39: $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ Values with Phenotypic Outliers illustrates the relationship between the two isotopic studies and the results of the craniometric analysis discussed previously. This figure demonstrates the distribution of isotopic values for the phenotypic outliers identified by principal coordinates analysis. Two of the genetic outliers in the population are non-local individuals; one the most extreme non-local group and two from the second groups (ITSK268; ITSK621 and ITSK642). Although three of the phenotypic outliers lie within a very small range of variation in strontium isotopes, the vast majority of these outliers lie in the more variable group of individual strontium isotopic values. This suggests that individuals practicing transhumant herding practices are the least likely to demonstrate close genetic relationships with other members of the population.

Overall, the combination of strontium and oxygen isotopic data lends support to the idea that a clear cluster of individuals with a very small range of strontium and oxygen isotopic values can be identified. These individuals have enamel values that fall within or very close to the narrow ranges defined by bone and animal samples. It seems likely that this group of individuals represents a relatively sedentary segment of the population, who had very limited involvement in mobile activities such as herding during the period in which the teeth analyzed were formed. A second group of highly variable individuals can then be identified. These individuals have a more variable range of both strontium and oxygen isotopic signatures. While these could represent large numbers of immigrating individuals from highly variable origin locations, it seems more likely that they represent the more mobile segments of the local population. These individuals may have been involved in seasonal transhumant practices, herding animals in the mountainous regions to the south of the Bafra Plain during the childhood or adolescent years during which the teeth analyzed were formed. Finally, there are two clear groups of non-locals, identified primarily through strontium isotopic analyses; these individuals display strontium isotopic values much higher than the remainder of the population, which are inconsistent with the local geology. However, these individuals have oxygen isotopic values virtually indistinguishable from the local İkiztepe population. Despite this, these individuals are clear immigrants to İkiztepe, and may or may not originate from the same or similar locations.

Chapter Seven: Relative Dating of İkiztepe Remains

Introduction

The preceding chapters have presented and discussed a number of aspects of the organization of the cemetery at İkiztepe, including grave good distribution, spatial organization and isotopic analysis of the skeletal remains. However, there is one vital aspect of the cemetery's development that has thus far remained completely unknown and unaccounted for. This is diachronic change, which could significantly inform the results obtained in previous chapters. Unfortunately, as previously demonstrated, we are limited in our ability to create a relative sequence of the burials within the İkiztepe cemetery due to our poor understanding of the material culture of Northern Anatolia. Even if a better understanding of the regional chronology could be developed, many burials at İkiztepe included no grave goods. In those that did, there are currently no comparable excavated sites upon which to build a comparative relative chronology, and the details of many of the grave objects have thus far not been fully published. Furthermore, due to the excavation techniques employed at the site, the ability to identify stratigraphic relationships between the burials is extremely limited.

It is clear that another method of relative dating is needed to provide a better understanding of the temporal development within the cemetery. One method that has been used successfully for this purpose at a variety of sites, predominantly in North America, is fluoride dating. One of its earliest and most memorable archaeological applications was in proving the Piltdown fossils to be fakes (Oakley & Hoskins 1950). Since then, fluoride dating has been applied in a variety of environments to facilitate the relative seriation of burials or archaeological deposits of faunal material (Schurr 1989; Ezzo 1992; Johnsson 1997; Schurr 1998; Tankersley *et al* 1998; Tankersley 1999; Schurr & Gregory 2002; Wrobel 2007). The greatest advantage of this method is its ability to seriate bone material in cases where grave goods, clear stratigraphic information, or associated datable archaeological material are absent. Furthermore, in comparison to radiocarbon dating, fluoride dating is comparatively inexpensive, and can allow for analysis of a larger and more broadly representative sample of the cemetery population. This relative sequence also has the potential to inform the careful selection of samples for radiocarbon dating, and better anchor the relative chronology with absolute dates.

The principle of fluoride analysis is that bone material, as it is exposed to a soil matrix in the post-mortem burial environment, absorbs fluorine from the soil at a relatively constant rate. Thus, with increased exposure to the burial environment, fluorine content will continue to increase. As fluorine is incorporated into bone, it replaces the hydroxide portion of the hydroxyapatite matrix of the inorganic portion of the bone (Molleson 1990: 352). In life, the amount of fluoride in bone is generally less than 0.6%, and often as low as 0.05% (Molleson 1990: 352; Wrobel 2007, Johnsson 1997). *In vivo* levels of greater than 0.6% are generally only observed in pathological cases (Molleson 1990: 352). After exposure to the burial environment, this percentage could theoretically reach levels as high as 3.8%, if all the available hydroxide has been replaced by fluoride (Wrobel 2007: 699). The addition of fluorine to the hydroxyapatite matrix creates fluoroapatite, which is highly stable; thus, once incorporated, the fluoride in the bone matrix is generally not lost (Johnsson 1997: 431)

Fluoride dating, as a relative dating method of skeletal remains, is not without potential pitfalls. Fluorine levels in soil may vary between sites within a region or between areas within a site, due to variation in soil composition. Thus, results of fluoride dating may not be comparable for different areas within a site or between different sites. A number of factors contribute to this variation in soil fluorine content. For example, differences in soil porosity or permeability that affect water drainage between different areas may contribute to variation in soil and bone fluorine concentrations (Schurr & Gregory 2002: 285; Wrobel 2007: 710-711). House floors, plastered pits, or other features that lead to poor water drainage could have significant effects on the absorption of fluoride into the bone matrix (Wrobel 2007: 710-711). Furthermore, higher soil pH increases the mobility of ions, leading to an increased rate of fluoride incorporation in associated bone materials (Wrobel 2007: 707). Soil is most acidic, however, during the primary decomposition of the body, meaning that fluoride incorporation is highest in the time period immediately following burial (Wrobel 2007: 707). As a result, Wrobel suggests that the season of burial may affect the incorporation of fluoride into the bone matrix; if the primary decomposition of the body occurs during a dry season, when there is little exposure to groundwater, absorption of fluoride may be substantially lower (2007: 707).

Despite these potential problems, the nature of the burial environment at İkiztepe makes it ideal for the application of fluoride analysis. As an intra-site analysis, it avoids the pitfalls of comparability between sites. Furthermore, due to the constrained spatial nature of the cemetery, variation in soil composition among the individuals under consideration is minimized. Wrobel (2007) notes difficulties in applying fluoride analysis in intra-site analyses due to differences in water drainage in different areas of the site. The remains from the İkiztepe cemetery were located on a slope, with water drainage among burials within the cemetery likely to be similar across areas. The one potential exception to this comparability in drainage conditions are the burials found at the lowest elevations within the cemetery, located at the bottom of the slope. To account for this fact, analysis was conducted to ensure there is no discernable effect on bone fluoride content caused by the differential drainage of water. Overall, the İkiztepe cemetery seems to be ideal for the application of fluoride dating. Most analyses of the effectiveness of fluoride dating have concluded that as long as the method is applied under the correct circumstances, and the results are interpreted with caution, this method can be extremely successful in the relative dating of different burials or archaeological deposits (i.e. Johnsson 1997, Tankersley *et al* 1998, Schurr & Gregory 2002).

The application of fluoride dating is also complicated by variation in fluorine content within the skeletal material itself. For example, fluorine absorption may not be constant throughout the bone matrix, as there is a diffusion profile of fluorine content within the bone, with concentrations decreasing towards the inside of the bone (Molleson 1990: 353). Furthermore, there may be differential absorption of fluorine between different skeletal elements due to differences in bone density, porosity and thickness (Schurr & Gregory 2002: 286). As a result, there may be significant variation between different bone types, such as between cortical and trabecular bone (Johnsson 1997: 431; Wrobel 2007). Thin bones such as ribs may be more sensitive to changes in soil conditions than thick, dense cortical bone (Johnsson 1997: 436; Wrobel 2007). However, Wrobel's results suggest that there is not a significant correlation between fluoride concentration and bone thickness, although this may be attributable to the small sample size of the study (2007: 706-707). Comparisons between different bone types (although in fossilized mammals rather than humans) suggested that horn cores and skull fragments may have a slightly increased fluorine contents compared to other bone types, such as mandibles, metacarpals, metatarsals and scapulae (Johnsson 1997: 435). Furthermore, differences in bone porosity and density between males and females, as well as between children and adults, may affect bone fluorine content (Wrobel 2007: 709-710). Pathological cases that change bone porosity or density may also interfere with fluoride absorption (Wrobel 2007: 710).

Consequently, it is necessary to choose bone samples that minimize the number of sources of variation in fluoride absorption. Thus, ideal bones samples are those that are from a single skeletal element, where trabecular bone and thin cortical bone is avoided. Unfortunately, there were some limitations in our ability to apply such sample selection procedures to fluoride dating in the İkiztepe sample. The ideal type of bone for such an analysis, compact bone from long bone shafts, was not available for analysis. The bone types that were available for analysis consisted solely of ribs and cranial fragments. However, due to issues of preservation, no one type of bone was available for all samples. Some samples had only ribs available (n=18) and some had only cranial fragments (n=39). Only 8 individuals had both bone types available for analysis. As a result, these two kinds of bone had to suffice for analysis. Fortunately, the difference in bone density, composition and thickness between these two bone types was reasonably minimal.

Fluoride analysis was conducted on all individuals for which isotopic analysis had been completed, and which had bone samples of any type available for analysis. Isotopic analysis was conducted on 72 individuals. Of these 72 individuals, 7 had no bone samples available for fluoride analysis (bringing the total analyzed to n=65 individuals), and 8 individuals had bone samples from both rib and cranium available for analysis. Due to the fact that uptake of fluoride may be variable across different skeletal elements, these 8 individuals were used as a means of estimating the difference between measurements originating from different skeletal elements within the sample. In addition, 8 samples were dissolved and mixed with the buffer solutions twice, to determine the error introduced by the sample preparation procedure. These samples included some examples of both ribs and cranial fragments (n=4 rib samples, n=4 cranial samples). This brought the total number of samples analyzed to 81 (65 individuals, plus 8 repeat individuals with samples from different bone types, plus 8 additional repeated samples on the same bone samples).

Sample Preparation

Small slices of bone were removed from the available samples using a diamond disc saw attached to a Dremel tool. External calculus and other contaminants had been previously removed by abrasion with a tungsten carbide burr attached to a Dremel tool. For both ribs and cranial fragments, small slices of bone (2-3mm thick) were removed using a Dremel MultiPro tool with a diamond disc saw attachment. These slices were removed from previously cut ends of bone, rather than from broken ends, to minimize contamination from the burial environment (see Tankersley *et al* 1998). The entire cross-section of the bone was used in order to ensure a bulk analysis of the entire diffusion profile through the rib or cranial cross-section (see Tankersley *et al* 1998). All tools were cleaned between samples to prevent cross-contamination of samples.

The bone slices enamel were then crushed to a fine powder prior to analysis, using an agate mortar and pestle. The enamel was immersed in acetone prior to crushing to prevent sample loss during the crushing process.

Approximately 40 mg of each sample were weighed into 15 mL polypropylene Falcon centrifuge tubes (varying between 40.0mg and 40.9mg) and soaked in 2 mL of concentrated H_2O_2 for 24 hours to remove organic contaminants (see Johnsson 1997: 431), and then rinsed 5 times with deionized water to neutrality. Samples were then placed in 2 mL of 4M HNO_3 for 24-48 hours, until the bone was completely dissolved. Where dissolution was not complete after 48 hours, the samples were placed on a hot plate at a temperature of approximately 60°C for 3-4 hours; this successfully completed the dissolution of the samples. The dissolved bone material in

HNO_3 was then transferred to 30 dram polycarbonate snap-cap vials (with a mouth wide enough to accommodate both the fluoride and the reference electrode). 8mL of a 15% sodium acetate solution was added. This solution was used to rinse the centrifuge tubes to ensure all remaining dissolved bone material was removed.

A solution of sodium acetate was used as a buffer to increase the pH of the solution to approximately 5-6, the range recommended for the fluoride electrode. A base of equivalent strength to the acid (i.e. 4M KOH) cannot be used because of its effect on the total ionic strength of the solution, which affects the accuracy of the fluoride electrode (ThermoFisher Scientific Inc. 2007*)*. Therefore, acidic solutions must be buffered with a 15% sodium acetate solution. It was determined that a ratio of 5:1 was sufficient to raise the pH of the 4M HNO_3 solution to approximately 5.5 (i.e. 4 parts sodium acetate to 1 part HNO_3). Thus, the 8mL sodium acetate was added to 2mL HNO_3 to create this ratio in the sample solutions.

Following this, an amount of TISAB II (Total Ionic Strength Adjusting Buffer) equal to that of the existing solution was added (i.e. a further 10mL). This solution was then analyzed using an Orion Model 94-09 Fluoride Ion Selective Electrode and a double junction reference electrode connected to a digital pH/mV meter.

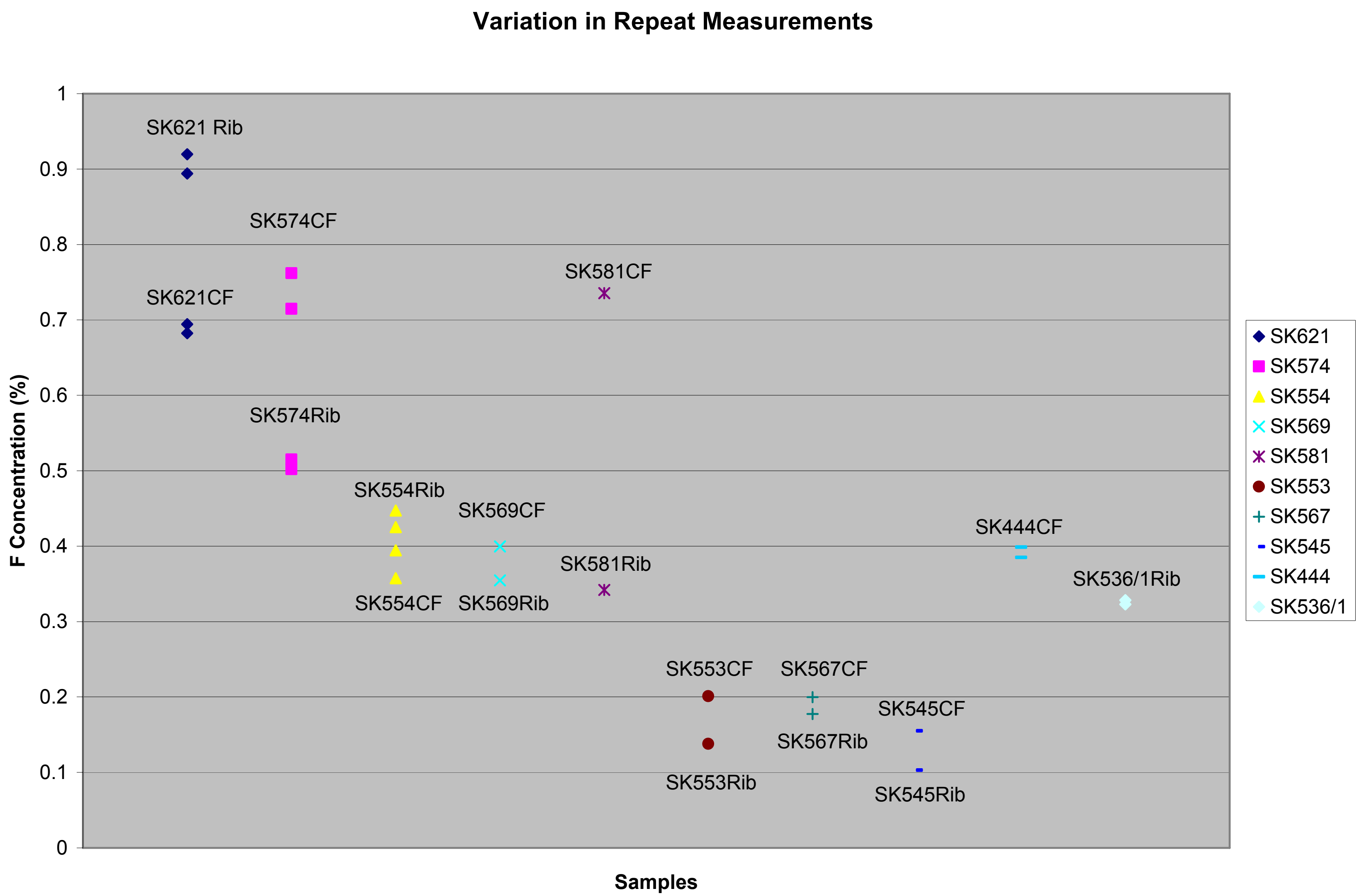
Solutions of known fluoride concentrations were used to calibrate the results provided by the fluoride electrode. A solution of 100 ppm fluoride was prepared, and then further diluted to create a series of standards of known concentrations in the range of values anticipated for the dissolved bone in 2mL HNO_3. These values were estimated from various studies that have measured fluoride concentrations in archaeological bones (Schurr 1989; Ezzo 1992; Johnsson 1997; Tankersley *et al* 1998; Schurr & Gregory 2002; Wrobel 2007*)*. The standards selected were: 2ppm, 5ppm, 10 ppm, 20ppm, and 50 ppm. These standard solutions were prepared in the same way as the sample solutions (2mL of known standard was diluted with 8mL of sodium acetate and 10mL of TISAB II). The millivolt values observed for each of these standards of known concentration were used to produce a calibration curve that allowed the interpolation of the concentrations of samples falling within this range based on their observed millivolt values. Standards were remeasured after every group of 10 samples to adjust for the drift of the calibration curve as the fluoride electrode adjusted. When the electrode was placed in each sample, time was allowed for the mV potential to stabilize before the reading was recorded. mV readings were recorded when the value remained stable for >10s.

The calibration procedure was repeated for each day that samples were run and used to calculate the fluoride values for that day. For each sample, two measurements were run, and the average of these measurements was used. In all cases, the measurements were repeatable to within 2-3 mV of each other. The resulting calibration curves based on the fluoride standards produced regression coefficients of 0.999 or better (using a Gompertz curve).

Reproducibility of Measurements and the Effect of Bone Type

Sample preparation was performed on 8 samples twice in order to determine the repeatability of the sample preparation procedure and measurement of the fluoride content. Repeat measurements on different preparations of the same sample were generally very consistent, with an average difference in concentration of 0.022 (n=8 pairs). The maximum difference between two repeat preparations of the same sample was 0.047. See **Figure 7.1: Variation in Repeat Fluoride Measurements.**

Figure 7.1: Variation in Repeat Fluoride Measurements



Due to the fact that the bone samples available for analysis were not always from the same bone types (i.e. similar skeletal elements), analysis was performed on pairs of samples from different bone tissues from 8 individuals. It was hoped that the measurements on these individuals would be able to help calibrate the results from different tissue types to allow for greater comparability of results from the different tissue types. Slightly greater variation was seen in measurements from different bone tissues in the same individuals, with an average difference of 0.065 (n=8 pairs). In five of the eight cases (ITSK553, ITSK554, ITSK545, ITSK567, ITSK569), the difference between the values obtained for the two tissue types was less than this average value. In two cases, the difference was between 0.21 and 0.22 (ITSK621 and ITSK574). The greatest difference between tissue types observed for a particular individual, however, was 0.39 (for ITSK581).

However, the values of one tissue are not consistently higher than the other. In two of the eight cases (SK621 and SK554), rib samples demonstrated a higher fluoride concentration than the cranial fragments. In contrast, in the other six cases, the opposite was true. It appears that the difference between the different tissue types (i.e. between ribs and cranial fragments) becomes more pronounced as the fluoride concentrations become higher (see **Figure 7.1: Variation in Repeat Fluoride Measurements**).

Due to the fact that no consistent difference between the two different tissue types could be observed, and that the average difference between tissue types in those individuals for whom both types were analyzed was relatively small, the absolute values for each of the samples were used in all cases, rather than calculating an offset for either of the tissue types. In the eight cases where both tissues were analyzed, the calculations that follow were based on values obtained for rib samples. Further work is clearly required to better understand the difference in fluoride concentration observed in different skeletal elements for the same individual.

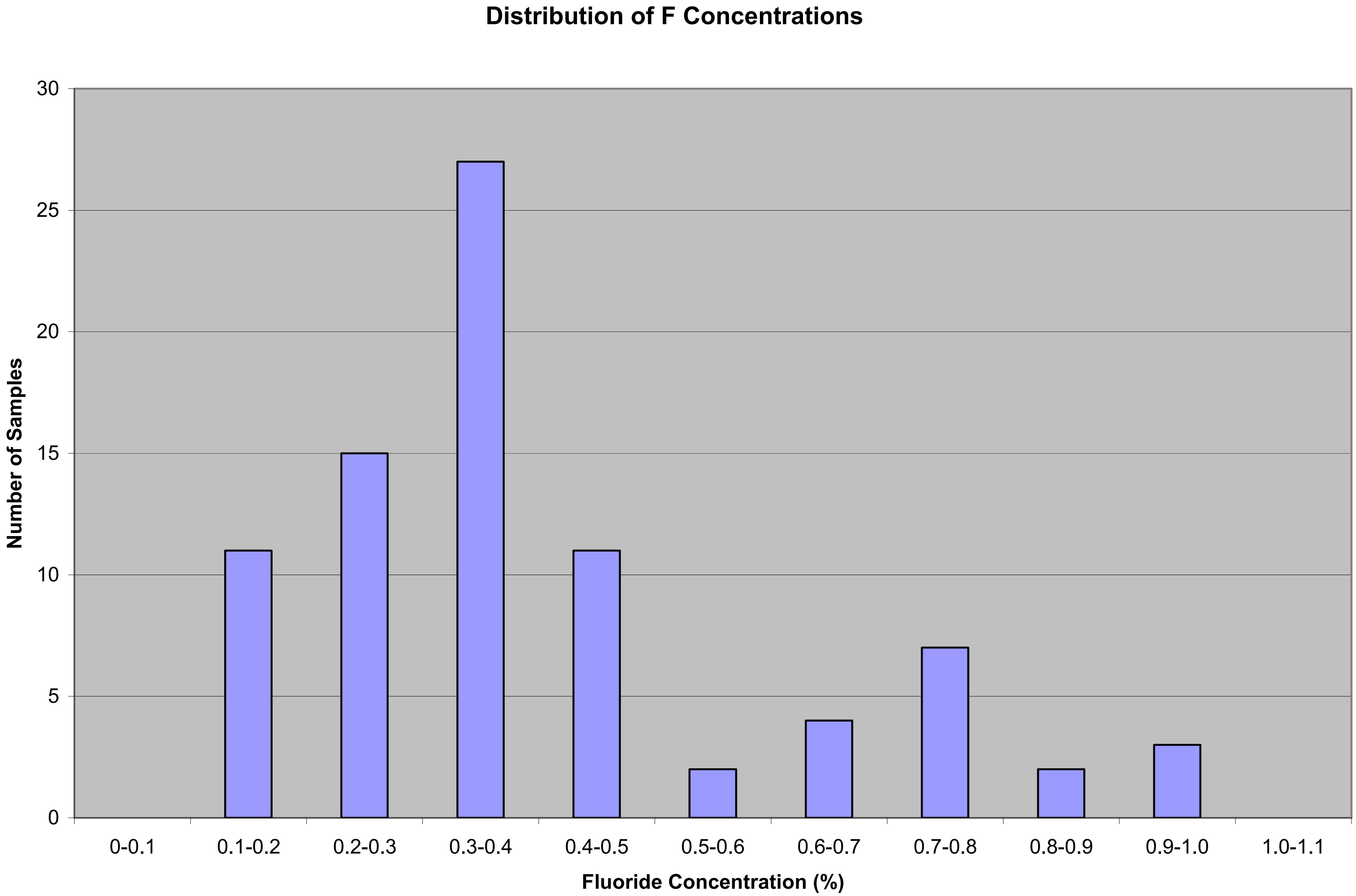
Fluoride Dating Results

The results of the fluoride analysis indicate that the bone fluorine concentrations range between 0.126 and 0.992% of the bone matrix by weight, with an average concentration of 0.383% ± 0.190% (n=65 individuals). The distribution of the fluoride concentration results can be seen in **Figure 7.2: Distribution of Fluoride Concentrations.** This figure demonstrates that the distribution of these values was bimodal. The primary, largest peak in the fluoride distribution occurs between 0.1 and 0.6% F. The majority of the sample falls within this range of values (n=56 individuals). However, a secondary, smaller peak appears between 0.6-0.9 % F (n=9 individuals).

A preliminary interpretation of this distribution suggests that the cemetery's period of use began with a small group of interments. Slightly later, although exactly how much later is unknown, the cemetery was used much more intensively. The second smaller peak in the fluoride distribution represents the earliest interments in the cemetery, while the larger peak represents the later and more intensive period of use.

However, the small size of the earlier period of use could represent a bias in the sampling methods employed. If there is a relationship between the spatial location of burials within the cemetery over time, spatial biases in sampling may lead to biases with the data's representation of the use of the cemetery over time. In this case, because a large number of burials in a central area of the cemetery were reburied, and are thus currently unprovenienced, few burials from this area could be sampled. This means that burials from the early period of use of the cemetery may be underrepresented if they were concentrated in this area. If this were the case, the later use phase of the cemetery may not actually have been more intensive than the early period of use. Spatial analysis of fluoride dating results may further illuminate this issue.

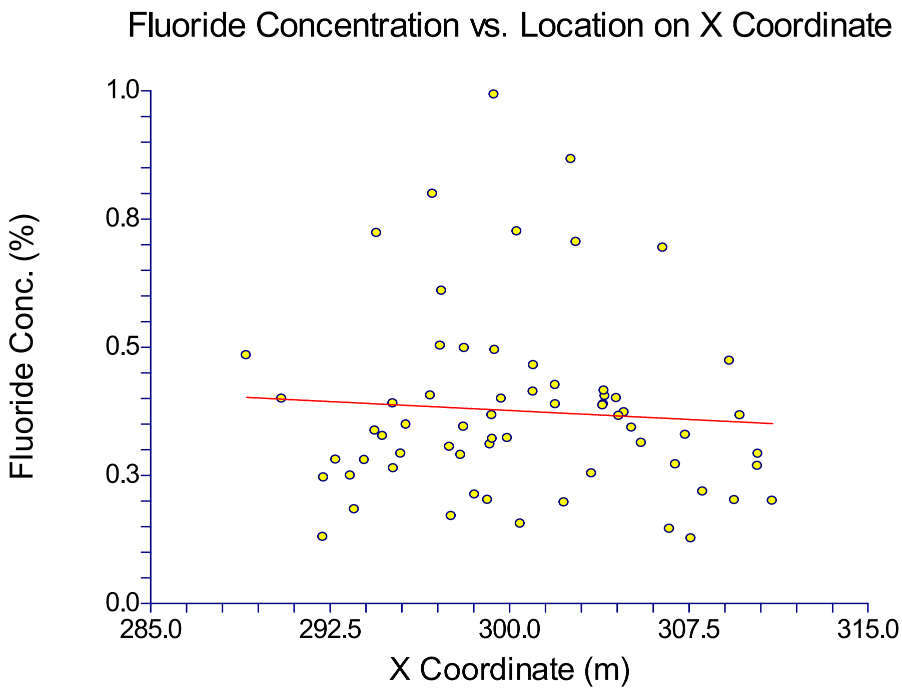
Figure 7.2: Distribution of Fluoride Concentrations



Spatial Patterns in Fluoride Concentration

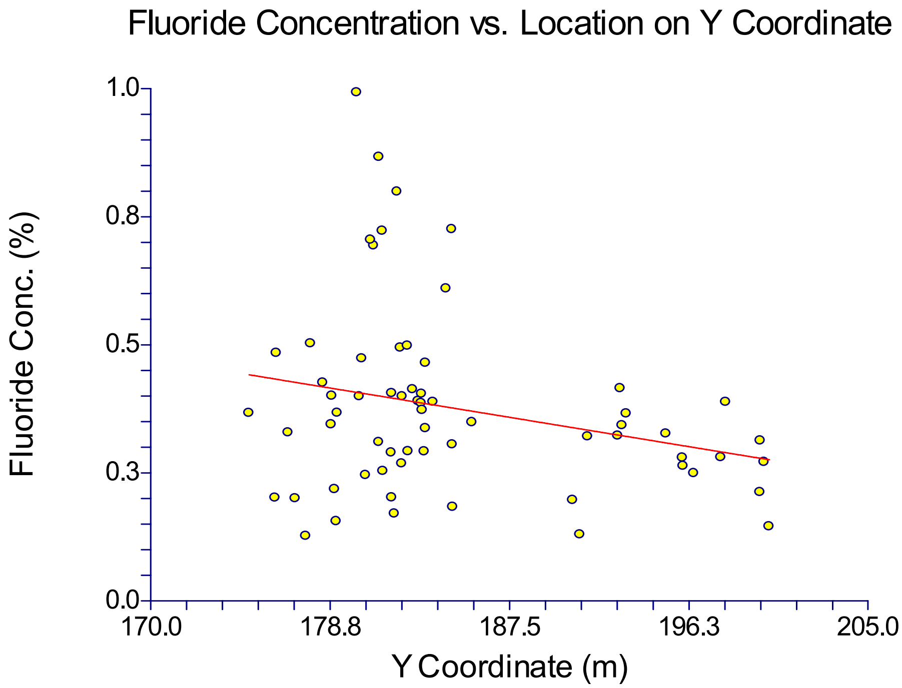
Fluoride concentrations were compared between individuals and their locations, based on the X and Y coordinates of the burial's location taken from the GIS map created for the İkiztepe cemetery (see **Chapter Three**). Initially, fluoride concentrations from bone samples were plotted spatially against the locations of the respective burials along the X (east-west) and Y (north-south) coordinates spatially within the cemetery. These relationships were tested for significant correlations by means of R^2 and the associated p-value of the correlation.

Figure 7.3: Fluoride Concentration (%) vs. Location on X Coordinate



R^2= 0.0050, y=301.37 -2.16x, p=0.5782

Figure 7.4: Fluoride Concentration (%) vs. Location on Y Coordinate

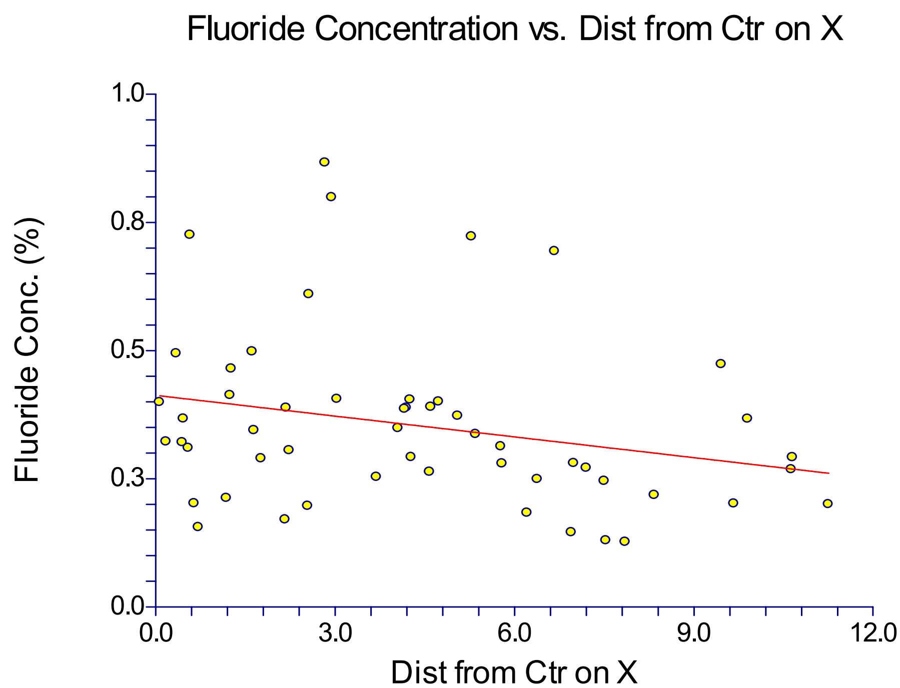


R^2= 0.0652, y=188.69 -9.97x, p= 0.0418

While the r^2 values associated with the linear regressions performed for both of these variables were quite low, the slope coefficient associated with the location on the y coordinate was determined to be significantly different from zero. This suggests there is a relationship between the time of the burial and its location on a north-south axis within the cemetery. The same, however, was not true for the location of the burial on X axis of the cemetery (i.e. east-west). Fluoride concentrations generally decrease from south to north, suggesting that the northern-most burials often tend, on average, to be younger than those to the south. Despite this, many of the youngest burials (i.e. those with the lowest fluoride concentrations) are still located in the southern portion of the cemetery. The individuals with the highest fluoride concentrations (i.e. the earliest burials) are concentrated in a circumscribed location in the central-southern portion of the cemetery. The gap in values evident on the Y axis (north-south) of the cemetery is the result of the portion of the cemetery that could not be sampled due to the lack of provenienced burials from this area. In general, these results suggest that the cemetery began in a central to southern location. As it expanded in the later period of use, it first remained within the original area of the cemetery, filling in areas within the southern portion of the area, and continued expanding to the north. Some secondary use of the southern part of the cemetery continued, however, during the latest period of the cemetery's use.

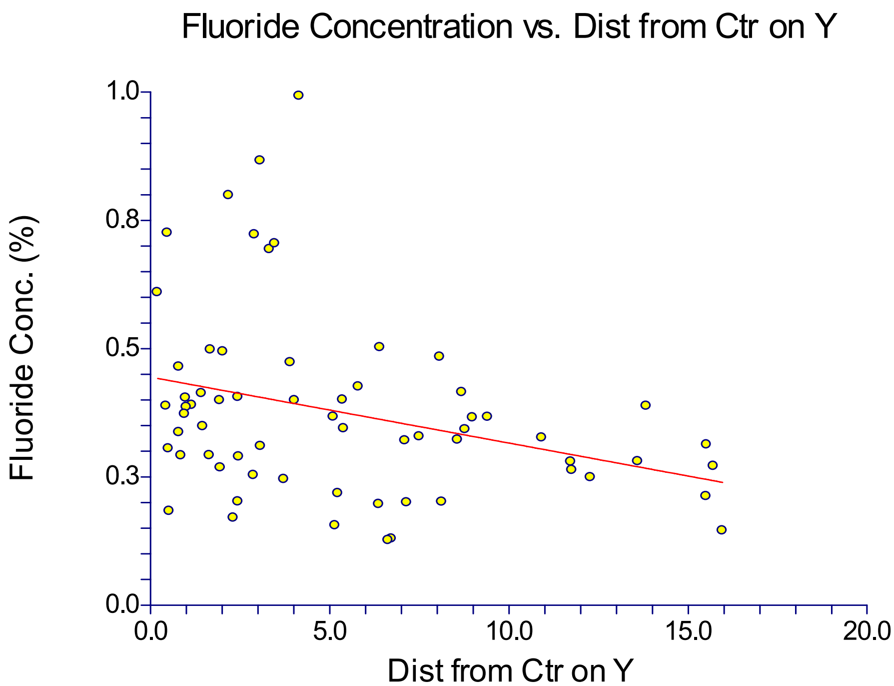
Correlations were also calculated based on the absolute distance of the burial from the centre of the cemetery in absolute terms along the X and Y coordinates.

Figure 7.5: Fluoride Concentrations (%) vs. Distance from the Cemetery Centre on the X Coordinate



R^2= 0.0643, y=0.41 -0.01x, p= 0.0670

Figure 7.6: Fluoride Concentrations (%) vs. Distance from the Cemetery Centre on the Y Coordinate

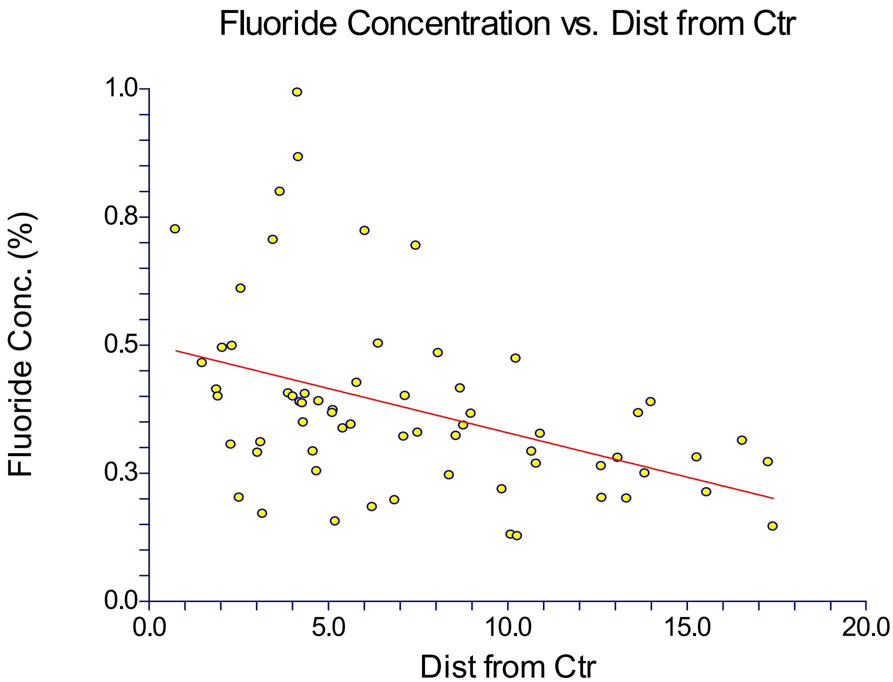


R^2= 0.1026, y=0.44- 0.01x, p= 0.0099

The r^2 values associated with these regressions are not particularly high, but the slope values for the regression lines were determined to be significantly different from zero, suggesting that a relationship between these variables exists. The slope value was significant only at a level of α=0.1 for the distance of the grave from the cemetery centre on the x axis; as observed with the raw x and y data above, the relationship between time and grave location was more significant on the cemetery's north-south axis. Thus, earlier burials were placed closer to the centre of the cemetery than later burials along both an east-west and north-south axis. Distance from the centre of the cemetery along both of these axes generally increased as time passed, although some of the latest burials were also located close to the centre of the cemetery. The group of burials with the highest fluoride concentrations (i.e. the earliest burials) is clustered in a specific location close to the centre along the Y axis (i.e. in a north-south direction), while along the X axis (i.e. in a west-east direction), this group is slightly more dispersed.

Finally, to confirm these results, absolute distances from the centre of the cemetery were calculated and plotted against fluoride concentration to look for a correlation between these two variables.

Figure 7.7: Fluoride Concentration (%) vs. Absolute Distance from Cemetery Centre



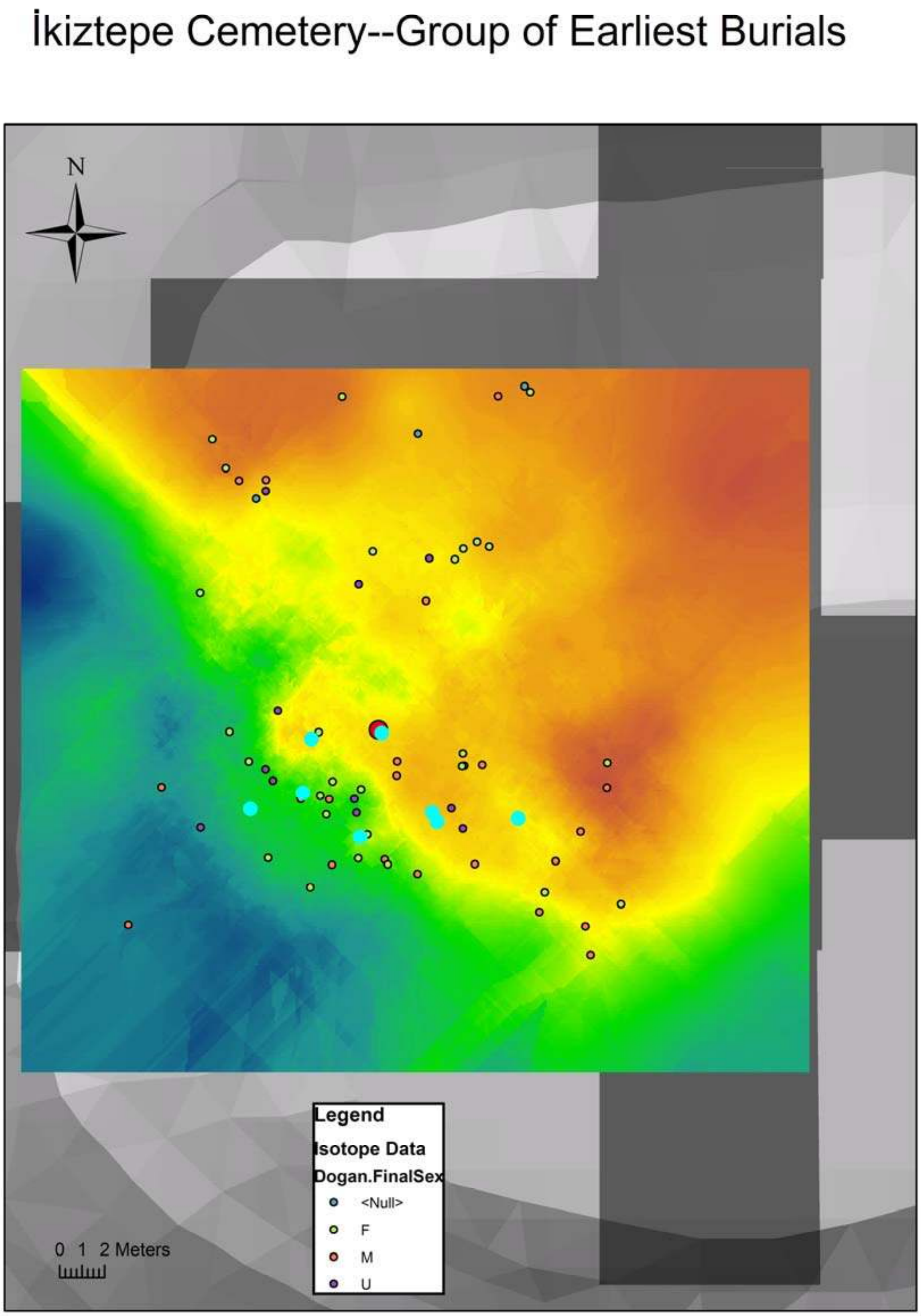
R^2=0.1800, y = 0.50 - 1.73x, p=0.0005

The r^2 value associated with this linear regression is higher than observed with the other spatial variables, but absolute distance from the cemetery centre still explains only a small portion of the variation in bone fluoride concentration. The slope value of the regression line, however, was determined to be significantly different from zero, suggesting that a significant negative relationship does exist between fluoride concentration and distance from the center of the cemetery. Individuals with the highest fluoride concentrations (i.e. the earliest burials) are generally clustered at distances quite close to the cemetery centre. This mirrors the results of similar tests above, which dealt with the distance of the burials from the cemetery centre solely along one axis.

While there is a great deal of variation in the values (see **Figure 7.7: Fluoride Concentration (%) vs. Absolute Distance from Cemetery Centre**), this result suggests that there is a distinct relationship between distance from the centre of the cemetery and the age of the burial. Higher fluoride values (i.e. older burials) are found closer to the centre of the cemetery, while lower fluoride values (i.e. younger burials) are found further from the centre of the cemetery. This suggests that burial within the cemetery began within a circumscribed area, and then expanded over time as additional burials were interred. The locations of the earliest group of burials within the cemetery (i.e. the secondary peak with fluoride concentrations between 0.6 and 1.0%) can be seen in **Map 7.1: İkiztepe Cemetery—Earliest Burials**. Interestingly, the location of this cluster of the earliest burials in the cemetery corresponds well with the location of the cluster of burials with the highest numbers of grave goods (see **Map 3.9: İkiztepe Cemetery—9+ Grave Goods)**.

When this central location, where both the earliest cluster of burials and the individuals with the greatest numbers of grave goods are located, is mapped spatially, it is concentrated in the central southern portion of the cemetery (see **Map 7.1: İkiztepe Cemetery—Earliest Burials** and **Map 3.9: İkiztepe Cemetery—Locations of Individuals with 9+ Grave Goods).** This can then be compared to the spatial distribution of the provenienced skeletal material that was available for examination, in order to determine the degree to which the areas for which no provenienced material was available may be causing bias in the examination of the temporal development of the cemetery (see **Map 4.1: İkiztepe Cemetery—Skeletal Material Available for Examination**). Burials with no provenienced material for analysis are concentrated in an east-west swath through the center of the cemetery; burials in the southwestern portion of the cemetery are also relatively poorly represented. The gap evident near the centre of the cemetery suggested that it was possible that lack of material available from this area had resulted in the earliest burials being underrepresented in the group of samples analyzed. When the three maps are compared, it is clear that the majority of the central cluster of burials (where both the earliest and richest graves are concentrated) is in fact represented for analysis. The lack of burials in the central part of the cemetery may suggest that the northernmost portion of this cluster is not represented. However, it is likely that the general reconstruction of two main periods of use for the cemetery, with a less intensive early period and a more intensive later period, is correct.

Map 7.1: İkiztepe Cemetery—Earliest Burials



In order to examine the possibility that sex-related differences in spatial placement were related to the expansion of the cemetery over time, fluoride concentration was plotted against absolute distance from the cemetery centre, and grouped by sex (both more and less certain sex estimates). This was used to test the possibility that while the earliest males may have been placed at the centre of the cemetery and females more peripherally, as the cemetery expanded, later males may have then been placed closer to the centre and overlapping with earlier females, obscuring the ability to observe sex-related differences in central/peripheral placement of burials.

Figure 7.8: Fluoride Concentration vs. Distance from Cemetery Center (Grouped by More Certain Sex Estimates)

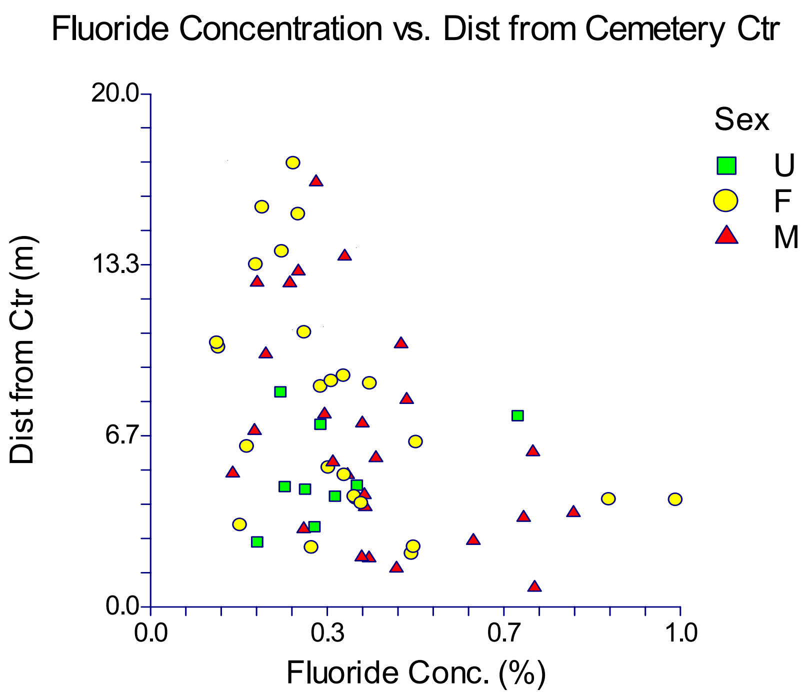
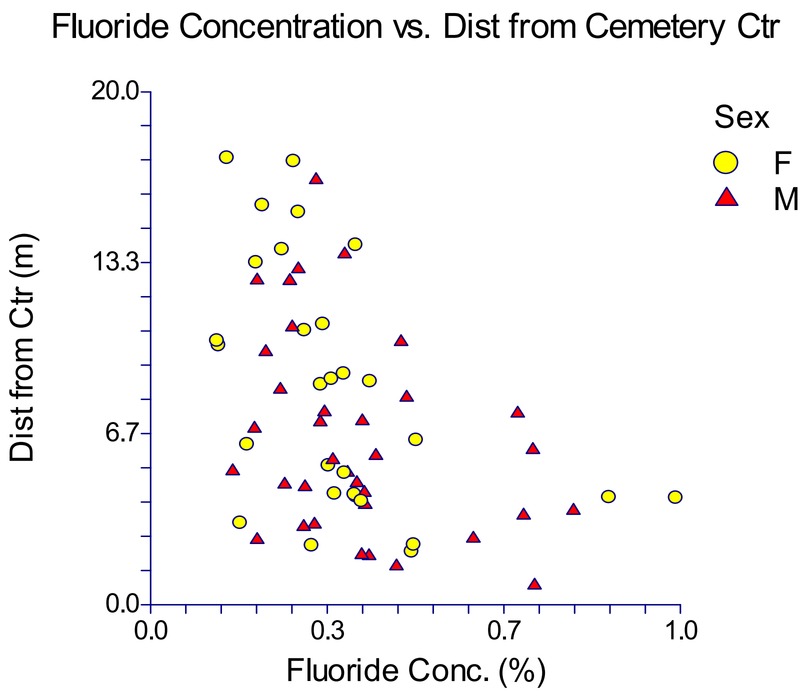


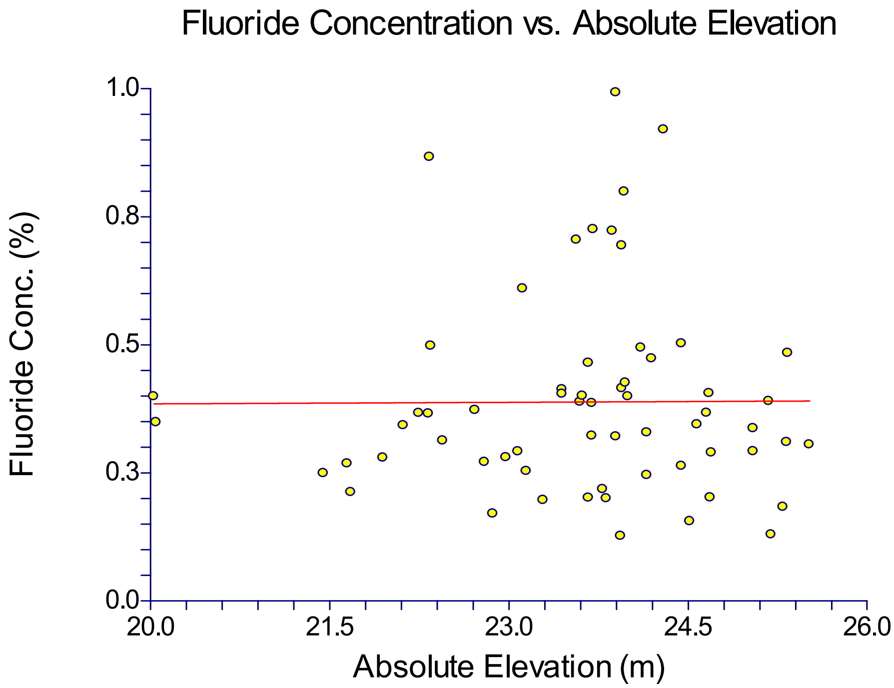
Figure 7.9: Fluoride Concentration vs. Distance from Cemetery Center (Grouped By Less Certain Sex Estimates)



Neither of these graphs suggest any clear pattern that would indicate that there was any relationship between time and the locations of males and females within the cemetery. In fact, these graphs lend support to the results obtained in **Chapter Three**, which indicated that while males may be buried, on average, slightly closer to the cemetery centre than females, that this difference between the sexes is not statistically significant.

Finally, fluoride concentrations were plotted against the absolute elevations of the burials in order to test for correlations between these two variables. The results of this test are important, because it provides evidence to address the issue of whether differences in water drainage at different elevations have had a confounding effect on the results of the fluoride dating, leading to problems with the reconstructions of the temporal development of the cemetery.

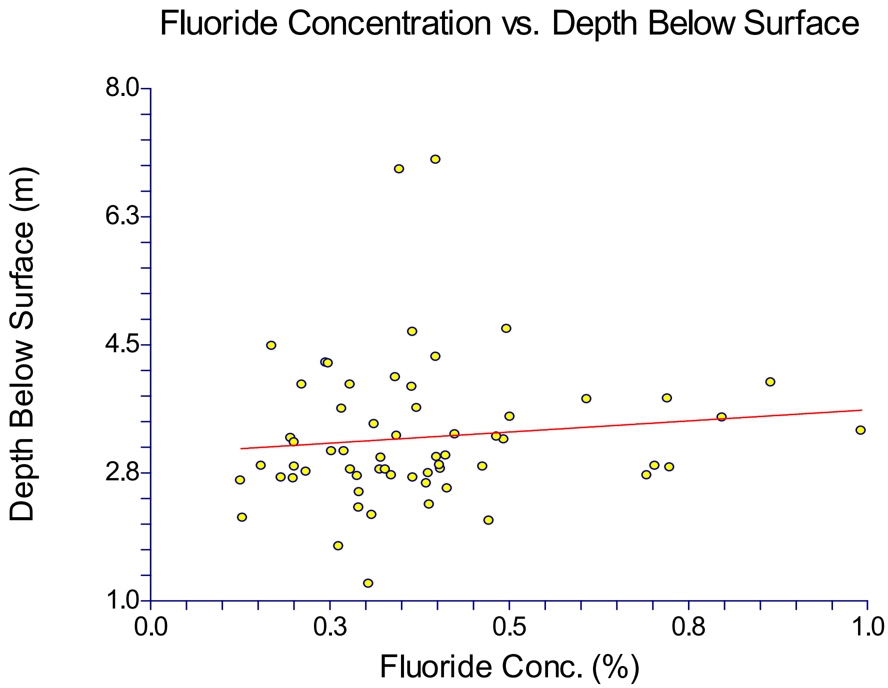
Figure 7.10: Fluoride Concentration (%) vs. Absolute Elevation (m)



R^2= 0.0000, y=0.36 + 0.001x, p= 0.9618

There appears to be no clear relationship between these two variables, as both the r^2 value and the slope coefficient are extremely close to zero. The earliest burials are concentrated at a particular elevation, as expected based on the known spatial clustering of these graves. Beyond this point, however, there is no indication that burials located at the bottom of the slope demonstrate any difference in fluoride concentrations compared to those located upslope. Thus, issues of water drainage do not appear to be affecting the results of the fluoride dating. Furthermore, there seems to be no temporal aspect to the placement of burials upslope or downslope from the location of the original group of burials.

Figure 7.11: Fluoride Concentration (%) vs. Depth Below Reconstructed Surface (m)



R^2=0.0124, y= 3.00 + 0.61x, p= 0.3927

This graph examines the possibility that there is a relationship between the age of a burial and the depth of this burial beneath the reconstructed slope surface on which the cemetery was located. The graph suggests that there is no evidence for an increase in depth with increasing fluoride concentration, as the slope coefficient of the regression line was not determined to be statistically significant. Thus, earlier burials show no evidence of occurring at greater depths than later ones, as might be expected. The graph suggests the possibility of a slight increase in the variability of the depths at which burials were placed over time; the greatest degree of variability in depth, however, is observed during the middle period of the cemetery's use.

Fluoride Concentrations and Grave Good Frequencies

Using the distributions of the fluoride concentrations in the bone samples as a rough indicator of the chronological development of the cemetery, there does appear to be a chronological pattern in the numbers of grave goods appearing in the graves within the cemetery. Generally, the earliest group of burials (the 2nd fluoride peak in the fluoride distributions) had medium numbers of grave goods. Individuals with between 4 and 7 grave goods are most common in this earliest period (see **Figure 7.12: Distribution of F Concentrations for Individuals with 4-7 Grave Goods)**, but individuals with between 1 and 3 grave goods were also common (see **Figure 7.13: Distribution of F Concentrations for Individuals with 1-3 Grave Goods**. In this early group, individuals with no grave goods, or with greater than 8 grave goods were rare (see **Figure 7.14: Distribution of F Concentrations for Individuals with No Grave Goods** and **Figure 7.15: Distribution of F Concentrations for Individuals with 8+ Grave Goods)**.

In contrast to the earliest period of the cemetery's use, during the more intensive later phase of use of the cemetery, differentiation in numbers of grave goods becomes more pronounced. Individuals with greater than 8 grave goods become more common, as do individuals with no grave goods (see **Figure 7.14: Distribution of F Concentrations for Individuals with No Grave Goods** and **Figure 7.15: Distribution of F Concentrations for Individuals with 8+ Grave Goods** and **Figure 7.16: F Concentration vs. Total Number of Grave Goods)**. However, internal patterns are also visible within these groups. Individuals with greater than 8 grave goods are concentrated within the middle period of the cemeteries use (i.e. clustering between F concentrations of 0.3-0.5 %. The number of grave goods appears to increase gradually between the beginning of the cemetery's use, and then fall quickly toward the end of the cemetery period. In contrast, the number of individuals interred with no grave goods appears to increase in the later period of the cemeteries use. In fact, the majority of the burials in the latest period of use are evenly distributed between those with no grave goods, or with 1-3 grave goods. However, individuals with greater than 3 grave goods do not occur.

Figure 7.12: Distribution of F Concentrations for Individuals with 4-7 Grave Goods

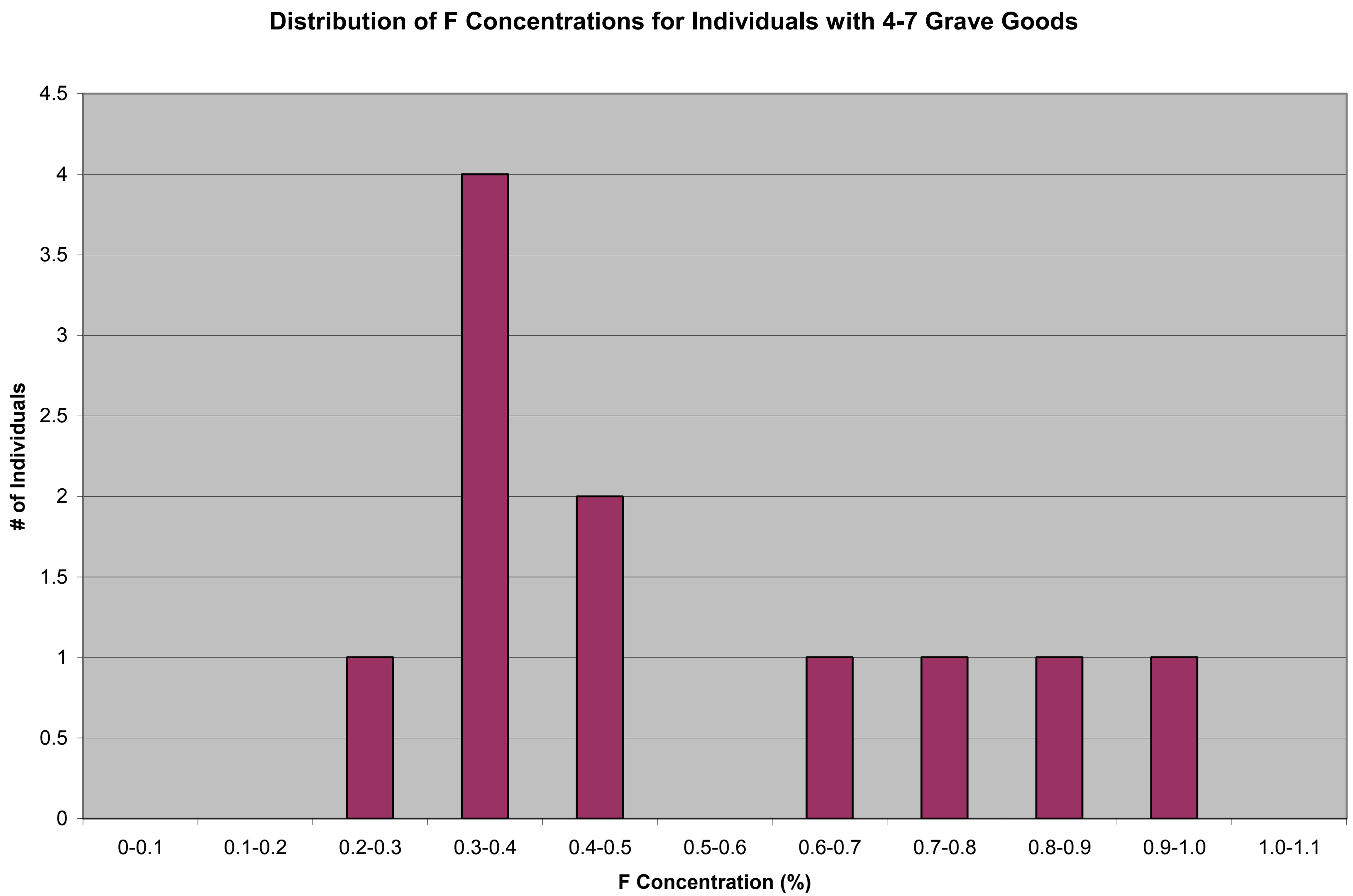


Figure 7.13: Distribution of F Concentrations for Individuals with 1-3 Grave Goods

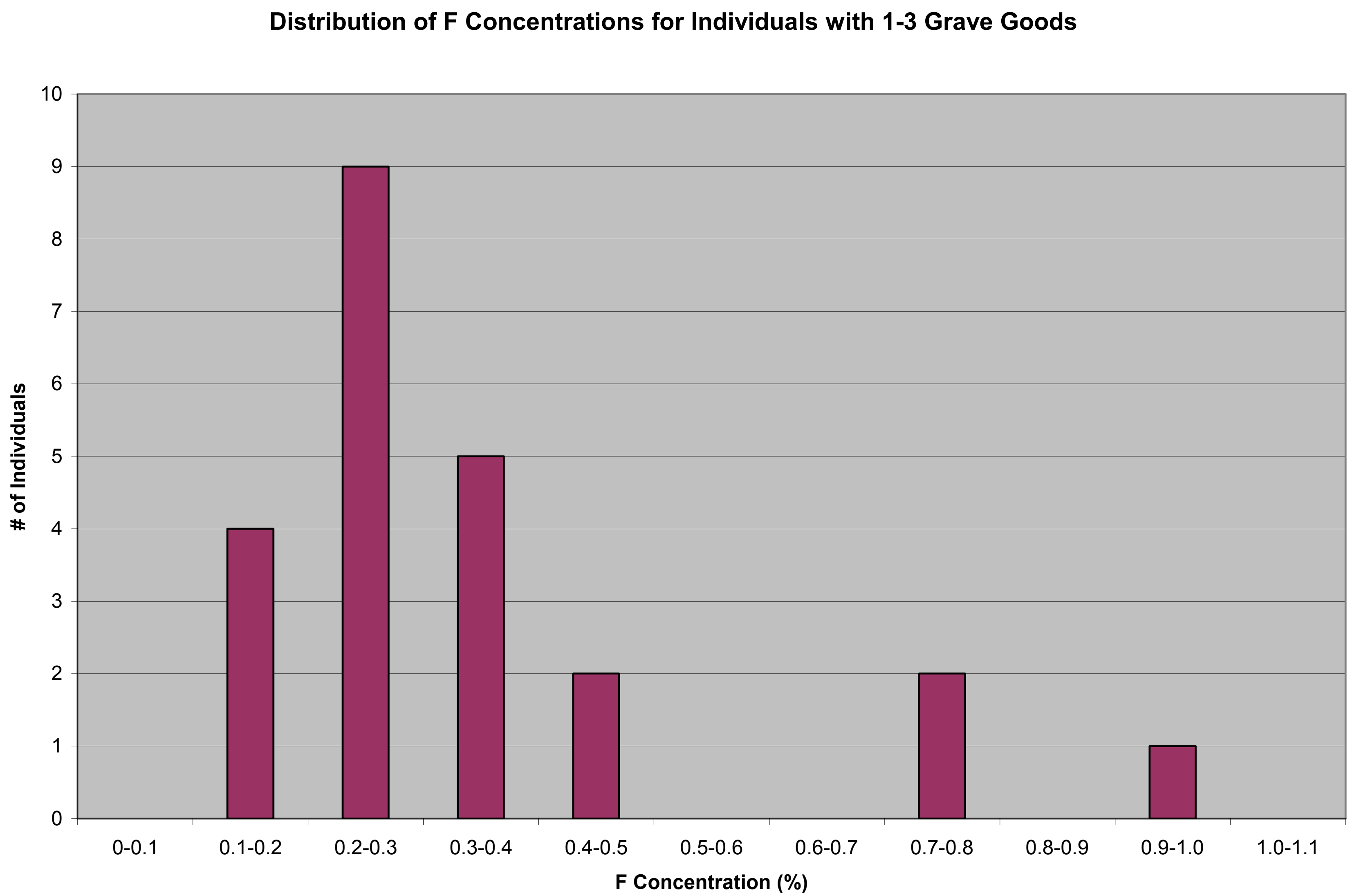


Figure 7.14: Distribution of F Concentrations for Individuals with No Grave Goods

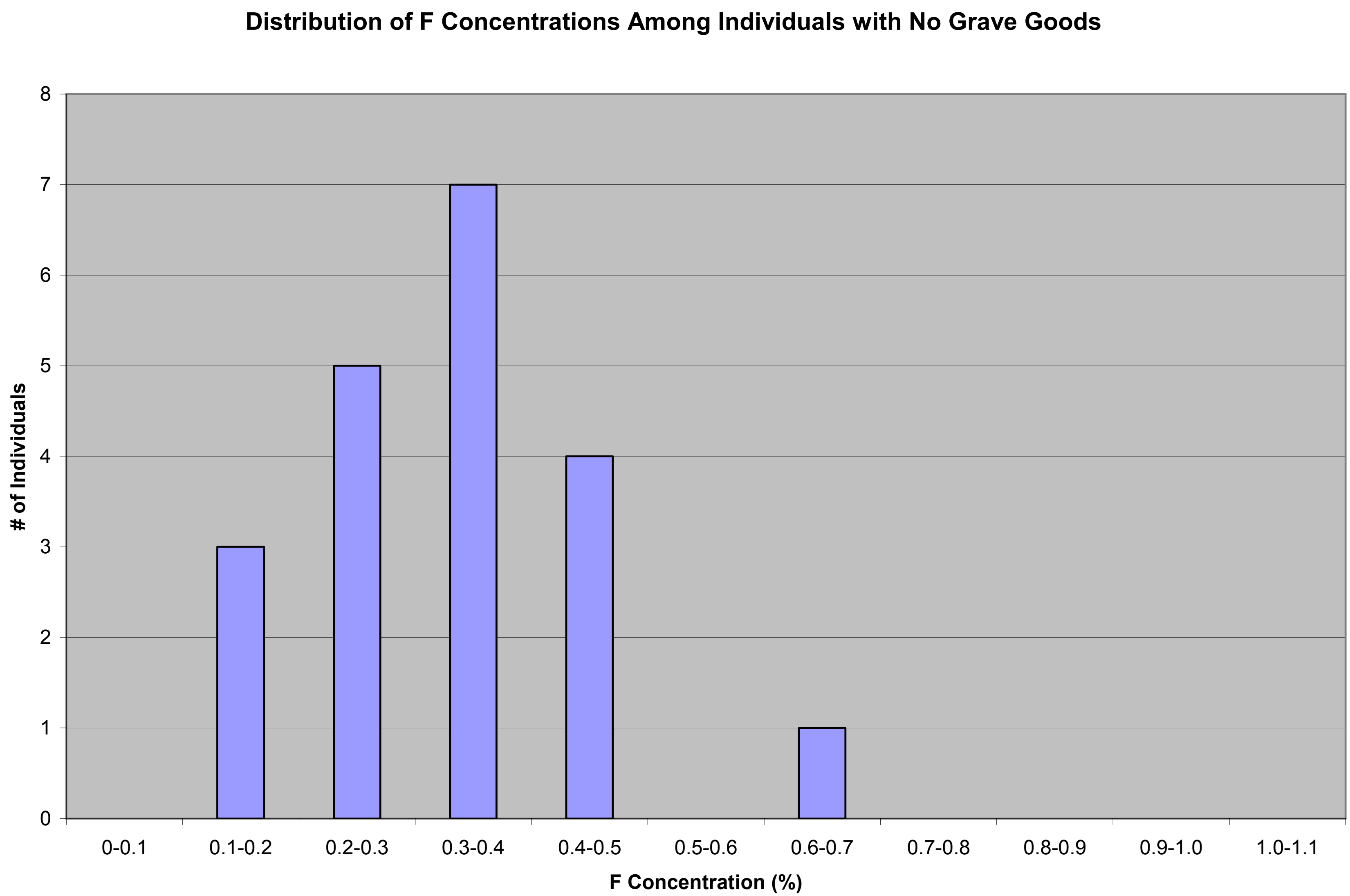
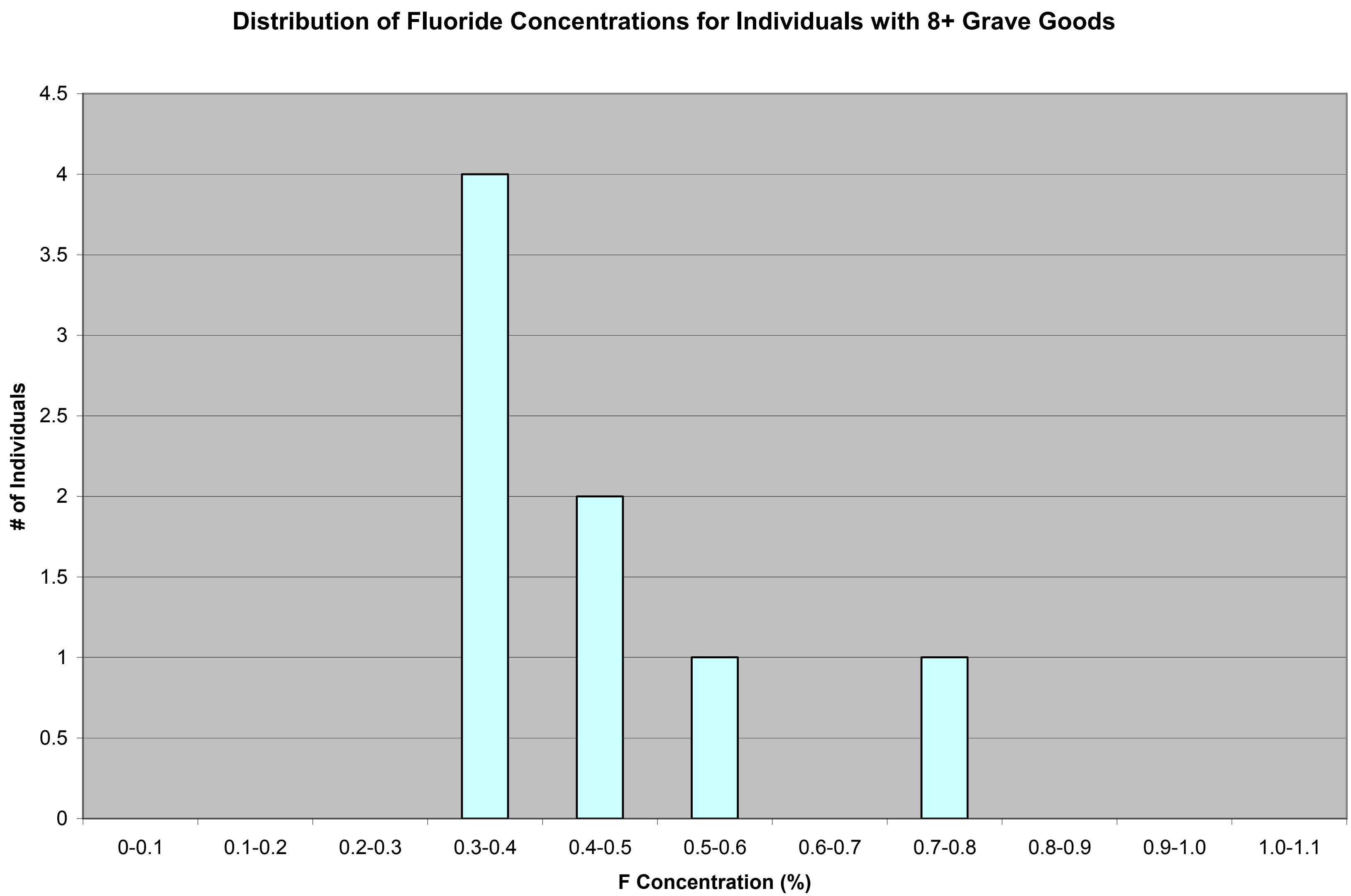


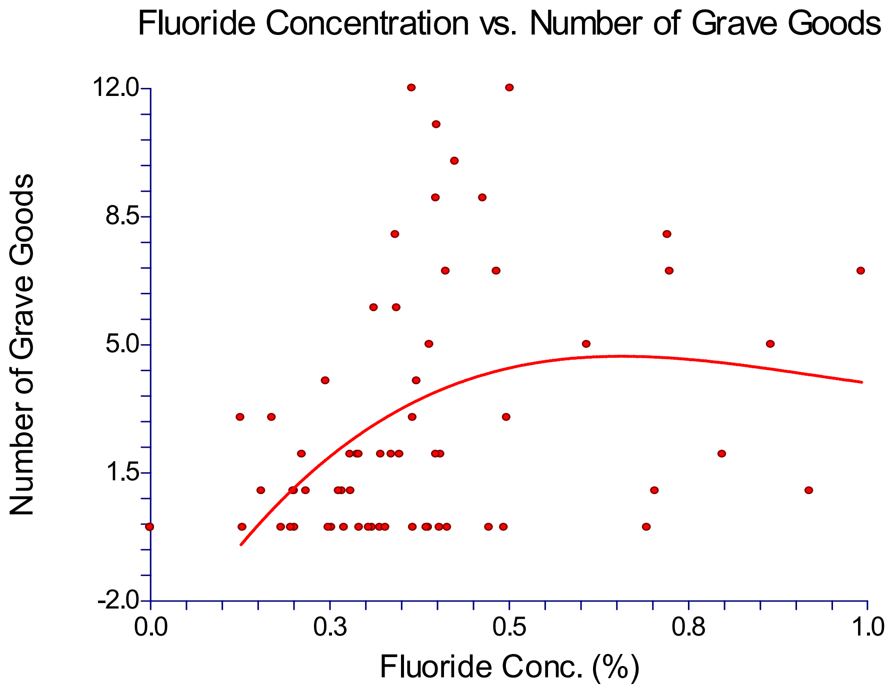
Figure 7.15: Distribution of F Concentrations for Individuals with 8+ Grave Goods



It is possible that this pattern may be the result of sampling bias. Because of the composition of the current skeletal sample, individuals buried in an east-west band through the central part of the cemetery were poorly represented, while individuals buried in more peripheral regions were more frequently available for analysis. This could potentially obscure a spatial pattern in the temporal inclusion of burial goods in the graves. Furthermore, a small number of the burials in the sample analyzed were selected specifically because of their "distinguished" status (Bilgi 2005), predominantly due to their high numbers of grave goods. Thus, individuals with high numbers of grave goods are preferentially included in the analyzed sample; the representation of individuals with no grave goods may not be as complete. As discussed above, individuals with the earliest burials and those with the highest numbers of grave goods were concentrated in an area to the south of the central band for which no skeletal material was available. Thus, it does not seem likely that early burials or those with high numbers of grave goods are significantly under-represented in the sample due to the spatial biases in the available material. The bias away from individuals with lower numbers of grave goods, however, may be more significant. There is, however, no specific reason at the present time to believe that these sampling biases would have a consistent effect on patterns visible in the relationship between the temporal development of the cemetery (using F concentrations) and the numbers of grave goods included.

Fluoride concentration was plotted against the number of grave goods in the grave in order to test for a significant correlation between the variables.

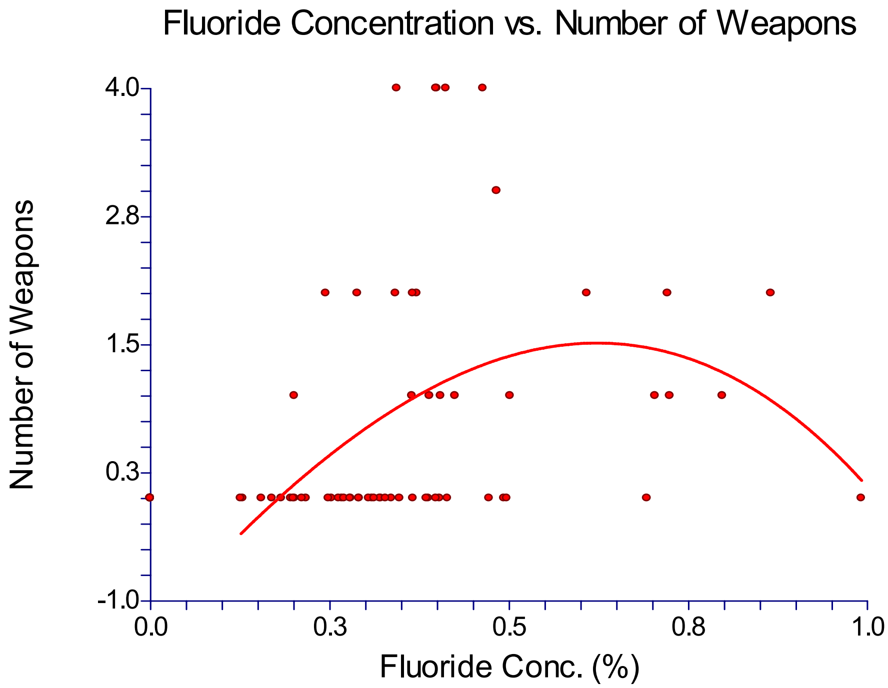
Figure 7.16: Fluoride Concentration (%) vs. Total Number of Grave Goods



r^2=0.149073

A linear regression performed on this data suggests that there is a general pattern where the number of grave goods decreases as bone fluoride concentration decreases (i.e. the average number of grave goods decreases over time) (r^2=0.0943, y=0.82 + 5.49x, p=0.0152). Thus, earlier burials have a higher average number of grave goods compared to those toward the end of the cemetery's use, and the slope of the regression line was determined to be significantly different from zero, suggesting that this relationship is significant. However, the r^2 value obtained in this regression is quite low, and as previously discussed, the individuals with the highest numbers of grave goods are concentrated in the middle period of the cemetery's use. As depicted in the figure above, a cubic relationship better describes the variation in the number of grave goods over time, and provides a higher r^2 value.

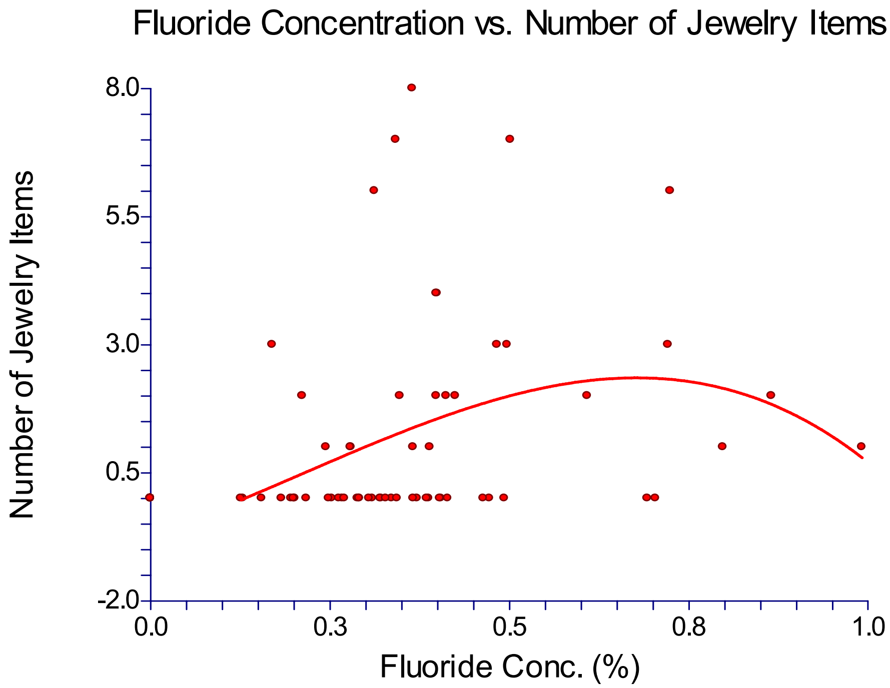
Figure 7.17: Fluoride Concentration (%) vs. Number of Weapons



R^2=0.151900

Similar to the pattern observed in the overall number of grave goods associated with the individuals, a linear regression suggests an overall decrease in the number of weapons associated with graves over time (r^2= 0.0664, y=0.12 + 1.76x, p= 0.0450). The slope coefficient associated with this regression line was determined to be significantly different from zero, suggesting that this relationship is significant. However, the r^2 value associated with this linear model is quite low; as observed with overall numbers of grave goods, a cubic model better describes the occurrence of weaponry over time and provides a better r^2 value, as depicted in the figure above. As in the pattern observed with total numbers of grave goods, the earliest values have medium numbers of weapons, while the individuals with the highest numbers of weapons are concentrated in the middle period of use of the cemetery. In general, numbers of weapons decrease significantly in the final period of the cemetery's use.

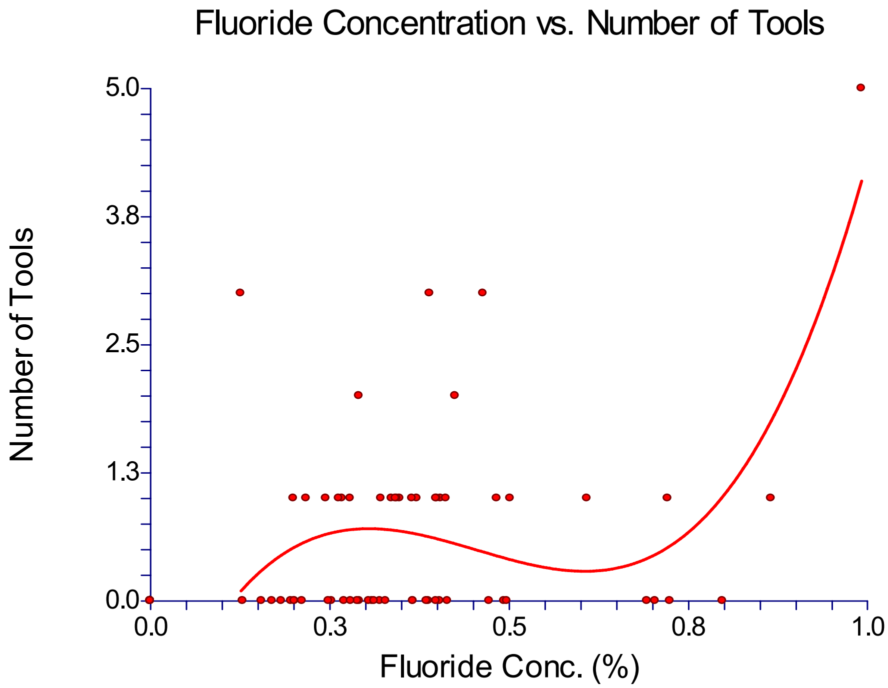
Figure 7.18: Fluoride Concentration (%) vs. Number of Jewelry Items



R^2=0.096846

As observed with previous grave good types, a linear regression suggests that there is also a slight decrease in the number of jewelry items occurring in the cemetery over time (r^2= 0.0583, y=0.21 + 2.70x, p= 0.0608). The slope coefficient associated with this regression line is significantly different from zero at a level of α=0.1, suggesting that this relationship is not as strong as observed among total numbers of grave goods and weaponry. Furthermore, the r^2 value associated with the linear model is quite low; once again, the data is better described by a cubic model, as demonstrated in the diagram above. The r^2 value associated with the cubic model, however, remains lower than observed with other grave good categories. Similar to the patterns observed with total grave goods and weaponry, the individuals with the highest numbers of jewelry items are concentrated in the middle period of use of the cemetery. Individuals buried with no jewelry items are concentrated in the middle and late periods of the cemetery's use; the earliest individuals have low to medium numbers of jewelry items.

Figure 7.19: Fluoride Concentration (%) vs. Number of Tools

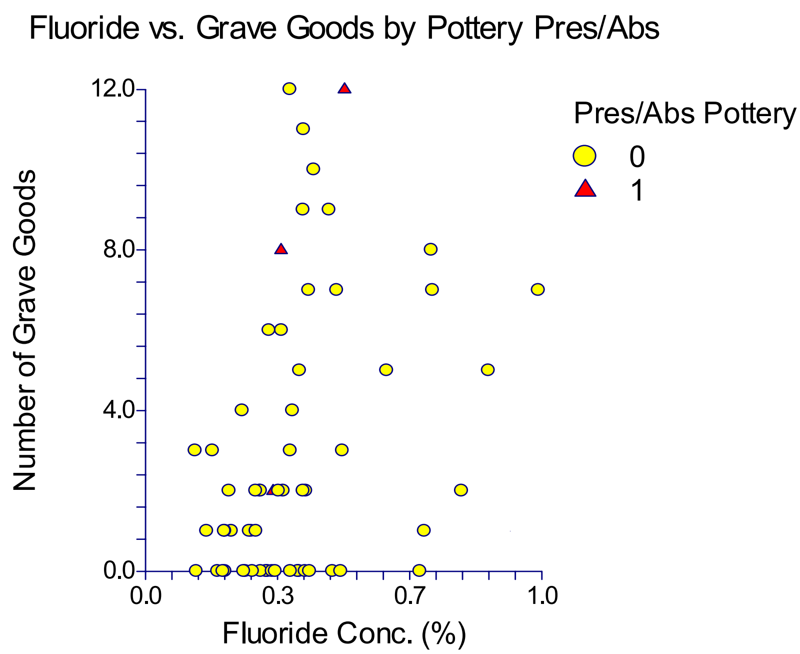


R^2=0.264547

Finally, fluoride concentration was also plotted against the number of tools found in the graves in in the İkiztepe cemetery. A linear regression on this data determined that, as with other grave good types, there was a decrease in the number of tools associated with graves over time (r^2=0.1142, y= 0.10 + 1.45x, p=0.0077). The slope coefficient associated with this regression line was determined to be significantly different from zero, suggesting a significant relationship between these variables. However, the r^2 value associated with the linear model is low; the data is better described by a cubic model, as depicted in the figure above, which provides a higher r^2 value. However, the slope of the linear model and the shape of the cubic models are both heavily affected by the number of tools found in the earliest burial analyzed, which had the highest number of tools in any of the burials for which fluoride concentration was measured. Apart from this individual, the highest numbers of tools were once again concentrated in burials from the middle period of the cemetery's use. Individuals with no tools were predominantly concentrated in the middle to late periods of the cemetery's use, although a few individuals with no tools were also found in earlier burials.

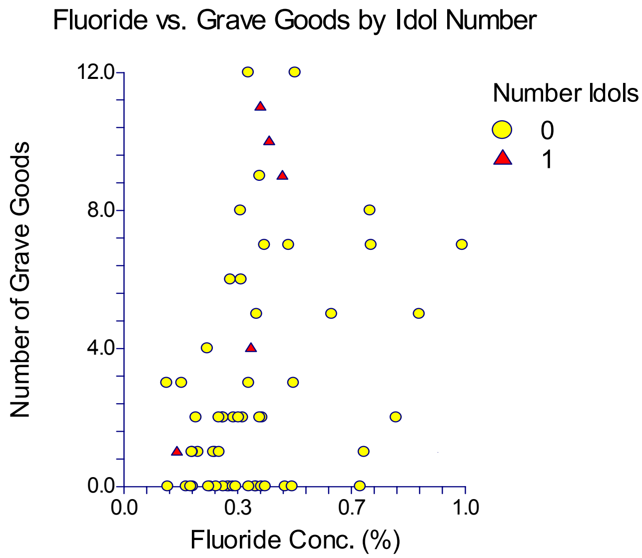
Fluoride concentration was plotted against the total number of grave goods and grouped by the presence/absence of various other less common types of grave goods to examine their occurrence in relation to time.

Figure 7.20: Fluoride Concentration (%) vs. Number of Grave Goods, Grouped by Presence or Absence of Pottery



This graph suggests that pottery tends to occur in graves with high numbers of grave goods, and also occurs in the middle period of use of the cemetery, the period to which graves with high numbers of grave goods are confined. However, only two graves which included pottery were analyzed for fluoride, which means that these patterns cannot necessarily be extrapolated to the remainder of the cemetery.

Figure 7.21: Fluoride Concentration (%) vs. Number of Grave Goods, Grouped by the Number of Idols



This graph suggests that idols often occur in graves with high numbers of grave goods (in 3 of 5 cases), as observed with the occurrence of pottery. These graves are concentrated in the middle period of use of the cemetery, to which graves with high numbers of grave goods were confined. Two additional cases occur in individuals with fewer grave goods; these cases are confined to the later period of use of the cemetery. This suggests that the occurrence of idols is limited to the middle and later periods of the cemetery, with no examples occurring in the earliest burials. When they first appear, idols occur in the richest graves, but later begin to occur in burials with few grave goods. Once again, these patterns are based on only five examples of graves with idols that were included in the fluoride analyses. A very small number of graves were found that contained two examples of these idols; however, none of these individuals underwent fluoride analysis.

There were no examples included for fluoride analysis that included figurines as a grave good.

Relationship between Craniometric Data and Fluoride Concentrations

Fluoride concentration data was compared to the results of phenotypic analysis based on craniometric information in order to examine the relationship between phenotypic similarity and development over time. The results of principal coordinates analysis grouped by the results of the fluoride analysis into early, middle and late periods are presented below, where early burials are represented by red crosses, middle burials are represented by teal triangles and late burials are represented by yellow triangles.

Figure 7.22: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 2, By Time Period
(red cross=early period burials, teal triangles=middle period burials, yellow triangles=late period burials)

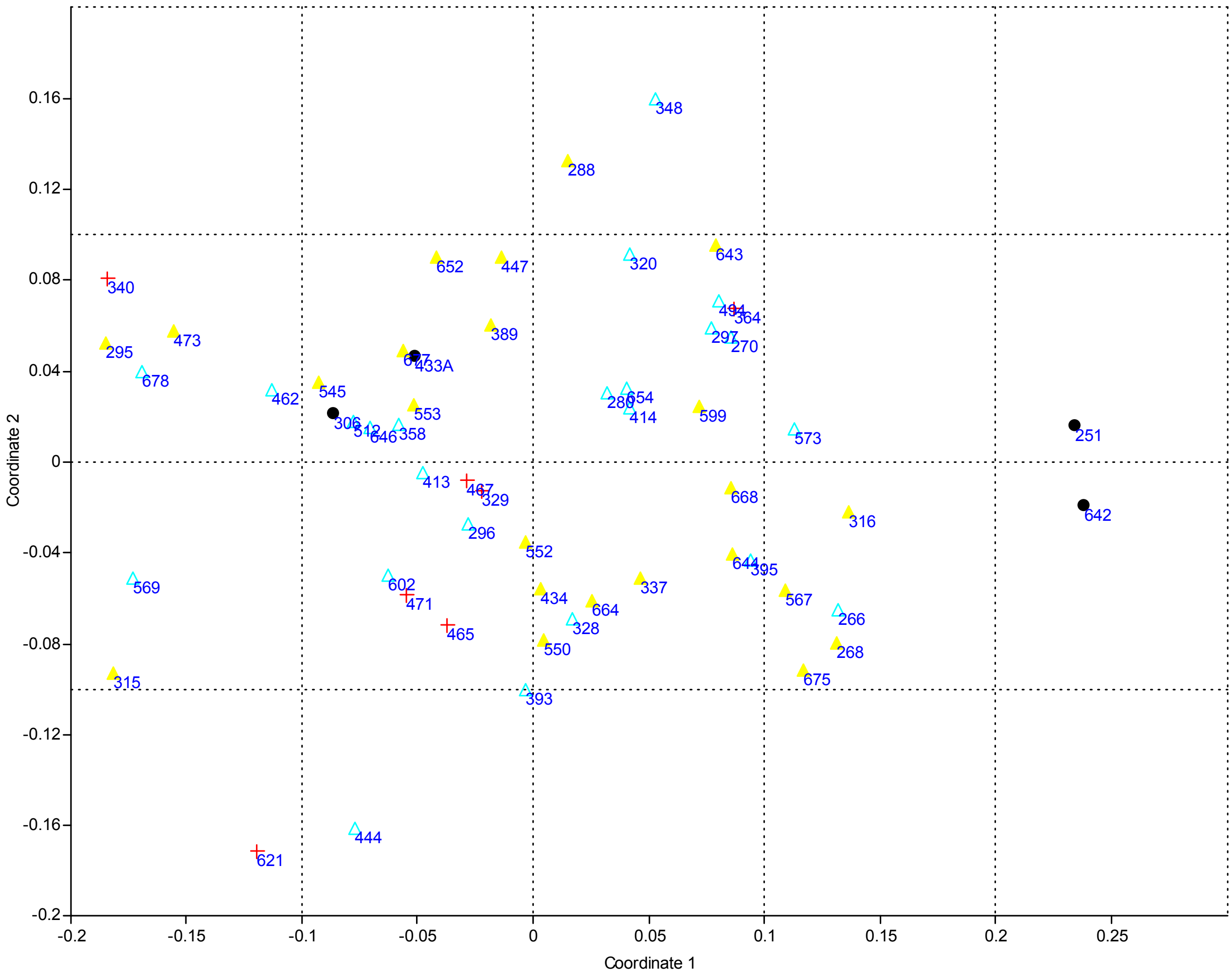


Figure 7.23: Principal Coordinates Analysis—Coordinate 1 vs. Coordinate 3, By Time Period
(red cross=early period burials, teal triangles=middle period burials, yellow triangles=late period burials)

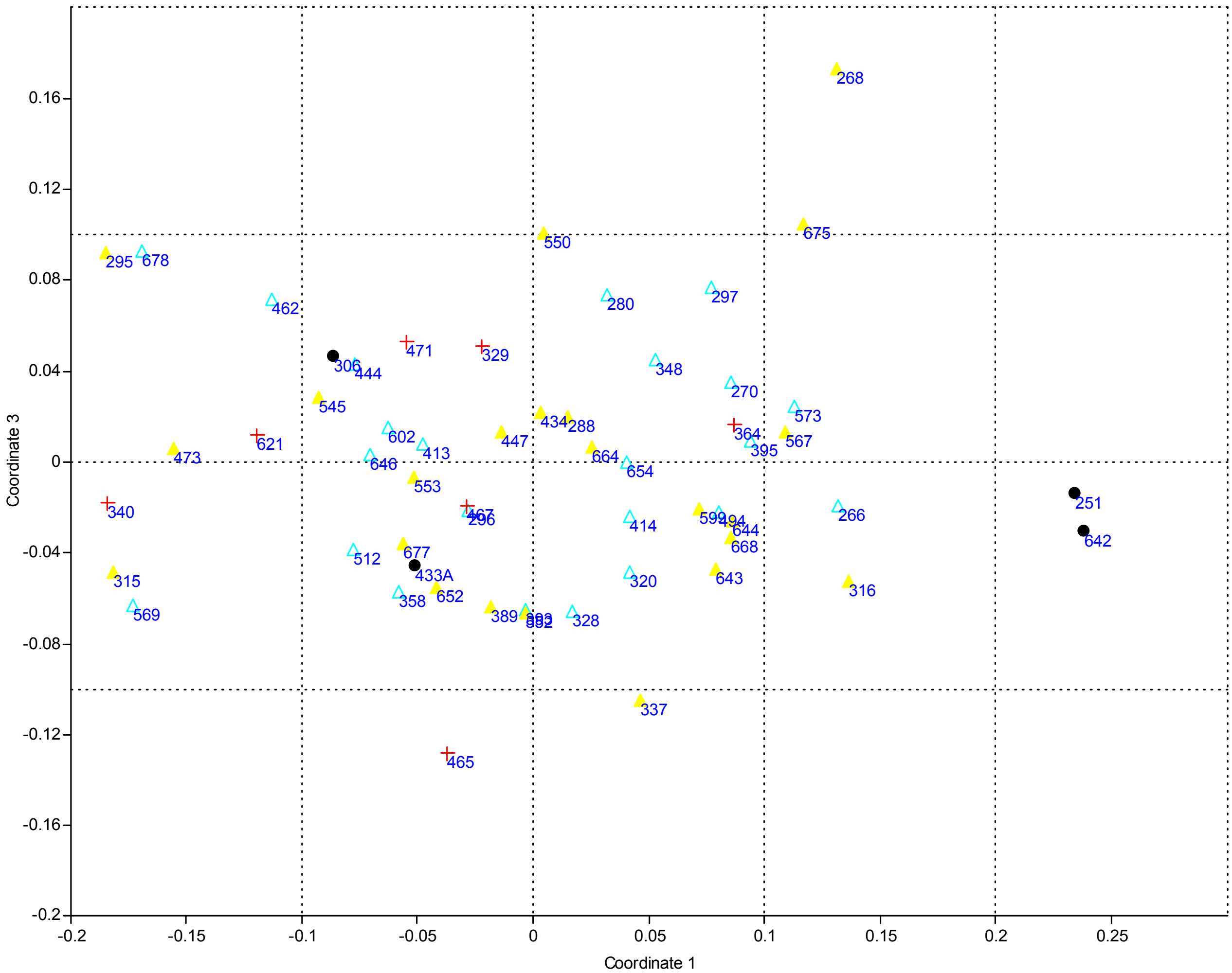
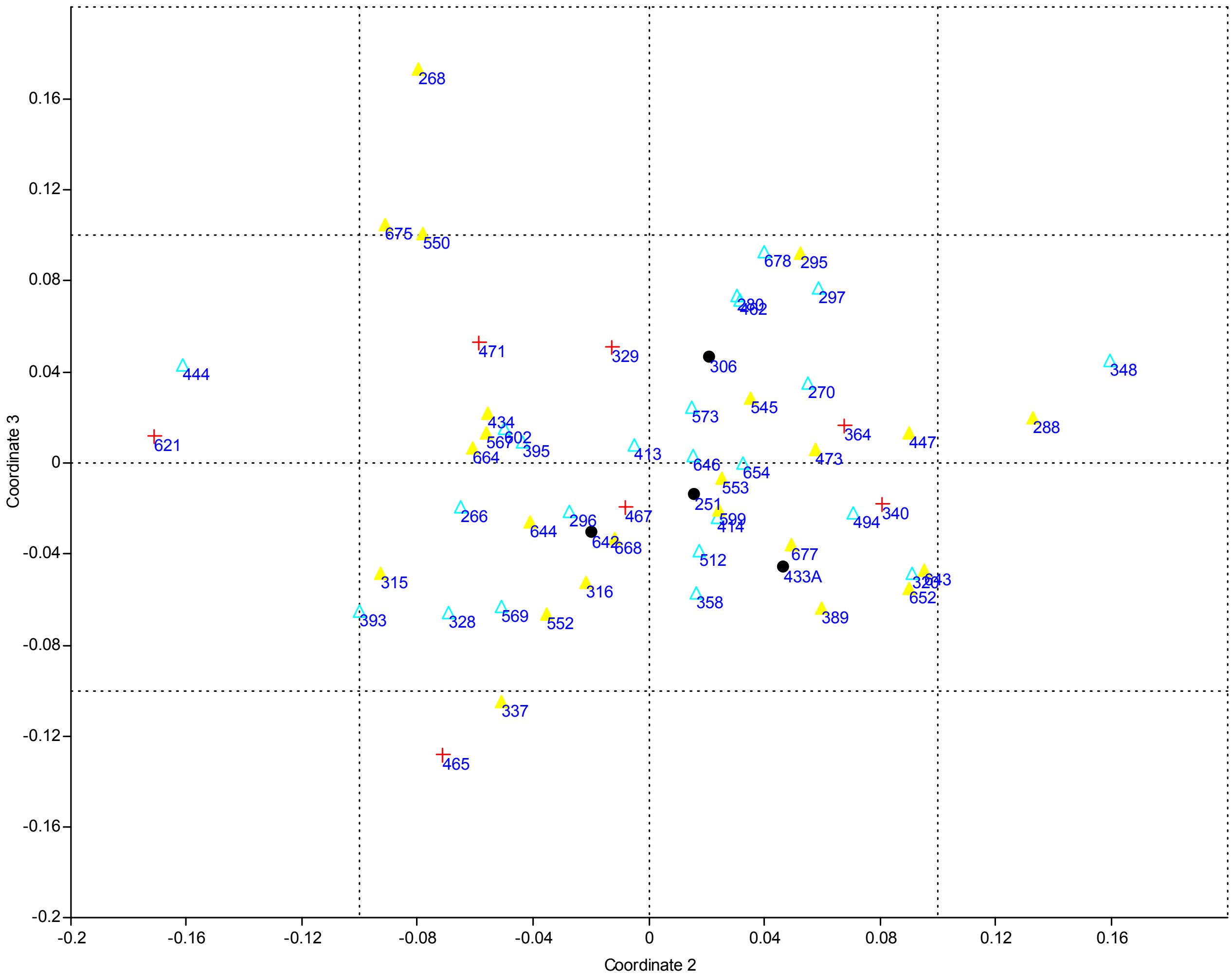


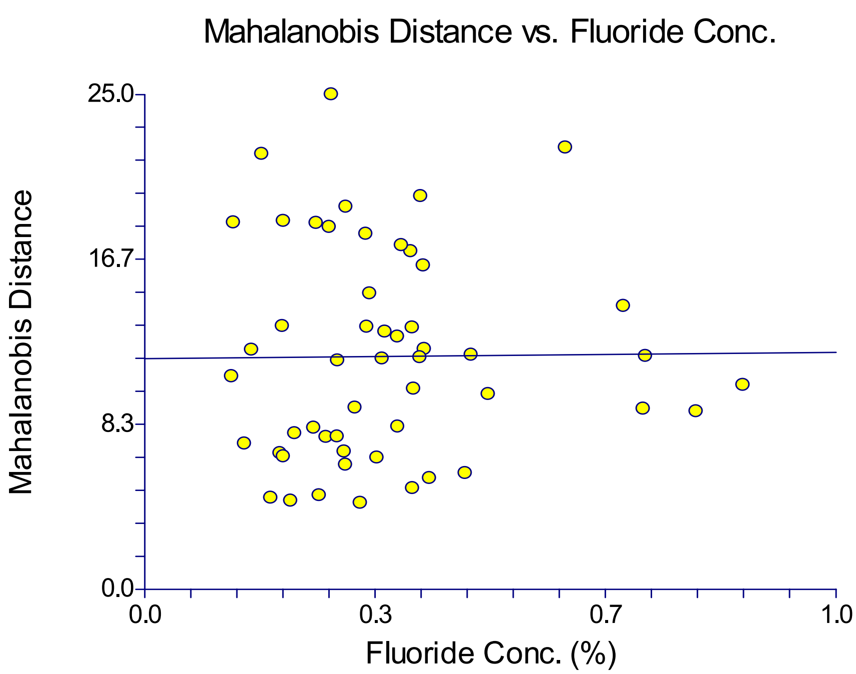
Figure 7.24: Principal Coordinates Analysis—Coordinate 2 vs. Coordinate 3, By Time Period
(red cross=early period burials, teal triangles=middle period burials, yellow triangles=late period burials)



These figures demonstrate a reasonable degree of clustering among burials dating to the earliest period of the cemetery's use. Four of the seven burials from the early period for which craniometric data is available are found relatively close to each other (ITSK329, ITSK465, ITSK467 and ITSK471), with three individuals found slightly more distantly (ITSK340, ITSK364 and ITSK621). Of these more distant individuals, two are general genetic outliers to the remainder of the population (ITSK340 and ITSK621). This suggests that these two early individuals did not contribute to the later gene pool of the population as significantly as the remainder of the earliest individuals. The clustering of the four early individuals is most noticeable in the first figure, which compares the first and second coordinates. These figures also demonstrate some clustering of burials dating to the middle and late periods of the cemetery. These figures also suggest that the degree of genetic variation within the population increased over time, with a particularly noticeable increase occurring between the early and middle periods.

Another important factor to consider is the potential for change in the population's phenotypic variability over time, as illustrated by the results of the fluoride analysis. **Figure 7.25: Mahalanobis Distance from Population Centroid vs. Fluoride Concentration** displays the distance of individuals to the population's centroid based on all of the measured craniometric variables over time in a visual manner.

Figure 7.25: Mahalnobis Distance from Population Centroid vs. Fluoride Concentration



This graph suggests that there is no evidence for any change in the average Mahalanobis distance to the centroid over time. However, it does seem that the majority of the population outliers suggested by the phenotypic data are concentrated in the later periods of the cemetery's use. This pattern is offset by the fact that most of the individuals closest to the population centroid are also concentrated in these later periods. The results of univariate Levene's tests comparing the variance observed in each of the craniometric variables during the various periods of the cemetery appear in **Table 7.1**: **Results of Levene's Tests Comparing Variability of Cemetery Sub-periods.** This table compares variability in the early period of the cemetery to the later and more intensive period of use (i.e. dividing the cemetery into two periods), as well as comparing the variance of the early, middle and late periods (i.e. dividing the cemetery into three periods). Significant results (at α=0.1) are indicated in italics.

Table 7.1: Results of Levene's Tests Comparing Variability of Cemetery Sub-periods

	Two Sub-periods		**Three Sub-periods**	
Abbreviation	**Test Value**	**P**	**Test Value**	**P**
UFH	0.0007	0.979276	2.1043	0.132393
UFB	4.0155	*0.050745*	2.4149	0.100385
LOH	0.0072	0.932642	0.8393	0.437794
LOB	1.4848	0.228866	1.6100	0.210489
IOB	1.0334	0.314265	0.9200	0.405311
NAB	0.0382	0.845816	0.9057	0.410647
NAH	0.5366	0.467392	0.2920	0.748119
IPL	4.0730	*0.048747*	2.3818	0.102589
EPB	0.1652	0.686159	0.4949	0.612722
IPB	0.5788	0.450439	0.8118	0.450061
BOB	0.7030	0.406881	1.1950	0.313812
BZB	2.5808	0.116235	3.6934	*0.034217*
MaxL	0.3854	0.537882	0.2010	0.818658
MaxB	0.2236	0.638311	0.2505	0.779344
BaPr	2.0568	0.162605	1.3824	0.268175

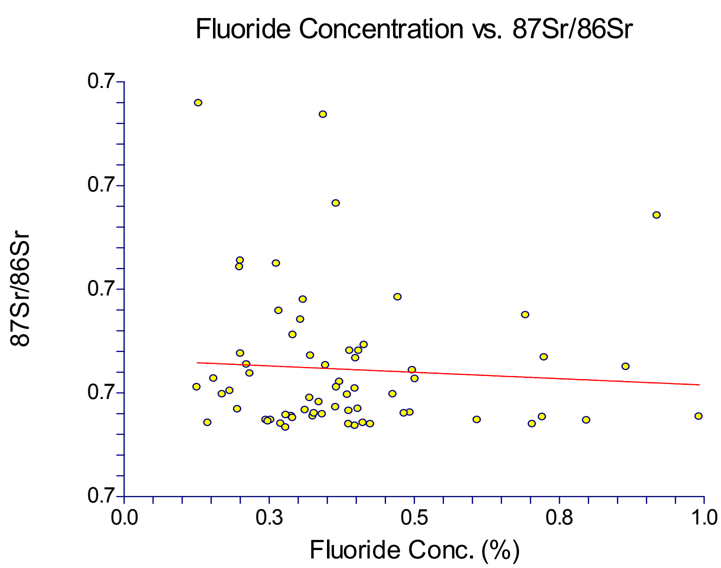
Few of these results are statistically significant; only IPL, UFB (two sub-periods) and BZB (three sub-periods) display significantly increased variability over time. However, some other variables demonstrate trends toward significant differences in variability between the various periods, although these differences are not significant (i.e. UFH and LOB).

It is possible that the combination of increased non-local individuals, increased isotopic variability, increased occurrence of phenotypic outliers and the increase in the intensity of use of the cemetery may point toward an increase in population occurring at İkiztepe between the early and middle periods of the cemetery's use.

Relationship between Fluoride Concentration and $^{87}Sr/^{86}Sr$ Isotope Ratios

Fluoride concentrations were also plotted against $^{87}Sr/^{86}Sr$ values in an effort to determine potential temporal patterns in strontium isotopic values.

Figure 7.26: Fluoride Concentration vs. $^{87}Sr/^{86}Sr$ Values

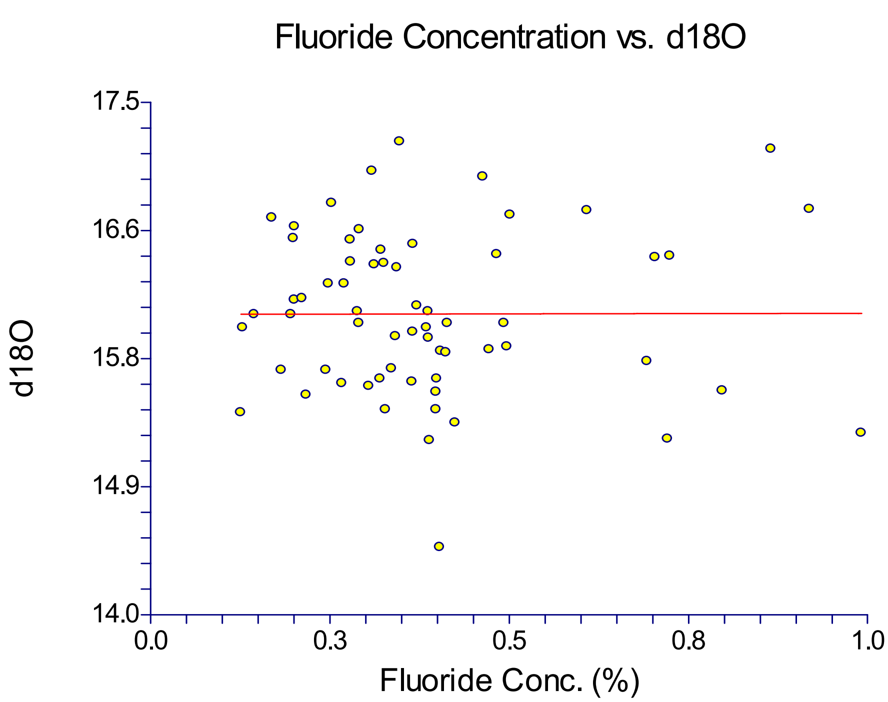


There is no significant correlation between the two variables (R^2=0.0048, y= 0.7093 - 0.0006x, p=0.5843). The regression indicates a slight decrease in average strontium isotopic values as fluoride concentration increases. This suggests that strontium isotopic values in the population did not significantly change over time. More significant, however, is that most of the non-local individuals are concentrated in the latest period of use of the cemetery. There is one non-local individual among the earliest burials (SK621), but in general, the non-locals are all late in the cemetery's use life. This may explain the trend towards increased genetic variability over time. Furthermore, the degree of variation in the strontium isotopic values appears to increase over time. According to the hypothesis that the increased variation is an indication of mobility, and likely transhumant pastoralism, this practice appears to have increased in prevalence over time.

Relationship between Fluoride Concentration and $\delta^{18}O$

Fluoride concentrations were plotted against oxygen isotopic values to examine potential changes in $\delta^{18}O$ over time.

Figure 7.27: Fluoride Concentration (%) vs. $\delta^{18}O$

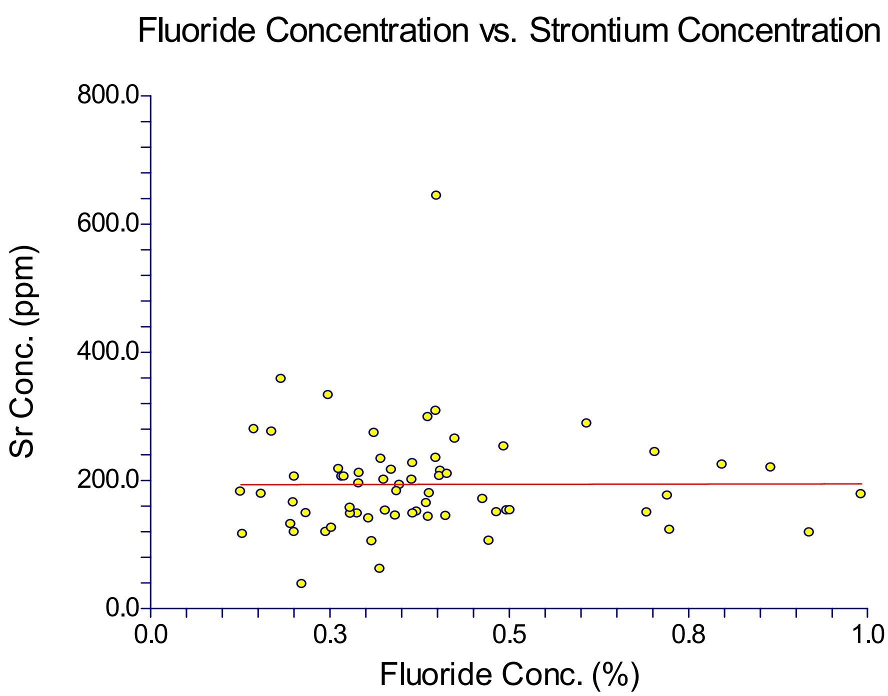


Once again, there is no suggestion of a significant correlation between the fluoride concentration and $\delta^{18}O$ (R^2=0.0000, y=16.05 + 0.007x, p=0.9844). The regression suggests that there is no change in oxygen isotopic values as fluoride concentration increases, which suggests that there is no evidence for change in oxygen values over time. There is also no evidence to indicate that variability in $\delta^{18}O$ values changed significantly over time.

Relationship between Fluoride Concentration and Strontium Concentration

In order to discern possible evidence of diagenetic changes that might affect the strontium isotopic values, the strontium concentration (ppm) were plotted against fluoride concentrations. If there was an incorporation of strontium into bone or enamel over time from ground water in the soil that could have had an effect on the strontium isotopic values or contaminated them, one might expect a relationship with fluoride concentrations, which also increase over time.

Figure 7.28: Fluoride Concentration vs. Strontium Concentration in Enamel

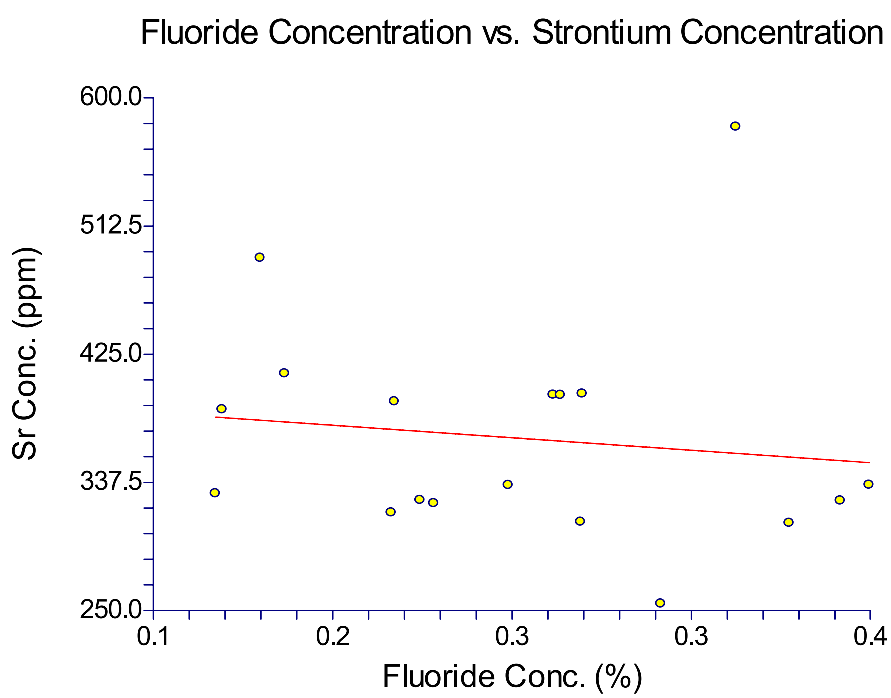


R^2=0.0000, p= 0.9805

However, the results failed to indicate any evidence of a relationship between enamel strontium concentrations and the fluoride concentrations of the associated bone. This lends support to the possibility that enamel strontium isotopic values were not contaminated by strontium absorption from the surrounding groundwater over time.

Fluoride concentrations were also compared to the strontium concentrations of bone for the 18 bone samples analyzed.

Figure 7.29: Fluoride Concentration vs. Strontium Concentration in Bone



R^2=0.0170, p=0.6062

These results indicate a slight negative relationship between fluoride concentration and strontium concentration in bone, although this result was not determined to be significant. This would argue against alteration of strontium isotopic values in bone by post-mortem diagenetic absorption of strontium from groundwater in the burial environment.

Age-Related Variation in Fluoride Concentrations (F Concentrations by Age Groups)

The following tables display the differences in fluoride concentrations in bone for different adult age groups based on estimated age at death. Tests were then performed to determine if there were any significant differences between the age groups in terms of bone fluoride concentrations. These tests were performed for both sets of available age estimates (those by Ursula Wittwer-Backofen (UWB), and those by Yılmaz Selim Erdal (YSE)). Age groups were defined as young adults (15-30 years), middle adults (30-45 years) and older adults (45+ years).

Table 7.2: Average Fluoride Concentrations for Adult Age Groups

	UWB				YSE		
	Young	**Medium**	**Old**	**Unknown**	**Young**	**Medium**	**Old**
N	20	15	24	6	23	37	5
Average	0.33499	0.37120	0.44619	0.32509	0.37503	0.35230	0.65319
Standard Deviation	0.17819	0.16921	0.21650	0.11410	0.15030	0.17727	0.26541
Min	0.12616	0.19619	0.18282	0.14487	0.12616	0.12897	0.37195
Max	0.91957	0.72168	0.99199	0.47275	0.86591	0.91957	0.99199
Range	0.79341	0.52549	0.80917	0.32788	0.73975	0.79060	0.62004

T-tests were conducted to test for differences in mean between adult age groups for bone samples. The results of these t-tests are presented in the tables below. For UWB age estimates, a significant difference was found at a level of α=0.1 between older and younger adults; other tests were not determined to be significant.

Table 7.3: Results of Paired T-Tests for Fluoride Concentrations by Age Groups (UWB Age Estimates)

	Young	**Middle**	**Old**
Young		t=0.6077, p=0.547528	t=1.8357, p=0.073492
Middle			t= -1.1396, p=0.261772

For YSE age estimates, two of the age-related t-tests were found to demonstrate a significant difference. Differences were detected between older and younger adults, as well as between older and middle adults. No significant difference was detected between middle and younger adults.

Table 7.4: Results of Paired T-Tests for Fluoride Concentrations by Age Groups (YSE Age Estimates)

	Young	Middle	Old
Young		t=-0.5109, p=0.611356	*t= 3.2572, P=0.003125*
Middle			*t=2.6216, p=0.008751*

Prior to conducting Levene's tests, Shapiro Wilk tests of normality were conducted. In almost all cases, for both UWB and for YSE age estimates, age groups were determined to not be normally distributed (UWB estimates: young adults, W=0.812549, p= 1.337483E-03; middle adults, W=0.8809814, p=4.907345E-02; YSE estimates: young adults, W=0.884447, p=1.225137E-02; middle adults, W=0.871541, p=5.225144E-04). The one exception to this trend was older adults, who were not normally distributed using UWB age estimates (W=0.8680631, p=4.821677E-03), but normality could not be rejected using YSE age estimates (W=0.91689, p=0.5100786).

A modified Levene's test was also conducted to test for differences in variance between the different age groups, in addition to the tests described above to look for differences in mean. This test detected no difference in variance between the age categories for either UWB or YSE age estimates (UWB: test statistic=0.4060, p=0.749238; YSE: test statistic=1.3967, p=0.255079).

Thus, there is some evidence to suggest that individuals who were older at their time of death may have higher fluoride concentrations compared to other, younger adult age groups. This is particularly evident for YSE age estimates, but is also visible for older adults vs. younger adults in UWB age estimates; furthermore, YSE age estimates suggest a significant difference in variance between the different adult age groups, although UWB estimates do not.

Figure 7.30: Box Plot of Fluoride Concentrations by Age Groups (UWB Age Estimates)

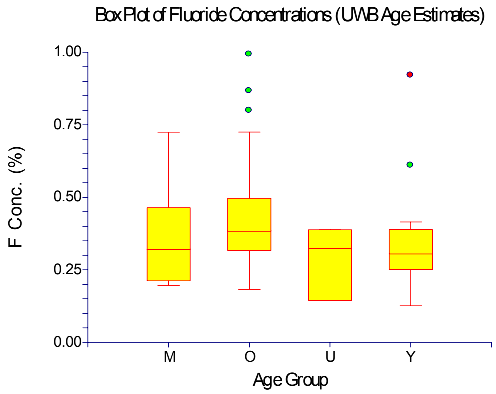
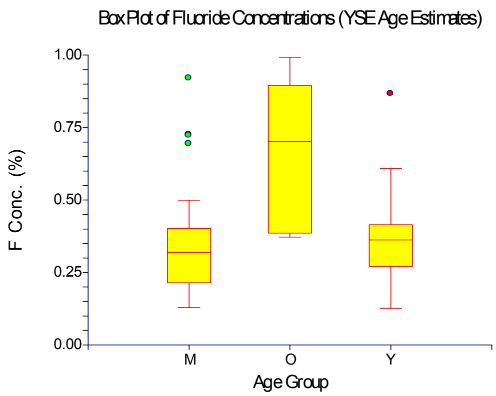


Figure 7.31: Box Plot of Fluoride Concentrations by Age Groups (YSE Age Estimates)



Sex-Related Variation in Fluoride Concentrations (F Concentrations by Sex)

The following table displays the differences in fluoride concentrations in bone for males and females. Tests were performed to determine if there were any significant differences between the sexes in terms of bone fluoride concentrations. These tests were performed for the most secure sexual designations (i.e. greater certainty in assigned sexes, with greater numbers of individuals of unknown sex) and less secure sexual designations (i.e. a lower degree of certainty in assigned sexes, with lower numbers of individuals of unknown sex).

Table 7.5: Average Fluoride Concentrations for Adult Males vs. Females

	More Certain			Less Certain		
	Females	**Males**	**Unknown**	**Females**	**Males**	**Unknown**
N	26	26	13	30	35	0
Average	0.39647	0.41333	0.33132	0.38292	0.38357	
Standard Deviation	0.23081	0.17371	0.13220	0.21865	0.16720	
Min	0.12616	0.15512	0.14487	0.12616	0.14487	
Max	0.99199	0.79813	0.69293	0.99199	0.79813	
Range	0.86583	0.64301	0.54806	0.86583	0.65326	

When dealing with the both the more certain sex estimates (i.e. greater degree of certainty), and the less certain sex estimates (i.e. lesser degree of certainty), no difference was detected between in the mean isotopic values between the sexes (more certain estimates, t=-0.5118, p=0.611072; less certain estimates, t= -0.3838, p=0.702441).

Prior to conducting a Levene's test to test for differences in variance between the sexes, a Shapiro Wilk test of normality was conducted for both sexes. Both males (more certain estimates, W=0.9208233, p=4.700682E-02; less certain estimates, W=0.8943667, p=2.799711E-03) and females (more certain estimates, W= 0.8194592, p=3.844091E-04; less certain estimates, W=0.810072, p=1.00601E-04) were determined to not be normally distributed. In all cases, the distributions of fluoride values were bimodal, similar to the overall distribution of values for the whole population.

In addition to testing for significant differences in the mean fluoride concentrations between adult males and females, a Levene's test was conducted to test for differences in variance. This test detected no difference in variance (more certain estimates, test statistic=0.6655, p=0.517879; less certain estimates, test statistic=0.6655, p=0.517879).

Thus, there is no evidence for any difference between males and females in terms of either average bone fluoride concentration, or in the degree of variation in the samples for each sex.

Figure 7.32: Box Plots of Fluoride Concentrations (More Certain Sex Estimates)

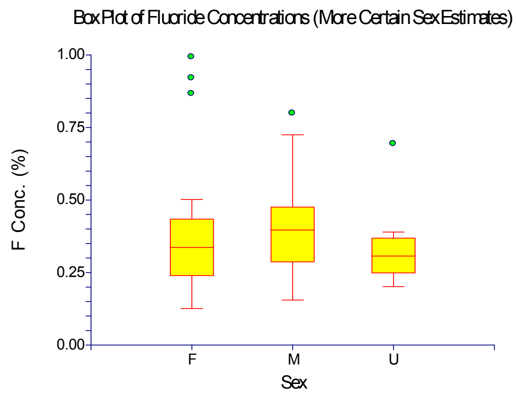
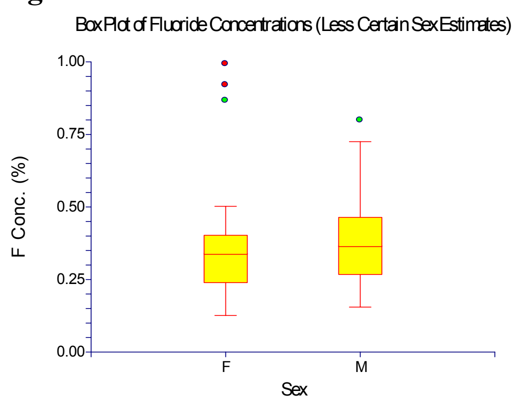


Figure 7.33: Box Plots of Fluoride Concentrations (Less Certain Sex Estimates)



F Concentrations by Disposition of the Body

Overall, there is surprisingly little variation in the methods used for deposition of the bodies within the cemetery at İkiztepe, a fact that creates significant difficulties in proposing potential sub-populations within the cemetery based on differences in burial practices. The main source of variation in depositional practices is in the direction of the placement of the body, which shows little obvious patterning. Thus, tests were conducted to determine if there was any difference in fluoride concentrations based on the direction in which the body's head was pointing.

The following table demonstrates the average fluoride concentrations for groups based on the head direction of the individual burial.

Table 7.6: Average Fluoride Concentration by Orientation of the Body (Head Direction)

	N	NW	W	SW	S	SE	E	NE	U
N	1	7	8	0	13	20	2	0	13
Average	0.12897	0.35540	0.44873		0.38615	0.38294	0.29914		0.38682
Standard Deviation	0.00000	0.15017	0.24735		0.17510	0.19374	0.14064		0.20960
Min	0.12897	0.16976	0.18282		0.19619	0.12616	0.19969		0.14487
Max	0.12897	0.60918	0.86591		0.79813	0.99199	0.39859		0.91957
Range	0.00	0.43942	0.68309		0.60194	0.86583	0.19890		0.77469

T-tests were conducted to determine if there were any significant differences between these groups. For burials oriented with the head toward the north or the east, the sample sizes were too small to conduct t-tests. Instead, a 95% confidence interval was calculated for the fluoride concentrations of the group with the largest sample size (burials with the head oriented toward the southeast). This interval was then compared to the average concentrations observed in the smaller groups. The table below shows the results of paired t-tests for different burial groups based on head direction.

Table 7.7: Results of Paired T-Tests for Fluoride Concentrations Based on Head Direction

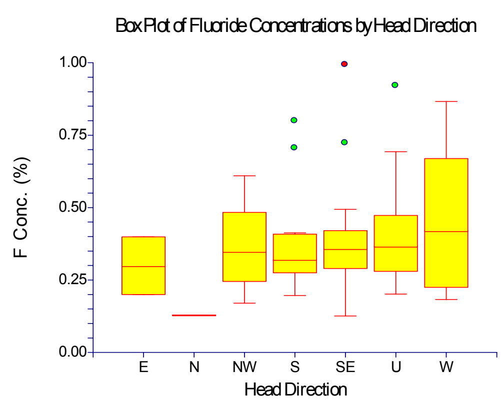
	N	NW	W	S	SE	E
N		Small sample size	Small sample size	Small sample size	Small sample size	Small sample size
NW			t= -0.8661 p=0.402133	t= -0.4117 p=0.686708	t= -0.3404 p=0.736392	Small sample size
W				t= -0.6803 p=0.504522	t= -0.7506 p=0.459629	Small sample size
S					t= 0.0483 p=0.961787	Small sample size
SE						Small sample size

None of the results of these t-tests were determined to be statistically significant. The 95% confidence interval for the fluoride concentrations of the group with a southeasterly burial orientation was 0.291-0.405. The single individual who has a northerly orientation has a fluoride concentration that lies outside this confidence interval, while the average for the group with an eastern orientation lies within this range.

Prior to conducting a Levene's test, the fluoride concentrations for these groups were subjected to Shapiro Wilk tests of normality to determine if they represented a normal distribution. For burials with heads oriented in an easterly direction, the sample size was too small (n=2) to conduct a Shapiro Wilk test, and thus a non-parametric Kolmogorov Smirnov test was performed. This test suggested that a normal distribution could not be rejected for this group (K-S statistic: 0.2602499). For burials with the head oriented in a northerly direction, the sample size was too small (n=1) to conduct either a Shapiro Wilk or a Kolmogorov Smirnov test. However, for the remaining four groups, Shapiro Wilk tests were conducted. Of these, two groups demonstrated a normal distribution (head oriented west, W= 0.9157928, p=0.3966639; head oriented northwest, W=0.9568481, p=0.7912824), while for the other two groups, a normal distribution was rejected (head oriented south, W=0.7992719, p=6.681992E-03; head oriented southeast, W=0.8339532, p=2.903729E-03).

A modified Levene's test was conducted to look for significant differences in variance between the different groups based on head orientation, which demonstrated that a significant difference did not exist between the various groups (test statistic=0.5298, p=0.714298).

Figure 7.34: Box Plot of Fluoride Concentrations for Burial Groups Based on Head Direction



Average fluoride concentrations were also calculated based on the position of the body. The vast majority of the burials in the İkiztepe cemetery were placed dorsally, with the arms at the sides. However, a small number of burials were placed in unusual positions, and the individuals were examined to see if unusual burial positions were related to the temporal development of the cemetery, as identifiable through the fluoride concentration of bone. Unusual burial positions included: individuals with legs or the entire body turned to the left or to the right, one individual buried face down, those buried in "unknown" positions and one individual who was buried in a more complex position. This individual had their trunk and head turned to the left, the legs turned to the right (the knees were probably originally placed above the body), with the arms placed under the body (SK389).

Table 7.7: Average Fluoride Concentration by Body Position demonstrates the values calculated for the various groups based on body position. These values were calculated for both specific burial positions (i.e. turned to the left, turned to the right, etc.), as well as for non-typical burial practices as a group. Thus, the "Not Dorsal" category in the table below can be divided into "Left", "Right" and "Other" categories; the "Left" and "Right" categories are also shown separately.

Table 7.8: Average Fluoride Concentration by Body Position

	Dorsal	**Not Dorsal**	**Left**	**Right**	**Unknown**
N	41	8	4	2	16
Average	0.41070	0.33667	0.29047	0.32116	0.33793
Standard Deviation	0.19976	0.16094	0.09246	0.00105	0.18133
Min	0.12616	0.18282	0.18282	0.32042	0.12897
Max	0.99199	0.69293	0.40367	0.32190	0.91957
Range	0.86583	0.51011	0.22085	0.00148	0.79060

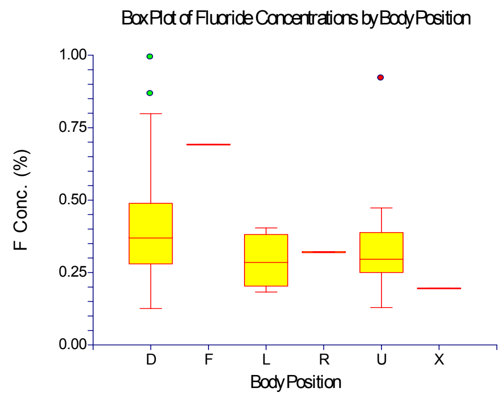
Due to the small sample sizes for all of the groups buried in non-dorsal positions, t-tests could not be conducted to determine whether any significant differences could be distinguished between individuals of different body position groups. Instead, a 95% confidence interval was calculated for the fluoride concentrations of individuals buried in dorsal positions. This interval was then compared to the average fluoride concentrations obtained for groups buried in non-dorsal positions.

The 95% confidence interval calculated for fluoride concentrations of the dorsal burial group was 0.328-0.405. The averages obtained for the groups of individuals buried on both their left and their right sides fall slightly below this range. Both of the individuals buried on their right side display fluoride concentrations very close to the lower end of the confidence interval, while three of the four individuals buried on their left side have values that lie below this range. The individual who was placed in a face down position displays a fluoride value lying above this confidence interval, while the individual buried in an atypical position has a value below this range. These results suggest that individuals buried in non-dorsal positions often tend to have fluoride concentrations lower than the lower limit of the 95% confidence interval observed for dorsal burials, suggesting a tendency for non-dorsal burials to appear in later periods in the cemetery.

Prior to conducting a Levene's test to look for significant differences in variance between the body position groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. These tests were not possible for the "Face Down" and "Atypical" categories, which had a sample size of one each. Furthermore, the sample size for the "Right" category was too small to allow a Shapiro-Wilk test to be conducted; thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.2602499). Thus, Shapiro Wilk tests could be conducted only for the "Dorsal" and "Left" categories, of which the dorsal burials were found to significantly deviate from normality (W=0.9012328, p=1.803378E-03), while for the "Left" category, a normal distribution could not be rejected (W=0.9985244, p=0.9955118).

A modified Levene's test was conducted to test for significant differences in variance between the different body position groups, and this test found no significant differences in variation (test statistic=0.8406, p=0.436655).

Figure 7.35: Box Plot of Fluoride Concentrations by Specific Burial Positions



F Concentrations by "Distinguished" vs. "Non-distinguished" Burials

Tests were conducted to determine if there was any difference in fluoride concentrations based on Bilgi's designations of burials as "distinguished" or non-"distinguished" burials (primarily based on the number of grave goods associated with them; 2005).

The following table demonstrates the average fluoride concentrations for burial groups based on their designation as a "distinguished" burial or not.

Table 7.9: Average Fluoride Concentration by Burial Groups

	Not "Distinguished"	"Distinguished"
N	51	14
Average	0.36462	0.45223
Standard Deviation	0.18545	0.19757
Min	0.12616	0.15512
Max	0.91957	0.99199
Range	0.79341	0.83687

T-tests were conducted to determine whether any significant differences could be identified between individuals who were located in "distinguished" burials and those who were not. The results of paired t-tests are shown in the table below; significant results are shown in italics.

Table 7.10: Results of Paired T-tests Based on Burial Groups

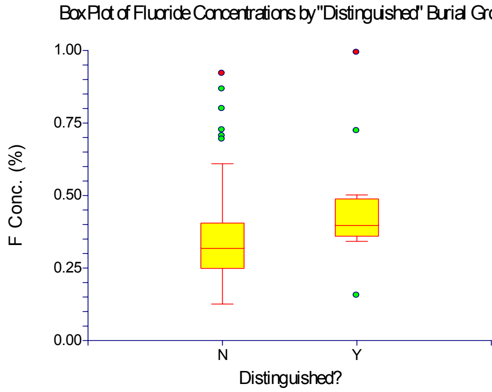
	"Distinguished"	**Not**
"Distinguished"		t= -1.5444 p=0.127501

The difference in fluoride concentrations between distinguished and non-distinguished burials was not determined to be significant. Distinguished burials do not have significantly higher fluoride concentrations, on average, compared to non-distinguished burials. Because "distinguished" burials were defined by Bilgi primarily or solely on the presence of large numbers of burial goods, these results are likely related to the discussion of the relationship between fluoride concentrations and numbers of grave goods addressed above.

Prior to conducting a Levene's test to look for significant differences in variance between the cranial trauma groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. Both distributions were found to be non-normal (Not Distinguished: W=0.8591364, p=2.346323E-05; Distinguished: W=0.8111848, p=6.885769E-03).

A Levene's test was conducted to test for significant differences in variance between the different burials groups based on their identification as "distinguished" or not, and this test found no significant differences in variation (test statistic=0.0522, p=0.819955).

Figure 7.36: Box Plot of Fluoride Concentration by Burial Groups



F Concentrations by the Occurrence of Cranial Trauma

Tests were conducted to determine if there was any difference in fluoride concentrations based on the presence of healed or unhealed cranial trauma. The following table demonstrates the average fluoride concentrations for groups based on the presence or absence of healed or unhealed cranial trauma.

Table 7.11: Average Fluoride Concentration by Cranial Trauma Groups

	None	Healed	Unhealed
N	58	3	4
Average	0.38131	0.32132	0.46169
Standard Deviation	0.19559	0.07683	0.16600
Min	0.12616	0.24494	0.32832
Max	0.99199	0.39859	0.70420
Range	0.86583	0.15365	0.37588

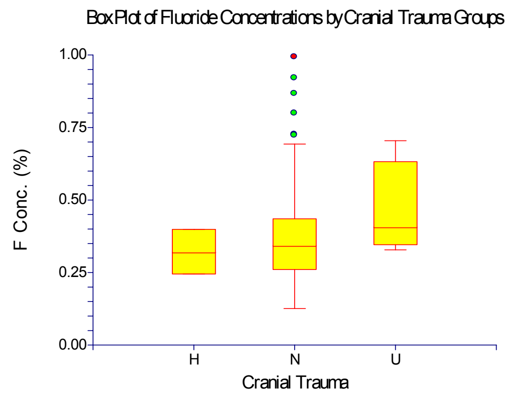
Due to the small sample sizes observed for both healed and unhealed cranial trauma, t-tests could not be conducted to determine whether any significant differences could be distinguished between individuals with healed or unhealed cranial trauma and those who had none. Instead, a 95% confidence interval was calculated for the fluoride concentrations observed in the group of individuals with no cranial trauma. This interval was then compared to the average fluoride values obtained for the groups with smaller sample sizes.

The 95% confidence interval calculated for the group displaying no cranial trauma was 0.292-0.388. While the average fluoride concentration observed among individuals with healed cranial trauma lies within this range, the average for the group displaying unhealed cranial trauma lies above this range. Three of the four individuals with unhealed cranial trauma display fluoride values above the upper limit of the 95% confidence interval, including one significantly above this range. This suggests a slight trend toward higher fluoride concentrations in individuals with unhealed cranial trauma, suggesting this group may tend to occur earlier in the cemetery's period of use.

Prior to conducting a Levene's test to look for significant differences in variance between the cranial trauma groups, Shapiro Wilk tests of normality were conducted to detect deviations from a normal distribution. The sample size for the "Healed" category was too small to allow a Shapiro-Wilk test to be conducted (n=3); thus, a non-parametric Kolmogorov Smirnov test was conducted instead, which found no significant deviation from normality (KS statistic: 0.1732447). Thus, Shapiro Wilk tests could be conducted only for the "Unhealed" and "No Cranial Trauma" categories. Of these, the "No Cranial Trauma" was found to significantly deviate from normality (W=0.8704259. p=1.728573E-05), while the unhealed cranial trauma was found to have a normal distribution (W=0.8228723, p=0.1499661).

A modified Levene's test was conducted to test for significant differences in variance between the different cranial trauma groups, and this test found no significant differences in variation (test statistic=0.6090, p=0.547097).

Figure 7.37: Box Plot of Fluoride Concentration by Cranial Trauma Groups



Discussion

The results of the fluoride dating suggest that the fluoride concentrations in the bone samples analyzed had a bimodal distribution. The majority of the samples had fluoride concentrations that fell between 0.1% and 0.6%. However, a second, smaller group existed with fluoride concentrations between 0.6% and 1.0%. The results point toward an early, moderate period of use for the İkiztepe cemetery, followed by a later, more intensive phase of use. The second, smaller group of individuals with higher fluoride concentrations represents the earliest group of burials interred in the cemetery at İkiztepe, and consists of 9 individuals (SK329, SK340, SK364, SK379, SK405, SK465, SK467, SK471, SK621).

Table 7.12: Characteristics of Individuals with Earliest Burials

Sk No.	Sex	Age	Head Direction	Body Position	Grave Goods	Tooth	Fluoride Date
ITSK329	Unknown/ Male	Middle Adult	Unknown	Face Down	None	URM 3	0.69 (Early Period)
ITSK340	Male	Older Adult	South	Dorsal	2 total: 1 knife, 1 stone pendant	LLM2	0.80 (Early Period)
ITSK364	Male	Middle Adult	Southeast	Dorsal	8 total: 2 spearheads, 1 harpoon, 1 ring, 3 earrings, 1 stone object	LLM3	0.72 (Early Period)

ITSK379	Female	Older Adult	Southeast	Dorsal	6 total: 3 harpoons, 1 disc silver pendant, 2 chisels	LLM2	0.99 (Early Period)
ITSK405	Male	Older Adult	South	Dorsal	1 spearhead	LRM2	0.90 (Early Period)
ITSK465	Male	Older (UWB)/ Middle (YSE) Adult	West	Dorsal	7 total: 1 spearhead, 1 frit necklace, 3 earrings, 2 bracelets	LLM3	0.72 (Early Period)
ITSK467	Female	Older (UWB)/ Young (YSE) Adult	West	Dorsal	5 total: 1 spearhead, 1 cutter, 1 harpoon, 2 earrings	LLM2	0.87 (Early Period)
ITSK471	Male	Young Adult	Northwest	Dorsal	5 total: 1 dagger, 1 spearhead, 1 harpoon, 1 frit necklace, 1 spiral ring	LRM3	0.61 (Early Period)
ITSK621	Female	Young (UWB)/ Middle (YSE) Adult	Unknown	Unknown	1 earring	LLM1	0.91 (Early Period)

There are some patterns visible in the characteristics of these individuals who represent the earliest burials in the cemetery. Males are better represented among this group than females; six of the nine individuals in this group are male, while only three are female. Furthermore, between six and eight of these individuals were middle or older adults; younger adults are much less commonly represented among the earliest burials. The majority of the burials for which the burial positions are known were dorsal burials, although one individual was buried in a non-standard position (ITSK329, buried face down). No pattern is visible in the direction of the burials in this group. Finally, only one of the nine earliest burials had no grave goods

(ITSK329). Three individuals had one to two grave goods, while the remainder (five individuals) had between five and eight grave goods.

There was some concern that the spatial bias in the samples selected for analysis in this study (due to the lack of provenienced skeletal remains from certain parts of the cemetery) might have obscured temporal patterns in the development of the cemetery. For example, a large portion of the centre of the cemetery was not represented by any analyzed samples; if some of the earliest burials were concentrated in this area, they might be underrepresented in the sample. However, the map of the locations of the earliest burials (see **Map 7.1: İkiztepe Cemetery—Earliest Burials)**, as determined by fluoride dating results, indicates that they were primarily concentrated slightly to the south of the gap in the cemetery where no provenienced material could be sampled. Furthermore, the correspondence of this area with the area in which the majority of individuals with large numbers of grave goods were located (see **Chapter Three**) suggests that this area can be considered as the centre of the cemetery, in terms of its concentration of the earliest and the richest burials. This implies that burials from the earliest period may not be significantly underrepresented in this sample, and thus that the conclusions about the two phases of use (i.e. in terms of their intensity of burial) may not be the result of spatial bias in sampling procedures.

Spatial analysis of the fluoride results suggests that following the original phase of use of the cemetery, where burials were placed in the central southern portion of the cemetery, the cemetery continued to expand by filling in the spaces between the earliest burials in the southern part of the cemetery, and gradually expanding northward. However, some secondary use of the southern part of the cemetery continued within the latest period of the cemetery's use. No evidence was found to support the idea that practices that preferentially placed males closer to the centre of the cemetery and females toward the peripheries were obscured by the spatial expansion of the cemetery over time. The fact that there is no relationship between the fluoride concentration of the burials and their absolute elevation demonstrates that there is not likely to be any differences in water drainage that might have confounded the fluoride results. Furthermore, the lack of relationship between fluoride concentrations and the depth of the burial beneath the reconstructed surface of the mound suggests that there were no significant time-related changes in burial depth.

Some temporal patterns in the appearance of grave goods can also be discerned from the results of the fluoride analysis. Generally, the earliest group of burials produced moderate numbers of grave goods. Individuals with between one and eight grave goods are common in this earliest period, while individuals with both no grave goods, or with greater than eight grave goods, were rare. Following this early period of the cemetery's use, the pattern observed in grave goods changes. In this period, differentiation in the numbers of grave goods becomes more pronounced. Individuals with greater than eight grave goods become more common, as do individuals with no grave goods. The patterns evident in the occurrence of grave goods suggest that the later phase of the cemetery's use may be divided into two sub-periods: a middle and a late period. Individuals with greater than eight grave goods are concentrated within the middle period of the cemetery's use (i.e. clustering between F concentrations of 0.3-0.5 %). In contrast, the number of individuals interred with no grave goods appears to increase in the late period of the cemetery's use (i.e. with F concentrations of less than 0.3%). In fact, individuals with greater than three grave goods do not occur during the final period of the cemetery's use.

Once again, it is possible that this pattern may be the result of sampling bias within the samples on which the fluoride analyses were run. As previously discussed, due to the locations in which the early burials and those with the highest numbers of grave goods are concentrated, it does not seem likely that early burials or those with high numbers of grave goods are significantly under-represented in the sample due to the spatial biases in the available material. However, there may be a bias away from individuals with lower numbers of grave goods, due to the intentional sampling of Bilgi's "distinguished" burials for analysis. Nevertheless, there is no specific reason at the present time to believe that these sampling biases would have a consistent effect on patterns visible in the relationship between the temporal development of the cemetery (using F concentrations) and the numbers of grave goods included.

There does appear to be some temporal clustering in the appearance of certain kinds of grave goods. For example, pottery appears to be clustered in graves with high numbers of grave goods appearing in the middle period of the cemetery's use, and idols appear to be found solely in the middle to late periods. However, in both of these cases, very few of the graves that contained these grave goods were selected for analysis. These conclusions thus are based on very small sample sizes and should be viewed with caution.

Plots that examine the relationship between fluoride concentrations and strontium isotopic values suggest that the majority of the non-local individuals, as identified by strontium isotopic values, date primarily to the latest period of the cemetery's use. One exception is ITSK621, which is attributed to the earliest group of burials in the cemetery. There is a general trend toward increasing strontium isotopic values in local individuals through time, although this trend was not determined to be statistically significant. There is also a tendency toward increased variation in strontium isotopic values over time. If this increased variation is interpreted as evidence for seasonal transhumant pastoralism, as discussed in **Chapter Six,** then reliance on this practice may have increased over time. There is no pattern evident between the oxygen isotopic values and fluoride concentrations.

Finally, a discussion of the results of the fluoride dating with regard to the radiocarbon dates previously presented is warranted. The fluoride concentration for ITSK602 was 0.36, which places it in the middle period of the cemetery's use; similarly, ITSK643 had a fluoride concentration of 0.26, placing it in the latest period of the cemetery's use life. These values correspond quite well with the radiocarbon dates presented in **Chapter Two** for these two samples. The two samples thus both date to the later and more intensive portion of the cemetery's use, suggesting that it is this period of use that occurs in the range of 3500-3000 calBC. The earlier, more moderate period of use of the İkiztepe cemetery must predate this, but was not represented in the samples sent for radiocarbon dating. Samples from the earliest group of burials must be analyzed in order to establish the date of the founding of the cemetery, but these results would suggest that this event precedes the dates presented, which already shift the cemetery significantly earlier than previously supposed.

Chapter Eight: Conclusion

Since the original publication of the volume describing the first seasons of excavation at İkiztepe (Alkım *et al* 1988), numerous scholars have commented on the remains from the site, often questioning the underlying chronological structure suggested by the excavators. The best-published sequence at the site, from Mound II, has been the primary focus of these scholars. The earliest period in this sequence has been suggested to date to the Neolithic period, placing the foundation of the site long before the Late Chalcolithic date traditionally given to this event. Sequences from the site's other mounds have received less attention, but have also been suggested to date earlier than previously believed, including material from Areas C and F on Mound I, which were both tentatively placed within the 4th millennium BC. No direct chronological reconsideration of the cemetery material has been attempted, but various scholars have suggested that such a re-analysis is sorely needed, based on various lines of reasoning. Parzinger, for example, suggests that the large difference observed in the absolute elevations of the burials (almost 7m), as well as parallels to Chalcolithic cemeteries in southeastern Europe, point to a foundation date for the cemetery during the Chalcolithic period (1993).

While results of this study indicate that the 7m difference in burial elevations is less likely due to the temporal depth of the cemetery, and more likely due to the placement of the burials on an ancient slope, there are other stratigraphic reasons to suggest an earlier date for the cemetery than the traditional one in the EBII-III that it has long been given. Among these is the concentration of ceramic forms traditionally associated with the Anatolian EBII-III period in the layers above the cemetery, rather than within the graves themselves. This provides a possible indication that the cemetery should be dated earlier than the EBII-III period.

Radiocarbon dates conducted as part of this study on human remains from the cemetery have shown that the cemetery is indeed substantially earlier than has been previously suggested. The date commonly cited for the majority of the graves is in the EBIII, ca. 2400-2100 BC, with a few earlier burials dating to the EBII. However, the radiocarbon dates obtained as part of this study suggest a period of use for the cemetery between approximately 3500-3000BC, in the transitional Late Chalcolithic-EBI period. These dates originate from burials dating to the middle and late periods of the cemetery's occupation, according to the results of relative dating methods conducted through the analysis of bone fluoride concentrations. None of the earliest group of skeletons, as identified by the fluoride dating results, have yet been dated. Bone material from this group of burials is currently being processed, and should be able to specify a more exact date for the cemetery's foundation.

While the size of the İkiztepe cemetery was remarkable even by the standards of the Anatolian Early Bronze Age, which boasts numerous large extramural cemeteries, it is virtually unheard of for the Anatolian Chalcolithic. Although the existence of extramural Chalcolithic cemeteries has been postulated at a number of sites, predominantly due to the lack of burial evidence dating to this period, none have ever been found. The present corpus of evidence for burial practices during the period contemporary with the İkiztepe cemetery predominantly consists of small numbers of burials, which are almost exclusively intramural. Burials of infants and children under the floors of excavated houses predominate, while the few burials of adults were generally simple inhumations or pithos burials. The latter burial type becomes ubiquitous during the Early Bronze Age, when larger cemeteries become commonplace. In contrast, the İkiztepe cemetery itself does not have a single example of a pithos burial, instead consisting exclusively of simple inhumation burials. Interestingly, most of the inhumation burials known in Anatolia contain bodies placed in a flexed position on the left or the right side. Extended dorsal burials are much less common. At İkiztepe, the opposite is true; flexed positions are relatively uncommon and the vast majority of the burials were placed in dorsal position. Similar burials were found at the nearby sites of Tekkeköy and Kavak, but are generally rare outside of the immediate area around İkiztepe.

Both large cemeteries dating to the Chalcolithic period and dorsal body placement in simple inhumation burials are more common in southeastern Europe, and particularly Bulgaria. Coastal Bulgarian cemeteries demonstrate relatively higher proportions of extended burials, particularly among men, compared to inland Bulgarian sites, which have produced predominantly flexed burials. Cemeteries at coastal sites were also more likely to have elaborate grave goods than inland sites, where grave goods were comparatively rare. The significance of the similarities between these burials and the cemetery at İkiztepe is not clear.

It has been suggested by the excavators of the site that the remains from Mound III, Level II are contemporary to the period of use of the cemetery. This assertion is particularly difficult to assess, given the state of publication of the pottery from both the cemetery and the Mound III settlement. However, if we work with the assumption that this assertion is correct, or at least that this settlement approximates the size and organization of the settlement that was contemporary with the cemetery, then we can conclude that the cemetery was likely used by the inhabitants of a small village. Mound III produced the remains of several houses constructed of timber and wattle-and-daub, with beaten earth floors. These houses generally had only one or two rooms; they also had courtyards in which installations interpreted as hearths or kilns were found. Although some of these installations were interpreted as relating to specialized pottery production, there is little evidence presented to support this idea. Furthermore, although Bilgi suggests that specialized metal production was also occurring at İkiztepe due to the frequency of metal weaponry found in the graves in the cemetery, little evidence for this has been found either. Some of the installations found within the Mound III structures were described as "hearth-altars", and were interpreted as having a cultic function due to the presence of idols within them. In general, the remains from the settlement on Mound III would point to the existence of a small village rather than a larger settlement. Furthermore, there is little indication from any other remains at the site that İkiztepe was ever a much larger settlement than the Mound III remains would indicate.

Analysis of the spatial organization of the cemetery suggests that burial occurred preferentially within one particular area, located in the central southern part of the cemetery within a slight curve of the ancient slope. This area is slightly to the south of the mean centre of the cemetery. It was also slightly to the south of a moderately sized area of the cemetery from which skeletal remains were not available for sampling for this study. Due to the reburial of a portion of the remains from the cemetery, no provenienced burials were available for sampling from a broad swath of the cemetery running in an east-west direction slightly to the north of this preferred burial area. The earliest burials in the cemetery were preferentially located in this area, as were the individuals with the highest numbers of grave goods. A number of other groups also seem to display a trend toward being centered in this area, including women and children buried with weaponry, individuals with high numbers of tools (3 or more), and individuals from Cluster 3, as identified by k-means clustering as part of a kinship analysis based on phenotypic data. Interestingly, individuals who represent phenotypic outliers from the rest of the population and individuals with outlying $\delta^{18}O$ values also display a tendency toward being buried in this area. It thus appears that there were no set rules in the placement of burials that allowed only particular groups or privileged individuals to have burials placed in this central area. Other individuals who were not members of these groups were also buried in this area of the cemetery, suggesting that burial placement in certain areas was preferential but not controlled. Spatial analysis of the results of fluoride dating, which provided a relative sequence for a sample of the cemetery's burials, suggested that the earliest burials in the cemetery were concentrated in the preferred south central area of the cemetery. Over time the cemetery expanded, filling in gaps between existing burials and expanding further to the north. The latest period of the cemetery's use appears to have made secondary use of the southern portion of the cemetery once again.

A gradual decrease in burial distance from the cemetery centre was observed with increasing age, from infants to children to adult females to adult males (also observed by Doğan 2006). This last group displayed the smallest average distance to the centre of the cemetery of any basic demographic group. However, despite the pattern of decreasing average distance among these groups, few of these differences were determined to be statistically significant. A significant difference does seem to exist between infants and children older than one year old. Infants are significantly more frequently placed in extremely peripheral areas of the cemetery, while children were not located at significantly greater distances from the cemetery center than adult females, and displayed similar distances to those observed in the young adult age group. Infants also have significantly fewer examples of all types of burial goods, including total numbers of grave goods. Children, on the other hand, often had significantly higher total numbers of grave goods than observed in infants. In fact, the average number of grave goods found in young children's graves (i.e. between one and six years of age) were higher than some older age groups, including adolescents and young adults. Children also displayed similar frequencies of individuals with higher numbers of grave goods to some adult age groups. Differentiation was apparently made between children and adults based on the types of artifacts that were associated with each group's graves. Few children's graves included items like weaponry or tools, but primarily contained jewelry items. A small group of children's graves, however, did contain objects such as weaponry and tools. The evidence thus points to a significant change in the societal attitude toward infants and children that appears to have coincided with the end of infancy (i.e., ~1 year of age). While infants appear to have been given less significance in terms of their burial treatment, children were treated differently and often appear to have been given greater social significance.

The existence of a social system organized around vertical social status differentiation is often inferred from the presence of richly furnished children's graves in a cemetery (Peebles & Kus 1977: 431, Brown 1995: 8, Baxter 2005: 103-105). At İkiztepe, children, particularly younger children, displayed higher average numbers of grave goods than many older age groups, as well as demonstrating a greater frequency of individuals with higher numbers of grave goods. This has been interpreted as having significance in terms of the importance of vertical social differentiation (i.e. see Bilgi 2005). Most grave objects associated with younger children, however, tended to consist of jewelry items, with few instances of other object types that have been primarily associated with adults, such as weaponry and tools. This suggests the importance of horizontal status differentiation as a possible explanation for the pattern of grave good distribution. Despite the importance of horizontal diferentiation, a few children's burials can be identified that contain some examples of weaponry and tools, objects that appear to be more typically associated with adult burials. These individual burials might thus be interpreted as evidence indicative of some degree of vertical status differentiation, in which the social status of the parents is ascribed to the child. This interpretation is the one favoured by Bilgi (2005), who suggests that a group of "distinguished" burials at the site, which include infant and child burials associated with weaponry and other grave goods, represent the "male rulers of the settlement and their families" (Bilgi 2005: 17). Philip (1989: 156) suggests that in burial contexts, weapons often function as markers of distinction, and serve to express personal status and group identities. The rarity of weapons in contexts clearly associated with female or child interments has also been noted by Philip (1989:156), who links the placement of metal weaponry in tombs directly to the display of personal status in men. These displays of status were likely associated with the role of metals in conquest and the acquisition of power, wealth and reputation (Philip 1989: 156, Philip 1995: 153). The appearance of weaponry in a small group of burials associated with women and children suggests the attribution of similar status characteristics to these individuals, despite the low likelihood or impossibility (in the case of young children) of these individuals having fulfilled this role within society.

The fluoride dating results suggest the existence of a moderate early period of use for the cemetery, followed by a more intensive later period of use. This more intensive secondary period can be subdivided into two periods, which may be known as the middle and late periods. The occurrence of grave goods demonstrates a temporal pattern in their distribution, when considered in terms of these three periods. In general, moderate numbers of grave goods were encountered in graves from the early period of the cemetery. Rarely do these early burials contain absolutely no grave goods. In contrast, the middle period of the cemetery's use witnesses a substantial increase in the differentiation occurring among burials based on the richness of the number of grave goods included in the graves. Graves with the highest numbers of grave goods occur almost exclusively during this period, but burials containing no grave goods also become common. Finally, during the latest period of the cemetery's use, the average numbers of grave goods appear to decrease dramatically. The highest numbers of grave goods occurring during this period are three or four objects, compared to graves with ten or more objects found during the preceding middle period. Furthermore, graves with no grave goods once again increase in frequency.

The analysis of multivariate craniometric data also provides some evidence for the overall organization of the cemetery. It might be anticipated that a cemetery such as the one excavated at İkiztepe would show evidence for organization along kinship lines. The results of the craniometric analysis, however, suggest that this was in fact not the case. Analyses that looked for correlations between biological and geographic distances between individuals (i.e. that would show that individuals who are more similar phenotypically and presumably genetically are more likely to be buried in close physical proximity to each other and vice versa) suggested that no such relationship existed. This pattern remained true when males and females were considered separately, to take into account the possibility of matrilineal vs. patrilineal burial placement.

Matrix decomposition and finite mixture analysis both suggested the possible existence of three lineage groups within the larger İkiztepe population that underwent analysis. K-means analysis was then used to separate the individuals for whom craniometric data was available into groups of presumably related individuals, with the number of clusters specified as three. Similar tests were performed to look for correlations between biological and geographic distances within these three clusters. These tests suggested that there may be lineage-specific aspects to burial placement within the cemetery. The individuals in Cluster 1 demonstrated a moderately high correlation (significant at α=0.1) between biological and geographic distance, suggesting that burial within Cluster 1 may be considered to be kin-structured. In contrast, however, both

Clusters 2 and 3 demonstrated no correlation at the cluster level, suggesting that among these groups, there is no evidence for kin-structured burial. This indicates that for the most part, the spatial organization of the majority of the burials in the İkiztepe cemetery appears to have involved arbitrarily placement, or organization governed by principles other than kinship relationships.

Methods were also employed that compared the relative variability observed in adult males and females within the İkiztepe population. The results of determinant ratio analysis suggested that males were phenotypically more variable than females, although this result was not determined to be statistically significant. The results of a Van Valen's test, however, suggested just the opposite. This test suggested that İkiztepe females were very slightly more variable than males. In general, however, the results of both of these variance comparison tests suggest that there is no clear trend toward greater variability among either sex. Sex-related differences in phenotypic variability are generally interpreted in reference to post-marital residence patterns. The lack of a clear pattern suggests that there may have been no fixed pattern of exogamous post-marital residence. It may point to either the practice of endogamous marriage within the İkiztepe population, or to equal levels of in-migration to İkiztepe among both sexes. It is also possible that both of these scenarios may be equally true and that a variety of marital practices were occurring concurrently in a culturally heterogeneous society. Non-local individuals identified by strontium isotope analysis included a roughly equal number of male and female individuals, who likely represented long-distance immigrants to İkiztepe. Once these non-locals are removed, within the remainder of the presumably local population, males were determined to display more variable strontium isotope signatures. This suggests one of two things; it could suggest greater numbers of short-distance immigration to İkiztepe among males compared to females. This idea is somewhat supported by the results of the determinant ratio analysis, but is argued against by the results of the Van Valen's test, which points to very similar levels of variation between males and females. Alternatively, this suggests greater short-distance mobility among males compared to females by local individuals who do not represent new additions to the İkiztepe gene pool. This scenario fits better with the results of the phenotypic variance comparison tests, and such an interpretation of the isotopic results is presented below.

The values obtained by the oxygen isotope analysis fell almost exclusively within a relatively narrow range. All of the oxygen values fall between 14.46‰ and 17.46‰, a range of 3‰. This represents a quite normal range of variation for a human population (Evans *et al* 2006, 2007, White *et al* 1998, White *et al* 2001; White *et al* 2004). Known isotopic values taken from precipitation in the Black Sea area suggest that despite the major changes in elevation observed in northern Anatolia that might be expected to result in observable differences in oxygen isotopic values, there was surprisingly little variation in the measured meteoric water values. As a result, the narrow range of results observed in the human population could mask the consumption of a variety of water sources from varying areas with similar isotopic values.

The oxygen isotopic values observed in enamel and bone were adjusted to calculate the values of the water sources consumed by the İkiztepe population. In doing so, the lowest bone and enamel values resulted in water values lower than those observed in the seasonal range of variation in isotopic values for meteoric water in the Bafra Plain, around the site of İkiztepe. In fact, a large proportion of the population has values that fall below this range of variation. It is possible that these values indicate the consumption of local water sources, but that environmental change over the past 5000 years resulted in shifts in the isotopic values of these water sources. It is probably more likely, however, that the values of the population were shifted downward by the consumption of water sources originating outside of the Bafra Plain, which had more negative $\delta^{18}O$ values. Water from the Kızılırmak River delta could potentially have lower $\delta^{18}O$ values than meteoric water in the coastal plain, due to the fact that much of its catchment area lies at significantly higher elevations than the Bafra Plain, where slightly (although not significantly—see **Chapter Six**: Expected Oxygen Isotope Values) lower values in $\delta^{18}O$ might be expected. The other possibility is the direct consumption by some or all of the population of water sources at higher elevations, likely from tributaries of the Kızılırmak, perhaps during the herding of animals in mountainous pasture areas. These herded animals were likely to have been sheep and goats, as well as cattle; domestic pigs would not have been herded and would have remained closer to the settlement. Until analysis of water samples from various locations along the course of the Kızılırmak River is conducted, it is not possible to differentiate among these different reconstructions. In addition, diagenetic contamination also cannot be fully ruled out as a potential factor affecting variability in oxygen isotopic values, until tests for sample integrity can be completed to characterize potential diagenetic changes to the bone and enamel tissues.

The results obtained through strontium isotopic analysis demonstrated much more variation than observed among the oxygen isotopic values. Using traditional methods of estimating local ranges of isotopic variation, using samples taken from archaeological animal samples and human bone samples, 65-75% of the İkiztepe population would be considered to be non-local. This would represent an unusually high rate of immigration. In fact, the strontium isotopic signatures show a tri-modal distribution, with the majority of the population showing a normal distribution with lower values (i.e. basically lower than 0.710), and with secondary peaks around 0.712 (7 individuals) and 0.715 (2 individuals). This suggests that a minimum of 9 individuals (of 72 analyzed, i.e. 12.5%) can be identified as likely long-distance migrants. The values of the majority of the remainder of the İkiztepe population can likely be explained by the consumption of a combination of a terrestrial diet with rather low strontium isotopic signatures, and a marine diet with a high proportion of fish, with a higher strontium isotopic signature similar to that of modern ocean water.

The degree of variation in human enamel values is much greater than the degree of variation observed in both human bone and animal enamel values. Samples of animal enamel, when taken from species with relatively low mobility, often display very low levels of variation (Price *et al* 2002; Bentley & Knipper 2005). This includes domestic pigs, which generally have a very narrow home range. This pattern has been borne out by the results of studies which have used archaeological pig remains as estimates of local isotopic variability (Price *et al* 2002, Bentley & Knipper 2005). Thus, the levels of variability observed in the animal enamel samples from İkiztepe are not particularly surprising. However, the reason why the human bone samples did not display similar levels of variability to human enamel is not immediately clear. It is possible that this pattern is the result of a number of factors, the most likely of which is some form of diagenetic contamination which reduced the variability of isotopic signatures in the bone samples from the site (Budd *et al* 2000). Because bone is significantly more permeable than enamel, it often absorbs strontium from the soil and ground water. This may alter the absolute values of the strontium isotopic signatures observed in bone, but it also significantly decreases the amount of variation observed in bone values (i.e. see Budd et al 2000). In this case, contamination may have artificially reduced the amount of variation in the isotopic values observed in the bone samples from this study, resulting in significantly lower levels of variation compared to the values observed in enamel samples from the same population. Tests to examine the degree of diagenetic contamination in the tissues may help to further clarify this issue in future. However, the similarity between the absolute values observed among the potentially contaminated human bone samples and the more likely uncontaminated animal enamel samples suggest that the local strontium isotopic signature at the site has change little over the last 5000 years.

The outliers (i.e. the secondary and tertiary peaks of the strontium isotopic distribution) have values that are significantly higher than can be explained by the majority of the local geological formations in the immediate area. There are two distinct groups of non-locals, one with values above 0.715 and one with values between 0.7115 and 0.7135. These individuals have been suggested to represent long-distance migrants, and it seems that there is no clear pattern with regard to which sex tends to be more migratory over long distances. There are also few observable patterns in terms of burial practices or grave goods that can be seen among the non-local individuals. This suggests that non-locals were relatively well-integrated into the İkiztepe community, and were not distinguished in any clearly archaeologically identifiable way from local individuals in terms of the way they appear in the burial record. Overall, there is also no clear pattern of spatial location that applies to both of these two groups of non-local individuals. While the first group of non-locals displays a tendency to be buried toward the peripheral areas of the cemetery, this was not observed with the second group of non-locals. These individuals, along with one of the individuals from the first non-local group were in fact buried closer to the cemetery's centre.

The apparent integration of non-local individuals demonstrates an important point, particularly when considered alongside a similar pattern observed in individuals identified as phenotypic outliers and those with outlying $\delta^{18}O$ values. Funerary practices are generally assumed to represent an important indicator of cultural identity, and a more accurate one for identifying immigrants than other forms of material culture. These results suggest, however, that such assumptions may represent an over-simplification of complex patterns of interaction and integration both within and among populations or cultural groups. While mortuary practices undoubtedly represent a means of expressing and negotiating group identities, the specific ways in which cultural affiliations are expressed in mortuary ritual may not be clear or consistent, particularly in areas where multiple cultural groups live side by side. Furthermore, it is not clear what forms the expression of cultural identities may take in mortuary rituals, nor how these expressions will be represented in the archaeological record, which can be considered to represent the material byproducts of these rituals (Reimers 1999:164). In many cases, many of the ways in which identity is expressed through the use of material culture may in fact also be invisible to archaeologists, either due to the transitory nature of the expression (i.e. the clothes of the living participants in the ritual) or due to the perishable nature of the materials used.

Studies of funerary ritual in immigrant groups tend to identify a fundamental conflict between the traditions of the group's community of origin, and the reality of their new life in a different culture. The performance of funerary rituals is often shaped by the need to recognize both of these aspects of identity, leading to a highly complex relationship in the expression of group identity between the adoption of new burial practices and the maintenance of old traditions. Kinship ties are likely to play a significant role in determining funerary practices. Where ties to kin in the area of origin remain strong, the need for a continued bond with family after death may dictate that the remains of the deceased individuals may be transported back to the home country (Oliver 2004: 238, Reimers 1999: 158). This practice, however, is often found to be relatively rare (Oliver 2004: 238). In contrast, where there is a lack of close kinship ties to the home country, individuals may wish to express their belonging in their new community by adopting its culture, language, and funerary practices (Oliver 2004: 236).

While the funerary ritual is in itself a complex representation of individual and group identity, the interpretation of the material remains associated with the ritual is even more problematic. The language in which the ritual is conducted, the actions and behaviours of the mourners, the way in which the funeral is announced to the community, and the size and composition of the group participating in the performance of the ritual may all convey and reflect the cultural identity of the deceased, while the deposition of the body and the grave architecture may closely conform to other burials in a multi-cultural cemetery (Reimers 1999: 164). In some cases, material aspects of the dominant culture may be adopted in a fashion that borders on the subversive, as a means of accentuating the distinction and separation of the immigrant community from the society as a whole (Reimers 1999: 163). Many of the ways in which people express and negotiate issues of ethnic and cultural identity through mortuary rituals in multi-cultural situations are through means that are likely to be almost invisible archaeologically (language, behaviour, etc.). Those aspects of the funerary ritual that affect the material culture associated with the burial are likely to have significance and symbolism that, while meaningful to the community itself, are likely to be inaccessible outside of their immediate cultural contexts. In some cases, these expressions of cultural identity may be intentionally made inaccessible to all but a particular group within that society. This suggests that many aspects of the expression of cultural and ethnic identities are not accessible through the study of the material byproducts of mortuary ritual behaviour, and that attempts to assign ethnic identities to various material characteristics may in fact lead to misinterpretation of the remains by archaeologists. The identification of potential immigrants to İkiztepe through isotopic analyses and the overwhelming similarity of their burial characteristics in comparison to other local members of İkiztepe society illustrate this point quite well.

The origin locations of the non-local individuals identified by this analysis can only be tentatively reconstructed, on the basis of known information about local geology. The values observed among the enamel samples for the two groups of non-local outliers are difficult to explain with the signatures derived from local geology of the immediate area, with values in the range of 0.712-0.715. The majority of local formations are likely to have signatures at or below the approximate level of modern Black Sea water (0.7093). Geological outcrops with strontium isotopic signatures high enough to explain the outliers are rare in the area of İkiztepe. It is likely that such high signatures were produced by consumption of food products from areas with granite outcrops or outcrops of continental crust. There are some small granite outcrops to the west of Sinop, but the values obtained from these formations are generally extremely high (i.e. 0.72-0.74), likely too high to adequately explain the values observed for these individuals.

Granitoid outcrops to the south of İkiztepe, in the highlands of the Kızılırmak River in the area around Yozgat and Kirikkale, are potentially more useful in their ability to provide comparative values. One possible interpretation is that the İkiztepe non-local individuals could originate from the vicinity of these outcrops. Contemporary archaeological sites, such as Alişar Höyük and Çadır Höyük are located in the eastern portion of one of the largest of these granite outcrops, the Yozgat batholith (Boztuğ *et al* 2007: 192-194). While studies have not provided a clear picture of the range of values observed within the Yozgat batholith itself, and particularly in its eastern portion, observed values in related granite outcrops to the west have produced values in the range of 0.712-0.715, as observed among the non-locals from İkiztepe. One plausible scenario is thus that some immigrants to İkiztepe with very high observed strontium isotopic signatures could have been born in the vicinity of Central Anatolian granite outcrops, such as those found around Alişar Höyük and Çadır Höyük, providing a potential place of origin for the non-local migrants. However, other potential locations of origin with similar high strontium isotopic signatures can not be ruled out. Based on observed values from the Strandja and Rhodope Massifs, it is possible that other potential sources of isotopic values for non-local individuals may be found in this region, which has high numbers of granitoid extrusions (Okay & Tüysüz 1999: 479-480, Okay *et al* 1996: 424, Okay 2008). Furthermore, studies suggest that formations with strontium isotopic signatures consistent with the non-local individuals at İkiztepe can be found in this area, particularly in plutons in the Pirin area, in the Central Rhodopes in Southern Bulgaria/Northern Greece (Zagortchev 1994, Harkovska *et al* 1998). However, an origin for these individuals in areas on the western Black Sea coast, previously suggested as an area with close connections to İkiztepe, seems unlikely.

The results of finite mixture analysis suggest that there are two distinct groups within the remaining local İkiztepe population (i.e. after the non-local individuals are removed). This includes one larger group of individuals displaying a fairly narrow range of variation, and a smaller group displaying a greater degree of variation. These groups are not clearly mutually exclusive, but rather overlap with each other to a substantial degree. The existence of a small group of individuals within the general population that displays an increased level of variability may be explained by the practice of seasonal transhumance. Such practices, still observed in the Black Sea region today, may have involved the seasonal movement of selected groups of individuals into mountainous areas for the purpose of pasturing animals. The segmentation of individuals between those remaining in the primary settlement and those involved in animal herding may have occurred either within or between households.

Interestingly, this group of more mobile individuals presents a much clearer pattern with regard to sex than observed in the non-local group. These individuals are predominantly men.

Many of these sex assignments are based on sex estimates with lower degrees of certainty, but the pattern is still observable through the use of more certain sex estimates. This suggests that mobile individuals, possibly practicing transhumant animal herding, were significantly biased toward the inclusion of males. This is in contrast to modern practices, where the responsibilities of *yayla* transhumant movements are predominantly performed by women and female children (Yakar 2000: 289). It is, however, consistent with ethnographic observations that herding practices are often performed by children and adolescents (i.e. these isotopic signatures represent movement prior to adolescence).

The exact routes taken by these mobile, and possibly transhumant, individuals are difficult to determine based on the available strontium isotope signatures, which potentially represent an average of isotopic values over the period of the formation of the tissues, during which time a number of movements may have occurred. The variability observed in this mobile group suggests that routes and locations used by these individuals may not have been consistent over time, and that different individuals or families may have varied in the paths they used. However, the areas exploited by these individuals must include local signatures that would create dietary inputs higher than the value of Black Sea water. Mixing with such inputs would create overall dietary averages as high as those observed in the mobile group of individuals. It seems likely that groups herding animals may have passed into the mountains through the Kızılırmak River valley, following the river up into alluvial pastureland higher in the mountains. Areas of the river or its tributaries that pass through zones consisting of metamorphic geological formations of continental origin could provide isotopic signatures high enough to explain the observed isotopic values.

The analysis of changes in strontium isotope values observed over time suggests that the majority of the non-local individuals can be placed in the middle or later periods of the cemetery's occupation. Only one non-local individual can be attributed to the earliest period of the cemetery's use (ITSK621). This suggests increasing levels of in-migration to the site over time, or at least during the second, more intensive phase of burial in the İkiztepe cemetery. Furthermore, the overall variability of the strontium isotopic signatures appears to increase over time. The majority of the "mobile", possibly transhumant individuals were also found in the later periods of the cemetery's use, suggesting that the practice of transhumance may have also increased in frequency over time. A slight trend toward increased genetic variability over time was also suggested by the craniometric data. It is possible that the combination of increasing non-local individuals, increased isotopic variability, increased number of phenotypic outliers and the increase in the intensity of use of the cemetery may all point toward an increase in population size occurring at İkiztepe during the use life of the cemetery, and specifically between the early and middle periods of the cemetery's use.

Although the topic has not been given much attention in the scholarly literature, there has been a tendency to describe the genetic forces acting upon Anatolian populations as being primarily the result of geographic and/or genetic isolation (i.e. Cappieri 1969, see Yakar 1985, Schultz 1989). Cappieri suggests that "in these small populations or tribes isolation has greatly favored the reduction of variability…furthermore, the endogamy which was generally predominant in all these settlements, restricted the inherent variability to extremely low limits or actually caused its decrease" (Cappieri 1969: 8). The results of this study argue strongly against this viewpoint. Rather, despite the potential for the geographic isolation of the İkiztepe population due to the barrier formed by the Pontic Mountains, there is evidence not only for substantial variability in the population, but for increasing variability over time. This suggests high levels of population mobility. Isotopic analysis also suggests the presence of relatively high frequencies of long distance migrants (nine individuals, or around 12.5% of the population analyzed), suggesting the maintenance of long-distance connections, likely through the movement of both people and goods.

The cemetery at İkiztepe, despite the appearance of variation in the numbers and types of grave goods, demonstrates remarkable homogeneity in overall burial practices. Other Chalcolithic cemeteries display at least some variation in burial types, but this is not apparent at İkiztepe. This should perhaps not be overly surprising, given the remarkable uniformity in burial practices seen in most of Western and Central Anatolia during the succeeding Early Bronze Age. However, the similarity in burial treatment within the cemetery belies the underlying population variability. Non-local individuals originating from distant points of origin appear to have been well-integrated in the cemetery, displaying few archaeological cues that would indicate their non-local origins. This has serious implications for the identification of immigrants based on archaeological evidence. Furthermore, the existence of two demonstrably different groups of non-local individuals, who display relatively similar isotopic values to others within their "group" may support the idea of the existence of migration streams. The immigration of at least one individual (that we are aware of—ITSK621) early in the life of the cemetery may have led later to increasing numbers of migrants from the same region. As suggested for *chain migration*, these individuals were probably influenced by the availability of information about their destination and by the existence of well-established routes of movement. Whether this migration was kin-structured is difficult to determine. Although non-local individuals do not demonstrate particularly close genetic relationships to each other based on the phenotypic analysis of the population, the familial relationships between these individuals may be masked by the contribution of these individuals to the local gene pool and the continuation of their family lineages through time. This is one of the major difficulties of dealing with a cemetery population, which represents a long-term collection of a population's lineage, rather than a snapshot of the population in time. The likelihood of a complementary counter-stream of individuals migrating to the other location should also be considered. The results of this study also support the idea that fully sedentary and nomadic or semi-nomadic segments of the population cannot easily be separated from each other by using archaeological evidence alone. Furthermore, the commonly held assumption of a clear dichotomy between mobile and sedentary groups may be overly simplistic and inappropriate. These groups appear to have co-existed at İkiztepe, and although the exact nature of the separation between these population segments is unknown (i.e. within familial or household units or between them), it would appear that these groups were closely inter-related.

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Appendix One: Chemical Data

SKNo	Tissue Type	Tooth/ Bone Type	More Certain Sex	Less Certain Sex	UWB Age	YSE Age	d18O	SD	87Sr/86Sr	Error	Sr (ppm)	Rib Fluoride Conc.	Cranial Fluoride Conc.
ITSK251	Enamel	URM2	F	F	O	M	16.52		0.70863	0.00002	175.9		
ITSK266	Enamel	LLM2	U	F	Y	Y	17.23		0.70916	0.00002	192.3		0.414582313
ITSK268	Enamel	ULC	F	F	Y	M	15.96		0.71548	0.00002	115.7		0.347997122
ITSK270	Enamel	LLM3	F	F	M	M	16.49		0.70939	0.00002	232.9	0.128971735	
ITSK277	Enamel	ULM2	U	M	Y	Y	17.03		0.71074	0.00003	104.4		0.321899818
ITSK280	Enamel	ULC	F	F	Y	M	15.56	0.09	0.71026	0.00003	140.0		0.309449646
ITSK288	Enamel	LLM3	F	F	O	M	15.67	0.41	0.70854	0.00002	357.6		0.304887735
ITSK295	Enamel	LLM3	U	M	O	M	16.63		0.70989	0.00002	211.0		0.182820701
ITSK296	Enamel	LLM2	F	F	O	M	15.68	0.01	0.70827	0.00001	215.9		0.291579404
ITSK297	Enamel	ULM2	U	M	Y	Y	15.19		0.70951	0.00004	179.4		0.336458415
ITSK306	Enamel	LLM1	F	F	M	M	16.68	0.11	0.71245	0.00002	131.7		0.389507887
ITSK315	Enamel	URM3	U	M	O	M	16.65		0.70944	0.00002	205.1		
ITSK316	Enamel	ULM2	M	M	M	M	16.07		0.70793	0.00002	147.8		0.201263024
ITSK320	Enamel	LLM2	M	M	O	M	15.8		0.70951	0.00002	214.4		0.289047424
ITSK328	Enamel	URM3	M	M		M	15.81	0.06	0.71080	0.00003	105.1		0.405021833
ITSK329	Enamel	URM3	U	M	M	M	15.73		0.71037	0.00002	149.4		0.472754938
ITSK337	Enamel	LRM2	U	M	Y	Y	15.67		0.70784	0.00002	118.7		0.692933908
ITSK340	Enamel	LLM2	M	M	O	O	15.53		0.70783	0.00002	223.8		0.244942028
ITSK342	Enamel	LLM3	F	F	O	Y	15.99		0.70802	0.00004	252.2		0.398587864
ITSK348	Enamel	LRM1	U	M	Y	Y	15.61		0.70837	0.00002	61.4		0.798131108
ITSK358	Enamel	LLM3	F	F	M	M	15.89		0.70806	0.00002	142.7		0.493530757
ITSK364	Enamel	LLM3	M	M	M	M	15.2	0.27	0.70791	0.00005	175.6		
ITSK389	Enamel	LLM3	M	M	M	M	16.05		0.70810	0.00003	131.1		0.320415492
ITSK393	Enamel	URM2	F	F	Y	Y	15.96		0.70845	0.00002	163.9		0.387973108
ITSK395	Enamel	LLM2	M	M	M	M	16.99	0.06	0.70846	0.00002	170.5		0.721677032
ITSK413	Enamel	LLM3	M	M	M	Y	15.79		0.70777	0.00002	143.9		0.991989023
ITSK414	Enamel	URM3	M	M	O	Y	14.46		0.70811	0.00003	206.0		0.196191831
ITSK433(A)	Enamel	LLM3	U	M	O	Y	15.87		0.70768	0.00002	183.1		0.385391243

ITSK434	Enamel	LRM1	U	M	Y	Y	16.81	0.07	0.70784	0.00003	125.4		0.464109966
ITSK444	Enamel	LRP2	F	F	Y	Y	15.52	0.03	0.70770	0.00003	234.4		0.704199775
ITSK447	Enamel	LRM2	F	F	Y	Y	15.99		0.70789	0.00003	194.7		0.412450336
ITSK462	Enamel	LLM3	M	M	O	O	16.11		0.70876	0.00003	150.9		0.403666168
ITSK465	Enamel	LLM3	M	M	O	M	16.45		0.70935	0.00002	122.3		
ITSK467	Enamel	LLM2	F	F	O	Y	17.18		0.70912	0.00002	219.5		0.252985342
ITSK471	Enamel	LRM3	M	M	Y	Y	16.76		0.70784	0.00002	288.0		0.398587864
ITSK473	Enamel	LLM3	F	F	Y	M	16.71	0.1	0.70846	0.00003	275.4		0.291094336
ITSK494	Enamel	LLM3	F	F	O	M	15.83		0.70904	0.00002	152.6		0.371947913
ITSK512	Enamel	URM3	F	F	Y	M	16.53		0.70863	0.00004	147.8		0.72486642
ITSK545	Enamel	LRM2	M	M	Y	M	11.3	1	0.70884	0.00005	178.5		0.865911995
ITSK550	Enamel	LLM3	M	M	O	M	15.5		0.70896	0.00003	148.1		0.609183971
ITSK552	Enamel	LLM2	F	F	Y	Y	15.38		0.70863	0.00003	181.9		0.16976144
ITSK553	Enamel	LLM2	M	M	M	Y	16.15		0.71168	0.00002	118.6		
ITSK567	Enamel	LRM3	F	F	M	M	16.57		0.71153	0.00004	164.9		0.497398749
ITSK569	Enamel	LRM3	M	M	O	O	15.61		0.70933	0.00003	643.4		0.366510001
ITSK573	Enamel	ULP2	M	M	O	M	16.37		0.71520	0.00002	182.5		0.48329121
ITSK599	Enamel	ULM3		M	Y	Y	15.58		0.71047	0.00003	205.1	0.328316629	
ITSK602	Enamel	URP1	M	M		M	15.93		0.71306	0.00003	226.3	0.103027915	0.155121627
ITSK621	Enamel	LLM1	F	F	Y	M	16.77	0.02	0.71277	0.00003	118.2	0.217514374	
ITSK642	Enamel	URM3		F	U	Y	16.98		0.71239	0.00002	229.7	0.126160103	
ITSK643	Enamel	LRC	M	M	M	M			0.71161	0.00004	217.1	0.137914778	0.201062682
ITSK644	Enamel	LLM2	F	F	Y	Y	16.26	0.22	0.70775	0.00003	205.2	0.425282722	0.375991375
ITSK646	Enamel	LLM2	M	M	O	M	16.39		0.70808	0.00002	273.3	0.17741595	0.199685809
ITSK652	Enamel	LLM3		F	U	M	16.05		0.70777	0.00002	279.2	0.354542953	0.399679251
ITSK654	Enamel	LLM2		F	U	M	16.07		0.70774	0.00002	298.0	0.343969827	
ITSK664	Enamel	LLM1	F	F	Y	M	16.41		0.70796	0.00004	147.3	0.502061804	0.738355994
ITSK668	Enamel	LLM1	F	F	M	M	16.16		0.70918	0.00002	37.8		
ITSK675	Enamel	LLM2	M	M	M	M	16.56		0.70766	0.00002	156.6	0.365135543	
ITSK677	Enamel	LLM3	F	F	O	M	16.26	0.27	0.70781	0.00002	332.4	0.342128906	0.735533375
ITSK678	Enamel	UM3		F	U	M	16.4		0.70793	0.00002	200.4	0.267481966	
ITSK257	Enamel	UM1	F	F	Y	Y	15.99		0.70965	0.00005	209.6	0.366260007	
ITSK339	Enamel	LLM3	M	M	O	M	15.4		0.70860	0.00002	307.7	0.919569412	0.688197988
ITSK343	Enamel	URM2	U	U	M	M	17.46	0.13	0.70868	0.00002	140.9		
ITSK405	Enamel	LRM2	M	M	O	O	16.44		0.70774	0.00004	243.4	0.262918189	

ITSK477	Enamel	LLM3	F	F	O	M	16.27		0.70849	0.00002	233.5	0.270538407	
ITSK536/1	Enamel	LRM2	M	M	O	Y	15.4		0.70800	0.00003	152.2	0.312484383	
ITSK379	Enamel	LLM2	F	F	O	O	15.24		0.70792	0.00002	177.9	0.144874611	
ITSK519	Enamel	LRM2	M	M	O	M	16.46		0.70800	0.00002	149.6	0.38765924	
ITSK554	Enamel	ULM2	M	M	M	Y	15.31		0.70774	0.00002	264.4	0.279644075	
ITSK574	Enamel	LRM1	F	F	M	Y	16.73	0.08	0.70883	0.00004	152.8	0.211736262	
ITSK578	Enamel	LLM3	F	F	O	O	15.24		0.70780	0.00003	219.5	0.278950169	
ITSK580	Enamel	LLM3	F	F	O	Y	15.59		0.70815	0.00003	200.4	0.248657449	
ITSK581	Enamel	LLP2	F	F	O	M	15.9		0.70798	0.00007	144.4	0.325979477	
ITSK545	Bone	Rib	M	16.46			0.08	0.70767	0.00003	411.6		0.103027915	
ITSK550	Bone	Rib	M	15.67				0.70770	0.00003	323.0		0.217514374	
ITSK553	Bone	Rib	M	15.39				0.70768	0.00003	392.5		0.137914778	
ITSK569	Bone	Rib	M	15.86				0.70799	0.00003	335.6		0.354542953	
ITSK573	Bone	Rib	M	16.28				0.70773	0.00002	580.0		0.343969827	
ITSK599	Bone	Rib	M	15.8			0.07	0.70771	0.00003	397.0		0.267481966	
ITSK602	Bone	Rib	M	16.18				0.70780	0.00002	309.6		0.366260007	
ITSK646	Bone	Rib	M	16.52				0.70781	0.00002	254.5		0.312484383	
ITSK675	Bone	Rib	M	15.21				0.70776	0.00002	310.4		0.278950169	
ITSK268	Bone	Rib	F	16.07				0.70779	0.00005	387.1		0.128971735	
ITSK552	Bone	Rib	F	15.46				0.70784	0.00002	329.7		0.126160103	
ITSK567	Bone	Rib	F	15.99				0.70781	0.00003	316.7		0.199685809	
ITSK644	Bone	Rib	F	15.42				0.70774	0.00002	396.9		0.270538407	
ITSK652	Bone	Rib	F	15.76			0.33	0.70771	0.00002	490.5		0.144874611	
ITSK654	Bone	Rib	F	16.1			0.1	0.70777	0.00002	324.8		0.38765924	
ITSK664	Bone	Rib	F	15.91				0.70780	0.00002	397.8		0.279644075	
ITSK668	Bone	Rib	F	15.75				0.70773	0.00003	325.2		0.211736262	
ITSK677	Bone	Rib	F	15.7				0.70777	0.00002	335.4		0.248657449	
3872AP1	Animal	Enamel	-	16.2				0.70772	0.00002	144.4			
3961AP1	Animal	Enamel	-	15.46				0.70755	0.00002	152.5			
3624AP1.II	Animal	Enamel	-	12.61				0.70704	0.00002	262.3			
3874AP2	Animal	Enamel	-	16.2				0.70773	0.00002	180.2			
3961AP2	Animal	Enamel	-	16.01				0.70766	0.00002	299.2			
3801AP2	Animal	Enamel	-	15.7				0.70769	0.00002	237.6			
3903AP1	Animal	Enamel	-	15.59				0.70759	0.00003	265.5			
3961AP3	Animal	Enamel	-	14.61				0.70772	0.00003	247.0			

Appendix Two: Burial Data

SKNo	More Certain Sex	Less Certain Sex	UWB Age	YSE Age	X	Y	Elevation	Head Direction	Body Position	Total Grave Goods	Weapons	Jewellry	Tools	Pottery	Idols/ Amulets	Figurines
ITSK251	F	F	O	M	303.608	192.456	24.06	S	D	0	0	0	0	0	0	0
ITSK266	U	F	Y	Y	295.7	185.7	20.05	NW	D	2	0	2	1	0	0	0
ITSK268	F	F	Y	M	292.22	190.96	25.20	N	U	0	0	0	0	0	0	0
ITSK270	F	F	M	M	299.94	192.81	23.70	SE	R	2	1	0	0	1	0	0
ITSK277	U	M	Y	Y	299.21	181.15	25.33	S	D	0	0	0	0	0	0	0
ITSK280	F	F	Y	M	297.52	184.74	25.52	U	U	0	0	0	0	0	0	0
ITSK288	F	F	O	M	293.54	184.76	25.30	W	L	0	0	0	0	0	0	0
ITSK295	U	M	O	M	295.48	182.58	25.05	U	U	0	0	0	0	0	0	0
ITSK296	F	F	O	M	294.4	183.43	25.05	SE	D	2	1	0	0	0	0	0
ITSK297	U	M	Y	Y	295.15	183.07	25.18	SE	D	5	2	1	2	0	0	0
ITSK306	F	F	M	M	297.86	181.074	25.16	U	U	0	0	0	0	0	0	0
ITSK315	U	M	O	M	299.11	181.78	24.69	U	U	0	0	0	0	0	0	0
ITSK316	M	M	M	M	297.99	181.76	24.70	SE	D	2	2	0	0	0	0	0
ITSK320	M	M	O	M	296.72	181.78	24.68	SE	D	2	1	0	1	0	0	0
ITSK328	M	M		M	309.23	180.32	24.20	U	U	0	0	0	0	0	0	0
ITSK329	U	M	M	M	306.44	180.9	23.95	U	F	0	0	0	0	0	0	0
ITSK337	U	M	Y	Y	292.25	180.5	24.16	NW	D	4	3	1	0	0	0	0
ITSK340	M	M	O	O	296.81	182.04	23.97	S	D	2	1	1	0	0	0	0
ITSK342	F	F	O	Y	299.41	182.2	24.11	SE	D	0	0	0	0	0	0	0
ITSK348	U	M	Y	Y	299.31	191.34	23.90	S	R	0	0	0	0	0	0	0
ITSK358	F	F	M	M	303.96	183.79	23.60	U	U	0	0	0	0	0	0	0
ITSK364	M	M	M	M	294.47	181.32	23.87	SE	D	8	3	3	0	0	0	0
ITSK389	M	M	M	M	302.31	190.61	23.29	S	X	0	0	0	0	0	0	0
ITSK393	F	F	Y	Y	303.93	183.22	23.70	SE	D	0	0	0	0	0	0	0
ITSK395	M	M	M	M	301.03	183.43	23.67	SE	D	9	6	0	1	0	1	0
ITSK413	M	M	M	Y	301.01	182.8	23.45	S	D	7	5	2	0	0	0	0
ITSK414	M	M	O	Y	304.02	183.24	23.45	S	L	0	0	0	0	0	0	0
ITSK433(A)	U	M	O	Y	303.964	180.459	23.05	S	D	3	1	0	0	0	0	0

ITSK434	U	M	Y	Y	303.46	181.35	23.15	U	U	0	0	0	0	0	0	0
ITSK444	F	F	Y	Y	299.69	180.2	20.03	E	D	2	0	2	0	0	0	0
ITSK447	F	F	Y	Y	310.42	183.37	23.08	SE	D	2	2	0	0	0	0	0
ITSK462	M	M	O	O	304.82	183.27	22.72	SE	D	4	3	0	0	0	1	0
ITSK465	M	M	O	M	300.34	184.71	23.71	W	D	7	1	6	0	0	0	0
ITSK467	F	F	O	Y	302.6	181.16	22.34	W	D	5	3	2	0	0	0	0
ITSK471	M	M	Y	Y	297.19	184.43	23.12	NW	D	5	3	2	0	0	0	0
ITSK473	F	F	Y	M	297.59	181.91	22.87	NW	D	3	0	3	0	0	0	0
ITSK494	F	F	O	M	298.14	182.55	22.35	W	D	3	0	3	0	0	0	0
ITSK512	F	F	Y	M	299.29	179.12	24.66	U	U	0	0	0	0	0	0	0
ITSK545	M	M	Y	M	300.48	179.07	24.52	SE	D	1	0	0	0	0	1	0
ITSK550	M	M	O	M	308.11	178.99	23.79	SE	D	1	1	0	0	0	0	0
ITSK552	F	F	Y	Y	307.62	177.59	23.94	SE	D	3	3	0	0	0	0	0
ITSK553	M	M	M	Y	309.44	176.09	23.67	SE	D	1	1	0	0	0	0	0
ITSK567	F	F	M	M	311.02	177.07	23.82	E	D	1	1	0	0	0	0	0
ITSK569	M	M	O	O	304.5	178.86	23.62	SE	D	11	5	4	0	0	1	0
ITSK573	M	M	O	M	298.11	178.83	24.58	SE	D	6	5	0	0	0	0	0
ITSK599		M	Y	Y	310.4	182.27	21.65	NW	D	1	1	0	0	0	0	0
ITSK602	M	M		M	309.67	174.81	22.25	S	D	3	2	1	0	0	0	0
ITSK621	F	F	Y	M			24.30	U	U	1						
ITSK642		F	U	Y	295.154	195.5	25.15	U	U	0	0	0	0	0	0	0
ITSK643	M	M	M	M	295.17	196	24.45	W	L	1	0	0	1	0	0	0
ITSK644	F	F	Y	Y	306.97	199.95	22.80	S	D	0	0	0	0	0	0	0
ITSK646	M	M	O	M	305.54	199.76	22.45	S	L	6	0	6	0	0	0	0
ITSK652		F	U	M	306.72	200.2			U							
ITSK654		F	U	M	301.95	198.08			U							
ITSK664	F	F	Y	M	292.76	197.84	22.98	U	U	1	0	1	0	0	0	0
ITSK668	F	F	M	M	298.57	199.75	21.68	W	D	2	0	2	0	0	0	0
ITSK675	M	M	M	M	293.96	195.97	21.95	S	U	2	1	1	0	0	0	0
ITSK677	F	F	O	M	293.37	196.52	21.45	S	U	0	0	0	0	0	0	0
ITSK678		F	U	M	294.72	195.16			U							
ITSK257	F	F	Y	Y	303.98	192.93	23.95	U	U	0	0	0	0	0	0	0
ITSK339	M	M	O	M	290.5	182.29	24.00	S	D	9	5	4	0	0	0	0
ITSK343	U	U	M	M	302.46	192.51	23.78	S	L	0	0	0	0	0	0	0
ITSK405	M	M	O	O	302.81	180.75	23.57	S	D	1	1	0	0	0	0	0

ITSK477	F	F	O	M	300.61	178.85	25.18	SE	D	0	0	0	0	0	0	0
ITSK536/ 1	M	M	O	Y	307.38	176.72	24.16	SE	D	0	0	0	0	0	0	0
ITSK379	F	F	O	O	299.38	180.07	23.90	SE	D	7	4	1	2	0	0	0
ITSK519	M	M	O	M	289.02	176.15	25.34	NW	D	7	4	3	0	0	0	0
ITSK554	M	M	M	Y	301.94	178.42	23.98	SE	D	10	3	2	0	0	1	0
ITSK574	F	F	M	Y	297.14	177.82	24.45	W	D	12	2	7	0	1	0	0
ITSK578	F	F	O	O	295.26	179.13	24.15	W	D	11	1	7	1	0	0	0
ITSK580	F	F	O	Y	304.6	193.23	22.33	NW	D	12	2	8	0	0	0	0
ITSK581	F	F	O	M	305.14	193.02	22.12	W	D	8	3	7	0	1	0	0