TRADE, EXCHANGE, AND SOCIAL RELATIONSHIPS IN SOUTHEASTERN POLAND: X-RAY FLUORESCENCE AND MITOCHONDRIAL DNA ANALYSES OF NEOLITHIC SHEEP

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Table of Contents

List of Tables

List of Figures

List of Appendices

Abstract

Social and economic factors were involved in intensified sheep rearing in southeastern Poland during the later Neolithic, 3800-3700 BC. Sheep from the sites of Bronocice, Zawarża, and Niedżwiedż, were used to document the importation and crossbreeding in this region. Portable x-ray fluorescence (XRF) was used to measure elemental strontium concentrations in sheep dental enamel. Based on these data it was possible to distinguish local from non-local sheep. At Bronocice large scale sheep importation began around 3650 BC lasting until 2700 BC. Small settlements raised sheep in the region, occasionally acquiring new stock from Bronocice. Sheep were probably not raised at Bronocice. Instead Bronocice was interested in wool and thread produced by small herders for weaving.

Mitochondrial DNA (mtDNA) was sequenced from sheep dating to 3650-3100 BC revealing close genetic relationships between herds from the three settlements. The sheep from the outlying villages were more closely related to sheep from Bronocice than sheep at Bronocice were to each other. Sheep from outlying villages were descended from sheep imported to Bronocice.

This long term pattern confirms the existence of important social relationships between distinct local and non-local groups with Bronocice. Multiple levels of socioeconomic activities were revealed based on the XRF data revolving around the importation of sheep to Bronocice, the redistribution of sheep to smaller settlements, the staging of annual sheep market in late spring and the likely production of textiles for export. An annual cycle is proposed involving four distinct social categories: 'elites' at Bronocice responsible for managing the annual sheep market, long distance traders importing sheep once a year, local sheep herders who acquired new

stock from the traders and who harvested and spun wool for exchange, and weavers who required raw materials for making cloth. It is possible that weavers, whose cloth production depended on access to wool and thread, controlled or were involved with the importation and redistribution sheep to local herders and that they in turn exchanged wool and or thread.

Foreword

I am not a geneticist, mathematician, statistician, physicist or chemist; instead I am an archaeologist. As such, I am well practiced in the art of borrowing methods and ideas from other disciplines and adapting them for use in my research, a common practice in American archaeology. I do not pretend to be an expert in how analytical methods borrowed from other fields work though I have attempted to learn as much as possible in order to apply them properly. I feel confident that my research, the results and interpretations, all conducted under the guidance of specialists, are valid. The ideas born out my research which are proposed in this dissertation are possibilities not definites. I do not believe in absolutes, or that people and behaviors can be reduced to numbers or statistical probabilities, and furthermore I do not think that the data generated from my methods can be explained in simple economic or political models. Economic and political behaviors are the end products of social factors, often emotionally charged by inter-personal relations and ideology, factors that cannot be identified or quantified, and which will forever remain outside the reach of archaeology.

My research used portable x-ray fluorescence and mitochondrial DNA analyses to identify differences and commonalities in sheep recovered from three mid-late Neolithic sites Bronocice in southeastern Poland. These data served as proxies for examining social relationships within and between settlements in the Bronocice region as well as investigating economic behaviors involving trade and exchange of sheep.

The end results served to reveal patterns and trends in sheep management and to identify groups of people who were involved. Funnel Beaker and Funnel Beaker-Baden cultures are assumed to have been patrilineal-patrilocal, that they had tribal and territorial identities, and that involvement in trade and exchange networks was based on family ties and political alliances. Some of these ideas can be reasonably predicated on ethnographic and economic analogies drawn from the field of anthropology. Granted assumption is a fragile field upon which to play with data and examine best fit scenarios.

Ed Rutsch told me a long time ago that one of the roles of archaeology is to tell a good story. Here is my tale of Funnel Beaker and Funnel Beaker-Baden life in southeastern Poland from 3800 – 2700 BC.

Chapter 1

Why Sheep?

Small scale breeding populations require the periodic introduction of new stock in order to maintain healthy, vigorous herds and to balance sex ratios. The reason that sheep were selected for this study was simply because they had no wild progenitors in central Europe, unlike cattle and pig that had wild relatives which could be used to invigorate diminishing stock. The main objectives of this dissertation were to document changes in sheep rearing practices at the site of Bronocice from 3800-2700 BC by measuring strontium concentrations in dental enamel and to identify family relationships using mitochondrial DNA between that site and smaller settlements at Żawarża, and Niedźwiedź in order to understand why sheep intensification occurred during the latter half of the 4th millennium BC. In the course of this study decision-making practices were recognized and interactions between the three communities were documented. The results suggest that elite households controlled large scale trade as well as local exchange in livestock, that specialized pastoralists imported sheep to Bronocice on an annual basis, and that localized sheep rearing was an economic specialty of smaller communities in which Bronocice did not take part. Bronocice was a market town, a place in which trade and exchange occurred on a regular schedule. The pivotal role of elites at Bronocice resulted in an ever increasing market trade involving not only livestock but cloth and other goods as commodities.

The later Neolithic period in southeastern Poland began ca 3800 BC with the emergence of Funnel Beaker culture and lasted until ca 2700 BC when Corded Ware and Globular Amphora cultures began to dominate the landscape (Milisauskas 2011) (Table 1.1). In other parts of

Europe located to the south and southeast this time span was marked early on by cultures with more sophisticated technologies and which were socially more complex. Those cultures are assigned to the Copper and Early Bronze Ages and are characterized by a great florescence of cultural expressions (Harding 2011). The terms used to denote cultural ages based on archaeological data however add confusion to understanding social and economic relationships across settlements from different cultures that date to the same time. Depending on location, Mesolithic, Neolithic, Eneolithic, Copper Age and Bronze Age cultures existed at the same time and were connected by trade networks involving social interactions and negotiations that spanned from northern Europe into southwest Asia (Milisauskas 2011). Further complications arise when looking at the same cultural tradition across modern national boundaries in which different names are used to identify the same archaeological cultures. For these reasons this dissertation will not emphasize the term 'Neolithic' but will instead refer to specific date range except when referencing the work of others.

The 4th millennium BC was marked in central Europe by the introduction of new technologies, economic and social changes, as well as the expansion of trade and volume and range of market goods. Many consider this period to be a formative stage or early developmental period preceding the Bronze Age (Anthony 2007, Sherratt 1997, Whittle 2002). In my opinion however the economic, technological and social indicators that most archaeologists consider hallmarks of the Bronze Age were already well established by the second half of the 4th millennium BC in Central and Northern Europe. The changes that mark the Bronze Age are essentially greater elaboration of individuals, accumulations of personal wealth, embellishment of rituals, and expansion of elite power and control over others. The Bronze Age is the first great age of *men* and their dominion over women, the poor, the weak, ethnic minorities and subjugated peoples.

Analysis of faunal remains from the site of Bronocice clearly revealed that sheep rearing intensified around 3650 BC (Makowitz-Poliszot 2007, Milisauskas *et al* 2012, Pipes *et al* 2009). In conjunction, fiber and textile production artifacts also increased in frequencies in household deposits (Pipes *et al* 2014). Many central European studies have assumed that the co-occurrence of sheep intensification and large concentrations of fiber and textile artifacts is indicative of wool production (Kulczyzka-Leciejewiszowa 2002, Gumiński 1989, Neustupný and Neustupný 1961). Others, like Sherratt and Ryder, have argued that wool production did not begin in northern and central Europe until the Bronze Age, or start of the 3rd millennium BC, when larger wooly sheep were introduced from the Anatolian Plateau (Sherratt 1983, Ryder 1983).

This study originally focused on the possibility that sheep intensification resulted from successful breeding practices based in part on social relationships involving the exchange and cross-breeding of localized herds. It was predicated on the assumption that intensification was a consequence of the increased value of sheep due to an incipient wool production industry and woolen textile production for trade. After completion of the x-ray fluorescence analysis it was realized that sheep intensification was largely the result of livestock importation. While localized exchange and cross-breeding of sheep no doubt occurred and contributed to the observed increase, the surge was made possible primarily through imports.

X-ray fluorescence (XRF) and mitochondrial DNA (mtDNA) analyses of Funnel Beaker sheep samples from southeastern Poland documented patterns and variations among populations from the settlements of Bronocice, Żawarża, and Niedźwiedź. XRF analysis was used to examine elemental strontium found in sheep dental enamel, while mtDNA analysis focused on identifying degrees of genetic relatedness among sheep from these three closely spaced Funnel Beaker settlements. Together these data sets revealed aspects of social relationships and economic activities involving the trade, exchange and breeding of sheep in this region of Poland. XRF analysis investigated the importation of sheep to the Bronocice micro-region over its entire occupational sequence (3800-2700 BC), as well as the Funnel Beaker occupational phases at Żawarża and Niedżwiedż. Analysis of mtDNA indicated close genetic ties existed between the sheep herds from the smaller settlements and those at Bronocice. However, the sheep from Bronocice were less closely related to each other. Both types of analyses confirmed the role of Bronocice as a market town which served to acquire and redistribute sheep regionally. The identification of mobility patterns and sheep genetic relatedness afforded the opportunity to investigate animal husbandry practices, specifically breeding and the exchange of livestock, as well as to consider possible forms of social interaction between communities.

Around 3800 B.C. Funnel Beaker culture expanded into southeastern Poland. By 3650 BC Funnel Beaker groups were well established throughout the region (Milisauskas and Kruk 1984, 1989). This was a time of economic prosperity and peaceful relations. Settlements were widely dispersed throughout the area and unfortified. Around 3650 BC a few Funnel Beaker settlements shifted from an emphasis on cattle rearing to intensive sheep rearing as indicated by faunal assemblages that had higher than expected frequencies of sheep relative to cattle and pig, a pattern atypical of Funnel Beaker sites within the region (Table 1.2) (Glass 1991, Midgley 1992). In some instances sheep ratios relative to pig were higher, in other cases they were nearly as high. Signs of intensification within the Bronocice region were observed in previous analyses of faunal assemblages from Bronocice (Table 1.3) and other regional settlement sites such as

Żawarża and Niedźwiedź (Makowicz-Poliszot 2002, Milisauskas *et al* 2012, Kruk 1980, Krysiak 1950, 1952, Krysiak and Lasota 1971, Pipes *et al* 2009, Sych 1964).

Sheep intensification coincided not only with the growth of Bronocice in size, population, and appearance of specialists within the community, but also with an increase in fiber and textile production artifacts. Small settlements like Żawarża, and Niedźwiedź yielded large numbers of spindle whorls but few loom weights in comparison. At Bronocice, incipient wool production was indicated not only by signs of intensified sheep rearing but also by the recovery of large quantities of loom weights, spools and spindle whorls from houses (Pipes *et al* 2014) (Table 1.4). The number of households within the settlement involved in fiber and textile production grew over time. Evidence of sheep intensification is strongly correlated temporally with weaving. A developing wool industry would have required more wooly sheep. At Bronocice, this was accomplished by establishing a system for importing large numbers of sheep into the region around 3650 BC which were then redistributed to smaller settlements such as Żawarża, and Niedźwiedź.

A. Theoretical Orientation

Theoretical models serve as vehicles for examining data within specific frameworks. Archaeologists are constantly searching for ways to model archaeological data in order to gain new perspectives and insights. The historical development of archaeology has evolved through several major paradigms. Culture History essentially provided descriptive narrative and offered insights into the process cultural change through migration and diffusion, ideas which became unpopular later in the later twentieth century. To his credit, Childe made attempts to explain cultural transformations seen in the material record using theories of diffusion of ideas and population migrations (Childe 1936 1942). Processual archaeology sprang into existence in 1960s and was an explosive new way of looking at the archaeological record. Scientifically orientated, it offered new tools for modeling archaeological data and sparked the development of many new subfields such as zooarchaeology. Still, it considered archaeological data at too great a social level and so failed to acknowledge the role the individual in the past (Trigger 1989). Dissatisfaction with processual models and the lack of concern for individuals within systemic approaches gave rise to post-processual archaeological theories (Bintliff 1991, Johnson 1999). Post-processual archaeologies are hard to classify, however in general they share a common concern for looking at the archaeological record in a more intimate fashion.

Agency and practice theory are component parts of a larger theoretical framework involving history, time and social structure in which individuals and their actions matter. They are bottom up approaches to reconstructions of the past. They emerged from the post-modern world and reflect a concern with giving voice to people who fall outside of Main Street history. Archaeology and history have overlapping interests in past cultures, time and social change. Agency and structuration are complimentary elements for understanding social process and social reproduction. Many of the concepts used in practice theory and agency were influenced first by the writings of Braudel, a French 20th century historian and founder of the French Annales school of thought (Braudel 1995). The central components are time, historical process and action. Braudel wrote an expansive history on the Mediterranean world during the reign of Philip II. He attempted to manage history at different levels, different scales of time, and discussed the level of changes seen at each scale.

Agency and structuration, or practice theory, are complimentary in that they focus on individuals and groups of people. Agents and agentive actions are structured, even when they move outside the boundaries of socially acceptable limits. Not all action however is structured or guided by agents. Some structures emerge due to the conglomeration of social behaviors and actions. Agency is defined essentially as social actions of individuals or groups of individuals who both operate within a system and outside of normal boundaries in order to promote their agendas. Archaeologists disagree at times in defining agents and what constitutes the meaning of their actions; whether actors are aware of the consequences of their actions; whether their actions had an impact. However applying agency theory to archaeological considerations is a way of explaining internal social change (Brumfiel 2000). One of the greatest challenges for archaeologists is being able to isolate operators and the processes by which objectives are achieved. Structuration and practice theory attempt to recreate actions and to understand the social tensions and temporal elements framing them.

Archaeology is burdened by a sense of historical trajectory. Archaeologists have adopted Braudel's temporal scheme and have used them in discussing temporal variations and change. But by themselves they provide no explanation for the process of social change because often events unfold outside of the main framework of history and for which no obvious accumulation of change can be demonstrated. Bourdieu wrote extensively on practice, the daily actions of people within their environments (Bourdieu 1977). Habitus is a term he coined to convey the knowledge that agents have of the world in which they operate. He also positioned agents in the material world, moving through space and actively creating the past (Hodder and Hutson 2003). He emphasized the actions of agents as being informed about social norms and acting within existing power structures in attempting to maintain or transform them (Barrett 2001). Giddens went further than Bourdieu with his ideas. Giddens developed the theory of structuration. He believed that agents were knowledgeable about their actions and aware of their consequences.

Furthermore he said that there exists a recursive relationship between agents and structures, in which agents were affected by social structure while social structure also could be affected by the actions of agents (Giddens 1979). Giddens points to the unintended consequences of agentive acts as key events in understanding social changes.

History is seen as a flow of time in which cultural reproduction forms the backdrop. Agents cause a significant rupture in the fabric of time and the flow of cultural reproduction. The rupture at times is small resulting in little or no change. At other times the rupture is too great and the direction of cultural evolution or the ability for a culture to reproduce itself is permanently damaged (Sewell 2005). Sewell breaks with Giddens in stating that Structure only exists through social practice. Social reproduction then occurs through practice and becoming is, in a sense, eventful. From his theoretical perspective resources are the tools of power and form the basis for agentive action.

Agency theory has been around for a couple of decades at this point. Archaeologists have tried to operationalize the concept, to develop methods that could be used in identifying the presence of agents and observing the process by which they affected other people and social structure in the past. Identifying agents is difficult. Some researchers believe that true agents are individuals who step outside of history. From that point of view, only those individuals that can be seen are agents. Sewell however says if it a mistake to lump agency (action) and intentionality (free will). There is a tendency to look first for the groups we assume had some sense of solidarity: men, women, children, ethnic groups, third genders, ‘elites’ (usually men). But clearly within these categories people most likely did not feel a sense of solidarity. Solidarity issues arise from self-interest in response to something. As such, they tend to be short term support networks, the composition of which might include odd combinations of people.

Another difficulty in seeing agents and their actions has to do with degree of visible resolution. Some agents are very 'loud' while others are nearly silent. Not all agents push for change within the structure, some work to maintain structure in the face of impending, threatening change. Visibility and intentionality are easiest to see when looking at the data from a dominant group or class within a society. Less obvious are those who were oppressed, meek, or retiring. Yet all people have the potential to be agents. Another problem with applying agency theory and structuration is distinguishing between processes that are evolutionary, slow cumulative changes that eventually result in the appearance of a new technology or cultural expression, and those changes which result from the introduction of new cultural forms through innovation or adoption of new cultures.

Some archaeologists consider the results or the product of agentive change, as the proper logical focus of our work (Gavin 2001). The 'Event' is a product of social forces involving agents and a change is social structure. The 'event' observed in the archaeological record however has to be considered in terms of its actual construction. Events are thought of as a moment in time whereas they are most often the end of point of a series of social movements resulting in change. By the time a 'change point' is identified archaeologically, e.g. the Bronze Age, many smaller events have taken place leading up to an observable change. So the challenge for archaeology is to backtrack, to search for clues of smaller more subtle indicators that something was going on, either conflictive or cumulative. A good example is seen in the surge in sheep production that occurred in the Bronocice region around 3650 BC.

The event is a compression layer of social forces and actions that resulted in structural change. Within the field of Historic Archaeology many post-processual theoretical models have been successfully combined with Middle Range Theory applications in order to disentangle the clues for social change. While it is true that Historic Archaeologists benefit from access to historical records, most often those records pertain only to the head of the household. Consequently all others are silent, as they are generally throughout time and space. It is also true that for the historic period there is a vast wealth of material remains that increase the probability that agents will have left their mark in the archaeological record in some fashion. However, many past cultures have also left a wealth of material remains. The problem in my opinion with locating agents and agentive groups is the gross resolution of analyses conducted on many projects, generally reflecting a lack of interest in small variability and resulting in poor resolution. The overarching interest of archaeologists in identifying patterns of behavior has limited their ability to see agents of change. While patterning reveals continuity and shared cultural identity, variability is a key to identifying agents and events as well as documenting long term small scale or household level social relationships.

The archaeological record is problematical because it represents the compression and compaction of time and actions. Archaeologists find long spans of time and wide geographic spaces two elements that can be addressed most comfortably. However Barrett criticizes how archaeologists approach the archaeological record and interpret it uncritically. He sees a flaw in archaeological approaches because they equate the archaeological record with societal norms and forget that remains are generated by people not by societies. Many approaches condense all groups, factions and agents into one archaeological layer (Barrett 2001). Barrett emphasizes that even though the archaeological is geographically rich it retains but a sliver of former cultural expression from which archaeologists generalize about cultures over wide areas.

Hodder addressed the issue of materiality in a number of publications. He points out that artifacts and material remains have multiple embedded meanings and significance, and that social structures are seen at different scales of time by identifying continuity and change (Hodder 1987). He suggests that style and subtle variation should be carefully considered as expressions of distinct groups in the past (Hodder 1992). Stylistic changes and regional variation are reflected in settlements patterns, burials patterns and material remains accumulated over time and space. It is harder to see however the actions of an individual or group within a short period of time. Some researchers, such as Lucas Gavin (2001), believe that greater clarity can be achieved by reconsidering certain kinds of archaeological remains in terms of the "event". But even seeing the results of events can require longer spells of time than just a moment.

The AngloAmerican archaeological literature abounds with examples Agency applications. They are varied and informative and draw their strength from close examination of the variability seen in archaeological data. For example, William Engelbrecht examined decorations on Iroquois pottery from multiple sites at the RMSC. Women were the potters in Iroquois society. Social tensions increased between the Iroquois tribes with the advent of European trade goods into their territory. The formation of the League of Nations worked to solidify control over trade to the benefit of the five, later six, founding tribes and to the eradication of most other tribes. The Iroquois had a tradition of adoption which they practiced with many of these tribes. As a matrilineal culture men moved into their wives' villages as such the variability of pottery patterns should be low. However, Engelbrecht was able to correlate an increase in variability in pottery decorations with increasing tribal conflict and the adoption of other members of conquered tribes by the dominant groups (Engelbrecht 2005). The distinct decorations seen on vessels can be considered a form of agency, of resistance to the norms of the dominant group. In maintaining their decorative styles the women who produced these pots controlled their sense of identity.

Françoise Audouze recently presented a paper at the first Institute for European Mediterranean Archaeology (IEMA) conference at the University at Buffalo (April 2008) which focused on Eventful archaeology. She discussed the results of a variability study in lithic production and distribution at a Paleolithic workshop in France. In this study she was able to show that the workshop not only produced quality lithics by skilled flintknappers but that children had been apprenticed there as well as based on depressions created by long-term sitting, presence of lithic cores of varying quality and correlation between skillfully knapped lithics and quality cores and lesser quality cores and poorly knapped lithics. While this may not agentive in the sense of creating rupture to the system, it is a structural view of intentional cultural reproduction and daily practice. Recreating the steps involved in manufacturing a lithic tool is not enough. She was able to demonstrate a learning pathway followed by apprentices over a period of time whose skill level increased incrementally with experience. But like Engelbrecht it was the close recordation of variability that permitted her to understand the processes involved in that workshop.

While ceramic studies on Neolithic sites have been used to demonstrated cultural traditions and affiliations I have not seen any studies that look at the hand of the potter. The level of refinement, sophistication, and micro-variability in decorative styles has not been used to tie households, generations, or even micro-regions together. Yet it is precisely at this level that one reveals the presence of individuals in the past and can track their movements across space. It is at this level that one can determined if men or women were moving into settlements.

European archaeologists traditionally have focused on questions concerning cultural origins and development, subsistence practices, burial practices and broader questions concerning migration, diffusion of ideas and debating the question of local developments in domestication and technology as opposed to their adoption from other cultures. The theoretical developments in the United States and Great Britain of processualism and post-processualism have only received lukewarm acceptance. In some cases there have been angry responses from European archaeologists. In 1999 a hissing contest began between French and AngloAmerican archaeologists concerning the lack of acceptance in Europe of processual and post-processual models (Scarre 1999, Coudart 1999). The unwillingness of French archaeologists to adopt AngloAmerican theoretical perspectives has been equated with an assault on the theoretical integrity of continental archaeologists (Coudart 1999). While doing an internet search on this topic I discovered that Coudart expended a lot of energy at different venues for putting down AngloAmerican theoretical frameworks. She insisted that French archaeology had a long tradition of building on past ideas unlike AngloAmericans who enjoy tearing down the work of their predecessors. While it may be generally true that western continental European archaeologists have a more descriptive approach to analysis nonetheless they have moved into the realm of interpretation along with AngloAmerican archaeologists. The paper that Audouze gave at IEMA is an example of moving towards structuration (Audouze 2008).

Hodder's stated (1991) that most archaeologists in European countries would continue to reject post-processualism because it appears to lack scientific integrity is still true. At the time of his writing the Soviet block was crumbling into ruins and some eastern European archaeologists were still playing out nationalist agendas. I believe that increasing globalization will eventually result in major changes in approaches to archaeological theory in all of Europe and an adoption of many processual and post-processual ideas. Just as AngloAmerican archaeology continuously searches far afield for seed ideas the central European archaeology looks to the west. This dissertation considers the importance of both patterning and variability over the long view and seeks to identify key household agents who influenced the development of extensive trade and exchange within the Bronocice microregion.

The site of Bronocice, Poland was occupied for about 1200 years, an extremely long period of time during the Neolithic and unusual as most settlements were typically abandoned after a few generations. Two related cultural traditions form the primary occupational sequence at the site: Funnel Beaker and Funnel Beaker Baden. During that sequence of time many changes occurred at the site including spatial and population expansion, construction of public works, reduction in house size, appearance of craft specialists and neighborhoods, and signs of increasing social tensions. These changes are easily seen archaeologically based on artifact typologies and changing frequencies, evidence of architectural structures, unique distributions of features and burial data (Pipes *et al in press*).

There is currently no agreement about the origins of Funnel Beaker culture. Based on earliest dates associated with funnel shaped pots some believe this culture emerged in Scandinavia, northern Germany and northwestern Poland, spreading south into Austria, Slovakia, Czech Republic, southern Poland, northern Hungary, and southwest Ukraine (Milisauskas 2011). Their arguments are difficult to dismiss since no earlier or comparable dates have been found in the southern reaches of this culture. Others believe Funnel Beaker was a local development in the southern areas, late Polgár cultures being influenced by developments outside the region which blended with local traditions, including southeastern Poland (Neustupný 2006). They see influences, possibly ideological, bolstered by greater population movements due most likely to trade over a wide geographic area (Midgley 1992). This is based primarily on the distribution of Funnel Beaker pottery vessel shapes and decoration appearing throughout central Europe. The appearance of Baden like ceramics is also believed to represent local adoption of a pottery form by local people. The cultural sequence in this region is as follows: Funnel Beaker, Phase 1 3800-3700, Lublin-Volhynian, Phase 2 – 3700-3650 BC, Funnel Beaker, Phase 3-3650-3400 BC, Funnel Beaker, Phase 4-3400-3100 BC, Funnel Beaker-Baden Phase 5-3100-2900 BC, and Funnel Beaker-Baden, Phase 6-2900-2700 BC. (Milisauskas and Kruk 1989, 1984)

Regionally settlements tended to range in size from 2-5 hectares, most of which were smaller rather than larger. During the phase earliest Funnel Beaker phase Bronocice was just another undifferentiated settlement. The only difference worthy of note between this site and any other with the region was the subsequent occupation by Lublin-Volhynian people. Their occupation stands out in sharp contrast to the surrounding Funnel Beaker settlements in terms of the layout of the settlement, material culture and faunal deposits. Unlike those who were there before and those who came after them the Lublin-Volhynian fortified the settlement with a ditch and palisade. They relied more heavily on wild animals and brought with them knowledge of copper working (Kruk and Milisauskas 1985). Crucibles recovered from their pits show they had a more sophisticated technology than the local Funnel Beaker people. They planted their settlement on top of the Phase 1 occupation. Within fifty years they were gone. The area was then used as a cemetery by subsequent Funnel Beaker people and never built on again. The ditch may have also served as an enclosure for managing livestock but that remains to be determined. What is most interesting is after their departure the site was reoccupied by Funnel Beaker and from that time on grew in size and increasing social complexity.

There are two lines of evidence that strongly suggest a lack of social integration and cooperation between local Funnel Beaker groups of the time and Lublin-Volhynian. The first is the construction of the fortification ditch and palisade. This was not built immediately since the construction impacted earlier Lublin-Volhynian occupation pits. Second, their faunal remains show an ageing population of cattle and sheep and very few neonates or juveniles. There is a wider range of wild species represented in the deposits and greater frequencies of these species than found in Funnel Beaker deposits either before or after the Lublin-Volhynian occupation.

The point is that their presence and subsequent disappearance at Bronocice marked this place and that some cultural memory lingered of them for a very long time. Currently it is unknown what happened, whether their presence was positive or negative, whether they were admired or hated, accepted or rejected by local Funnel Beaker people. But the changes in occupation suggested by the archaeological evidence reveal that very soon after their departure things changed significantly at this site, whereas surrounding Funnel Beaker settlements remained small. In terms of this discussion it can be said that their presence was Eventful, that agents were involved, whose actions may still be visible.

Livestock management is fundamentally an economic practice predicated upon complex social relationships. The degree of success may be observed archaeologically and measured by herd size, livestock health, and mortality patterns as indicated by Neolithic faunal assemblages. A group's degree of success is greatly dependent upon understanding livestock nutritional needs, healthcare, and reproductive strategies, as well as upon social cooperation and interaction, all of which are necessary for successfully managing livestock. In order for any domesticated livestock to thrive they must rely on humans for food, water, shelter and care. That dependence brings with it an annual cycle in which human actions, past and present, can be predicted.

B. Wooly Sheep? – That is the Question

Benecke and others considered that that wool-bearing sheep were introduced during the Late Neolithic in Europe based on faunal assemblages showing increases in sheep relative to cattle, and shifting age at death profiles, in which adults formed the majority during the later phases of the Neolithic. These are also clear signs of livestock specialization (Benecke 1994, Bogucki 1988, Gregg 1988, Greenfield 1988 *et al*, Milisauskas and Kruk 1984, Sherratt 1983). Ryder believes that wool-bearing sheep were introduced during the Bronze Age (Ryder 1983) basing his opinion on a range of data consisting of 1) the presence of small undifferentiated sheep from Neolithic sites, 2) an examination of pictorial imagery (figurines, etchings, engravings and paintings of sheep and women producing textiles), 3) written records about wool-bearing sheep, and 4) an examination of fibers/ textiles from earlier periods (Ryder 1983, 1982, 1981a, 1981b).

Both opinions are probably correct to a certain extent. There are sheep assemblages from middle Neolithic sites in southeastern Poland, including Bronocice, Żawarża, and Ćmielów, that indicate specialized stockherding, possibly associated with dairy and wool production (Krysiak 1950, 1952, Makowicz-Poliszot 2002, Milisauskas and Kruk 1984, 1989, Vigne and Helmer 2007). Additional sources of archaeological data, such as fiber and weaving related artifacts, support the idea that wool production was happening during the mid 4th millennium BC. Nonetheless textile production on a scale large enough to controlled and managed at the state level, such as Ryder documented around 3000 BC in Uruk, clearly did not occur throughout central Europe. State level societies did not exist anywhere in Europe at that time (Milisauskas 2011). Archaeological finds in Scandinavia and other areas with good preservation such as bogs that have demonstrated the extensive use of wool fabrics in making cloths in later times (Barber 1991). It is apparent that all industries during the Neolithic in Europe began as household craft production.

Sherratt labeled the introduction of wool-bearing sheep and milk production as the Secondary Products Revolution (SPR) and tied it to the spread of horse riding people into central Europe from the area around the Black Sea (Sherratt 1983). Anthony and others have linked linguistic evidence to wool-bearing sheep (Anthony 2007, 1986, Sherratt 1997, 1983, 1981). The concept of the SPR has been scrutinized in the last ten years or so. Researchers have isolated components and reassessed them in light of more sophisticated archaeological data. As a result, the concept is losing credibility (Greenfield 2014).

Fat residue tests on ceramic pots from Hungary, Britain and elsewhere have found traces of milk showing that dairy production was a common practice throughout Europe by the early Neolithic (Bartosiewicz 2005, Bogucki 1982, Copley *et al* 2003, Craig et 2005, Craig *et al* 2003, Vigne and Helmer 2007). Examinations of cattle skeletal remains have been shown to exhibit pathologies associated with physical exertion related to plowing, and plow marks have been identified in ancient fields suggesting that plowing was already in place by the middle Neolithic in parts of central and eastern Europe (Milisauskas and Kruk 1991, Johannsen 2005, Fabiš 2005). And last, age at death profiles, increased frequencies of sheep, large numbers of fiber related artifacts, and traces of wool fibers have begun to suggest that wool-bearing sheep and textile production may been present earlier than 3000 BC in Europe (Shishlina 2003, Pipes *et al* 2014).

The idea that wool-bearing sheep were absent in central Europe prior to the Bronze Age was solidified by the extensive writings of Ryder, stressing the lack of physical evidence earlier in Europe for wool-bearing sheep (1983, 1982, 1981a, 1981b). Ryder conducted an exhaustive survey into the history and biology of sheep and their varied relationships with humans. He concluded there was no evidence to support the presence of wool-bearing sheep prior to 3000 BC. Unfortunately the reification of the 'non-wool-bearing' sheep concept has limited the interpretation of sheep faunal assemblages and obscured aspects of Neolithic household economics. This review of the basis for the belief that only non-wool bearing sheep existed in central Europe until late in the Neolithic examines evidence that suggests otherwise, and considers the implications for women, their relationship to sheep and the household production of cloth.

The evidence against wool-bearing sheep is circumstantial, based mainly on negative evidence and assumption. There are three types of data upon which the argument rests: the small stature of Neolithic sheep, suggesting undifferentiated breeds and primitive traits such as hair; the significance of 'meat on the hoof' age-at- death profiles; and the lack of wool fiber or textile remains. Ryder and others point to the small size of domesticated sheep and their descendants imported to Europe by Linear Pottery groups Neolithic sites as evidence of primitive, undifferentiated sheep (Ryder 1983, Glass 1991, Gregg 1988, Greenfield 2005). There were no wild progenitors of sheep or goats in Europe by the time Linear Pottery people started their migrations. This is important because small flocks can quickly die out due to factors relating directly to breeding and reproductive issues, a few of which include insufficient males or females, genetic problems associated with in-breeding, infertility, and high infant mortality rates. Successful maintenance of small flocks therefore would have been dependent on social relationships between groups of people throughout the Neolithic. Small herds or flocks would have necessitated breeding relationships with surrounding settlements and probably a continued importation of new livestock (Lacy 1997).

The genetic evolution of sheep involving the reduction of kemps, the increase in wool, and the loss of molt, permanently altered its relationship to humans. Today there are over 1600 sheep breeds with extremely varied quality, texture, length and color of their coats (Maddox and

Cockett 2007). Genetic studies on goats from the south of France and Italy indicate that Neolithic samples exhibit great genetic diversity said to reflect a constant influx of new breed stock (Fernández *et al* 2006, MacHugh and Bradley 2001). Although the same type of data is not yet available for sheep, the results of future studies will most likely be similar. There are sheep genetic studies however on the origins of sheep which show the existence of multiple ancestral lines (Hiendleder *et al* 2002). A recent genetic study indicates that there were definitely two ancestral lines, possibly three, based on y-haplotype markers (Meadows *et al* 2006). This suggests the possibility that sheep introduced into Europe by Linear Pottery people and by subsequent migrations were already composed of different breeds in the early Neolithic. Faunal analysts measure skeletal elements to look at size variation among breeding populations by which they can detect the presence of different breeds. When regression analyses have been done size differentiations have been interpreted as sex-related and regionally specific as opposed to reflecting potential breed differences (Higham 1968, Davis 1987, 1984, Redding 1984).

In 1973 Payne proposed three herding models that became the foundation for the interpretation of sheep and goat faunal assemblages ever since (Payne 1973). The models provide a method for estimating age at death, sex ratios, and reconstructing kill-off patterns in sheep and goats. Kill-off patterns are assumed to reflect decisions influenced by social factors including the value of an animal at death, the stock, the environment, and the time of year. Slaughter age is linked to the investment of effort by the farmer and the value of the return product.

Model A addresses meat production. In this model males are killed as soon as they reach maximum weight, essentially at the end of the juvenile period. Some females are kept for replacement of old individuals and for increasing the herd if desired. Model B centers on milk production. In this model lambs are eliminated as soon as possible in order to eliminate competition over milk. Model C centers on wool production. In this case adults are the main economic focus and breeding is limited to the replacement of individuals and increase of the herd. Armed with these three possibilities researchers applied the ABC modeling method and labeled sheep assemblages accordingly.

While the model is affective for examining distinct age at death patterns it fails to account for biological issues as well as other social factors that can potentially impact kill-off patterns. The most important biological factor is that sheep have very high infant mortality rates even in modern breeding populations often reaching fifty percent annually (Payne 1973). Ethnographic data as well as archaeological data indicates that these animals were consumed by humans. There is no way to determine if high frequencies of immature sheep represent natural death or deliberate kill-offs. It is also difficult to distinguish males from females most of the time because of the fragmented nature of faunal assemblages. When horned breeds are present mature males can be distinguished from females (either because females are hornless or based on size when both sexes have horns). Also, if sheep burials are present size can be used at times to distinguish sex.

Ryder clearly stated that ancestral sheep have always had an under-layer of wool (Ryder 1983:16). The development of the fleece involved selecting for a reduction of the outer hairs, known as kemps, an increase in the length of wool hairs, color, and elimination of the annual molt. The essential point of contention actually centers on the amount of wool Neolithic sheep could produce since weaving requires large amounts of thread. The poor preservation of fibers made it difficult to discuss whether or not wool thread and fabrics ever existed. Archaeologically recovered fibers and textiles from European Neolithic sites examined by Ryder have all turned out to be flax (Barber 1991, Ryder 1983). However, identification of degraded fibers is difficult, especially when they are carbonized and light microscopy is used (Good 2001). A simple argument can be made against Ryder's assumption that not finding them is the same as not having existed. People in the Neolithic kept domesticated mammals and ample evidence shows that they slaughtered them and in doing so removed their pelts which were used in a variety of ways. To date, not a single hair from any of these animals has been recovered, an indication that preservation is a major factor that needs consideration. The very circumstances that ensure the preservation of flax cause the destruction of wool and vice versa. Studies have shown that by the Bronze Age the number of archaeological textile remains rises significantly. This is equated with an increase in production and exchange of textiles throughout Europe, the Mediterranean, and southwest Asia (Good 2001). But survival rates may also be due to changes in burial context favoring preservation. Currently the oldest textile remains in Europe come from the site of Novosvobodnaya in the Caucasus associated with the N. Caucasus Majkop culture (3700-3200 BC). They were recovered from a kurgan grave and consist of wool, flax and cotton-like fibers twisted together and woven on tablet or disc.

C. Evidence in Support of Wool-bearing Sheep

Demonstrating the presence of wool-bearing sheep archaeologically is difficult. However, indirect lines of evidence used in complementary fashion may suggest their presence. I do believe that only through the examination of genetic markers that will wool-bearing breeds be definitively recognized (Arranz *et al* 1998, Buchannan *et al* 1994).

The site of Bronocice, located in southeastern Poland, provides primary data arguing for the presence of wool-bearing sheep beginning in the middle Neolithic. A large faunal assemblage was recovered from multiple phases of occupation (3800-2700 BC) that included significant sheep and goat components. During the first two phases of occupation sheep and goat were infrequent. However by Phases 3 (3650- 3400 BC) and 4 (3400 – 3100 BC) sheep increased significantly and were characterized by a preponderance of adults and high ratios of sheep to goat (20:1). Settlement size human population density increased considerably from Phase 3 (3650- 3400 BC) to Phase 5 (33100 – 2900 BC). By Phase 5 the settlement was occupied by Funnel Beaker Baden people and a new emphasis on cattle rearing dominated animal husbandry practices.

In southeastern Poland most faunal assemblages from Funnel Beaker and Funnel Beaker Baden sites contain a ranked order of domesticated mammals in which cattle predominate followed secondly by pigs, third by sheep and last by goat. At three sites in southeastern Poland sheep are in second rank position: including Bronocice, Żawarża, and Niedźwiedź (Milisauskas and Kruk 1984, 1989, Makowicz-Poliszot 2002, Krysiak 1950, 1952). Bronocice in particular stands because it was occupied for 1200 years and sheep remained in second position throughout that time. This unusual pattern may in part be due a cultural memory retained from the original migration into the area by Linear Pottery people, or it may be due do something relating to the value of the sheep raised in that area.

There are three significant lines of faunal evidence suggesting the presence of wool-bearing sheep at Bronocice. First, there was a noticeable increase in the size of sheep herds during the Middle Neolithic. In Phase 3 there was marked increase in the frequency of sheep relative to cattle (31% to 41%) that remains high through Phase 4 (27% to 47%) after which they decrease. The change by Phase 5 is a reflection of increasing emphasis on cattle rearing by the Funnel Beaker Baden. Second, there was an increased presence of adult sheep during Phases 3 and 4. Adults constituted 66 % in Phase 3 and 84 % in Phase 4, whereas there was significant increase in juveniles during Phase 5 (68%). These age-at-death profiles indicate potential changes in animal husbandry practices. The high frequency of juveniles from Phase 5 is associated with ritual activities, signaled by a high repetition of specific body parts (Pipes 2014). Third, some evidence suggests the presence of a new breed of hornless sheep during Phase 5, prior to which sheep were horned. Other archaeological data is available that lends support to the presence of wool-production at Bronocice. A summary of spindle whorls and loom weights at Bronocice will provide a frame of reference.

Four factors are relevant to understanding spinning and weaving at Bronocice. First, there were different sizes and shapes of spindles whorls present throughout all phases. These differences signal the manufacture of different threads and possibly the presence of women from different places. During Funnel Beaker Phase 1 (3800-3700 BC) a fair number of spindle whorls were recovered from eight pits. The settlement was small, as was the population, and sheep were already second to cattle. Only two pits contained loom weights suggesting that the vertical loom was a rare tool and was probably shared across households. Second, loom weights exist for all phases except Phase 2 and are also differentiated by size and shape. These signal difference in the manufacture of cloth of varying widths, weaves and the use of different threads. Phase 2 was a short term occupation by an outside group from the east who disappeared after fifty years (Kruk and Milisauskas 1985). Their deposits contained spindle whorls but no loom weights indicating the use of ground looms or tablets for weaving. Interestingly, during their occupation sheep represented 42 % of the domesticated mammal assemblage relative to cattle, higher than any other phase. Possibly they introduced a wool-bearing breed of sheep to the region. Third, while there is overlap in spindle whorl and loom weight distributions, the former are common in pits from Phases 3 – 6, whereas the loom weights are not. The two artifact types represent two distinct technologies and involve different levels of skill and time. Last, the number of pits containing loom weights increased greatly from Phase 3 to Phase 5, declining only slight in Phase 6, showing a continued emphasis on cloth production. Phase 6 is worth noting because by then population declined by 75 % cloth production had not.

It is clear that a specialized form of specialized animal husbandry practice appeared at Bronocice though the meaning is still subject to debate. Economically the presence of a wool-bearing breed has social implications for women involving gendered patterns of livestock ownership and modes of household production. Ethnographic studies often link women and sheep in horticultural societies. Spinning and weaving are also associated with women's tasks. Thread production was clearly important within households at Bronocice throughout all periods as shown by a wide distribution of spindle whorls in pits. Most likely women and girls helped with this task. The limited distribution of loom weights indicates that weaving was restricted. Weaving involves greater skill than spinning thread so it is likely there were fewer weavers. It may even be that there fewer weavers than households. The advantage in switching from flax to wool is the reduction in time involved in making thread. Processing flax for thread production involves many complicated and time consuming steps, whereas wool is quicker to prepare for spinning (Barber 1991). In Mesopotamia, McCorriston correlated the loss of the women's social position and power with the shift in linen production to wool textiles (McCorriston 1997). Written records from Uruk show that the production of wool in workshops was state controlled. Women lost the ability to control the production and distribution of cloth because they could no longer directly access the resources used to make linen.

The large numbers of sheep at Bronocice would probably have been herded separately from cattle. Increasingly from Phase 3 -6 the environment changed from forested to open parkland. If wool-bearing sheep are not watched they quickly wool volume to briars. Herding sheep may have been a gendered task, possibly for children while wool plucking might have been done by all. Female ownership of small livestock, and control over cloth production are considered forms of economic power in past small scale agricultural communities. There are two factors, documented ethnographically and historically through historical records and imagery affecting loss of power and control over commodities by women (Barber 1991). Holden and Mace did a linguistic analysis of Bantu languages, social structure and cattle. They showed a correlation between existing societies and showed a loss of matrilineality in those that became cattle specialists (Holden and Mace 2003). Women in patrilineal societies are outsiders and must form alliances with other women to achieve control and power. Possibly sheep at Bronocice were owned or managed by women who controlled cloth production during the Middle Neolithic. In Phases 5 and 6 the economic emphasis on cattle rearing and the development of elites may have impacted women's control over livestock and cloth production. By Phase 6 there was no decrease in cloth production though the population declined and cattle-rearing accelerated. Perhaps by Phase 6 Bronocice women had also lost control over cloth production and it had become a commodity of exchange controlled by men.

D. Modeling Trade and Exchange - Mobility Patterns and Degree of Genetic Relatedness

During the mid 4th millennium BC in southeastern Poland central place settlements such as Bronocice obtained sheep from outside areas through long distance trade while smaller agropastoral communities obtained sheep through exchange with central places. Exchange *involved social relationships based on cultural identity and social ties such as marriage and partnerships while trade involved social relationships based on the transfer of valued goods, materials and livestock by elites with specialized pastoralists.*

Previous faunal studies documented intensified sheep rearing occurred at Bronocice, Niedżwiedż, and Żawarża during the late-middle Neolithic (Burchard 1977, Makowicz-Poliszot 2002, Milisauskas *et al* 2012, Pipes *et al* 2009). Sheep intensification is in part a measure of reproductive success. Genetic health was in part accomplished by crossbreeding herds and livestock exchange. Social practices involved in livestock breeding can be modeled using ethnographic and archaeological studies of small scale subsistence farmers and pastoralists whose economic practices are often structured around kinship ties at the household level within and across settlements (Akeret and Rentzel 2001, Arbuckle 2006, Bender 1978, Bogaard 2004, Bogucki 1988, Blanton 1994, Craig *et al* 2003, Craig *et al* 2005, Dehlon *et al* 2008, Ebersbach 1999, Glass 1991, Gregg 1988, Halstead 1996, 2006, Hendon 1996, Higham 1969a, Mainland 2007, Marciniak 2005, Marti-Grädel *et al* 2004, McPeak and Doss 2006, Midgley 1992, Payne 1973, Rowley-Conwy 2005, Ryder 1983, Sherratt 1997, Sieff 1997, Spector 1991, Steinmann 1998, Turner 1999, Valamoti 2007, Wangui 2003).

The three sites selected for inclusion are closely spaced and existed during a period of time when low level hierarchies were forming. Archaeological investigations at Bronocice revealed that this settlement became a central place around 3650 BC and that it dominated the region economically and possibly politically (Milisauskas and Kruk 1984). Smaller settlements were integrated within its sphere of influence and interacted with it economically and socially. It is likely that these agropastoral groups raised sheep for wool and provided with raw materials for spinning fibers as well as spun thread. Households as Bronocice in turn wove woolen textiles which were an important economic commodity.

People, past and present, create and maintain social relationships that are often based on access to goods, mates, services, ideas and technologies. While forms of trade and exchange can range from simple to extremely complex and occur between local and non-local groups, all forms are similar in that the act of swapping creates a relationship between the parties. Economic theory identifies increasingly complex levels of exchange and trade that are characterized by the value and distance over which commodities are swapped and differentiated social roles of the players involved.

Zvelebil applied economic theory in a consideration of the role exchange as a basis for many social relationships during the Neolithic in the Baltic Sea region. Each level was organized at along different social lines and served a range of goals including mate exchange, reproduction and spread of ideas and technology (Zvelebil 2005). At the regional level exchange linked communities and happened at regular intervals. He suggests that it was reciprocal in nature, occurred among kinfolk, and involving informal exchange of local commodities. At the interregional level fictive kin or real groups exchanged materials of a practical nature and that in some cases it may have involved direct procurement. The third level of exchange involved long distance movement of exotic goods and was controlled by elites and specialized traders. The proposition is predicated on economic theory

Ethnographic studies show that livestock often form the basis of gifting and trading between groups and households that are related through a range of social mechanisms including kinship ties, political affiliation and business ties. Demonstrating genetic ties across herds from the three sites can serve as a proxy for human social ties between these communities.

I) Hypothesis 1

The surge in sheep frequencies beginning in 3650 BC in southeastern Poland resulted from stock-building through the importation of sheep. Variability and patterning seen in elemental strontium of sheep dental enamel can be used to segregate livestock into groups of local and non-local animals. The presence of high frequencies of non-local individuals within an assemblage represents stock-building made possible by importing sheep through long distance trade.

Sheep were present in higher than expected frequencies in faunal assemblages from some of the Funnel Beaker sites located in the Bronocice micro-region beginning around 3650 B.C. X-ray Fluorescence was used to measure Strontium levels in dental enamel in order to discriminate between local and non-local individuals within selected assemblages and to address the question of animal mobility. X-ray Fluorescence (XRF) technology can be used to measure Strontium levels in dental enamel. Strontium signatures in herbivores are dependent on the geological substrates of pasturelands. Growing plants absorb Strontium through the root system that is then ingested by sheep during grazing. Depending on the age of geological substrates Strontium concentrations vary (Balasse and Ambrose 2002). Strontium concentrations are deposited in bone and teeth differentially. Strontium is permanently deposited in teeth during formation replacing calcium whereas in bone strontium is continuously replaced due to remodeling. After deposition in the ground the porous nature of bone increases the likelihood of groundwater contamination. The dense nature of dental enamel reduces that possibility. For that reason this study was restricted to testing teeth and not bone. Strontium levels may vary within a dental row depending on the physical location during the time a tooth was erupting. Though the three selected sites were situated within the same geographical zone and located on the similar substrates express low variability in strontium levels. Animals introduced from outside the region will show very distinct strontium concentrations.

II.) Hypothesis 2

Close genetic ties indicate closely related sheep between communities. Sheep found in small Neolithic communities will tend to be more closely related genetically to those from at the closest central place whereas sheep found in central places will be less closely related genetically because these settlements were depots for imported animals.

At Funnel Beaker sites in southeastern Poland faunal assemblages with high frequencies of sheep relative to cattle and pigs recovered from closely spaced settlements are composed of maternally related individuals, some of which represent livestock transfers between communities. Maternally related sheep can be detected using mtDNA analysis to identify close genetic relationships.

Mitochondrial DNA (mtDNA) analysis can detect close genetic relatedness among individuals within and across populations (Budowle *et al* 2005, Hiendleder *et al* 1998). Hypervariable regions of the D-loop of the mtDNA can be used to identify maternal relatedness among individuals and between groups. Within the D-loop, base pairs of nucleotides may have substitutions which reveal 1) the presence of different maternal lines within a group and 2) identify related individuals. Currently, no ancient DNA studies have focused on small scale breeding practices. Instead, genetic studies have focused on broader issues of genetic relatedness such as the origins and processes of domestication, the introgression of genetic diversity, and the contribution of wild progenitors in domesticated cattle and pigs (Beja-Pereira *et al* 2006, Guo *et al* 2005 Hiendleder *et al* 2002, Larson *et al* 2007, Meadows *et al* 2005). These studies provide important information concerning distributions and genetic compositions of modern domesticated animals in parts of the world, but contribute little to understanding the social mechanisms by which humans managed livestock breeding or maintained the genetic health of herds (Lacy 1997). Identifying close genetic relatedness in small breeding population provides a way to observe crossbreeding between households and regional communities (Budowle *et al* 2005, MacHugh *et al* 1999, MacHugh *et al* 2001).

Table 1.1 Generalized chronology of archaeological cultures in the Bronocice region located in southeastern Poland (after Milisauskas 2011).

Time Span	Archaeological Culture	Regional Groups Present	Trading Partners
2700-2500 BC	Corded Ware		
3100-2700 BC	Funnel Beaker-Baden	Globular Amphora, Corded Ware	Bodrogkeresztúr, Tripolye, Baden, Michelsberg
3800-3100 BC	Funnel Beaker	Malice, Baalberg	Triploye, Boleráz (Baden)
4200-3800 BC	Lengyel-Polgár	Lublin-Volhynian	TiszaPolgár, Triploye
4700-4200 BC	Stroke Ornamented Pottery		Tisza
5500-4700 BC	Linear Pottery		Bükk

Table 1.2. Faunal assemblages from sites in southeastern Poland, by Number of Identified Specimens (NISP) and Relative Percent (Rel%). The phase of occupation comparable to those at Bronocice and the site distance from Bronocice is indicated.

Species	Gródek Nadbużny[1] Phase 1,3 260 km		Zawichost-Podgórze[2] Phase 3 120 km		Kamień Łukawski[3] Phase 3 120 km		Żawarża[4] Phase 3 12 km		Niedźwiedź[5] Phase 4 25 km		Ćmielów[6] Phase 4 100 km		Donosy[7] Phases 3, 4		Donatkowice[8] Phase 4	
	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%
Sheep/Goat	252	.13	251	.16	403	.14	406	.22	428*	.18	276	.115	309	.22	12	.09
Cattle	1265	.64	1017	.64	1676	.59	1193	.67	1421	.61	1578	.65	869	.65	120	.87
Pig	453	.23	323	.20	582	.21	194	.11	495	.21	566	.235	173	.13	5	.04
TOTAL NISP	1970	1.00	1591	1.00	2661	1.00	1793	1.00	2344	1.00	2420	1.00	1342	1.00	137	1.00

[1]Krysiak 1956, [2]Krysiak 1966, [3]Krysiak and Lasota 1971, [4,7,8] Makowicz-Poliszot 2002, [5]Kruk 1980, [6]Krysiak 1950, 1952
*Greater MNI than Pig.

Table 1.3. Relative Frequencies (Rel. %) of sheep, cattle and pig from Bronocice by Phase, Minimum Number of Individuals (MNI).

Species	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		Phase 6	
	3800-3700 BC		3700-3650 BC		3650-3400 BC		3400-3100 BC		3100-2900 BC		2900-2700 BC	
	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%
Sheep (*Ovis aries*)	26	.25	22	.26	41	.31	68	.26	108	.26	31	.21
Cattle (*Bos taurus*)	53	.52	46	.54	55	.42	137	.53	203	.50	74	.50
Pig (*Sus domesticus*)	24	.23	17	.20	34	.27	52	.21	98	.24	42	.29
TOTAL MNI	103	1.00	85	1.00	130	1.00	257	1.00	408	1.00	147	1.00

Table 1.4. Number and relative frequency of fiber and textile production artifacts from Bronocice by phase. Data for Phase 2 is unavailable.

Site	Phase	Spindle Whorls		Loom Weights		Spools		Total Assemblage	
		#	%	#	%	#	%	#	%
Bronocice	1	9	.82	1	.06	1	.06	11	1.00
Bronocice	3	24	.45	19	.36	10	.19	53	1.00
Bronocice	4	80	.45	78	.45	17	.10	175	1.00
Bronocice	5	115	.58	57	.30	27	.14	199	1.00
Bronocice	6	75	.45	86	.51	7	.04	168	1.00
Żawarża	3	22	.88	3	.12	-	-	25	1.00
Niedźwiedź	4	50	.96	2	.04	-	-	52	1.00

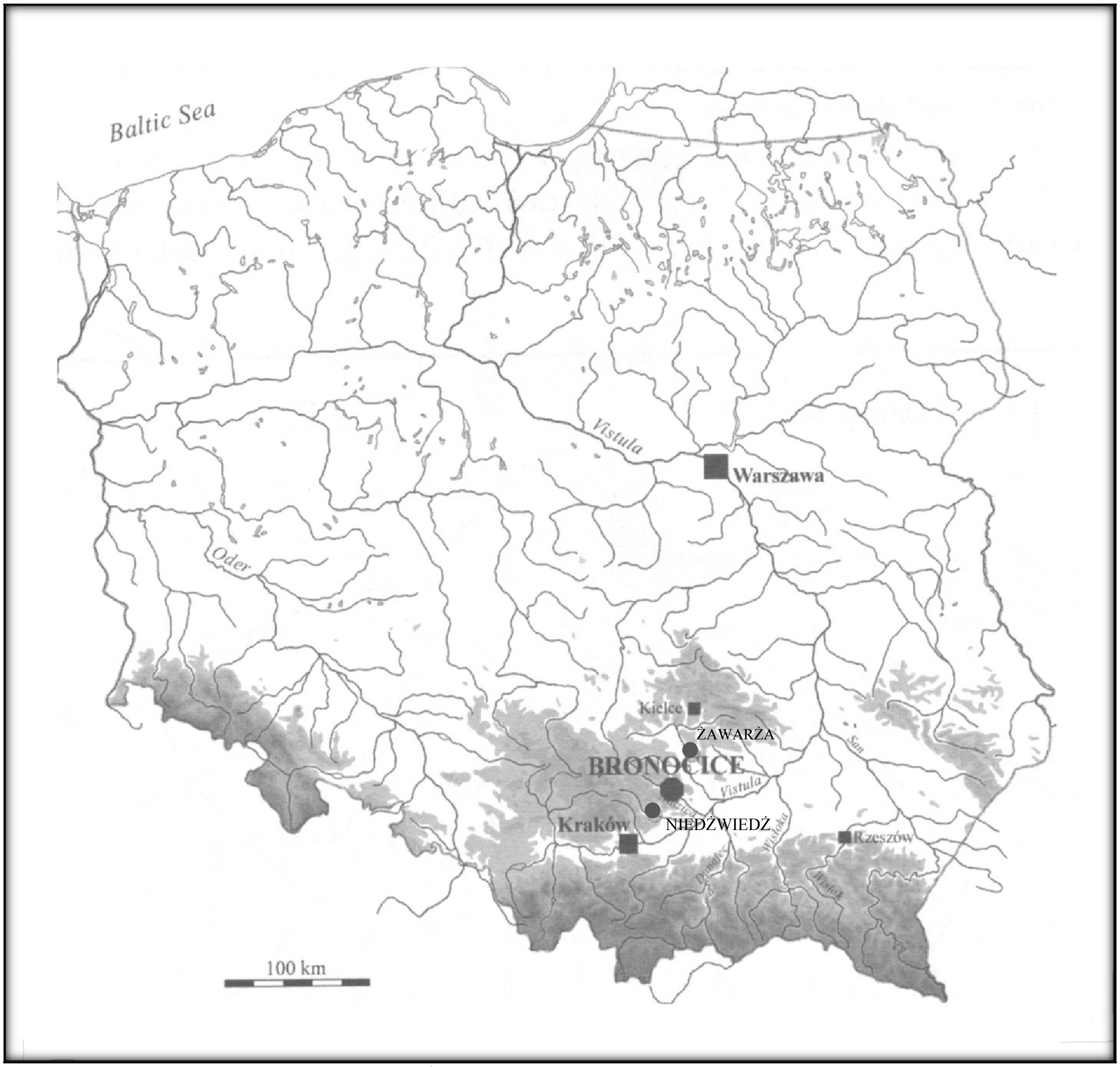


Figure 1.1. Locations of Bronocice, Żawarża and Niedżwiedż in southeastern Poland.

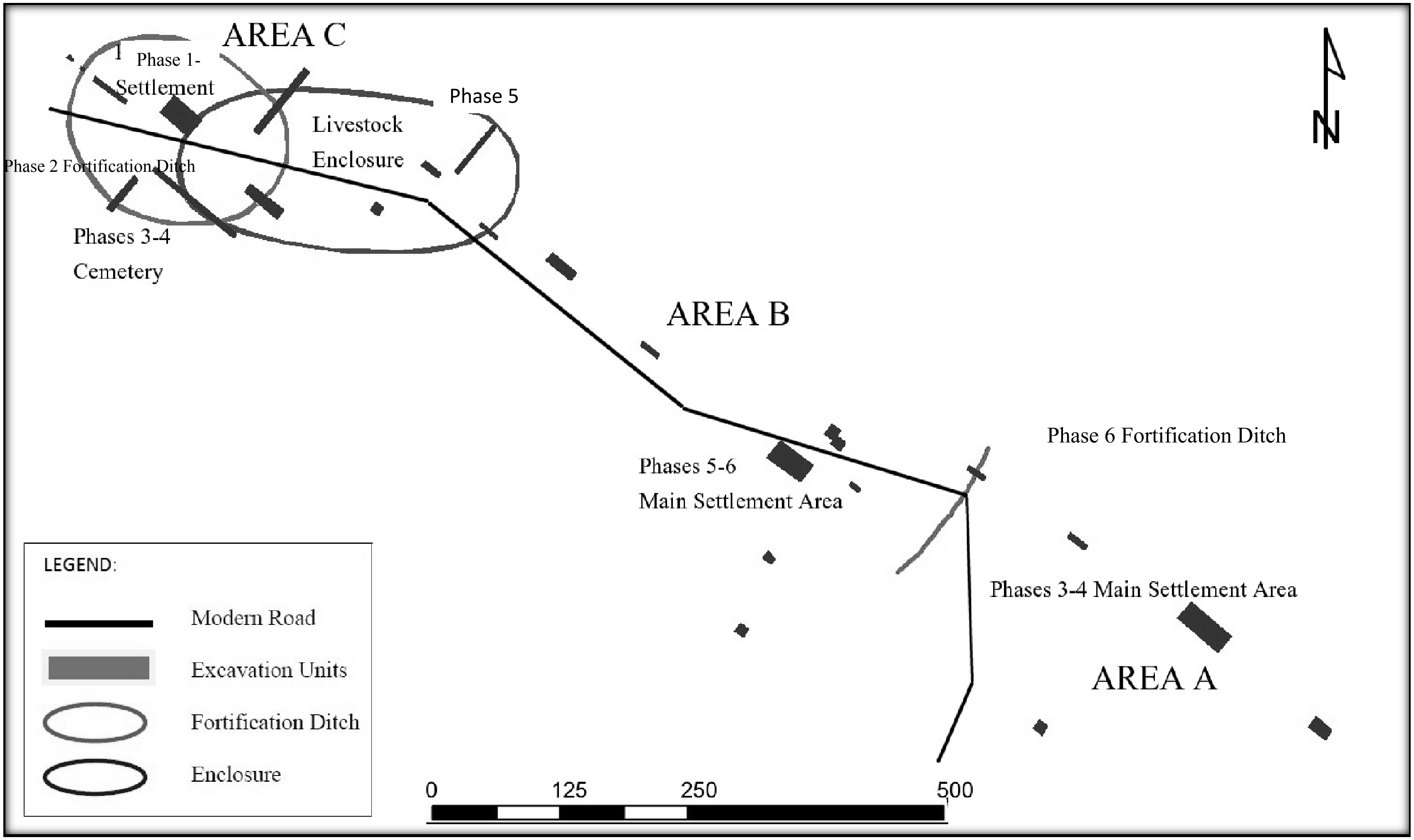


Figure 1.2. Site plan indicating main areas of settlement at Bronocice and key features including phases, fortification ditches, and livestock enclosure.

Chapter 2

The Neolithic in Southeastern Poland 5200-2700 BC

A. Culture History

In the Old World a web of agropastoral cultures began to spread during the Neolithic beginning in southwest Asia, and encompassing Europe and the Mediterranean Basin. Change happened faster at the center while in the hinterlands of central and northern Europe it was slower. Consequently, depending on where archaeological research is conducted, archaeologists apply different terms to the 4th and early 3rd millennium BC. In southeastern Poland this stretch of time is the referred to as the later Neolithic. However, in Hungary and Ukraine this time is known as the Copper Age or Chalcolithic, while in the Fertile Crescent it is the Bronze Age.

The 4th to early 3rd millennium BC was a dynamic and formative period in southeastern Poland, influenced to some degree by events taking place in other parts of the Old World through trade and outside cultural influences and developments. In southeastern Europe and southwest Asia technological advances and social hierarchies developed earlier in time. In the hinterlands of central Europe rapid changes began to appear during the mid 4th millennium BC. For nearly a thousand years Funnel Beaker culture dominated a wide area of central and northern Europe during which time important technological and cultural changes occurred. Funnel Beaker cross-cultural interactions were extensive, reaching from the Baltic Sea to the Mediterranean Sea, and well into western and eastern parts of Europe. In southeastern Poland, some of the cultures with which Funnel Beaker people located interacted over time included Lublin-Volhynian, Comb and Pit, Bodrogkeresztúr, Tripolye, Baden, Globular Amphora and Corded Ware cultures (Hodder 1990, Furholt *et al* 2008, Milisauskas 2011, Whittle 1985, Wiślański 1970).

The Neolithic was an intensive period during which social, economic and technological developments occurred which laid some of the foundation for western civilization. The breadth and diversity of these changes influenced all cultures to some degree. The period was so expansive that the term ‘Neolithic’, meaning ‘new stone age’, is really too limited. Intellectual creativity, social discourse, the exchange of thoughts and observations, led to the creation of new ideologies and forms of social structure from which material expressions, technologies and actions flowed. Many Neolithic theories contain elements of interest to the study of social and political structure, the nature power and control, and household organization, and norms of behavior. Many theories are predicated on burial data, undeniably a rich source of information and which have proven useful in investigating social organization (Levy 1989, Shanks and Tilley, 1982, Renfrew 1976).

Many have discussed the interrelatedness of social change or technology, as well as various other causative agents (Hodder 1982, 1990, Sherratt 1981, Shennan and Edindorough 2007). It is apparent that social change and technological developments are tightly interwoven and that specific interpersonal dynamics, as well as dumb luck and opportunity, have had important consequences in human history. It remains a matter of some speculation as to why some areas developed and others lagged behind.

Force of personality and a coalescing of events were likely important factors where the Neolithic is concerned (Gavin 2001). A glance at ancient written records reveals the discursive relationship between social organization and technological developments. Elites, trade and social conflicts are frequent topics of many texts. The lack of written records in European prehistory blinds the present to the underlying roles played by individuals and the events they witnessed and engaged in. The fluorescence of a particular group, not culture, occurred in the past within the context of unique circumstances involving location, leadership and opportunities. Superficially, archaeologists see patterning in settlements, cultural and biological remains, burial patterns, and styles, shapes and sizes in artifact assemblages. Archaeologists are programmed to seek patterns and to dismiss irregularities. However, irregularities are the best indicators of the unique events of a particular group and settlement and serve as a reminder that each site was reflects the dynamic and changing the world within which its residents existed. How fortunate that some of the material consequences of thought and action remain in the archaeological record to encourage our efforts.

1. Early Neolithic Cultures

a. Linear Pottery

The Neolithic period in southeastern Poland was characterized by multiple cultural transformations resulting from the influx of people from parts north and south. Rather than replacing local residents archaeological evidence suggests that new groups tended to blend with local people (Nowak 2006). The cultural transition to the Neolithic in southeastern Poland was marked by the arrival of Linear Pottery farmers from southeastern Europe, most likely people from the Great Hungarian Plain (Figure 2.1) (Bogucki 2007, Bogucki and Grygiel 1993, Kruk and Milisauskas 1999, Milisauskas 2011). Radiocarbon dates reveal the slow but constant inroads they made, first in the south, then spreading gradually further north and west into Germany and France as well as Sweden. Regional areas of resistance occurred in the northwest parts of Europe by Mesolithic hunter-gatherer groups lasting over several centuries. Mesolithic sites have been found in close proximity to LBK settlements, for example the site of Glanów in Kuyavia (Nowak 2006). Many of these show signs of cultural interactions and trade (Bogucki

1988). In the north, Linear Pottery people were influenced by the Ertebølle culture. Ertebølle people were the earliest Mesolithic group to adopt agriculture and produce its own pottery. Over several centuries Mesolithic people developed their own pottery traditions and eventually accepted agriculture and livestock herding (Bogucki 2007, Gebauer 2004, Thorpe 1996, Wentink 2006). Within the greater context of European prehistory, the Neolithic period in southeastern Poland (5200-2700 BC) coincides with major events in southeastern Europe, namely the transition to the Chalcolithic period. That period was marked by greater social differentiation, technological advancements, the use of metals and the acquisition of personal wealth.

Linear Pottery farmers successfully colonized most of central Europe. To a great extent we understand little about what drove these people into new lands, whether it was due ideological, social, political or environmental factors. However, some insights may be gained about the logistics of their movements. They must have had prior knowledge about the lands into which they moved. In the history of the United States, Europeans scouts and traders first investigated the continent prior to the arrival of settlers. These individuals identified potential resources, settlement locations, as well as geological and environmental challenges that lay ahead. And so it must have been with the First Farmers. Furthermore, frontier settlements are doomed to fail and suffer greatly if they are not provisioned. It is known through genetic studies that Linear Pottery groups in fact had constant resupplies of crop seed and livestock (Budja 2001). In terms of basic livestock management practices maintaining a certain herd composition and size is critical to successful stockherding (Bogucki 1988). There is ample DNA evidence for domesticated mammal species recovered from Neolithic sites which expresses great genetic variability, a direct result of constant influx of new livestock over an extended period of time (Larson *et al*. 2007, Meadows 2005, Medjugora *et al* 1994, Negrini *et al* 2007).

In southeastern Poland the initial occupation by Linear Pottery people was limited to loess soils, settlements were situated above the flood plain in a heavily forested environment. They practiced an intensive mixed form of fixed plot agriculture and animal husbandry (Bogaard 2004). Their practices resulted in very limited land use and small impacts to local environments. Their settlements were small in size, essentially undifferentiated, and generally situated on lower river terraces (Bogucki and Grygiel 1993, Kruk and Milisauskas 1981). Linear Pottery culture was based on small scale intensive garden agriculture and livestock breeding with an emphasis on cattle (Bogaard 2004). Furthermore, it is likely that the advancement of Linear Pottery settlements along river drainages resulted in many instances from leap frogging, where the next generations split off and established themselves further upriver. The maintenance of social relationships and cultural identity was maintained along river routes and reinforced through long distance trade. These supply lines most likely formed the basis of some long distance trade networks that existed in later times stretching to the south and southeast. Though extensive trade networks already existed with hunter-gatherer groups in the Baltic region dating to the Mesolithic (Czekaj-Zastawny *et al* 2011, Zvelebil 2006).

b. Lengyel-Polgár

In the lowlands of Poland located to the north, Linear Pottery culture was eventually succeeded by a well-defined descendant cultural tradition based on pottery style known as Lengyel (ca 4800-3800 BC). However, in southeastern Poland, Linear Pottery culture was more heavily influenced by cultures to the southeast which resulted in a varied cultural landscape referred to collectively as the Lengyel-Polgar cycle. Lengyel-Polgar groups are mainly distinguished by distinctive pottery styles and vessel shapes and marked by a succession of small cultural groups which included the Malice (Dębiec and Pelisiak 2008), Modlnica and Złotniki-Wyciąże groups. The latest Lengyel-Polgar cultural group to emerge in southeastern Poland was the Lublin-Volhynian (ca 4200 BC). The origins of this group have been the subject of much debate but are now believed to have developed in southeastern Poland (Kadrow 2011). This culture may have developed in part as a consequence of the demand for high quality flint by Tiszapolgar groups (Zakościelna 2006). Lublin-Volhynian controlled access to and production of high quality flints. They were the first to produce very long blades of high quality flint which they traded first to the Tiszapolgar. Later Funnel Beaker groups inherited this tradition and traded flints with Bodrogkeresztur and Triploye groups to the south and east.

With the exception of the later Lublin-Volhynian group, Lengyel cultural and economic traits were similar to Linear Pottery culture, including settlement patterns, subsistence practices, and burial traditions. The Tiszapolgar culture had the greatest outside influence on all Lengyel-Polgar groups in southeastern Poland during this period (4500-3600 BC) though most of what is known of this culture comes mainly from burials and only rarely from settlements. There is also clear evidence of contact with Triploye culture as well (Videiko 1999). Other influences include Comb Pottery culture thought to be associated with contemporary Mesolithic people located to the east (Nowak 2006).

2. Later Neolithic Cultures

a. Funnel Beaker

The mid 4th millennium BC was marked by an increase in population density and settlement types throughout central Europe and the emergence of regionally distinct cultures identified by different pottery types. A marked cultural break occurred with the appearance of

Funnel Beaker people. Funnel Beaker culture has been investigated using settlement data, burials, and artifacts studies (Midgley 1992, Milisauskas 2011, Sherratt 1997). These studies have focused heavily on aspects of material culture and shown that regional variability existed (Wiślański 1970). Funnel Beaker culture was distributed over a major portion of central Europe and sites were more diverse in terms of their locations, soil types and elevations. Faunal studies have shown a great variation in terms of animal exploitation practices, including wild species and domesticated mammal species (Glass 1991, Midgely 1992, Bogucki 1988, Higham 1969a, 1969b, 1967, Bökönyi 1971, Bartosiewicz 2007a). The variation in assemblages has been used to classify sites by function. Some sites in the Alpine Foreland show unusually high frequencies of pig as well as differences in sizes believed to represent different breeds and not just sexual dimorphism (Glass 1991).

Linear Pottery groups colonized extensively throughout Europe but did not always incorporated Mesolithic groups. Funnel Beaker succeeded in merging and absorbing Mesolithic people into the Neolithic way of life (Zvelebil 2005). Funnel Beaker groups began to appear in southeastern Poland around 3800 BC. Although the origins of Funnel Beaker culture are still debated, it likely originated in the northwest and emerged after the acceptance of agricultural practices by hunter-gatherers (Czekaj-Zastawny *et al* 2011, Nowak 2006). The earliest Funnel Beaker sites are found in northern Europe which suggests its influence spread from Germany, then north to Denmark, south to Slovakia, Moravia and Czech Republic, east to Poland and also the western portion of Ukraine (Midgley 1992, Milisauskas 2011, Sherratt 1997, Pelesiak 2007). Funnel Beaker culture is recognized by its unique style of pottery. Within this cultural horizon regionally distinct Funnel Beaker pottery styles have been recognized which likely reflect incorporation and adoption of local traditions and cultural consolidation (Midgley 1992).

In comparison with other 4th millennium BC European cultures to the south and southeast, Funnel Beaker culture lagged in terms of technology and social complexity. However, in other ways their settlements exhibit many similarities with Copper Age cultures located on the other side of the Carpathian Mountains.

On the Great Hungarian Plain marked changes occurred in subsistence practices and social restructuring appears to have begun during the Early Copper Age. Communities dispersed, tells were abandoned, and small groups of mobile hamlets became the norm. Stockherding grew in importance, livestock became a major source of wealth, and social differentiation increased. Long distance trade was restructured and livestock practices changed (Parkinson *et al* 2004). All of these patterns were evident in the Funnel Beaker occupation of southeastern Poland from 3650-3100 B.C. (Milisauskas and Kruk 1984).

Funnel Beaker culture lasted nearly 1000 years in Poland. There is ample evidence of long distance trade over large areas and between different cultures (Czekaj-Zastawny *et al* 2011, Videiko 1999). In northern Poland the site of Dabki yielded pottery linked with the Vistula and Oder regions, as well as copper age artifacts that show links with the *Bodrogkeresztúr* culture of the Tisza Valley (Czekaj-Zastawny *et al* 2011). Funnel Beaker settlements in western Ukraine reveal interactions with Tripolye Culture as well (Pelesiak 2007) through the presence of flint artifacts made of materials from southeastern Poland. There is some evidence for the movement of raw materials, goods, animals and people by water. At the site of Stralsund in northeast Germany a 12 meter long canoe was uncovered dated 3850 BC which suggests large scale river transport was in operation and well organized (Czekaj-Zastawny 2011).

Funnel Beaker burial traditions differed significantly from earlier agriculture groups as well. Linear Pottery and Lengyel-Polgár burials typically expressed gender through the position of the body as well as the inclusion of grave goods. In southeastern Poland Funnel Beaker burials on the other hand were non-gendered; the body was laid on the back in an extended position, rarely with grave goods. In this region Funnel Beaker burial traditions also include long barrows and cemeteries. The presence of long barrows is suggestive of the megalithic traditions found in northwestern Europe, generally accepted as reflecting lineage based social relations (Hodder 1990, Levy 1989). Longbarrows are typically found away from central place settlements as were cemeteries (Kadrow 2011). Occasional burials were located within the settlement though it might argued that these atypical events were due to factors such as bad weather, social unrest, or simply a non-Funnel Beaker household.

The mid 4th millennium BC in southeastern Poland (3800-3100 BC) was not only a time of changing economic practices but also of emerging social differentiation within Funnel Beaker society. In southeastern Europe and southwest Asia increasing cultural complexity was already well underway. But southeastern Poland lagged behind partly due to physical distances and geographical barriers as well as little exposure to technological advances, especially to metal working. Via long distance trade with cultures located to the immediate southeast raw materials, finished products, marriage partners and livestock were imported into the region.

A few Funnel Beaker sites such as Bronocice, however, grew into large and permanently occupied settlements including Ćmielów, Gródek Nadbużny, Książnice Wielkie and Złota (Burchard and Eker 1964, Gumiński 1989, Kadrow 2011, Kowalczyk 1962, Rauhut 1962). These sites share a number of characteristic traits. Several were positioned on top of former Lublin-Volhynian settlements, the last cultural iteration of Lengyel-Polgár culture. The Lublin-Volhynian sites tended to be fortified with palisades and ditches. For a short stretch of time both Funnel Beaker and Lublin-Volhynian settlements may have coexisted. The overall size and density of Funnel Beaker settlements within the region was far greater than those of Lublin-Volhynian. Some of these Funnel Beaker larger settlements show signs of having been burned at least once. They were all permanently occupied and existed for centuries. Analyses of flint, pottery and other exotic materials, have shown that these settlements were involved in long distance trade (Burchard and Eker 1964, Gumiński 1989, Kadrow 2011, Kowalczyk 1962, Rauhut 1962).

Like Linear Pottery and Lengyel-Polgár farmers, Funnel Beaker people raised cereal crops and herded cattle, pig and sheep. But some of their cultural practices were quite distinct from these earlier cultures. Funnel Beaker settlements were more variable in terms of size and location, as were the composition of their herds and stockherding practices (Glass 1991, Midgley 1992). Settlement and economic practices varied across regions. Larger settlements are found mostly in the southeast whereas northern settlements are smaller in size. Some sites were specialized flint production centers such as the site of Gawroniec in Ćmielów (Kadrow 2011). During the Middle Neolithic Funnel Beaker groups settled in the uplands, away from lower river terraces. Settlements are found extensively distributed over the region and indications are the population expanded. Their settlements were unfortified, generally small, 1-2 hectares and occupied only one to two generations. It is possible that many of the smaller settlements were mainly occupied during winter months and that during the rest of the year most people were tending their herds (Kulczyzka-Leciejewiczowa (1999). By the latter part of the 4th millennium BC signs of intensified animal husbandry practices appeared. It is unclear whether this was initially an adaptive response to increasing environmental changes or a deliberate intensification for other reasons.

b. Funnel Beaker-Baden

Around 3500 BC the Baden cultural complex began forming in central Europe (Figure 2.4) (Furholt *et al* 2008, Horváth 2008 *et al*, Wild *et al* 2001). There were two forms of Baden cultural expression. One involved the migration of Baden people into the southwestern part of Poland in the vicinity of Krakow. The other cultural expression was the adoption of Baden traits by Funnel Beaker groups in the southeast and in the lowlands of Poland (Horvath *et al* 2008, Zastawny 2008). For communities like Bronocice, the Baden culture emerged as a strong economic competitor and political opponent. At Bronocice there appears to be a shift in cultural identity expressed in ceramics that merged Funnel Beaker and Baden stylistic elements. The adoption of Baden pottery stylistic elements suggests the influence of increasing political hegemony.

It was during the first part of the Funnel Beaker-Baden occupation ca 3100 BC that the population in the Bronocice micro-region reached its highest peak at around 600 people (Milisauskas and Kruk 1984). The rise in population density corresponds with a major change in settlement pattern. During the previous Funnel Beaker phases the regional population had been increasing but was extensively distributed across the landscape. Coinciding with the growing influence of Baden culture on the region Funnel Beaker settlements became concentrated in and around Bronocice leaving large areas of land unoccupied (Milisauskas and Kruk 1989).

Faunal assemblages during the late 4th millennium early 3rd millennium BC show increasing emphasis on cattle rearing and a corresponding decline in pig, sheep and goat rearing. Cattle gained greater symbolic value as well as increasing in economic value. They are found ritually buried in cemeteries, deliberately positioned in relation to human burials (Milisauskas 2011, Whittle 2002). Within the Bronocice region there was a decrease in agricultural practices

(Milisauskas and Kruk 1989). The amount of land utilized for agriculture decreased during this period though the size of the herds necessitated large amounts of pastureland. Fleming suggested that increasing livestock specialization may have been due to decreasing soil fertility (Fleming 1972). However, there was no decline in soil fertility in southeastern Poland. The introduction of the ard and the wagon cart are often cited as evidence for increased social hierarchy (Sherratt 1981). There are indications at Bronocice of increasing social differentiation during the Funnel Beaker-Baden period which was marked first by the construction of an enormous enclosure (4.6 hectares) and later of a defensive ditch and palisade. Large numbers of handled cups, often correlated with feasting and alcohol consumption and indicative of the presence of resident elites, were recovered in many settlements. A reduction in the size of houses also occurred and a growing divergence of craft specialists appeared (Pipes *et al* in press). Another important symbol of social hierarchy was the appearance of wheeled vehicles in many parts of Europe including southeastern Poland. Indirect evidence at Bronocice exists in the form of a ceramic the surface of which is decorated with the oldest images of wheeled vehicles in Europe (Milisauskas 2011).

3. Early Bronze Age cultures

Signs of Early Bronze Age cultures are apparent evidence towards the end of the occupational sequence at Bronocice ca 2700 BC. A small number of ceramics from Corded Ware and Globular Amphora groups were recovered during excavation indicating their presence within the region and the settlement at Bronocice. Other Funnel Beaker settlements dating late in the Neolithic also show signs of interaction with these two cultural groups. Furthermore radiocarbon dates of Globular Amphora and Corded Ware burials overlap slightly in time with the end of Funnel Beaker settlements in southeastern Poland.

Globular Amphora culture is defined by a set of traits, ‘forms, ornamentation and technology of ceramics, macrolithic flint products (axes and chisels), amber artifacts, cist graves, ritual features with animal burials etc. (Szmyt 2008, 2006). This culture is known mainly from burials stretched from southeastern Poland to the Black Sea and existed from 2950-2350 BC (Szmyt 2010). Globular Amphora culture may have formed as early as 3500 BC in southeastern Poland (Nowak 2006, Sysiak *et al* 2010). Globular Amphora culture is known mainly from burials and traces of settlements and camps that take the form of pits, rarely of structures. Like Lublin-Volhynian and Funnel Beaker groups they continued the practice of mining high quality flint in the Holy Cross Mountains (Babel *et al* 2005). Globular Amphora groups coexisted with Funnel Beaker groups in some parts of western Ukraine and possibly southeastern Poland (Szmyt 2010). This presence of this group within the sites selected for this study was minimal.

Corded Ware groups overlapped in time with Globular Amphora groups as well. Corded Ware culture existed 2800/2700-2300/2200 BC and is distinguished by three horizons (Włodarczak 2006). Corded Ware culture is remarkable for being widespread throughout much of Europes. Corded Ware culture is known primarily from burials, tumuli and cemeteries, as well as some settlement data. The largest concentration of Corded Ware burials lies in southeastern Poland (Włodarczak 2006). Burial information reveals a social hierarchy existed in which males, possibly warriors, were in positions of power. Tumuli are often located on loess hilltops with a prominent view, while cemeteries are sometimes found in river valleys. This pan European identity is hard to explain in an age when communication and travel were difficult, and maintaining and reinforcing a specific set of social values across a vast territory surely a challenge. The earliest Corded Ware group is known as the A horizon about which little is known (2600-2500 BC). It is characterized by single male graves in tumuli oriented west to east. The only Corded Burial found at Bronocice dates to this horizon (Figure 2.5).

Some suggest that Corded Ware people originated from the Pontic region and bringing with them advanced technologies such as the wheeled cart, and horse-back riding. In southeastern Poland however it may be that Funnel Beaker-Baden and Baden settlements adopted their lifestyle. Many archaeologists believe they were male dominated, patriarchal, pastoral nomads who placed a heavy reliance on stockbreeding (Gimbuttas 1989, Whittle 2002, Sherratt 1997, 1981, Thorpe 1996, Zvelebil 2006). There is strong evidence that within their homeland they practiced transhumance. Adjacent areas were densely populated by other cultural groups and transhumance appears to have been a response to the physical constraints of the landscape as well as the social competition with agriculturalists (Anthony 1986, 2007). The domestication of the horse and the introduction of riding changed the speed at which people could move across the landscape. This may have been a major factor in increased conflicts resulting from cattle raiding.

The general lack of settlement data for Corded Ware and Globular Amphora groups within southeastern Poland has been cited as strong evidence that they were pastoralists nomads. As long as agricultural settlements continued to exist Corded Ware people could trade for grains. However, they eventually disappeared off the landscape. The presence of cereal grains in Corded Ware burials and plough marks beneath tumuli suggests they may have practices agriculture as well.

Coincidental with the appearance of Corded Ware people in southeast Poland, Funnel Beaker-Baden population in the region dropped by as much as 75 percent. Some settlements such as Bronocice became fortified with ditches and palisades. Furthermore male burials from this period contain an increased number of artifacts such as projectile points which are often considered a sign of social conflict (Milisauskas 2011).

The appearance of Corded Ware and Globular Amphora people signaled the end of settlement occupation in southeastern Poland for a long time. Corded Ware sites, while rare, are often located near Funnel Beaker-Baden settlements but at higher elevations on the uplands and tend to consist of burial mounds and graves. The placement of burials in elevated areas most likely had symbolic meaning (Milisauskas and Kruk 1989). By the time Corded Ware and Globular Amphora groups appeared in southeastern Poland the landscape was an open parkland. Parkland settings offer open grazing lands characterized by pastures and patches of wood (Boffa 1999). Open parklands result from human agricultural and pastoral activities (Redman 1999). Pastoralism favors open parkland settings because they are well suited to herding cattle sheep and goat, as well as pigs, and they are rich in resources. Grassland areas provide grazing for livestock while trees such as oak provide mast for pigs, nuts and fruits for people, and fodder (Petit 2003). They are a transitional landscape whose continued existence requires active management by pastoralists through the browsing, foddering and grazing of livestock. Light-grazing benefits open grasslands and encourages plant growth, while heavy grazing destroys a landscape (Redman 1999). Certain species of animals can rapidly degrade an environment, especially goats if are not actively managed (Hughes and Stoll 2005). Because parklands are greatly valued by pastoralists they tend to be protected lands both today and in the past (Harrison 1996).

According to Harrison open parklands were created in the fourth millennium BC and were present extensively across vast regions of western, eastern and southern Europe (Harrison 1996). These regions resulted from agricultural activities and increasing population densities.

Archaeological studies have demonstrated cycles of degradation and recovery and that people shifted back and forth from agricultural to pastoral lifestyles in the Mediterranean (Redman 1999, Harrison 1996).

Corded Ware groups would have recognized this type of landscape as a valuable resource for supporting their livestock. Modern day pastoralists have complicated social arrangements that mitigate conflict between groups in terms of ownership and rights of access (Dicko *et al* 2006, Lesorogo 2005). Use and concepts of ownership may have contributed to social conflict between Funnel Beaker-Baden and Corded Ware people that was irresolvable, or maybe they joined them.

B. Settlement Information

The region around Bronocice marks one of the southeastern-most expressions of Funnel Beaker culture. This area was densely settled by Funnel Beaker people (Figure 2.3). The initial Funnel Beaker settlements consisted of small upland communities. These were dispersed and differentiated in size and population. Dispersed small settlements dominated while larger settlements were less frequent and more widely dispersed. Most small settlements were occupied for a few generations and then abandoned.

The first Funnel Beaker settlements appeared in the region around 3800 B.C. This period is generally referred to as Phase 1. The classic phases of Funnel Beaker settlements date to 3650 – 3400 B.C. (Phase 3) and 3400-3100 B.C (Phase 4). Archaeological survey has shown that within a few generations a settlement hierarchy developed within the region consisting of three sizes, large (18ha), medium (5+ ha) and small (1-2 ha). Bronocice was the only large site within the micro-region occupying 52 hectares, including settlement and enclosures, by 3100 BC (Milisauskas and Kruk 1984). The two subsequent Funnel Beaker phases within the region however were marked by an increasing expansion of small settlements, population, and extensive agricultural practices that denuded the upper slopes of the forest canopy resulting in heavy siltation of the river basin, changes in topographic features, and the appearance of grasslands. Kruk suggested that grasslands were maintained by rapid rotation of agricultural fields. Farming affected the composition of trees and contributed to the increased presence of pine in settlement areas (Kruk and Milisauskas 1999, Milisauskas *et al* 2004). The areas settled on the slopes and uplands in Southeastern Poland experienced significant changes to the landscape associated with agricultural and animal husbandry practices. Studies investigating soil erosion and sedimentation rates, malacological data and botanical remains have indicated a change occurred in the landscape from dense forest landscapes to increasingly patchy forest and open grasslands. These changes were due to the reduction of the forest canopy through various means including fire, cutting down trees, planting fields, cropping, grazing and browsing (Kruk *et al* 1996).

The sites of Bronocice, Żawarża (12 km), and Niedżwiedż (25 km) were chosen for this study because their economies were based in part on intensified sheep rearing and because they are located within relatively short distances of each other (Figure 2.6). Both Żawarża and Niedżwiedż were small satellite sites measuring 2 hectares in size. They are synchronic dating to Phases 3 and 4 respectively. The high frequencies of sheep remains recovered from all three sites further offered an opportunity to investigate possible social ties between the settlements. For an overview of the excavations at Bronocice see Milisauskas and Kruk 1977.

1. Bronocice

The State University of New York at Buffalo and the Institute of Archaeology and Ethnology, Polish Academy of Sciences conducted a cooperative archaeological project at the Bronocice site, Świętokrzyskie province, 1974-78. The Director and Principal Polish investigator of this cooperative project was Witold Hensel and Sarunas Milisauskas was the Principal American investigator. Much has been written about the site describing the remains, its subsistence economy, ecology, settlement context and social hierarchy (Kruk and Milisauskas 1981, Milisauskas and Kruk 1989, 1984, Milisauskas 2011, Pipes *et al* 2009). Bronocice was a vast settlement measuring a total of 52 hectares. Approximately one percent of the site was tested archaeologically. The site was occupied by several distinct cultural groups from 3800-2700 B.C.

The settlement was a destination for trade and exchange of commodities. The well documented presence of exotic imported flints indicates the presence of well established trade networks (Milisauskas 2011). Within the context of long distance trade animal imports were an important component. During the middle Neolithic occupation in southeastern Poland most sites were dispersed over a wide area and consisted of small hamlets (Figure 2.4). Bronocice was the largest and most complex settlement found in this region (Milisauskas and Kruk 1984, 1989, Kruk and Milisauskas 1981, 1999). A rank-size distribution study of settlements within the region indicated a low-level of incipient social hierarchy existed in the region during the Middle Neolithic and that Bronocice emerged as a central place around 3650 BC, a position it maintained for several hundred years (Milisauskas and Kruk 1984). The large size and complexity of the settlement are major indicators that Bronocice dominated the local economy and that trade and exchange of livestock occurred with surrounding communities. Textile production is well documented at Bronocice by the presence of spindle whorls, loom weights and spools. Ethnographic studies, historical records, and illustrations reveal that weavers had high status in many cultures past and present (Barber 1991, McCorriston 1997, Ransborg 2011). For that reason the correlation between sheep and textile production is emphasized throughout this study.

The increasing importance of fiber and textile production is indicated by the growing number of households engaged in production over time (Tables 2.1 and 2.2). Phase 3 is unique in comparison with all other phases. If it the only time that there were more households engaged in textile production than in spinning. Near the end of Phase 3 there was an adjustment and the number of households engaged in spinning exceeded those weaving, a trend that continued through Phase 6. This is interesting as it corresponds with the beginning of large scale sheep imports at the state of Phase 3. In the discussion that follows all structures, whether they were barns or houses, are equated with households because many caches of loom weights were recovered from barns as well as houses. Looms may have been kept and used inside barns.

a. Phase 1 (3800-3700 BC) Funnel Beaker Occupation

The initial occupation of the region by Funnel Beaker groups (Phase 1, 3800-3700 BC) was characterized by small, semi-permanent settlements, typically measuring 1-2 hectares in size. These settlements were extensively distributed along the upper levels of the loess belt and unfortified. No single settlement, including Bronocice, dominated the local economy. Analysis of faunal assemblages from this early period indicated that cattle rearing dominated stockherding practices and pigs were second in importance. Sheep and goat were of little significance.

The Phase 1 settlement at Bronocice was located in the western portion of the site and measured about 2 hectares (Figure 2.7). The layout of the settlement consisted of a residential core, Unit C2, with barns located on the outer edges though were also a couple in the heart of the settlement (Appendix F). The outer barns were smaller structures than those within the village. Most of the buildings were oriented northeast to southwest. A couple of buildings however were oriented in the opposite direction. This change in orientation suggests rebuilding occurred and marks the presence of at least two Funnel Beaker generations within the same location. No burials were recovered dating to this period. However, some of the Phase 1 pits intruded into earlier burials resulting in the recovery of fragments of human remains during excavation. It appears that new construction impacted earlier burials unknown to the builders. It is impossible at this point to identity the cultural affiliation of those burials. One building in particular was worthy of note (C2.5, see Appendix F). This structure had a set of stairs leading to a deep and large cellar, the function of which is unknown. Variability in size and internal complexity of structures indicates differences in function and association with subgroups within the community.

Within the settlement five structures (Table 2.1) contained textile-related ceramic artifacts, two were barns and three were houses. Four of these structures were in Unit C2, the other in Unit B6. Spindle whorls were present within each structure. One loom weight and one spool were recovered from a barn. Weaving was clearly not a major activity in the settlement at this time. The limited distribution of artifacts indicates spinning and weaving was highly localized. In fact, only 1 weaving household is indicated (Table 2.2).

b. Phase 2 (3700-3650 BC) Lublin-Volhynian Occupation

Radiocarbon dates suggest the Phase 1 occupation was either followed by, or possibly contemporaneous with, the Phase 2 by Lublin-Volhynian people (3700 – 3650 BC). Some of the Lublin-Volhynian pits intruded into Phase 1 pits. The size of the settlement remained small (Figure 2.8). A structural reconstruction of houses and barns based on pit orientation and postmold patterns revealed intensive use of the Unit C2 area (see Appendix F). Varying structural orientation suggests that rebuilding occurred. In Units C1 and C3 structures appear to have been positioned over the fortification ditch. In one a staircase appears to lead into the ditch. Archaeological investigations of the ditch failed to locate any break. Access into the settlement therefore was through these structures (Figure 2.9).

Lublin-Volhynian culture was originally thought to have moved into the region. However it seems more likely now that they were the descendant population eventually blending with Funnel Beaker groups that migrated into the area. Lublin-Volhynian culture was more technologically advanced. Their sites have produced evidence of copper mining. They also controlled access to and production of valued flint mines in the region. Sites in Hungary, Ukraine, Slovakia, Czech Republic, Germany and the Baltic region have yielded flint blades from this region (Barber 1991, McCorriston 1997). An extensive trade network existed based on valuable flint resources whose ownership and control over exploitation may have been contested by Funnel Beaker people. At Bronocice, Comb and Pit and Tripolye pottery indicate direct contact occurred between the Lublin-Volhynian and these cultural groups (Kadrow 2011, Kruk and Milisauskas 1981). Their subsistence economy was based on grain agriculture and livestock herding.

The Lublin-Volhynian settlement at Bronocice was initially unfortified. However, a clear sign of social isolation from their Funnel Beaker neighbors was expressed by the eventual construction of a fortification ditch and palisade around the settlement. Other Lublin-Volhynian settlements in southeastern Poland and western Ukraine (Kadrow 2011) were also fortified at this time. Whether this was the result of social conflict or perhaps a need to protect their trade or to enclose their livestock is unclear.

At Bronocice one Lublin-Volhynian burial is worth mentioning. This double burial consisted of an elaborated grave containing the skeletons of a woman and man both aged about

40 years at death. This burial chamber was two tiered and contained pots, faunal and floral remains, as well as flint and bone tools and jewelry. The woman was the first to be buried. She was carefully laid out. But the man was unceremoniously placed in the chamber on top of her (Figure 2.10). Her burial treatment clearly marks her as a high status individual within the community. But it is worth noting that her grave is unique among elaborated Lublin-Volhynian burials, most of which were accorded to high status males. The placement of the man conversely indicates low status suggesting he may have been a servant or slave, perhaps sacrificed on her behalf.

There are no clear signs of violent conflict between the Lublin-Volhynian and Funnel Beaker people, or evidence that the settlement was burned or attacked. However, during the preliminary examination of the Bronocice faunal assemblage it was observed that the Lublin-Volhynian faunal deposits were characterized by a greater range and frequency of exploited wild fauna. Also cattle were slaughtered at latter in life in comparison with Funnel Beaker deposits. It can be stated with a fair degree of confidence that Lublin-Volhynian people relied more heavily on wild fauna and managed livestock differently. While consumption of wild mammals may simply reflect dietary preference, it may also been due to economic factors beyond their control. Circumstantial evidence suggest there was a lack of cooperation and social integration with local Funnel Beaker settlements which may have created a situation in which they could not gain easy access to new breeding stock. At this time little textile related data is available. The count presented in Table 2.1 is incomplete. At least one weaving household was present (Table 2.2).

c. Phase 3 (3650-3400 BC) Funnel Beaker Occupation

Within the region the overall population size and number of Funnel Beaker settlements grew significantly, most likely through migration from the northwest, but also through merging with local people. All traces of Lublin-Volhynian people disappear by 3650 BC coinciding with the beginning of great social and economic developments in the region during Phase 3 (3650-3400). Instead of being abandoned after one or two generations, as commonly happened at Funnel Beaker settlements, the site of Bronocice was resettled by Funnel Beaker people. This new settlement however was resituated in the eastern portion of the site from which later spread to the west (Figure 2.11). The settlement was larger than either of the previous ones and measured 8 hectares.

Artifact data recovered from units across the site revealed that specialists were already present in the settlement by Phase 3. Signs of increasing ritualized behavior were suggested by the presence of a ceramic drum (Pit 13-A2) and a ceramic rattle (Pit 12-B-road) (Figures 2.12 – 2.13). Other ceramic drums have been found at many Funnel Beaker sites throughout Europe and Poland including one from Opatowice, Pikutkowo and Site 1 at Radziejów (Gabałowna 1962). They appeared around 3600 BC and continued until about 2800 BC (Aino 2006). It was suggested that their appearance is associated with influences from Moravia and Bohemia. The one from Pikutkowo was in a cattle burial though many others come from human burials and non-burial contexts (Bakker 2010). It is assumed that they were used in ritual contexts, likely religious in nature. Other uses might be suggested but at the very least they are signs of music. And of course the most famous of all vessels from Bronocice, the one with the wheeled cart motif, also dates to this transitional period c. 3400 BC (Figure 2.14).

During Phases 3 and 4 Area C was used as a cemetery. Several burials were found in highly patterned arrangements (Figure 2.16). Location and alignment, as well as proximity, suggests that these represent family groupings (Pipes *et al* 2009). In some instances, the location of graves within former houses and their parallel orientation to each other suggests family ties. These are classic Funnel Beaker burials (Figure 2.17). The bodies were placed on their backs and few to no burials goods included. The graves are essentially unelaborated with no gender indicators. Burials however also occurred within residential areas. One grave in particular is of note. It consists of a woman, aged about 50 years at death, buried in non-traditional fashion (Figure 2.18). She was buried face down inside a house as opposed to a burial shaft, a possible sign of disrespect. It is possible that she was a weaver as a loom weight and a spindle whorl were recovered from her grave.

The transitional period from Phase 3 and 4 was marked by a marked increase in sheep and textile and fiber production artifacts. It is during Phase 3 that faunal deposits show significant increase in sheep frequencies relative to cattle. This increase noted previously is believed to correspond with an incipient wool industry (Glass 1991, Makowicz-Poliszot 2007, Pipes *et al* 2014, Greenfield *et al* 1988). Studies of wool types dating to the Bronze and Iron Ages have shown that multiple sheep breeds existed in Europe by then (Rast-Eicher and Jørgensen 2013). Though somewhat later in time, the development of distinct breeds would have had to occur earlier during the Neolithic as it takes time for these changes to happen.

As we will be seen later, the XRF data indicated that this was the period during which sheep were first imported to the region in large numbers. The old Lublin-Volhynian ditch was adaptively reused as an animal enclosure, likely for corralling livestock brought in for trade. There was a large barn within the enclosure in C2.

The main residential area concentrated in Unit A1. Area A contained densely packed residential houses and barns, especially in A1 and A3. Nine structures were dated to Phase 3. Six of those contained textile related artifacts. Fifty percent of these were involved in fiber production, while 67 percent were involved in textile production. This is a significant jump in the number of households from Phase 1 and Phase 2. This is the start of major textile production at Bronocice which appears to be related to wool production. There are no indications that bast fiber production increased. This is the only phase in which the numbers of households involved in textile production exceeded the number involved in fiber production.

It is hard to accept the two trends as coincidental. During the transitional period an additional 11 structures were identified. All of these structures contained textile and/or fiber production artifacts (Table 2.1). Fiber production artifacts were found in 91 percent of these structures (Table 2.2). Textile production artifacts were found in only 63 percent. This reestablished the trend in which the percentage of fiber production households exceeded the number involved in textile production. From this time on fiber and textile production remained very high.

By the end of Phase 3 and the start of Phase 4 Bronocice was a large and well-integrated village. The complex layout of the settlement indicates rebuilding occurred several times (see Appendix F). The degree of specialization detected across this large area points to an increasingly hierarchical society.

d. Phase 4 (3400-3100 BC) Funnel Beaker Occupation

Social and economic changes accelerated during Phase 4. The settlement expanded to 22 hectares, population density rose and sheep imports grew. New radiocarbon dates confirm that the greatest expansion occurred at the transition point to Phase 4. The rapid expansion resulted in lots of new construction blurring the archaeological view of the transition to Phase 4. Phase 4 was a period of social consolidation, architectural standardization and economic stabilization.

The Phase 4 settlement was detected in several units including Area A, Area B and Area C (Figure 2.18).The residential community expanded westward into Area B. The orientation of buildings observed in B1 suggests that house size and orientation was planned as opposed to the organic development seen in A1 (See Appendix F).

Specialists were not only well established within the settlement but grouped according to craft, a pattern that continued through the end of the settlement. Weavers were mainly located in Area B (Units B2, B5, B7), a baker in Area A (Unit A2), specialized barns within the enclosure in Area C, cattle barns and a grain storage barn in Unit A3. Other specialists included an axe maker and a lithic tool maker. There is some indication that there may have another large enclosure oriented north-south existed in the vicinity of the Phase 5 enclosure. Large construction projects require lots of labor. Organizing large labor indicates the presence of elites able to marshal or hire laborers.

Unit B6 also shows signs of specialized use. A large number of postmolds, storage pits and cellars dating to all Funnel Beaker occupations were encountered. They suggest repeated construction of pens and huts in this area, perhaps used to fatten and slaughter animals (Figure 2.19). Faunal remains found in this area indicate high frequencies of cattle and sheep metapodial. A ceramic sieve was found in pit 95-A1suggests cheese production was practiced (Figure 2.20).

Architectural building methods became standardized during this phase (Pipes *et al in press*). Other signs of increasing architectural refinement began to appear, especially the adaptive reuse of earlier ceramic vessels for floor and shelf tiling, as well as the use of clay to line pits and ledges. Additionally, a stone ramp was built in Area A3 leading to the cellar of one of the dairy barns (Figure 2.21). As was the case in Phase 3, a couple of ceramic drums were found (Figure 2.22).

Seven head of cattle were found slaughtered and left in place in the basement of a dairy barn in Unit A3. This is barn with the walkout basement that appears to connect with the stone ramp. One individual's head was found on a quern with its throat slashed (Figure 2.23). The walls of the pit showed signs of a fire. There were also signs of fire along the stone ramp. Destroying livestock is repeatedly mentioned in biblical texts as a form political retaliation between enemies (Borowski 1998). Perhaps that is what happened at Bronocice. The historic road that runs through the site offers additional evidence for a large scale conflagration at Bronocice during Phase 3/4. In several locations pits and soils are fire-reddened (Figure 2.24). Signs of violence and burning were also seen at Gródek Nadbużny (Gumiński 1989). Loss of property, in the past or in the present, is economically devastating.

The use of Area C as a burial ground continued during this phase but a couple of individuals were found within the residential area. One individual was found inside a pit and appears to have died when the building collapses. The other burial in 125-A1 was that of a child placed within a house pit.

Twenty-six structures were identified dating to Phase 4. Textile and fiber production artifacts were found in 19 of them (Table 2.1). Fiber production artifacts were present in all structures. Textile production artifacts however were present in only 63 percent of these, or 12 structures. A high percentage of households within the settlement were involved in both producing fibers and textiles (73 percent). It is likely that fiber production included bast fiber as well as wool thread. Only 46 percent of households were involved in weaving.

By the end of Phase 4 the settlement was very large and organized into neighborhoods.

e. Phase 5 (3100-2900 BC) Funnel Beaker-Baden Occupation

By Phase 5 the settlement reached its greatest size and population density (Figure 2.25). The incorporation of various stylistic elements reveals the well established influences of Baden culture on Funnel Beaker society in southeastern Poland (Figures 2.26-2.27). Though some ceramic vessels dating to Phase 4 already showed Baden influences, for instance those from Pit 8-B2 (Figure 2.27). This shift in ceramic style signals the merging of cultural traits rather than a migration of new people into the area based on trade relationships. Whatever the form of contact and association implied by the Baden-like ceramics, it is likely that most people living in Bronocice at this time were in fact members of the descendant community. Baden settlements were located to the west and south of the Bronocice region.

The Bronocice regional settlement pattern underwent a major change. Most notably outlying settlements decreased and became concentrated near Bronocice. The great increase in population at Bronocice probably was the result of people moving into the settlement vicinity from settlements rather than a rise in birthrate or large influx of outsiders.

Architectural changes occurred at Bronocice during this phase as well. Standardization of pits is evident in size, shape and construction. Houses were notably smaller in size than during earlier phases indicating nucleation of households (Pipes *et al* in press). Locations within the settlements continued to be associated with specific trades, e.g. most weavers were concentrated in units B2, B5 and B7, the baker contained to be in Unit A2. One house pit found along the modern road in Area B contained evidence of a flint axe workshop, while another flint workshop was found to the south in Unit B8. The management of livestock occurred in the western portion of the site (Area C) where there was not only the large enclosure but also barns and a couple of farmhouses. By Phase 5 sheep were in decline relative to cattle and pig however, their numbers were still large (Milisauskas *et al* 2012, Pipes *et al* 2009, Pipes *et al* 2014).

Trade was an important part of the economic life of Bronocice and the construction at the start of this phase is a clear sign of the significance of livestock imports (Figure 2.25).

Other commodities included flint and textiles, salt, and probably textiles, wool and thread. Salt production is tied to livestock activities. Salt is a critical mineral required by cattle and other species in large volumes. A few salt crucibles were found in pits at Bronocice indicating salt production occurred in the settlement. Evidence of salt mining and refining has been found at a large number of sites in the Wieliczka area, a short distance away near Krakow, that show long term associations with Lengyel, Malice, Funnel Beaker and Baden occupations. Archaeological investigations have revealed evidence of salt mining in that region consisting of hearths, evaporation pits, pottery and briquetage (Harding 2013).

Fiber and textile production remained major activities (Tables 2.1 and 2.2). Seventy percent of household structures contained signs of both types of production. Of these, 96 percent were involved in fiber production and 68 percent in textile production. Clearly textiles remained an important trade commodity. This large enormous enclosure signals that major social changes also occurred at this time. Its construction represents a public work project from which can inferred control and organization over labor existed. In increasingly complex and hierarchical societies forms of social cooperation are detected through large scale constructions such as enclosures and ditches, which serve act to reinforce community identity (Neustupńy 2006, Parkinson and Duffy 2007).

Further signs of social differences were indicated by ritualized activities. Animal burials were found in a few pits and included roe deer, sheep and dogs (Figure 2.28). Another pit was notable for the presence of 11 sheep mandibles, all left-sided, which suggests ritualized behavior as well. There were instances in which human skulls were placed in the bottoms of pits. One pit in particular is of particular interest, 2-B5 (Figure 2.29). It had a series of dark linear stains radiating out from the edge of the pit, which were clearly wooden in origin but of unknown function. This pit may have been framed with wood. In the bottom of this pit was a skull with a bead necklace around the neck. The presence of jewelry indicates that this was a non-Funnel Beaker individual. A study of Funnel Beaker burials and household pit contents indicated that they did not wear jewelry (Pipes *et al 2009*).

Another much larger grave was found in Unit B1. This contained the remains of 17 individuals whose bodies were arranged in a circular pattern within the pit (Figure 2.30). Based on the presence of elaborate jewelry found on most individuals it is also evident that they were not Funnel Beaker people. Perhaps they were a wedding party and represent an attempted political alliance that failed. In an article published in *Homo* (Szostek *et al* 2014) isotopic analysis was used to determine origins of the individuals buried in this grave. Unfortunately the researchers used animal bone from the burial as a benchmark of comparison and assumed that these were locally born and raised. Their results indicated most were Funnel Beaker. But, as will be shown in Chapter 3, the chance that the animals they used for comparative purposes were local is very slight. The burial was placed in a wood-lined chamber. Vertical and horizontal posts were visible in the floor and side walls of the excavation unit (Figures 2.30-2.31). The bodies were positioned in circular fashion with the oldest male placed on top. These people may have been executed. If so that that singular event may have triggered political and economic retaliation. By Phase 6 the settlement was in full retraction, diminishing in size and population.

f. Phase 6 (2900-2700 BC) Funnel Beaker-Baden Occupation

Marked social and environmental changes occurred during the final phase of occupation at Bronocice, 2900-2700 BC. A new fortification ditch was constructed that included a palisaded wall (Figure 2.32). Once again, the construction of the ditch is a sign that control over labor continued to be exercised by elites. The fortification of the settlement is an indication of social unease. Whether this was in reaction to increasing Baden pressure or other forces such as disease or famine, is as yet poorly understood. It is clear however is that by this time the population diminished greatly, the settlement shrank in size and the outlying settlements had disappeared. Furthermore, palynological evidence indicated that the local environment was severely degraded (Kruk *et al* 1996). The uplands were denuded of forest and transformed into open grasslands, which area good for grazing cattle but not for agriculture. Faunal data from Phase 6 show a heavy reliance of cattle with decreasing frequencies of sheep and pig.

Fiber and textile production artifacts were found in all but one the structures (Table 2.1). Of these all were involved in fiber production and 75 percent in weaving (Table 2.2). Economically trade in textiles continued to be important. Other goods and livestock continued to be traded at the settlement. No burials were found dating to this phase, only the isolated bones mentioned above found in household pits. This indicates a shift in burial traditions occurred, away from the settlement but not in Area C. Baden and Funnel Beaker-Baden end around 2700 BC (Horváth *et al* 2008). The social and environmental changes that took place towards the end of Phase 6 coincide with the appearance of Corded Ware and Globular Amphora people in the area (Milisauskas 2011, Kruk and Milisauskas 1999). Some Corded Ware and Globular Amphora ceramics were recovered in low frequencies. One Corded Ware burial was found in Unit B1of an older man dated 2900 BC (Milisauskas and Kruk 1989) (Figure 2.33). This elaborated grave was rich in grave goods and points to a man of prestige. Corded Ware culture marks the end of the Neolithic period in Poland.

2. Żawarża, Phase 3 (3650-3400 BC) Funnel Beaker Occupation

Excavations at Żawarża took place from 1959 to 1963 (Kulczyzka-Leciejewiczowa 2002). The settlement at Żawarża dates to Phase 3. Currently no radiocarbon dates are available so that the temporal assignment is based on ceramic typology which places the site occupation sometime during Phase 3 (3650-3300 BC). This was a single component site occupied for one or two generations. The community was small, consisting of 9-12 houses (Figure 2.34). Though no traces of actual structures were found, hearths and ash pan ledges were distributed in an arch around a common area. The internal structure of the houses included deep cellars reached by stairs, conical pits for storing grain, and shallow pits containing millstones. These houses were small with hearths located at one end. Like at Bronocice, the structures were semi-subterranean in which cooking occurred on platforms within the cellars. In houses built of lightweight frames, storage might have been easier by carving ledges and shelves into the loess soil rather than building shelving on wattle and daub walls and straining the walls of the structure. One of these structures differed from the rest and appears to have been an oven or kiln (Pit 76). Storage pits found in association with these structures indicate grain was stored in each house. The site is very different Niedżwiedż where there is apparent connection between houses. Nonetheless the presence of storage pits within or near each house indicates individualized property.

The arrangement of houses in the settlement indicates a common focus, namely the center which may indicate that animals were herded communally and kept in a kraal. One other site is known to have had a similar circular distribution of dwellings around a common at Stryczowice, Switokrzyskie Province (Kulczycka-Leciejewiczowa 2002). That settlement, probably also of a circular arrangement, was surrounded by a deep and wide ditch.

Faunal remains were dominated by cattle though sheep were present in high frequencies and dominated by adults. As this is a single component site it is not possible to observe patterns over time. Fiber and textile production artifacts were recovered from several pits across the site. The majority were spindle whorls (Table 2.3). Unlike Table 2.2, Table 2.3 summarizes the fiber and textile artifacts by location (pit and yard) and includes bone weaving tools, e.g. beaters. Nearly all households were involved in spinning and weaving. The distribution of these types of artifacts indicates their disposable nature. They were found inside and outside of structures, refuse pits and in the well. One oblong loom weight and two 'mini axe' loom weights were recovered. Their distributions overlapped. The oblong loom weight is the standard form found in Funnel Beaker settlements. The mini axe loom weight has been at Gródek Nadbużny, Kiązce Wielke and Bronocice (Figure 2.35) (Gumiński 1989). It is likely that these artifacts belonged to women of other cultures as they quite distinct. Other signs of weavers were few. Two bone beaters were found in the yard between Houses 7 and 8 and House 10. As was the case at Bronocice, more people appear to have been engaged in fiber spinning than weaving.

Żawarża may have been occupied seasonally by the majority of the residents. A study of Funnel Beaker seasonal camps by Kulczycka-Leciejewiczowa (1999) examined the ephemeral nature of seasonal camps, the range of species herded and the kinds of artifacts found in pits. Based on her findings it is clear that these camps were summer camps and that settlement sites like Żawarża were winter camps. Furthermore the presence of spindle whorls reveals that spinning was a year round activity most likely done by women.

Ethnographic comparisons suggest that most herders would have been young people spending their summers tending to livestock while older members remained in the settlement and farmed. Evidence of both farming and livestock herding were found at the site. Sheep were more abundant than pigs. Cattle were the most important species raised at the site. Daub contained imprints of emmer wheat, spelt wheat, common wheat and barley as well as weeds. Flint tools were obtained via trade with people living near flint sources. The flint assemblage was overall small and the tools showed signs of re-sharpening but not of production. Most tools were made of Jurassic flint (60 Km) though others flints were also evident including Swieciechów or chocolate flint (100 Km) and Volhynian flint (300 Km). The occupation is thought to have lasted 20-30 years.

3. Niedżwiedż, Phase 4 (3400-3100 BC) Funnel Beaker Occupation

All of the information presented on the excavation of Niedżwiedż is second hand obtained through publications and discussions with Professor Milisauskas (Burchard 1977, Burchard and Lityńska-Zając 2002, Makowicz-Poliszot 2007). The site was excavated by Barbara Burchard from 1965 to 1973 and was a joint project of the Zakład Archeologii Małopolski IHKM, the University of Michigan and the State University of New York at Buffalo (Burchard 1977).

The settlement was located on the western edge of the Bronocice region, bordering on Baden territory (Zastawny 2008). It was a boundary settlement between Funnel Beaker and Baden territories. This was a small, multi-component site measuring 2 hectares which was occupied sequentially though not continuously by Linear Pottery, Funnel Beaker, Corded Ware and Trzciniec groups. Sixty-five Funnel Beaker pits were uncovered. Four radiocarbon dates were obtained from different parts of the site indicating that it is contemporary with Phase 4 at Bronocice and was occupied for a longer period than Żawarża (3380 BC, 3340 BC, 3320 BC and 3140 BC, calibrated dates). Niedżwiedż was more complex than Żawarża. It was a multi-component site occupied intermittently by Linear Pottery, Funnel Beaker, Corded Ware and Trzcizniec cultures (Burchard 1977).

Though it does not appear to have been a large site (2 hectares), the persistent use of this location for settlement highlights the fact that the location was significant to ancient people. It is distinct from most other small Funnel Beaker settlements in the region which were typically occupied only once. Perhaps Niedżwiedż sat on a trade route or was a border hamlet between the main Funnel Beaker territory in southeastern Poland and the Baden culture located to the west and south. Niedżwiedż had other unique features, one of which is expressed in some of the pottery that has a distinctive style known as 'Niedżwiedż' style (Burchard 1977). This resembles the Funnel-Beaker Baden style that emerges at Bronocice late in Phase 4. A copper awl was recovered in Pit 38 which was clearly introduced by someone from the south as metal working was not a Funnel Beaker skill.

The settlement is different in arrangement than Żawarża. No circular pattern to houses was found. Instead, excavations uncovered postmolds associated with two houses identified as longhouses (Figure 3.36). This architectural style is rarely associated with Funnel Beaker building methods. However, post buildings were also found at Gródek Nadbużny (Gumiński 1989). Postmolds delineating the structures were clearly visible. These areas are referred to as House 1 and yard 1, and House 2 and yard 2. House 2 was large, measuring approximately 16 meters long and 7.20 meters wide. The postmolds of House 2 were more substantial in size than those of House 1. House 1 was smaller. Other postmolds were located near both structures suggesting other buildings or perhaps pens (Figure 3.15). Deep and shallow pits were located. It is possible that internal pits were cellars like those at Bronocice and Żawarża.

Deposits were found inside and outside of the structures. One Funnel Beaker burial was found as well as three animal burials in another pit. One pit within House 2 contained a human skull, reminiscent of skulls found at Bronocice which were also placed in pits. Imprints of cereals grains such as einkorn and emmer wheat were found in daub fragments indicating that farming was practiced in the area. The distance between the two houses is great. Whatever may have been in between was long ago destroyed by farming activities and soil erosion. No information is available for the fiber and textile production assemblage at Niedżwiedż. However, there is an image of a ceramic pot with the impression a woven textile on its bottom (Burchard and Lityńska-Zając 2002). In addition, a copper awl from Pit 38 may be a beater (Burchard 1977). A few signs of non-Funnel Beaker exchange were seen in the presence of a small nephrite axe Pit 75, a non-local mineral, and a copper awl in Pit 38.

Ritualized behavior was observed in Pit 101, which contained a triple animal burial, and Pit 117, which had an unusual kidney shaped pit containing a beef haunch covered by three stones. Pit 101also contained traces of an outdoor cooking hearth and located next to House 2. The burials consisted of an old dog and two lambs. There may be some symbolic meaning associated with this configuration since dogs are of major importance in herding sheep. One human burial was recovered within the settlement (Pit 46). It was a typical Funnel Beaker burial in which the body was placed in an extended position on its back. Pit 60/61 was similar to Pit 2-B6 at Bronocice. It contained a single human skull, perhaps representing a trophy.

The faunal data from Niedżwiedż revealed that cattle were the most intensively raised species. However, sheep were present in greater frequencies than expected on Funnel Beaker sites. Additionally, nearly 60 percent of them were adults were slaughtered indicating they were raised for purposes other than meat. Little information is available about the spindle whorls and loom weights recovered from the site other than basic counts. Very few were recovered from the site (Tables 2.1 and 2.2).

Table 2.1 Relative frequencies of structures with and without fiber and textile related ceramic artifacts by site and occupational phase.

Site	Phase	Structures with fiber and textile artifacts		Structures without fiber and textile artifacts		Total Number of Structures by Phase	
		#	%	#	%	#	%
Bronocice	1	5	.38	8	.62	13	1.00
Bronocice	2	2	.18	9	.82	11	1.00
Bronocice	3	6	.67	3	.33	9	1.00
Bronocice	3/4	11	1.00	-	-	11	1.00
Bronocice	4	19	.73	7	.27	26	1.00
Bronocice	5	28	.70	12	.30	40	1.00
Bronocice	6	16	.94	1	.06	17	1.00
Żawarża	3	6	.50	6	.50	12	1.00
Niedźwiedź	4	2	1.00	2	1.00	2	1.00

Table 2.2 Relative frequencies of structures with fiber or textile production artifacts or both.

Site	Phase	Structures with fiber production artifacts		Structures with textile production artifacts		Structures with fiber and textile artifacts	
		#	%	#	%	#	%
Bronocice	1	5	1.00	1	.20	5	1.00
Bronocice	2	2	1.00	1	.50	2	1.00
Bronocice	3	3	.50	4	.67	6	1.00
Bronocice	34	10	.91	7	.78	9	1.00
Bronocice	4	19	1.00	12	.63	19	1.00
Bronocice	5	27	.96	19	.68	28	1.00
Bronocice	6	16	1.00	12	.75	16	1.00
Żawarża	3	11	.91	11	.91	5	1.00
Niedźwiedź	4	2	1.00	2	1.00	2	1.00

Table 2.3. Summary of fiber and textile production artifacts from Żawarża.

House #	Yard (closest to house#)	Spindle Whorls	Oblong Loom Weights	Mini Axe Loom Weights	Bone Beaters
1	-	2	-	-	-
3	-	-	-	2	1
4	-	3	-	-	-
6	-	1	1	-	-
7	-	4	-	-	-
-	7-8-9	1	-	-	1
8	-	2	-	-	-
9	-	2	-	-	-
-	9-10	2	-	-	-
10	-	2	-	-	1
-	10-11	2	-	-	-
12	-	1	-	-	-
	Total	22	1	2	3

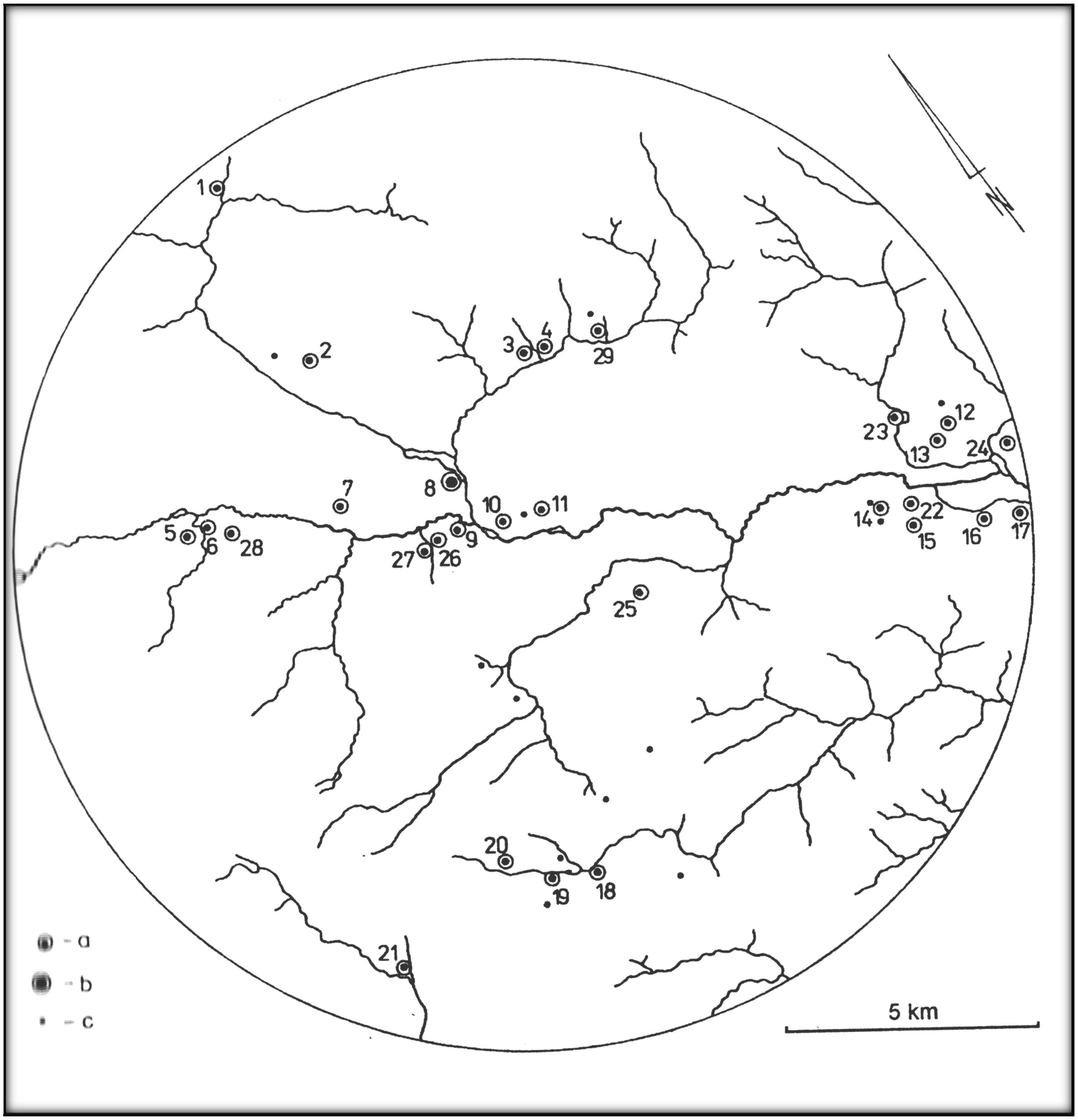


Figure 2.1 Distribution of Linear Pottery Settlements within the Bronocice region 6500-4500 BC.

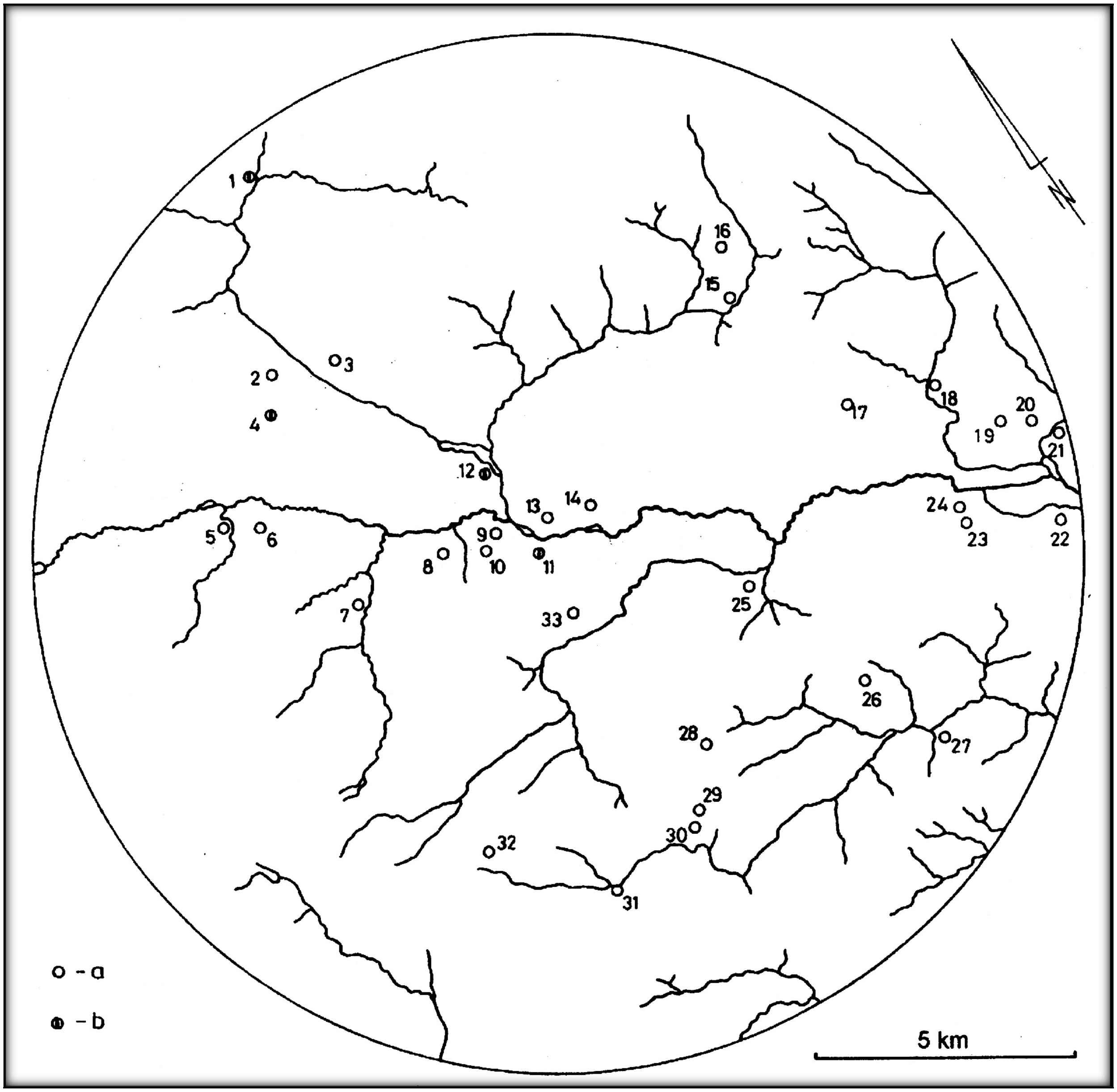


Figure 2.2 Distribution of Lengyel Settlements sites within the Bronocice region 4400-4000 BC.

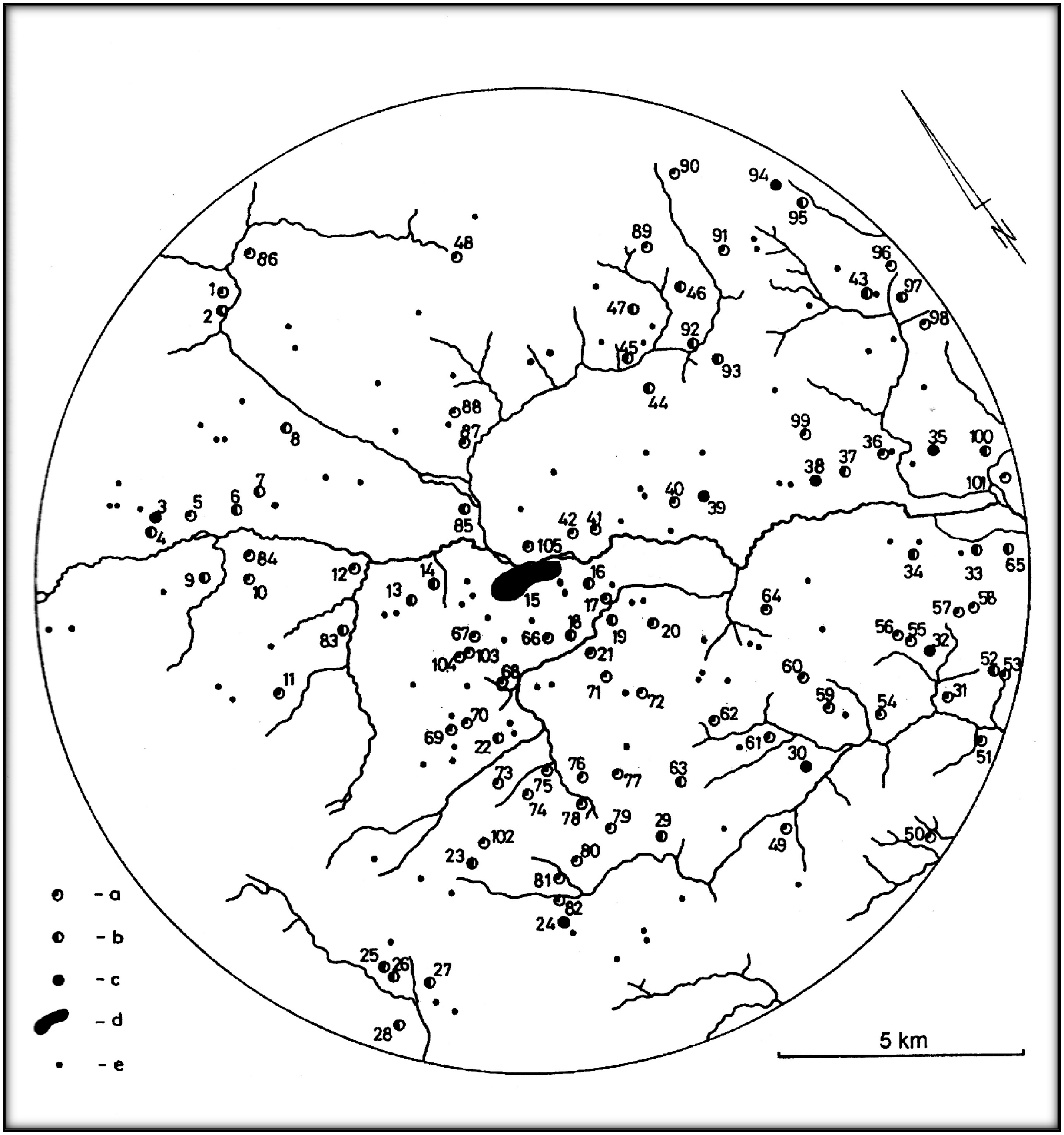


Figure 2.3. Distribution of Funnel Beaker Settlements within the Bronocice region 3700-3100 BC.

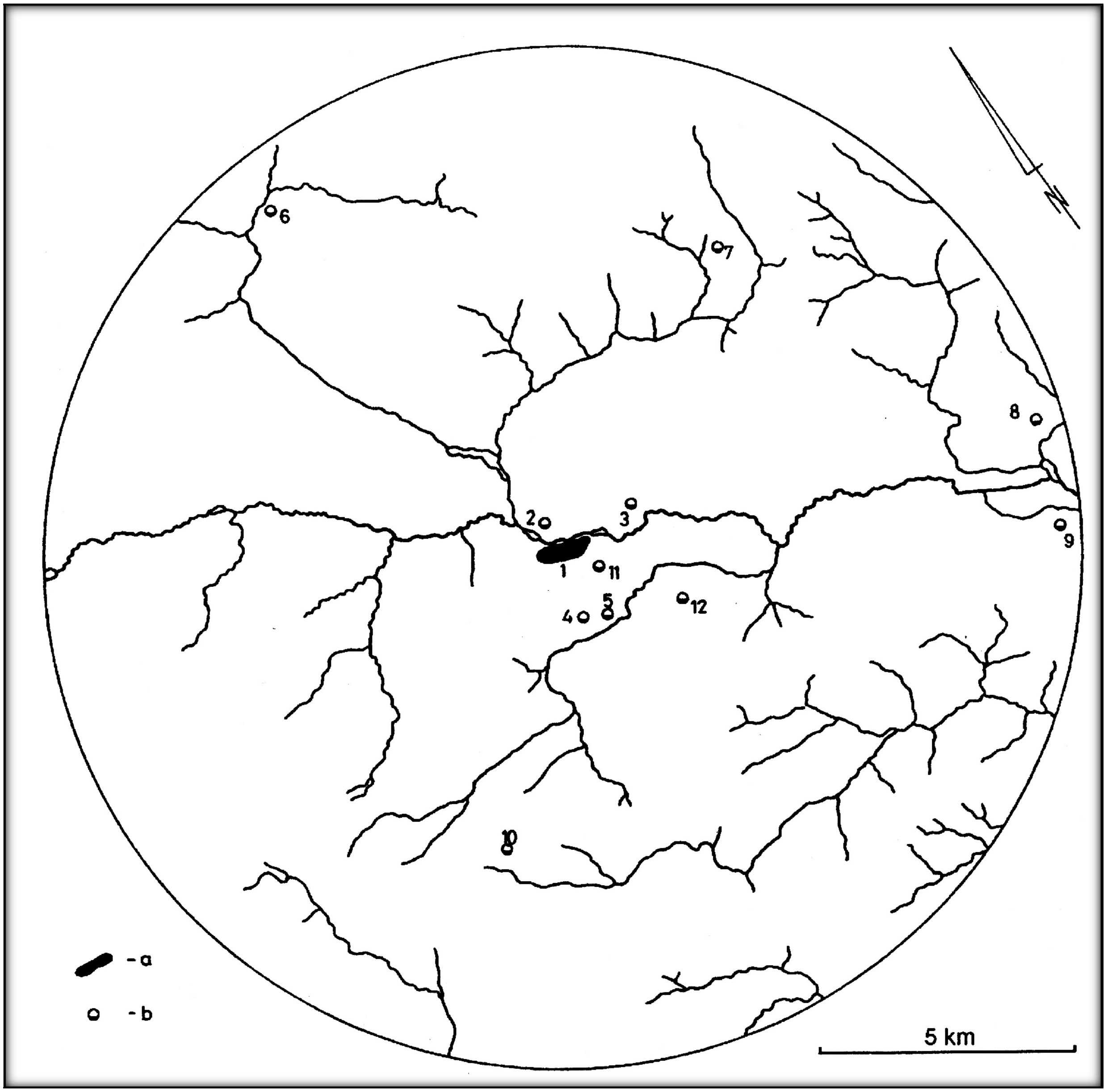


Figure 2.4. Funnel Beaker-Baden settlement within the Bronocice region 3100-2700 BC.

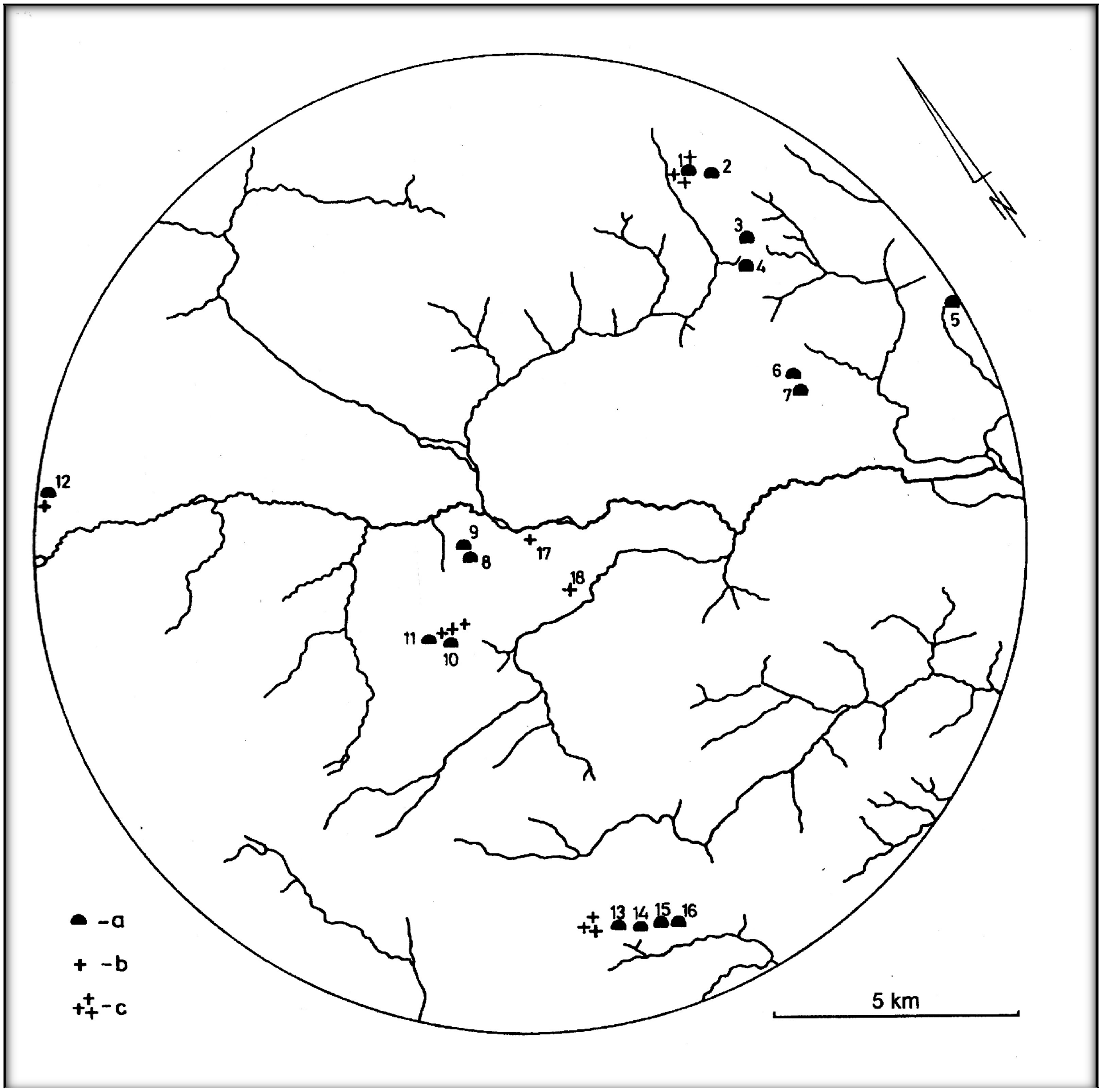


Figure 2.5. Distribution of Corded Ware Burials within the Bronocice region, 2900-2500 BC.

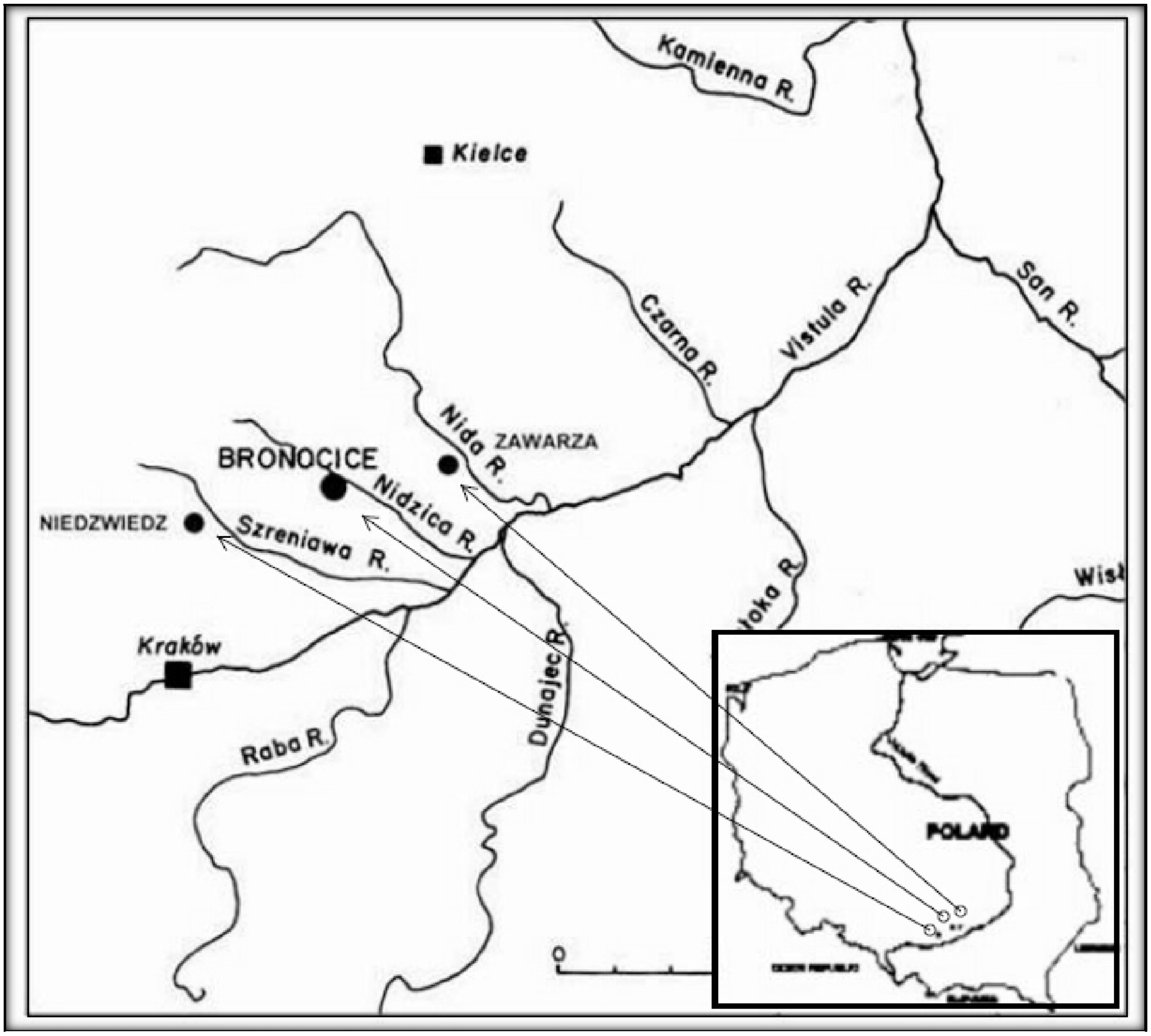


Figure 2.6. Site location map.

Figure 2.7. Units in which traces of the Phase 1 Funnel Beaker settlement were found.

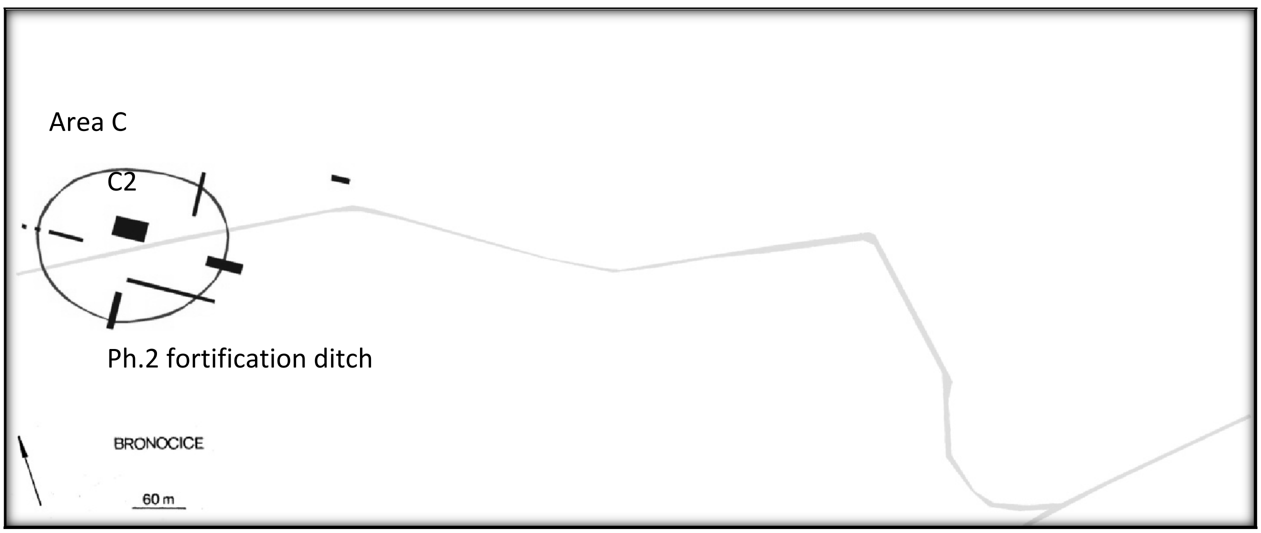


Figure 2.8. Units in which traces of the Phase 2 Lublin-Volhynian settlement were found.

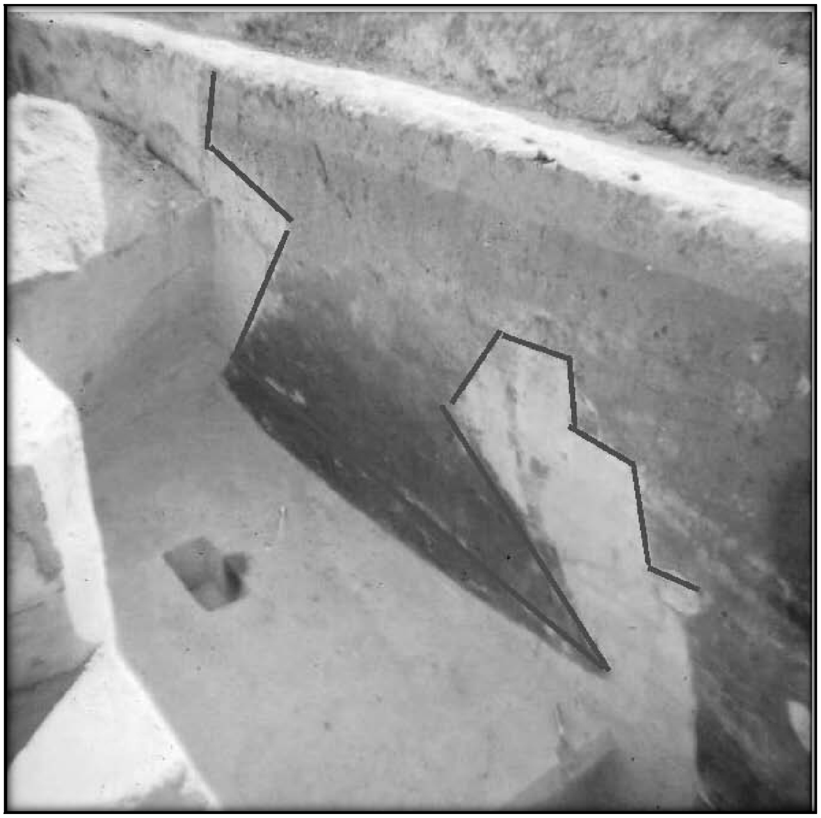


Figure 2.9. Edge of structure C1.2 and Pit (86-C1) spanning the Phase 2 ditch and stairway leading into the settlement.

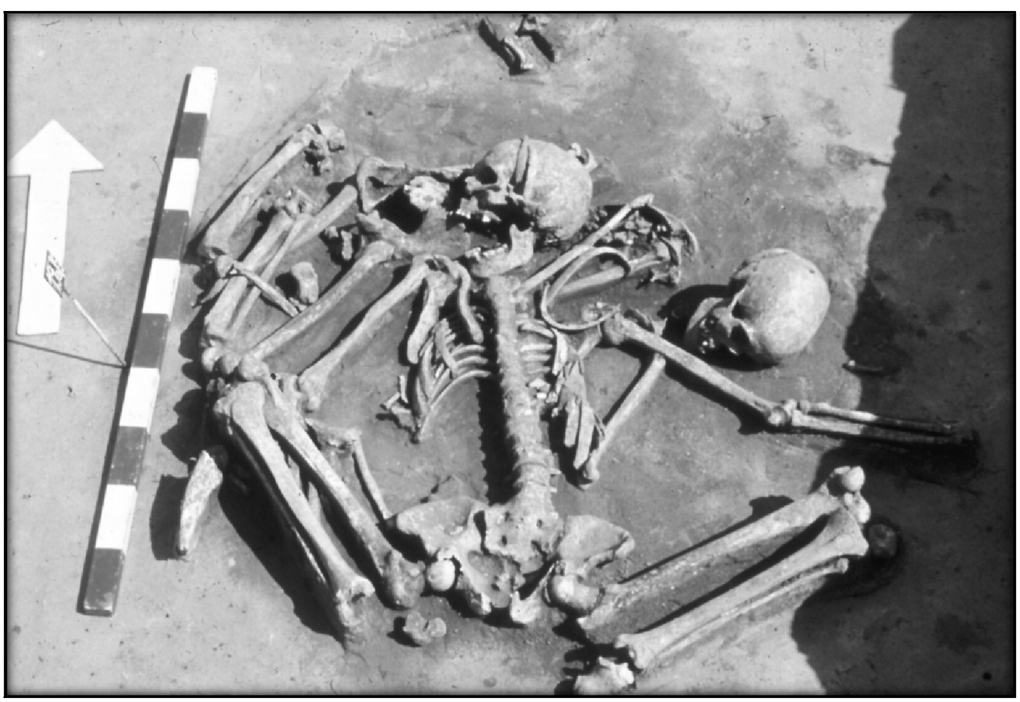


Figure 2.10. Double Lublin-Volhynian burial, Unit C2.

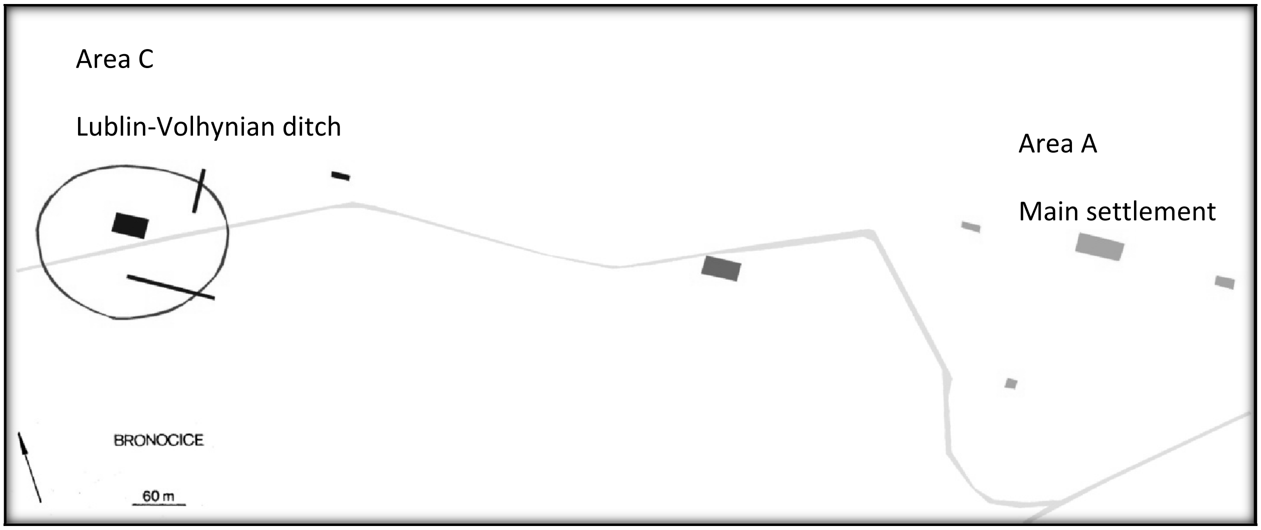


Figure 2.11. Units in which traces of the Phase 3 Funnel Beaker settlement were found.

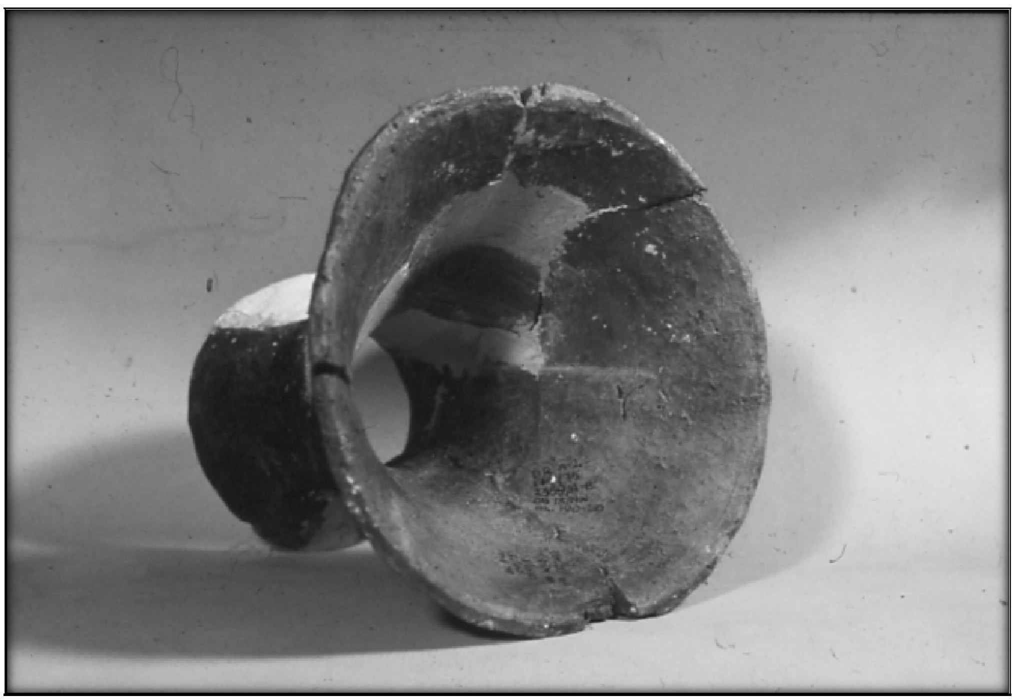


Figure 2.12. Drum.

Figure 2.13. Ceramic rattle.

Figure 2.14. Vessel with wheeled cart motif.

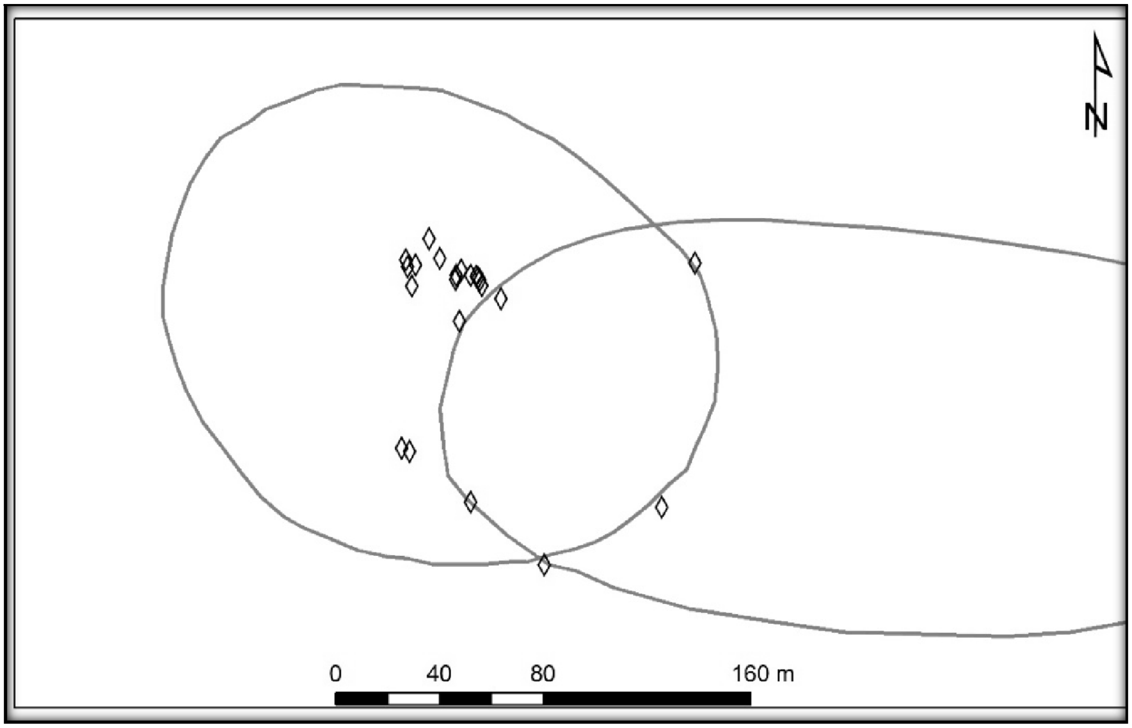


Figure 2.15. Distribution of burials dating to Phase 3/4 in Area C.

Figure 2.16. Classic Funnel Beaker Burial, Unit C5.

Figure 2.17. Woman buried face down inside house in Unit A1.

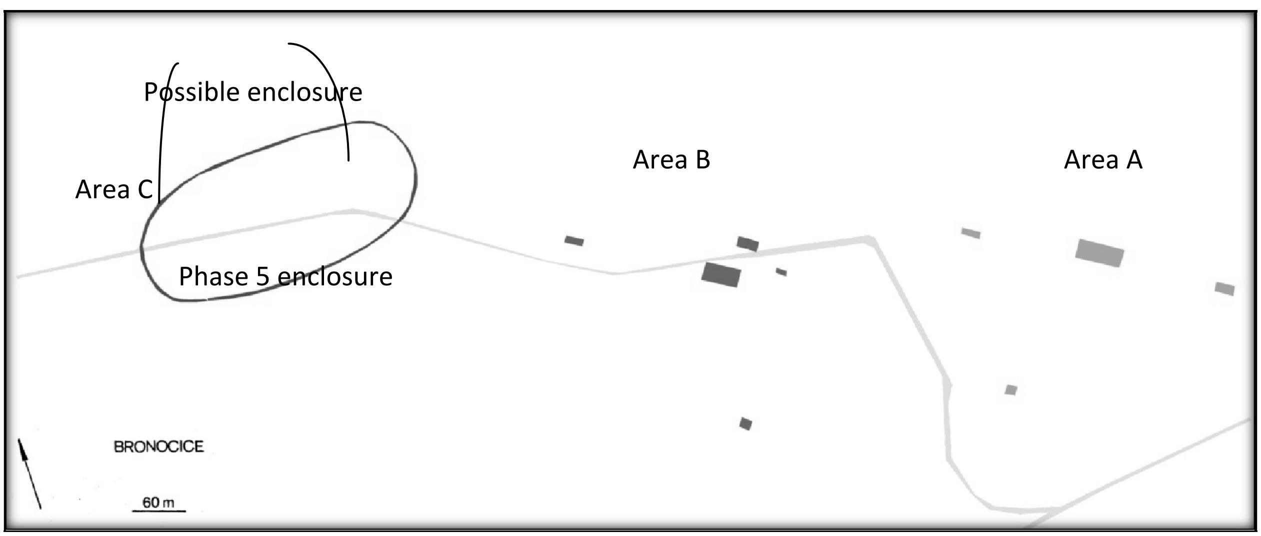


Figure 2.18. Units in which traces of the Phase 4 Funnel Beaker settlement were found. Signs of another possible enclosure predating the Phase 5 were found in Area C.

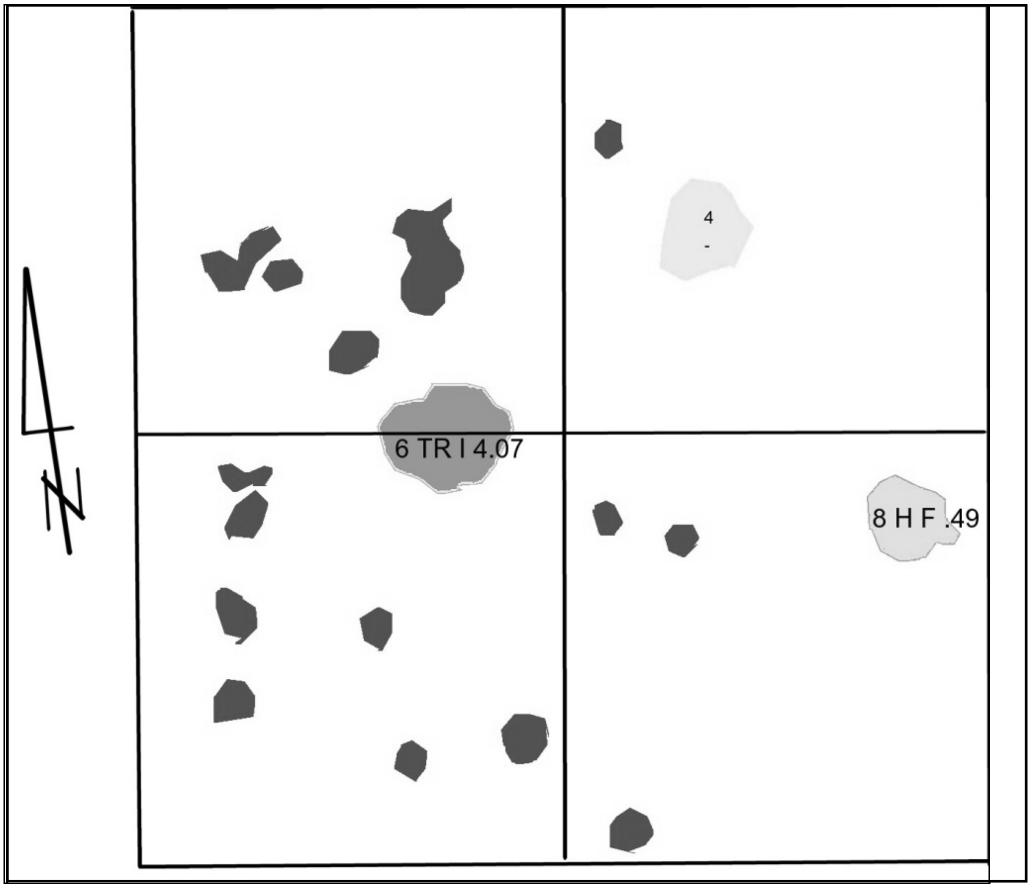


Figure 2.19. Unit B6 postmolds and Phase 4 pits.

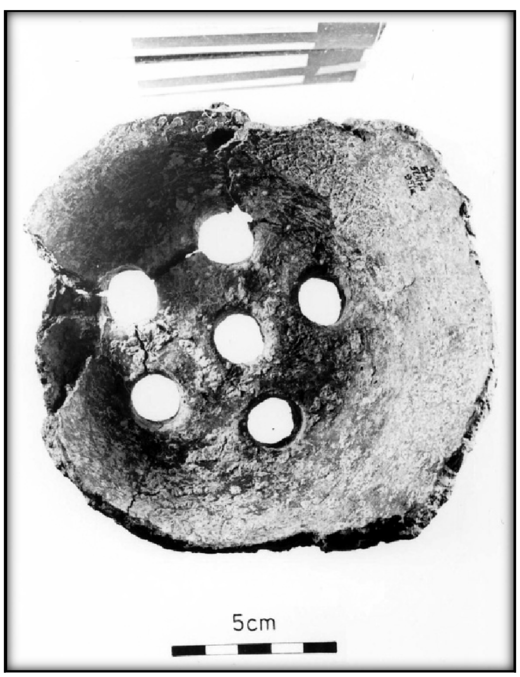


Figure 2.20. Ceramic sieve.

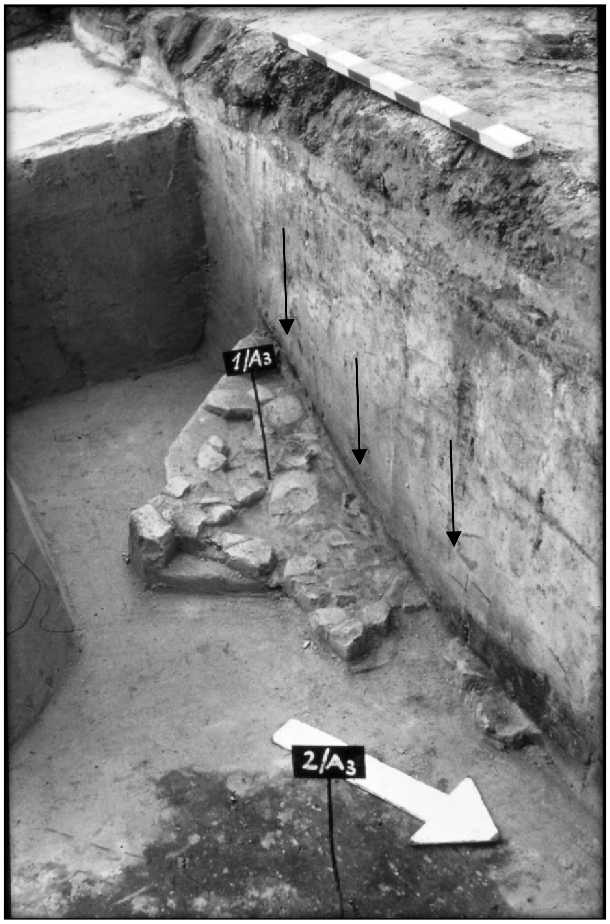


Figure 2.21. Stone ramp in Unit A3. Note fire-reddened soil along the ramp (black arrow).


Figure 2.22. Drum.

Figure 2.23. Seven slaughtered head of cattle in pit 21-A3. Note the head of one on the quern.

Figure 2.24. Evidence of burning can be seen in the profiles of pits exposed along the historic road (Area A).

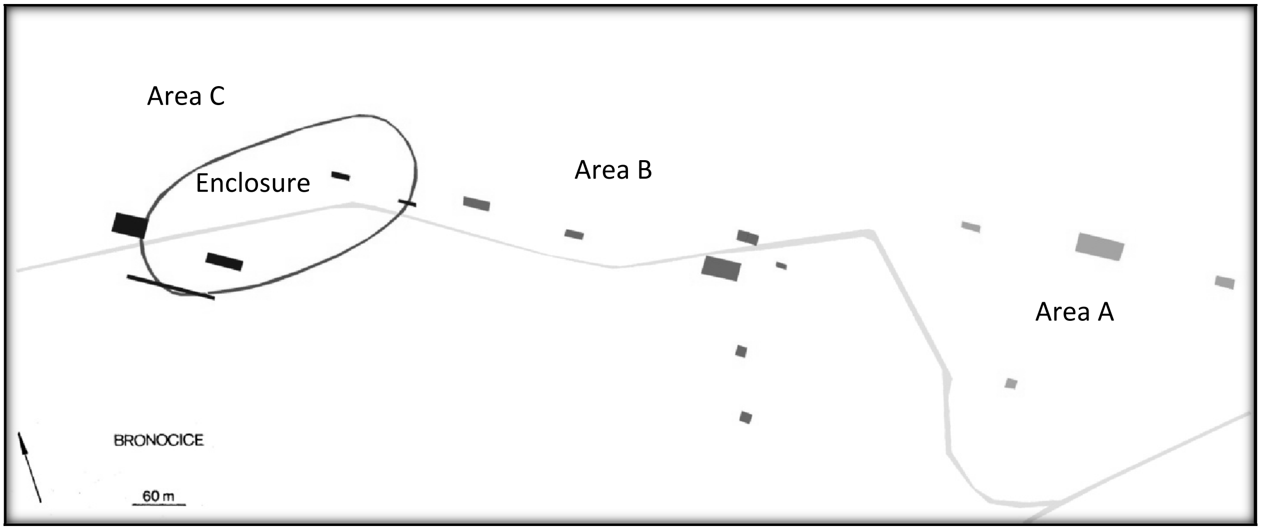


Figure 2.25. Units in which traces of the Phase 5 Funnel Beaker settlement were found.

Figure 2.26. Classic Funnel Beaker pot from Phase 4.

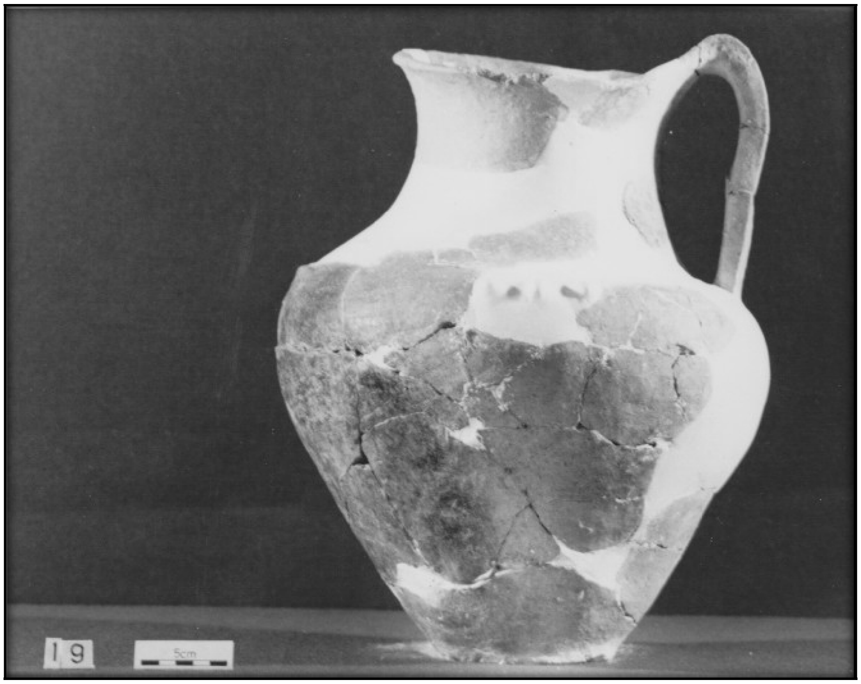


Figure 2.27. Funnel Beaker-Baden vessel. The large handle is a Baden influence.


Figure 2.28. Burial of a roe deer, Pit 22-B1.

Figure 2.29. Skull positioned in the bottom of pit 2-B6.

Figure 2.30. Multiple burial, Pit 36-B1. Note horizontal postmolds in side wall.

Figure 2.31. Multiple burial 36-B1. Note vertical postmolds in bottom of the pit.

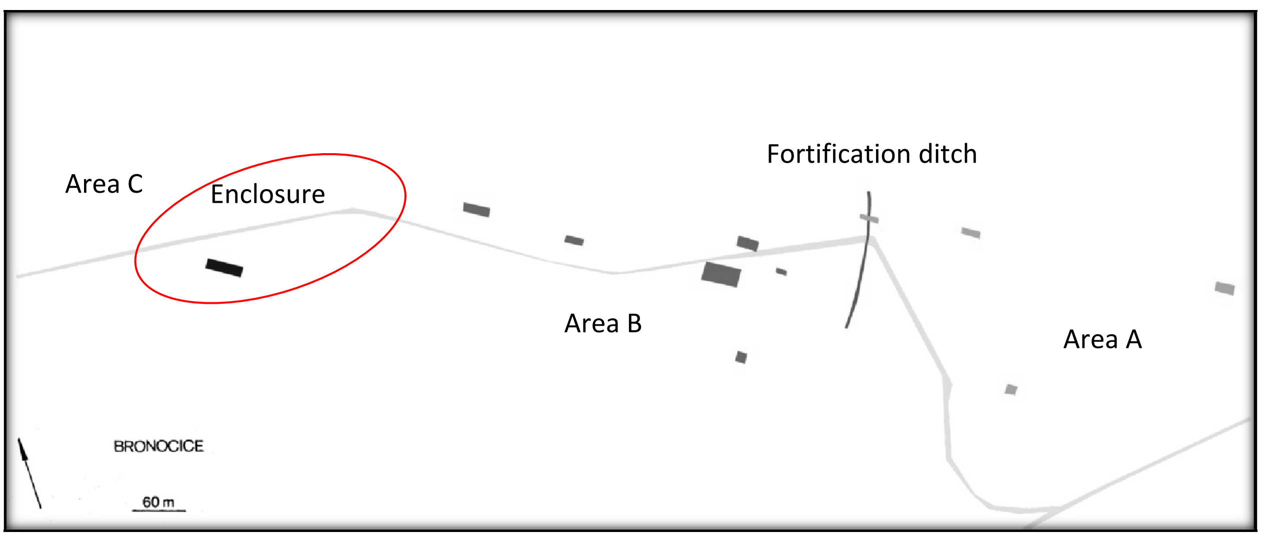


Figure 2.32. Units in which traces of the Phase 6 Funnel Beaker settlement were found. A new fortification ditch was built in Area A.

Figure 2.33. Corded Ware burial post dating the Phase 6 settlement.

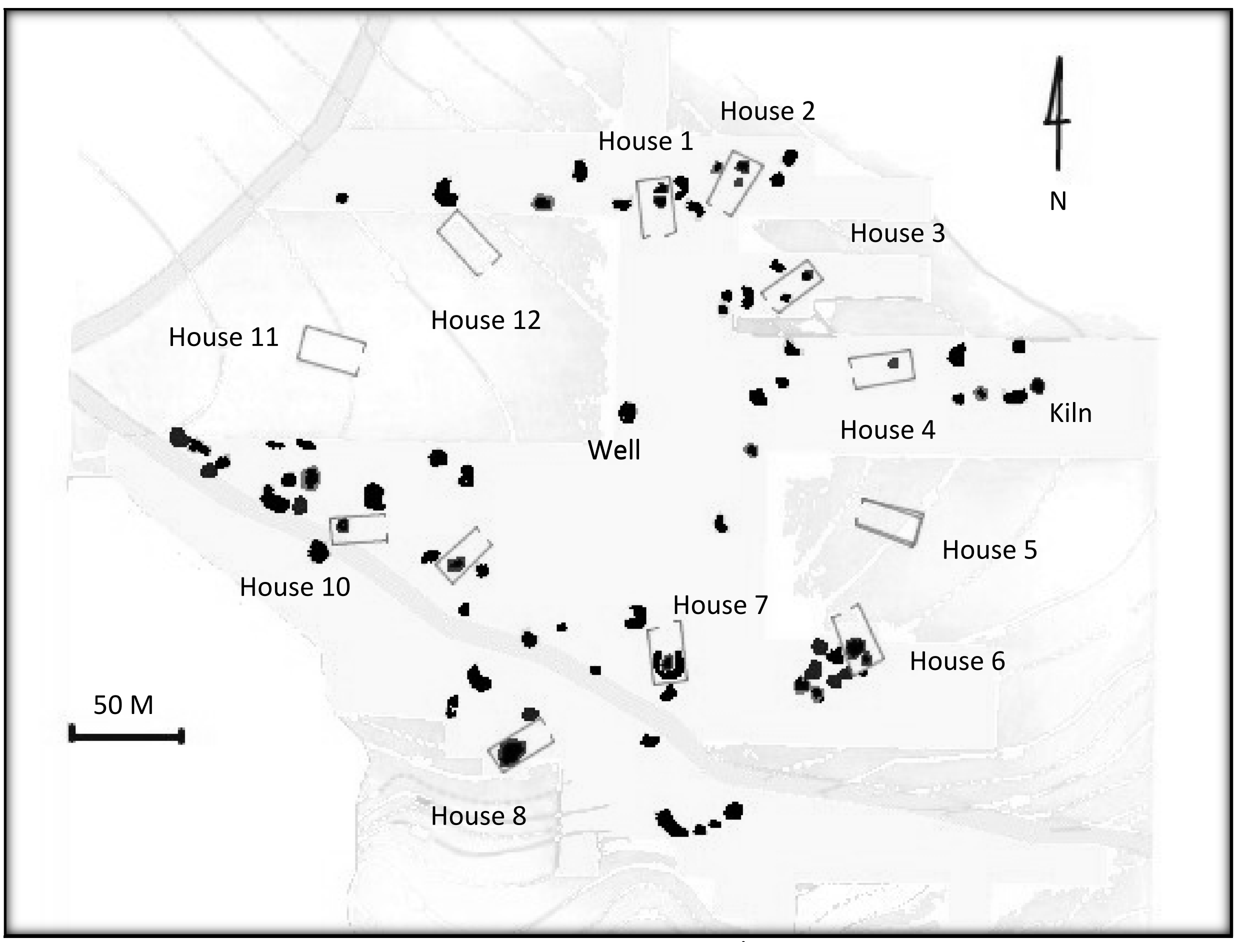


Figure 2.34. Remains of the Funnel Beaker settlement at Żawarża, Phase 3.

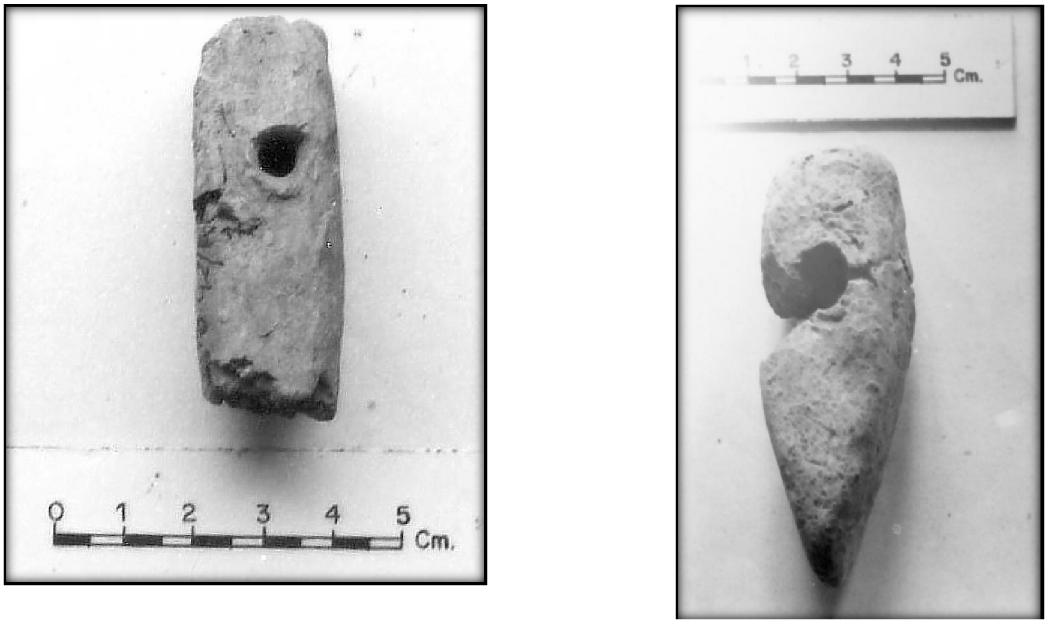


Figure 2.35. ‘Mini axe’ loom weights from Bronocice: left, Phase 3, Pit 42-A1, right, Phase 5, Pit 56-B1.

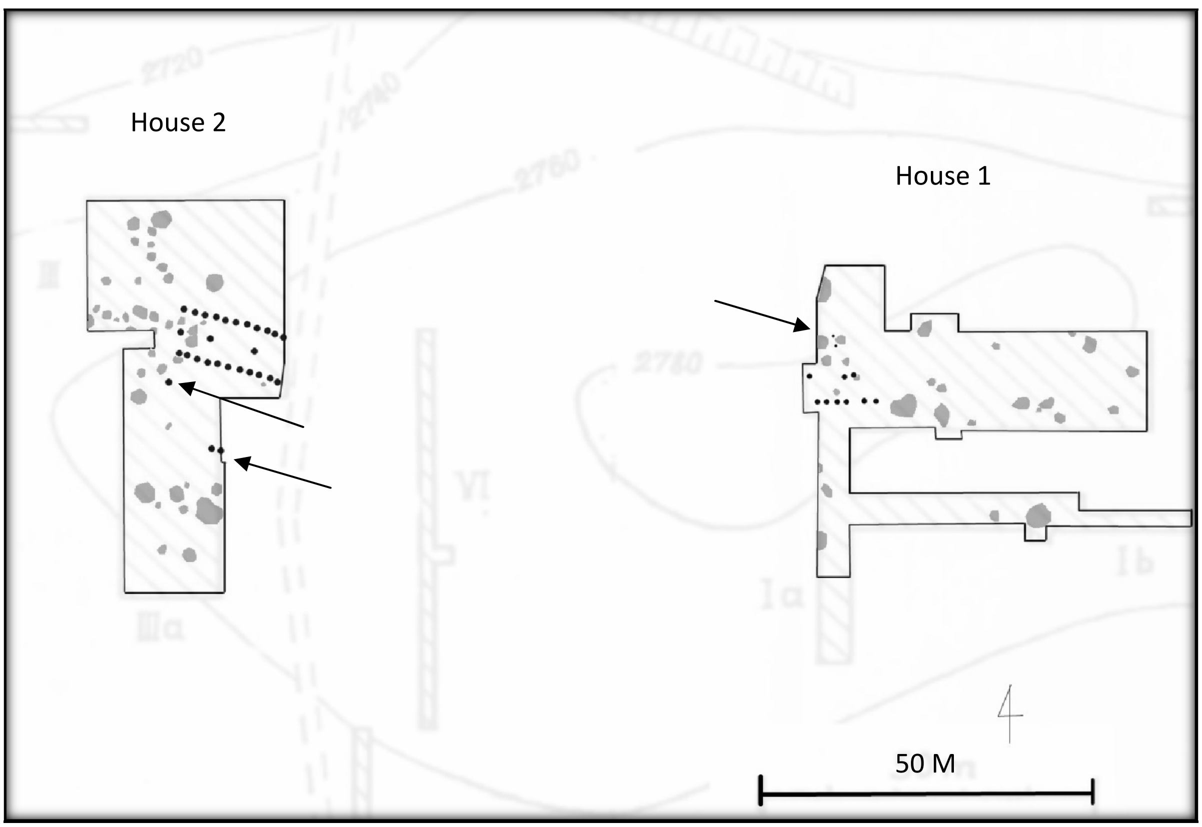


Figure 2.36. Remains of the Funnel Beaker settlement at Niedźwiedź, Phase 4. Arrows indicate other unidentified structures.

Chapter 3

Faunal Remains and Livestock Management in the Bronocice Region

Faunal remains have been used to address issues such as animal husbandry practices, consumer behavior, diet, and ritualized behaviors including feasting and animal sacrifice (Milisauskas 2011, Reitz and Wing 1999, Russell 2012, Whittle 2002). The kinds of faunal data typically examined include range of species, relative importance of species, age at death profiles, butchery practices, body part distributions, and temporal and spatial variability. Currently there are few studies available that inform about livestock breeding practices and relate them to social interactions during the Middle and Late Neolithic (3800 BC – 2700 BC) in southeastern Poland.

Faunal analyses conducted on assemblages from Funnel Beaker sites across central Europe have demonstrated a fairly consistent pattern of animal husbandry practices with occasional variability generally depending on environmental setting (Bökönyi 1972, 1974, Ebersbach 1999, Glass 1991, Marciniak 2005, Midgley 1992). Many of these studies have interpreted faunal broadly, only rarely considering the significance of intra-site or inter-site variability (Gumiński 2005, Hachem and Auxiette 1995). Other studies have focused on the logistics of feeding animals through the analysis of dung samples, and cereal and weed profiles (Akeret and Rentzel 2001, Bogaard 2004, 2005, Delhon *et al* 2008, Mainland and Halstead 2005) and seasonal shifts related to pasturage (Bentley and Knipper 2005).While all of these studies contribute to the understanding of cultural behaviors they are essentially limited to explanations on the regional scale or more specifically the site level, but shed little light on the interactions between localized communities or among households (Burchard and Eker 1964, Gregg 1988, Hatting 1978, Higham 1969a, 1969b, 1968, Kowalczyk 1962, Kulczycka-Leciejewiczowa 2002, Lasota-Moskalewska 1982, Lasota-Moskalewska *et al* 2008, Makowicz-Poliszot 2002).

Previous studies conducted on the Bronocice faunal assemblage considered inter-site temporal and cross-cultural variability (Milisauskas *et al* 2012, Pipes *et al* 2009). Cattle and sheep remains were found concentrated in specific deposits. Wild mammal and domesticated mammal species frequencies have been shown to fluctuate between deposits and across time. High frequency repetitions of specific skeletal elements have been correlated with ritualized behaviors. Pig and wild mammals were represented by limited body part distributions suggesting they were not raised at Bronocice and that instead meats, possibly preserved, were brought there. These data indicate an increasing level of socially complex, the existence of specialists among households and outside the community, and rising regional integration over time. Preliminary findings on a small sample of test pits from the six occupational phases indicated that from the earliest to the latest period it is possible to link differences to specialized behaviors pointing to the actions by distinct actors in the past. The gross analysis at which faunal remains are generally examined and interpreted generally fail to consider that variability is just as important in interpreting remains as patterning, that it often signals a shift of priorities.

Domesticated animals are essentially kept in captivity all of their lives. They are controlled by people to varying degrees depending local social practices. Control extends to breeding, nursing, grazing, foddering, sheltering, and culling. They are exploited during life as well as in death. Methods of exploitation vary greatly. Keeping animals imposes restrictions not just upon the animals but also those who care for them. The interaction of livestock and their keepers is highly patterned and ritualized regardless of the type of economy they belong to. The patterns of behavior are reproduced daily, seasonally, and yearly. Decisions are based upon those recurring cycles and require forethought and planning.

Breeding is an important part of animal husbandry practices. It requires cross-breeding and exchange among small scale agricultural communities for biological reasons such as maintaining health and vitality, and controlling the sex and age ratios of livestock animal. Breeding involves social interactions with people outside of a household who own livestock as well for social reasons such as issues of marriage, property ownership, alliance, and control or power over resources, people and space.

Isolation of livestock will result in poor breeding and is a bad reproductive strategy. Successful stock breeding requires annual replacement of animals slaughtered, or killed by other agents, as well as the input of new genetic material in order to maintain healthy herds. Domesticated livestock are primarily dependent on human intervention to care for their many needs. In order for people to meet the needs of their animals they establish social networks of support, exchange and reciprocity, and to create social relationships based on kinship and marriage, with groups outside of their own settlement. The size of a herd is a significant factor in determining whether to outbreed or exchange livestock with herds from other settlements. The smaller the size of the herd the more critical it becomes to establish out-breeding relationships and to exchange animals when a difficult situation arises such as an overabundance of males (Payne 1973, Redding 1984). Herd size in small scale societies requires the periodic input of new breed stock in order to avoid the affects of genetic drift and founders affect (Bancroft *et al* 1991, Lacy 1997). Every year stockherders face the same choices; they must decide which animals to slaughter, how many of the offspring to keep and which to exchange.

DNA analytical methods have expanded dramatically over the past decade. Consequently several avenues are now available for investigating genetic relationships and origins. Genetic databases have grown and published sources of genetic information are available on the web. Previous studies have revealed several patterns in genetic relatedness that relate to the domestication of cattle, sheep, goat and horse (Beja-Pereira *et al* 2006, Cymbron *et al* 2004, Davis 1987, Edwards *et al* 2007, Fernández *et al* 2006, Hiendleder *et al* 2002, Lindgren *et al* 2004, Luikart 2001). These studies have focused more on the domestication of animals and possible cross-breeding between imported domesticates and wild progenitors. Little effort has been made to look at the genetics of small scale breeding populations and livestock management practices during the Neolithic.

Unlike cattle and pit, sheep and goat had no contemporary progenitors in central Europe during the Neolithic. Genetic studies indicate that there was a strong and long term line of communication and exchange between local people and non-locals and the importation of sheep and goats for trade. DNA studies on domesticated goats have shown that archaeological samples from Italy and France show a high degree of genetic diversity (Guo *et al* 2055, Luikert *et al* 2004, MacHugh *et al* 2001, Tapio *et al* 2006). This line of evidence essentially demonstrates that along coastal areas there was a perpetual flow of new genetic stock introduced into breeding populations via long distance trade. In the same way it is possible to consider the livestock at Bronocice. The breeding requirements of small herds necessitated the out-breeding of all domestic animals and by default the creation and maintenance of social relationships between residents of different settlements. The cyclical nature of animal breeding means that these relationships take on a seasonal aspect as well. It may be that sheep are particularly complicated because of the lack of wild progenitors. So the creation of social relationships involving the trade, exchange and breeding of sheep is of particular relevance.

At a few sites in southeastern Poland dating to the period 3650-3100 BC sheep increased in economic importance relative to pig and cattle. Ryder among others speculated on their economic importance as being primarily a source of meat prior to the development of wool based economies (Ryder 1983, Sherratt 1997). Traditionally archaeologists have assumed that sheep were kept primarily as meat on the hoof during the Early and Middle Neolithic (Bogucki 1988). The assumption is predicated a model of herd management that involves killing off young animals for meat when that is their primary function in a society (Greenfield 2005, Payne 1973, Redding 1984). In spite of being better adapted to open areas and drier climates, sheep adapted well to many different environments across the northern plain. Sheep are best adapted to drier climates. Sheep are grazers whereas goats are browsers. They exploit different kinds of resources though overall they prefer grasses. Environmental changes that occurred in this region of Poland include a shift away from heavily forested to open parkland opened greater areas for grazing sheep as well as other species (Kruk *et al* 1996). Because sheep did not have wild progenitors in Europe during the Neolithic their presence on Neolithic sites throughout central Europe indicates that people had continuous success in managing their needs.

The age at which sheep are slaughtered varies depending on the purposes for which they are raised. The range of sheep products is greater than just meat and hides. They are used to graze cropped fields in order to fertilize the earth, for milk which in turn can be made into cheese, for fibers plucked or sheared, and for ritual sacrifice. They are easy to herd manage. Like cattle the dominant female is the only animal that the shepherd needs to control. If they serve primarily as a food it is said that they are slaughtered early in life whereas if they are kept for dairy purposes or for wool they are slaughtered later in life. A dairy herd will consist mainly of females, the males being slaughtered early in life and the females late in life. A wool herd on the other hand will consist of older animals including males and females as well as wethers or castrated males. Intensification where animal husbandry practices are concerned typically involves diversifying livestock, increasing the number of animals kept and grazing more than one species on the same unit of land. It can be seen through the creation of enclosures, housing and pens. The result however is an increase in human effort and attention to care and maintenance of animals.

The characterization of breeding populations is one of the main objectives of using non-recombinant DNA materials to establish phylogenetic structures indicating lines of descent of mammalian species (Chiraroni *et al* 2008, Edwards *et al* 2007, Larson *et al* 2007, Lindgren 2004). Unfortunately no y-halpotype data is yet available for Bronocice. However, mtDNA data was obtained for sheep and showed some of the sheep genetic relationships between Bronocice and outlying settlements. The XRF data however revealed that much of the success in sheep rearing was due to large scale importation of sheep for nearly 1000 years to Bronocice. The mtDNA data provided connections between Bronocice, Żawarża and Niedżwiedż indicating that that people established and maintained social relationships across settlements. Though exactly what form those relationships took is a matter of speculation, their existence is not. Those social links were part of the social fabric of the Bronocice region. Social cohesion and cooperation were necessary parts of successful stockherding and probably depended upon good social relationships perhaps in the form of household alliances and support networks across communities. Lithic remains indicate that social relationships were often based on trade and exchange as well.

A. Household and Gender Based Animal Husbandry Practices

Social structure and tasks in the past were likely structured around households and gender. The household is considered the unit of production during the Neolithic but it is also the unit of organization (Bogucki 1988, Hendon 1996). Blanton studied households and dwellings across several cultures (Blanton 1994). He found that households vary according in composition beginning with nuclear families and at times including a range of extended family members. The house itself creates structure among the residents. The house gives residents of place and association. Identities are tied to houses and are created through household relationships and between households. The household structure varies but is generally differentiated by gender and by task. There are varying levels of cooperation within the household structure but it is the unit itself which makes important decisions. The variation seen in social relationships within households is so varied that cultural anthropologists emphasize task orientation. People who do things together share a gendered role (Hendon 1996). Food preparation, weaving, child rearing, animal herding, etc. are gendered roles seen in the ethnographic. Hendon further suggests that technology and material culture serve to structure social relationships.

Feminist archaeologists have searched for ways to identify gender differences in the archaeological record, especially since the rise of post-modern theoretical perspectives. Initially they looked primarily at material remains that could identify women. But these kinds of efforts eventually gave to a search for gendered roles (Hays-Gilpin 1998). Gender roles are believed to be fluid and vary considerably both internally and externally within societies. They are reflective and defined in relation to others. One way for archaeologists to envision past gendered roles is to consider ethnographic comparisons. Ethnographies can provide useful analogies for understanding past gender roles and relationships (Claesson 1994, Spector 1998).

Ethnographic data provides useful analogies for understanding for social structures and practices involving Pastoralists and farmers (Nandris 1984, Voight, Halstead 2006, 1996). However, it is hard to know what models are most appropriate. Much of the ethnographic literature focuses on pastoral societies in Africa. Many of the African ethnographies focus on societies heavily impacted by colonialism and control by the state (Sieff 1997, Turner 1999, Steinman 1998). Gender constructions are very difficult to identify, reconstruct and understand even within living cultures. Some perspective can be gained by looking at pastoralism in Africa. The construction of gender and the roles of women and men among the Massai tend to be fluid and contested, carrying multiple layers or meaning. The concept of the patriarchal pastoralist is seen as invalid because it is too simplistic to accommodate the politics of gender interactions or the shifting that takes place when an individual moves through generational cycles (Hodgson 2000). It is difficult in light of some of these issues to see how archaeologists can project real understanding of complex gendered roles onto remote cultures accurately.

However, some aspects of these studies seem to be relevant with regard to the social relationships found within households. It is unclear if behavioral models that originate from very different ethnic and ideological backgrounds necessarily express animal husbandry practices similar to those practiced in Europe during the Middle and Late Neolithic. For that reason examples are drawn from different cultures.

Decision making practices are negotiated. Interested parties sometime have conflicting agendas that result in decisions that seem illogical and self-destruction. McPeak and Doss studied conflictive decision-making between husbands and wives in Gabra society, Northern Kenya (McPeak and Doss 2006). In this pastoral society it is the women's responsibility to build houses and enclosures every time the household moves. The husband decides when they will move. Men will split the herd and leave lactating cows at home where their wives milk them daily. It turns that women control how milk the family consumes and are able to sell the rest when they settle near towns. Increasingly, men find themselves challenged by their wives who do not wish to move nor to stop at great distances from settlements because they then cannot sell milk. The authors considered three models of decision-making 1) Cooperative, decisions are made cooperatively among household members, 2) Traditional, husbands make all decisions and 3) Contested, women contesting men's decisions. They found that individuals are more to promote their own self-interests first. Men prefer to keep their wives away from settlements even though it may be profitable mainly because they do not benefit directly (McPeak and Doss 2006).

Payne looked at Norwegian historic records including as tax roles to examine Saami households during the late 19th early 20th century (Paine 1965). Although political harassment influenced the level of detail contained in those documents, the author found that households tended to be more or less self-sufficient, although those with dependent children were less likely to be so. In those cases he found that it was common for two or three related households to form a single cooperative unit and work together at managing and herding livestock. It was also common for children to be adopted into other households where there were few or no children. He also found that siblings, married and single, would come at times and help for short periods. So cooperation was essential and took different forms depending on the needs of the household.

Ethnographic studies indicate that increased focus on cattle rearing is often associated with issues of power, prestige and control over resources. Ebersbach (1999) conducted a modern historical and ethnographic study of 30 Swiss villages located along lakeshores in which she found that most of the grain grown was used to feed cattle as well as humans. The three top reasons for raising cattle included traction, dung and dairy. Social reasons included prestige, ideology, investment and transportation. Fields and cattle were found to be in competition with each other, and meat was considered to be a by-product of raising cattle. Halstead and others recently have also argued that increases in grain cultivation may have been to feed animals as opposed to being limited human consumption (Halstead 2006).

B. Livestock Management Practices at Bronocice, Żawarża and Niedżwiedż

Mixed agricultural communities like that of Bronocice would have had a wide range of tasks that required coordination and cooperation in order to function well. These would seasonal tasks relating to farming and stockherding, in addition to other household tasks. It is beyond the scope of this essay to address all of them adequately. With regard to livestock management the most obvious tasks features herding livestock throughout most of the year including grazing and browsing, watering, breeding, birthing, sheltering, and foddering in the winter and culling the herd. Other tasks would have focused on the collection and processing of by-products such as milk, dairy products, dung and wool. A survey of ethnographic information reveals a wide of range practices across the world in terms of who manages larger and smaller livestock, who owns livestock, who is responsible for the slaughter of animals and the processing of carcasses, as well as who handles milking and production of dairy products, the plucking or shearing of wool, the processing of wool into thread and weaving.

The scale of agricultural practices and size of herds are two factors that seem to affect the composition of those involved. Small scale agricultural communities that practice mixed farming and herding tend to be egalitarian and matrilineal societies (Holden and Mace 2003, Reid 1996, Turner 1999, Wangui 2003).

Herd management involves many daily, seasonal and annual tasks. Daily tasks include watering and feeding, and dung collection. Cyclical tasks involve herding animals during warmer seasons, collecting fodder, harvesting and grains for winter months, and maintaining enclosures. Annual cycles include the birthing, breeding, and slaughter of livestock. Management decisions are complex and involve consideration of the herd composition including ages and sex ratios, numbers of animals needed to replace those that have died or will be slaughtered, numbers of animals needed for social obligation events such as feasts relating to marriage and religious ceremonies, and whether or not an increase in herd size is desired (Gregg 1988, Higham 1969, Payne 1973, Bogucki 1988, Glass 1991).

According to Fleming, changes in agriculture and animal husbandry practices followed an evolutionary trend throughout many parts of central. Agricultural settlements were small, situated in forests, with small numbers of livestock that required foddering during the winter. The settlements increased in size over time, shifted to slash and burn agriculture and shorter fallow periods. Animals had better foods as a result of grasslands. Towards the end of the Neolithic population densities throughout central and northern Europe appear to have declined sharply though that may simply reflect a shift from sedentism to nomadic pastoralism making it difficult to determine numbers. Fleming suggests that the appearance of pastoralists throughout central Europe is the cause. Competition over pasturelands might have pushed people into smaller tracks of land which they overgrazed and farmed (Fleming 1972). Environmental data show in many areas landscapes became degraded. Shennan and Edinborough have also correlated the arrival of Corded Ware people with the drop in population through central Europe (Shennan and Edinborough 2007). Others suggest that farmers became pastoral nomads (Anthony 2007, Milisauskas 2011, Sherratt 1987). The shift from sedentary farmers to pastoralists would have involved dramatic changes within the household structure. Ethnographic research has shown that pastoral nomads generally are patriarchal in structure. But little is currently understood about the social causes of the transition of these people from a sedentary life to a pastoral nomadic one.

Archaeological examination of faunal remains the range of domesticated animals kept at Bronocice included cattle, sheep, goat and at times pig. The rank order remained cattle, sheep, pig and goat throughout the 1200 year occupation. It should be noted that at no time were goats present in significant numbers. Horse and dog were also recovered. Horse was not present in significant frequencies. It is only during the last phase that they may be represented by s domesticated species. For that reason it will not be considered further in this discussion. Dogs appear in every phase except Phase 2. Though they were not abundant until the late Neolithic phases, they were nonetheless pervasive. The lack of dogs in Phase 2 is curious, especially since during this period the site was occupied by a small group of Lublin-Volhynian outsiders. All three species require special attention during winter months. They need to be watered and fed. Water requirements are rarely mentioned in archaeological reports a rather odd omission considering the volume required to keep large animals alive. At Bronocice the river was within a short distance. Unless there was a stream nearby livestock would have been taken down to the river's edge for watering twice a day. During the winter animals would have had to be enclosed in some fashion, most likely near the place where fodder and probably grains were stored. Dung would have been collected and stored. These tasks would have been managed by members of extended households. There are questions that arise concerning management of livestock. In some communities livestock are communally herded. In other words, rather than herd all species together, each species would have been herded separately but composed of all the stock from households within the community. Herding cattle and sheep is not as complicated as it may seem. The shepherd only has to control the lead female. Control the lead female and she controls the herd.

Earlier deposits (Phases 1and 2) yielded significantly smaller densities bone within refuse pits than did later ones (Phases 3-6) (Milisauskas and Kruk 1989, 1984). Based on these remains, herd sizes are estimated to have been very small initially, with a preponderance of cattle in relation to sheep and pig, slightly more than 2:1. During Phases 3 and 4 there was a significant increase in the number of sheep relative to cattle. This increase appears to relate to specialized sheep rearing, possibly due to wool production. The latter phases indicate a shift towards cattle specialization. The emphasis during 6 on cattle may actually relate to an increase in dairy production. There was a also shift in the distribution frequencies of cattle sizes, where small and medium size cattle from Phases 1-5 ranged in frequencies from 18 to 35 percent. By Phase 6, small and medium size cattle rose to 45 percent. Some have suggested that increasing numbers of small cattle indicates they were stressed. But it could also represent dairy herds as size is one of the ways females are distinguished from males.

At Bronocice agricultural and pastoral activities would have been managed by households. Based on the XRF analysis it does not appear that sheep herding was a major concern of residents. The presence of sheep remains recovered from household deposits suggests instead that the majority of these were culled from arriving sheep herds. Based on the presence of a few pens, sacrificial burials and correlation of sheep age-at death profiles with non-local strontium signatures it would appear only a few sheep were kept at the site, probably for dairying, meat or ritual purposes. Cattle on the other hand were kept at Bronocice.

In the earliest occupation at Bronocice fixed plot agriculture was practiced with close cropping of livestock which eventually shifted to extensive slash and burn agriculture and pastoralism. As labor demands increased, tasks, responsibilities and social relationships changed. Fixed plot agriculture and close cropping of livestock is intensive, involving small amounts of land and close control over the movements of livestock in order to take advantage of manuring (Bogaard 2004). Animal and humans most likely lived in closer proximity. Relationships between household members were probably fairly egalitarian. Women traditionally are known to handle food preparation. But in small egalitarian households many tasks were probably shared by all able members of the household. As the settlement region expanded and fields were located further away some members of the household would have been sent to herd animals farther out. Men most likely tended the fields especially with the introduction of the plow during the late middle Neolithic. Perhaps young men herded livestock as it does not require a lot of people. Control over a flock is established by controlling the lead female. Certain times of the year would have required large labor pools, including the harvest, birthing, milking and wool collection. It is probable that multiple relative households pooled their labor in order to meet labor requirements.

Control over things other than just livestock need to be considered as well. If it is assumed that cattle, sheep and goats were milked and that the milk was converted into other dairy products such as butter, cheese yogurt, other tasks become apparent as well. Because women are generally assumed to have control over the domain of cooking and food preparation it may also be that dairy foods would have fallen under their control as well. The control of wool if present, as a product that could be exchanged and as a source of material for making textiles, Sasson used ethnographic information derived from data obtained during the 1940s to create a study using simulated models of animal husbandry and small scale farming in Palestine. By calculating the energy produced within four areas by pastoralists and sedentary farmers, the author showed that pastoralists did not provide enough energy to support their population. The results were used to argue that ancient societies could not have subsisted only on Pastoralism and that they would have had to practice some form of agriculture in order to me*et al*l of their dietary needs, even if they traded for grains with sedentary populations (Sasson 2006).

There are a range of tasks that faunal deposits can readily address include herding, protection, penning, milking, wool production and weaving, and meat production. As the settlement evolved from intensive fixed plot agriculture to extensive slash and burn, and eventually to intensive herding certain aspects of the household structure changed. Recent dental analyses have shown it is possible to find evidence for the penning in enamel wear patterns (Mainland 2007). Certainly genetic studies have not only demonstrated that modern European pigs are descended from the European wild boar and not the species imported by Linear Pottery groups, but also great genetic variation indicating repeated cross breeding between domesticated and wild pigs during the Neolithic. (Giuffra *et al* 2000). This suggests that pigs may not have been actively managed but were instead allowed to run wild, and were probably rounded up in the fall for slaughter. Gregg however suggests that pigs were housed during the winter (Gregg 1988). Cattle are also believed to have had wild introgression by male aurochsen especially in the northern regions of Europe (Götherström *et al* 2005). Genetic tests have demonstrated that the contribution comes only through the male line and that it is very small. The lack of mtDNA from aurochs forms the basis for arguing against independent centers of domestication in Europe (Edwards *et al* 2007, Scheu *et al* 2008). From this it can be inferred that female cattle were protected and carefully bred. Penning implies intensive care of animals that would rely on people for food and water. Ethnographic data indicates that milking is labor intensive with large herds and requires pooling labor resources. This activity occurs over an extended number of months each year and coincides with the birthing season. One herder could have managed 2-300 ovicaprids but not if the landscape was a patchwork of fields and pastures (Halstead 1996).

Archaeologists tend to rank meat production as one of the most important products of raising cattle. However, increasingly studies have shown the presence of milk beginning in the early Neolithic and continuing through modern time (Craig *et al* 2005, Craig *et al* 2003). Legge and others have suggested that the value of milk as a food resource was greater than meat in Neolithic societies (Ebersbach 1999, Legge 2005). Halstead discusses evidence for product exchange between pastoralists and farmers. He suggests that mortality patterns normally associated with meat on the hoof may in fact result from a product based economic concern in which pastoralists exchange young, milk and cheese products for grains and other products from farmers. Meanwhile farmers keep these animals until they reach a certain weight and then slaughter. These kinds of complex strategies are not addressable by conventional herding models such as suggested by Payne (1973).

Small-scale mixed herding requires the least effort. Animals are moved as unit to pasture and to crop fields. During the winter they are stalled and foddered. Large scale herds on the other hand have to move over larger areas of land in order to ensure continued quality food. If not their health declines as does their reproductive chances of success. For that reason herds may be split by nutritional consideration; pregnant animals will receive the best food. Faunal data can be used to address some of these questions indirectly by looking at dental wear patterns and dung composition (Akeret 1999, Mainland 2007, Mainland and Halstead 2005, Greenfield and Arnold

2008). Mainland examined dental patterns from sites in Hungary and found evidence of penning animals for reasons suggesting milking or fattening of animals (Mainland 2007). Rowley-Conwy suggests the presence of shed teeth can also be used as evidence of penning pigs (Rowley-Conwy 2000). Dung studies have shown that leaves and branches were used to fodder animals during winter months at several sites and have been used to show that transhumance was practiced in some parts of Europe (Delhon *et al* 2008, Valamoti 2007).

Based on ethnographic data household tasks likely became increasingly gendered. Control over livestock and associated by-products were probably aligned with gendered tasks. Milk and cheese products were probably controlled by women who would have produced them. Livestock ownership was probably controlled men who herded them and managed their care at different times of the year. Labor shortages were most likely met by pooling extended families together at certain times of the year. As farms became more extensive and herds taken further afield members of the family less mobile such small children and elders would have taken on more household related tasks. Eventually, as the landscape became increasingly degraded the difficulties in farming and animal husbandry would have resulted in a need to move. Ethnographically, herders the decision to move is made by men. Animal husbandry practices changed considerably over time at Bronocice. In alignment with economic reorganization social changes that most likely occurred include redefined household relationships, increase in tasks and gendered roles, and a shift in authority.

C. Selection of X-ray Fluorescence and Mitochondrial DNA samples

Selection of the faunal remains was accomplished in two ways. The material from Bronocice was selected by the analyst while the material from the other two sites was selected for the analyst in Poland. The faunal remains from all three sites were identified by Danuta Makowicz-Poliszot during the 1980's and 1990's. The data, originally hand-written and generated in Polish, were transcribed into English and entered into a Microsoft Office Access database. Age at death determinations were based on epiphyseal fusion and dental eruption patterns. Specific ages were not used. Instead four general age group designations were generated including of Juvenile, Subadult, Adult and Senile. Slaughter profiles and herd compositions were based upon these categories.

Sheep skeletal remains from the sites of Bronocice, Żawarża and Niedżwiedż were obtained through the Polish Academy of Sciences, Krakow. These samples represent four sheep populations, two from Bronocice from Phases 3 and 4, one from Żawarża and one from Niedżwiedż. The original design included 20 individuals for each population. These sample sets are disproportionate representations of actual herds from each site. It is not possible to estimate the original population size of each herd though the settlement sizes are well documented. Bronocice was significantly larger than the other two sites. It is assumed therefore that the populations from Phases 3 and 4 at Bronocice were larger than the other two and so the sample sets from the smaller sites are more representative than those from Bronocice.

Two sets of samples were required; one for the XRF study which spanned 3800-2700 BC; another set for the mtDNA study which was limited to 3650-3100 BC. The list of all specimens can be found in Appendix A. The preferred faunal tissue chosen for samples were cranial, especially teeth. Mandibles and maxillas were selected in as many instances as possible. However, longbones and podiae were selected when cranial bones were not available. This resulted in a decrease in number of samples available for XRF analysis. It was decided that a minimum of twenty individual sheep should represent each phase and site. In actuality it was not possible to obtain twenty individuals for both studies for a variety of reasons. In some cases there were not enough dental specimens for a particular occupational phase, while in other instances it was impossible to know if dental specimens represented distinct individuals or were the same individual when obtained from the same pit. In addition, samples were selected that represented as wide a spatial distribution as possible for each phase.

Two more factors influenced the selection of samples from Bronocice. First, a study was done on the architectural remains from Bronocice that resulted in the creation of 'houses' based on stratigraphic, postmold, and pit interpretations and a reassignment of pipes to later phases (Pipes *et al in press*). Pits that were formerly assigned to Phase 3 were often reassigned to Phase 3/4. The original temporal assignment of pits was based on ceramic analysis. But the architectural study revealed that often times the earlier phase ceramics had been recycled by the builder for use as tiles on subterranean shelves and floors. The second factor was a reconsideration of radiocarbon dates and a new set of radiocarbon dates (unpublished), which changed some of the chronological pit assignments to different phases (see Appendix G for original listing of radiocarbon dates). In some cases greater confidence was placed in the ceramic associated with a deposit. Some of the ceramics dates earlier in time but were recycled as tiles leading in several instances temporal confusion.

Chapter 4

Portable X-ray Fluorescence Analysis

Portable X-ray fluorescence (herein XRF) is a non-destructive method of elemental analysis that can be used to measure strontium concentrations in dental enamel. Bruker Elemental Inc. kindly provided a Portable XRF unit cost-free for this study. Sheep dental specimens were analyzed from all phases of occupation at Bronocice as well as from Żawarża and Niedźwiedź. Though Phases 3 and 4 (3650-3100 BC) are the main period of interest in this dissertation, earlier and later sheep dental specimens from the site of Bronocice were included in order to provide temporal context of sheep management strategies. XRF samples were obtained from the Funnel Beaker occupations at Żawarża and Niedźwiedź. XRF samples were obtained from all six phases of occupation at Bronocice making it possible to document important sheep management practices over a longer period of time (3800-2700 BC). The broader temporal context revealed clear differences in strontium levels between sheep samples dating to earlier phases. In the earliest two phases the range in strontium values was far lower than the later ones. The differences indicate that sheep were initially locally bred and that later they were increasingly imported from outside the Bronocice micro-region marking a major shift in sheep management strategies.

The samples used in the XRF exercise were limited to dental specimens: Bronocice n = 86, Żawarża n = 10, and Niedźwiedź n = 6. Some of these were later used for DNA testing. Appendix A lists all of the specimens tested using XRF and also indicates which were also used for DNA testing. Appendix A also indicates the skeletal element tested, as well as general age-at-death of each individual. Appendix B contains the results of the XRF readings for all teeth sampled in this study.

The value in measuring in strontium levels in dental enamel is that it equates with geological space. Elemental strontium levels were measured in the earliest and latest erupting teeth available for each sheep. Because these specimens were archaeological in nature were sometimes fragmented and incomplete. The latest forming teeth in sheep are the incisors which were unfortunately missing in every case. Other teeth were also frequently missing which is why the dental data may random at times. Nonetheless, the results of the XRF analysis made it possible to segregate sheep into local and non-local populations and not only to document sheep movements across space but also changes in husbandry practices over time.

A. Biological Absorption of Strontium and X-ray Fluorescence Detection

Strontium and other elemental concentrations are found in mammalian teeth and bone. Herbivores such as sheep are specialized feeders that absorb strontium by grazing on grasses and other vegetation. The level of strontium absorbed by plants which are then consumed by herbivores is affected by the composition and age of geological substrates that vary geographically (Balasse and Ambrose 2002, Bentley 2006). Strontium concentrations in animals vary by species dependent on their feeding habits and their trophic position in the food chain. Herbivores, such as sheep, are specialized feeders that absorb strontium by grazing on grasses and other vegetation. The level of strontium absorbed by plants is determined by the composition and age of geological substrates that vary geographically. Carnivores, on the other hand, are one level removed in the food chain, absorbing strontium by eating other animals such as herbivores.

During dental formation strontium is absorbed and replaces calcium in the apatite structure of teeth thus becoming fixed in the enamel and becoming a permanent marker of geological place. Strontium is absorbed over the course of a lifetime in bones but which are continuously remodeled throughout an individual's life. Strontium concentrations in bones may differ from that in teeth depending on the movements of an animal to different grazing areas. Strontium in dentine is also not fixed. The recovery of an individual's skeleton exhibiting distinctly different concentrations of strontium in their teeth and bones can be used to detect spatial movements and to inform about the locations in which it was born and died if the areas had different geological substrates (Lambert 1997, Balaase and Ambrose 2002, Heijligers *et al* 1979).

Measuring strontium levels has been used successfully to identify local and non-local people at several sites including Linear Pottery and Corded Ware burials in Germany and Lusatian and Przeworsk burials in Poland (Haak *et al* 2008, Bentley *et al* 2002a, 2002b) It has been demonstrated that comparing strontium levels in teeth and bones can provide evidence for the movement of individuals and populations when they exhibit different strontium signatures (Bentley *et al* 2002b). The method has been shown to be affective in animal studies, most specifically in animal husbandry studies examining transhumance (Hedman *et al* 2008, Bentley and Knipper 2005). A study of strontium isotope levels in cattle, pig and sheep teeth in the Black Forest region of southern Germany revealed unique patterns of livestock management for each species (Bentley *et al* 2002a). Pig teeth exhibited a low range of strontium variability indicating that they were locally raised. Cattle and sheep teeth, however, had variable ranges revealing that the animals were moved to upland pastures and most likely were associated with distinct households or lineages that used different properties.

There are several methods available for measuring strontium levels in teeth and bone that range from highly destructive, partially destructive, and non-destructive techniques. The method selected for this project was portable XRF, a non-destructive method. Early applications of XRF involved grinding teeth to a powder and reducing them to ash in order to concentrate the strontium component. However it has been demonstrated that whole teeth can be successfully measured as well (Kubota *et al* 1974, Boas and Hampel 1978).

The method chosen for this was portable x-ray fluorescence. It proved to be an excellent method for distinguishing patterns of movement among sheep allowing for temporal and spatial comparisons. Absorption in teeth happens over a brief period of time, lasting only as long as a tooth is being formed. Mammalian dental formation is species specific. Unlike humans, sheep are born with a full set of deciduous teeth which are replaced with permanent teeth over a period of 3 ¾ years (Schmidt 1972). Variability in dental eruption rates do exist between sheep populations, but generally dental formation and eruption is highly patterned. The age at which a sheep is slaughtered may be determined by examining its row teeth which may include different combinations of milk and permanent teeth, as well as teeth in various stages of eruption. Therefore information about where an animal was born and died can potentially reside within a set of teeth that includes a combination of deciduous and permanent teeth. Animals that were raised in a single location will show little to no variation in strontium levels regardless of when their teeth were formed and erupted. Conversely, animals that have been moved across the landscape will have distinct variations in strontium levels if their teeth formed in different locations. This was the underlying premise in using XRF to distinguish sheep locally born and raised from outsiders at Bronocice, Żawarża and Niedźwiedź.

The XRF study was designed to test and evaluate strontium levels in sheep dental samples. An attempt was made to sample sheep from as many depositional contexts as possible at each site though that was not always possible. Table 4.1 summarizes the total number of sheep that were available for each phase at Bronocice and the number and percentage that were sampled. The percentage of samples drops across the time as the number of available sheep increases. 70 individuals (24 %) of the Bronocice sheep assemblage, 10 individuals at Żawarża (10%) and 10 individuals at Niedżwiedż (6%) were tested.

Sample selection was also designed to test a range of individuals slaughtered at different ages as well as to test for temporal and spatial variability at each site and for each phase. Multiple individuals from the same pit were sometimes selected to test for diagenic influences such as ground water contamination. Preference was given to individuals with a minimum of two or more teeth. In these cases the earliest and the latest erupted teeth were tested. Archaeological data, however, do not always present the ideal situation and so many individuals in the study were represented by a single tooth. Even so, a single tooth can provide useful information when the eruption age is considered within the context of the herd and teeth other individuals from the same phase and site.

B. X-ray Fluorescence Methodology

Prior to XRF analysis dental specimens were extracted from maxillas and mandibles. The dental specimens were cleaned by dry brushing and on occasion washed with regular tap water.A Tracer III handheld XRF device made by Bruker Elemental Inc. was used to analyze the dental samples selected for the study. The handheld device came with a stand and a platform that was fitted onto the reading window. This facilitated placement of the specimen and maintained a stable platform during testing. A protective cover was placed over the sample before each test.

A filter was used to optimize the readings for strontium. Bruker Elemental provided a set of filters recommended for use with certain materials, such as teeth. Using a filter the XRF device was restricted to an X-ray depth of 2 mm which in most cases was sufficient to read the entire enamel of a tooth. Da Silva *et al* used a depth setting of 1.8 mm to analyze human incisor teeth (Da Silva *et al* 2008). However, sheep enamel tends to be thicker than human incisors. A study conducted by Kubota determined that no strontium variations were observed between prepared ground dental samples and whole teeth. Other studies have shown that XRF can be used on whole teeth (Kubota *et al* 1974, Boas and Hampel 1978).

The XRF device works on the principle of photon excitation. It sends a photon beam that pulls an electron in the K shell orbit of an elemental atom forcing an electron from either the L or M shells to replace it. In the process energy emitted in the form of wavelengths characteristic of that element forms a peak fluorescence which is detected and recorded by the device. While XRF analysis is a non-destructive and inexpensive methodology, the down side is that it requires a lot of time to test and evaluate large sample sizes. Initial timed trials were run at increasing intervals of 15 seconds beginning with 30 seconds and ending at 120 seconds. No changes in the elemental readings were detectable after 45 seconds. Based on the results of the test it was decided to read each dental specimen for 60 seconds three times. Each tooth was read three times and the results averaged. One Standard Deviation was calculated per phase population and site.

The XRF test results were run on a spectral analyzer (SP1PXRF software) and checked for errors. Readings were done using the Soils Mode setting and converted to text files. A program called ARTAX, developed by Bruker Elemental Inc., was used to convert spectral images to qualitative data. A typical spectral reading includes a wide range of elements as illustrated in Figure 4.1. The peak intensity readings of strontium were converted into semi-quantified data by the software program ARTAX using the element Rhodium as an elemental constant to normalize all values. The program calculates elemental ratios using all readings from a group, which in the case consisted of all sheep readings. This method of conversion assumes all of the samples all have similar density and structure. Although like spectral imaging this is a relative comparative method it facilitates data presentation by allowing graphing of values in Excel.

1. Potential Factors Influencing Strontium Levels

As with any method, there were concerns about possible factors affecting the results and interpretation of the data. Currently, a major problem with XRF is lack of calibration from one instrument to the next and between manufacturers. A comparative study was done using portable XRF devices of different makes and models across 14 laboratories across the United States. Each lab tested the same set of metal alloy samples of known historic provenience and the results of the analyses were compared (Heginbotham *et al* 2010). The findings were that currently there is no way to reproduce the exact same quantitative values from one XRF lab to another. However, all of the labs were able to distinguish the metal alloys using qualitative analysis. Qualitative analysis is therefore possible using any XRF device as it is independent of absolute values providing instead measures of relative elemental concentrations. In this study the data are used simply as relative indicators of more or less strontium and the results used to distinguish sheep into basic groups based on similarities and differences in strontium levels.

Aside from problems with the instrumentation, there were several other concerns with the XRF analysis (Table 4.2). Environmental factors can potentially affect the concentration of elemental strontium in bone or teeth thereby skewing the results of both XRF and isotopic analyses. In humid areas elemental concentrations can be affected by changing land use (Herpin *et al* 2002). Bone and teeth are sensitive to diagenic processes once buried (El-Kammar *et al* 1989). As such elemental concentrations may be impacted by heat, soil chemistry, and moisture (Hedges 2002, Lambert *et al* 1985, Pate *et al* 1989, Tuross *et al* 1989). While heat can affect strontium levels in bone and teeth, it was not considered to be a significant problem since southeastern Poland has a temperate climate.

The micro-region of Bronocice is a complex system of rivers, terraces and uplands that are composed of five different ecological zones (Figure 4.2). Funnel Beaker sites tend to be found on the edges of the uplands. These settlements were placed on degraded chernozem and brown earth soils. The underlying substrate in this region consists of Cretaceous, Jurassic and Tertiary rocks, a limestone layer overlaid by thick strata of loess deposits. The average elevation in this region is 200 – 300 m above sea level (Śnieszko 1996). Bronocice, Żawarża and Niedżwiedż share similar site locations and soil types. Though no attempt was made to identify specific locations, it was assumed that smaller differences in strontium levels represented local geographical distances while larger strontium levels represented greater geographical distances as well as differences in elevation.

Soil chemistry was discounted as a problem because all of the samples were retrieved from closed contexts at depths of 1 meter or more. Drouet *et al* (2007) conducted a controlled study on forest soil formations in central Belgium. This area is similar to southeastern Poland consisting of limestone substrate overlaid with a thick layer of loess soils. They examined how strontium and calcium were affected by soil leaching and mineralization, the vertical distributions of these elements, and their concentrations in soils. They found that biologically available strontium was primarily concentrated in the upper humic layers and that soil water interaction, considered to be the primary means of strontium displacement, was negligible with increasing depth.

Groundwater contamination was discounted as well for a number of reasons. Only dental specimens were selected for XRF analysis. Bones are porous and more subject to the influences of water, whereas teeth are dense, less permeable, and known to be chemically resistant to diagenic influences (Pollard 2009). Drouet *et al* (2007) found that the influence of groundwater in strontium accumulation in bone is not instantaneous but instead requires long-term exposure. Hydrolytic action is known to be a major cause of DNA degradation (Poinar 1999, 2003). Though it was not possible to sequence all of the DNA samples of sheep due to contamination issues, nonetheless DNA was extracted from 75 sheep indicating that groundwater contamination was not a factor affecting strontium levels.

It was also questioned whether other factors might affect the data such as uneven distribution of strontium in dental enamel and variable absorption rates of strontium due to biological development. To examine variability in strontium levels within dental enamel each tooth was tested on three separate surfaces; the lingual (tongue side), buccal (cheek) and occlusal (grinding) surfaces. In general, there were very slight variations in strontium levels between readings though on occasion some readings were noticeably higher. Generally, variability of strontium values ranged from .01 to .005 percent which was not considered sufficient to affect the classification of a tooth as having been formed within or outside the local region.

On occasion greater variations occurred between readings of a single tooth. It was unclear why at times there were large differences in strontium levels within a tooth. A couple of possible explanations are proposed. First, when the handheld XRF unit's battery pack was low, readings became erratic or completely blown. It was not always apparent to the researcher that this happened. Second, the tooth may have been poorly placed over the reading window and the root read instead of the enamel. And third, some of the teeth were cracked while others had greater amounts of dentine exposed. The unit may have read dentine instead of enamel. Although dentine also has a hydroxyapatite structure in which calcium is replaced by strontium it is not fixed. Instead the dentine is subject to change over the course of an individual's lifespan. The higher readings seen occasionally on readings from occlusal surfaces may be the result of dentine exposure. Overall this test series indicated that strontium levels did not vary significantly in tooth enamel. Variability in strontium levels was managed by averaging the results of multiple readings.

Another testing concern was the potential affect of developmental age on the rate of strontium absorption in an individual's teeth. The underlying assumption is that the absorption rate is constant at any age and that variability is tied to local geological substrate and linked to mobility patterns. Interpreting strontium levels would be more difficult if the absorption rate was also affected by the developmental age of teeth. If developmental age were a factor there should be a consistent pattern in the difference or similarities of specific teeth across individuals, such as deciduous m1, permanent M3. This was investigated by looking at individuals represented by a combination of deciduous and permanent teeth. An individual remaining in the same location throughout the period of years during which teeth are formed should have close or similar levels of strontium in deciduous and permanent teeth if the absorption rate remains constant. strontium levels were found to be the same in teeth of different developmental ages for some individuals and not for others. Therefore strontium absorption rates appear to remain constant in an individual's developmental life. Variability observed in strontium levels therefore is more likely to be tied to movement across different geological zones.

2. Establishing Local Strontium Ranges for Bronocice, Żawarża, and Niedżwiedż

Determining the range of local strontium values was accomplished by comparing readings between settlements and time periods at Bronocice, and then correlating them with age-at-death profiles. Age-at death simply means the biological age at which an individual died, e.g. 3 years old. The smaller settlements and the two earliest phases at Bronocice showed a preponderance of individuals ranging between 9,500 and 16,000 peak intensity values. The later phases at Bronocice however had a preponderance of young individuals with peak intensity values exceeding 16,000. Local strontium ranges were determined by comparing readings from deciduous teeth and first molars with readings from later erupting teeth within the same individuals. The underlying premise is that animals born and raised in the same area will show little variation in strontium values between teeth. Animals born in one place and moved as new teeth were formed will show greater variation in strontium values. Without a base range variability of strontium peak intensity values it would not have been possible to interpret mobility patterns or to separate individuals into local and non-local animals.

The Bronocice Phase 1 strontium levels were used to establish the local range and for comparison with all later phases and sites. Like surrounding Funnel Beaker settlements the Phase 1 Funnel Beaker occupation at Bronocice was small, probably seasonal and focused mainly on cattle rearing. During this phase and the next sheep populations were small in comparison with cattle and pig populations (Milisauskas *et al* 2012, Pipes *et al* 2009). Phase 1 concentrations were more varied that those from Phase 2. Social factors that might shed light on why that is significant must be considered here. During Phase 1 the Funnel Beaker occupation at Bronocice was small and undifferentiated from surrounding communities. These small settlements are thought to have been occupied on a semi-sedentary basis, most likely during the winter months. The Phase 2 Lublin-Volhynian occupation was a permanently occupied fortified settlement. Less variability in strontium concentrations may be due to restricted movement of the herd. Nonetheless the majority of dental specimens fell within the strontium peak intensity range of strontium Range = 9,000 to 16,000. The standard deviations for both phases were nearly identical with this range.

Beginning with Phase 3 there is a noticeable distance between this range and subsequent phase standard deviations. This range was set as the standard for comparing all of the data from Bronocice. The same procedure was followed for Żawarża and Niedźwiedź though the sample sizes were smaller. A comparison of deciduous and permanent M1 teeth determined the base range for Żawarża to be slightly narrower, strontium Range =10,000 to 15,000: SD 2562. As was the case with the Phase 1 and 2 data, most values in this range also fell within one Standard Deviation. However, Niedźwiedź did not show the same degree of patterning, showing instead a lot of variability. Though Żawarża and Niedźwiedź date to Phases 3 and 4 respectively, in many ways their settlement and subsistence patterns more closely resembled those of Bronocice in Phase 1. The range in strontium levels at these two sites was small and overlapped considerably with each other and those in the earliest phases at Bronocice. At Bronocice strontium levels from Phase 3 to Phase 6 were greater and more varied than the other sites. The greater range, 9,500-16,000 was used as the local range for all three sites.

Dental eruption patterns were used to classify individuals by age (Table 4.3) while strontium levels were used to classify individuals as either local or non-local in origin. If the strontium level of the earliest erupting tooth tested fell within the established local range at the site, the animal was classed as local and if it was above or below the local range the animal was classed as non-local. Within the local group most individuals were born and raised in the same area. However, some of them were moved outside the region and later returned. Within the non-local animals some animals were adults when they arrived while others were very young. In the latter case, these individuals have later erupting teeth that had local strontium levels.

In sheep, deciduous teeth begin to form within a week of birth. By two months after birth all deciduous teeth are formed (NSW Agriculture 2003). In some individuals however they are present at birth having formed *in utero*. Table 4.3 summarizes generalized dental eruption rates for sheep (after Schmidt 1972). The first molar erupts at about ½ year. Deciduous teeth and the permanent first molar (M1) are most likely to bear signatures for local ranges. Should the majority of animals have similar strontium levels for deciduous teeth and first molars it may be assumed that they represent a local signature or range. Any individual exhibiting a great difference between a deciduous tooth and an M1 may be assumed to have moved within the first six months of life.

Strontium levels for deciduous teeth and permanent M1s from the three sites and all occupational phases were compared. Deciduous teeth from Bronocice Phases 1 and 2, and from Żawarża, and Niedżwiedż fell primarily within the established local range. The same was true of permanent first molars. In contrast deciduous and permanent first molars from Bronocice phases 3-6 tended to have strontium values that fell outside the local range. While arguments can be made for establishing different 'local' ranges, it actually does not matter as the main goal is simply to establish a benchmark for comparative purposes. As will become evident, this proved to be a very effective strategy for assessing livestock management practices in terms of seasonal movements and the importation of animals in later periods.

Standard deviations were calculated for each sample population. Standard deviation measures the range of variability from the mean within a set of values. For the two earliest sample populations and Żawarża, the majority of individuals were local. A few individuals determined to be non-local fell outside one standard deviation. The remaining populations were composed of a majority of individuals determined to be non-local or indeterminate. In those cases, non-local individuals fell outside one standard deviation. The use of standard deviation supported the establishment of the local range and served to characterize both types of populations when they were composed of a majority of either local or non-local individuals. However, it should be noted that a significant portion of the sample populations from Phases 3, 4 and 5 were not tightly clustered around the mean. Also, when strontium levels were compared by tooth (Figures 4.3 and 4.4) the standard deviation is quite large and shows no clustering. This is probably due to sheep being drawn from multiple herds in different areas as opposed to a single source of importation.

C. Primary Sheep X-ray Fluorescence Data by Site and Phase

Information about the samples is provided along with a site plan and table indicating the pit and structure from which they came. The tables provide the age-at-death of each sheep, sampled teeth, and mobility classification. The graphs indicate the qualitative strontium values for all dental specimens from each site and phase. Individuals are identified by alphanumeric code indicating site, individual, and dental specimen, e.g. BS21M1 = Bronocice Sheep 21 permanent M1. The most obvious pattern noticed throughout most phases was decreased in strontium levels in the latest developed teeth from individuals. This decrease corresponds with the movement of animals towards the settlements. The second important pattern was an inversion in the frequencies of local versus non-local animals observed at Bronocice. Most of the sheep from Phases 1-2 at Bronocice, and Phases 3 and 4 at Żawarża and Niedźwiedź, were locally raised animals. But Phases 3-6 at Bronocice sheep were primarily non-locally born.

1. Bronocice

a. Phase 1 (3700-3800 BC) Funnel Beaker Occupation

The earliest Funnel Beaker phase of occupation at Bronocice was located in the northwest section of the site referred to as Area C (3800-3700 BC). Samples were obtained from three excavation units, mainly from unit C2. A few samples also came from units B6 and C1 (Figure 4.5). Unit C2 was the most densely occupied area in the settlement at this time. Unit B6 is located at a fair distance from the main settlement. Currently it is debated if the pit (5-B6) from which the sheep sample was taken was contemporaneous with the Area C occupation. It is included here because of an early radiocarbon date (Appendix G). This pit was part of a small house with pen that may have been a shepherd's hut.

Ten sheep were tested by XRF, seven of which were represented by two teeth (Table 4.4). A total of 17 teeth were tested. The group was composed of three juveniles, a subadult and six adults. Overall most of the strontium levels were fairly tightly clustered around the mean suggesting that sheep were grazed within a short distance of the settlement (Table 4.4). One individual represented by a deciduous molar (BS21) had a value that was higher than the local range, two others represented by the M1 (BS16, BA17) also had higher values.

Seven of the sheep were locally born animals were, the other three were born outside the area. Two of the non-local individuals were adults while the third was a juvenile. Perhaps the juvenile was a male that arrived with its mother. Seven sheep were represented by two teeth. With one exception (BS20), strontium values decreased as the individuals aged indicating that sheep were herded towards a common location, namely Bronocice.

Statistically BS16, BS17 and BS20 are confirmed as non-local individuals because they fall outside 1 Standard Deviation of the Phase 1 population (Figure 4.6). The three non-local animals had similar high levels of strontium which indicates the likelihood that they were obtained from the same source. Somewhat surprising BS21 also falls outside the majority population even though the actual strontium values for both of its teeth fall within the designated local range. BS14 was represented by two teeth the oldest of which also fell outside the group. However, the earliest erupting tooth was within the local range which may mean this sheep was grazed outside the region for a while.

The data suggest a couple of herding patterns. One set of sheep was introduced from outside the local region (BS20, BS16, and BS17). The majority of sheep belonged to a herd that moved within a restricted range. Seasonal movement is indicated based on dental eruption ages. For example, permanent M1s had higher strontium levels whereas later permanent molars had lower values. This patterning suggests that pregnant sheep were kept away from the settlement, perhaps in more sheltered areas such as lower terraces during the birthing season. Another sheep (BS14) was born locally but lived in a herd that moved away from the region and was returned later in life. This individual was slaughtered because of a cracked molar, as was BS18. Both of these individuals were adults. Still another sheep never left the area (BS21) before it was slaughtered. It was born at Bronocice and killed as a juvenile, probably because it was a male.

The progressively lower strontium values observed later erupting teeth such as P4s, M2s and M3s suggests directional herding back to the settlement.

b. Phase 2 (3700-3650 BC) Lublin-Volhynian Occupation

The Phase 2 settlement at Bronocice was occupied by Lublin-Volhynian (3700-3650 BC). They were a subgroup of Lengyel-Polgár people who occupied the region. Their settlement lasted perhaps 50 years and was located in the same vicinity as the earlier Phase 1 Funnel Beaker settlement in Area C. Similarly the densest evidence for Lublin-Volhynian was found in Unit C2. Five other units in Area C contained signs of their occupation (Figure 4.7). Sheep samples were taken only from Unit C2. Unlike the earlier unfortified Funnel Beaker settlement, the Lublin-Volhynian built a large fortification ditch and palisade thereby enclosing the settlement. Some phase 2 pits were impacted by construction and others were found on the outside of the ditch. This suggests a growing anxiety and a need to separate themselves from the surrounding Funnel Beaker groups.

Dental specimens from ten sheep were examined, of which four animals were represented by two teeth (Table 4.5). A total of 14 teeth were tested. Most of the sheep were mature adults, though there was also a juvenile, subadult and senior individual. Strontium values were tightly clustered around the mean (Table 4.5). Of the four individuals represented by two teeth, three had decreasing strontium values in later erupting teeth indicating movement towards Bronocice. The fourth (BS25) had increasing strontium values suggesting a different life history.

Seven sheep were determined to be locally born and three were clearly born outside the local area though they did not have the same origins. These three had strontium levels that fell above or below the local range. BS22 was represented by a permanent M1 that had a higher value than the local range. BS26 and BS27 had lower values. Based on similar strontium values in the same tooth it is possible that BS26 and BS27 belonged to the same herd and were imported to the region from a different area than BS22.

Most individuals had strontium values that fell within one standard deviation with the exception of those already identified as non-local due to strontium values outside the local range (Figure 4.8). BS22, BS26 and BS27 fall outside the standard deviation and are confirmed as non-local animals.

Three distinct patterns are indicated by the data. The largest herd was composed mainly of local individuals. The slight strontium variability observed in local animals suggests that most of the sheep had limited mobility within the region. Restricted mobility may have been a consequence of increasing social tensions in the region. It appears that sheep were shepherded during the day and returned to the settlement in the evening for protection. Two smaller herds are suggested based on lower and higher strontium values. The two individuals with low strontium values are similar to one sheep from Phase 3 and two from Żawarża. They had a very different life history, as did BS22 and originated from two different areas.

c. Phase 3 (3650-3400 BC) Funnel Beaker Occupation

Around 3650 BC (Phase 3) a new Funnel Beaker settlement was established in Area A, in the eastern portion of the site (Figure 4.9). It was during this time that Bronocice began to grow in size and population and to dominate the regional economy. As this phase ended (3400 BC) the settlement expanded into Area B. The earlier fortification ditch in area C constructed during Phase 2 by the Lublin-Volhynian was likely used as an animal enclosure. Human burials were found within the former settlement in Area C dating to Phase 3 indicating that Funnel Beaker people also used the area as a cemetery.

Fourteen sheep were tested, of which ten were represented by two or three teeth (Table 4.6). Twenty-five teeth were tested. All of the samples were obtained from Unit A1. This area contained the densest evidence of household remains. Small faunal deposits were found in other excavation units but failed to yield cranial elements that could be used for XRF analysis. The structure of this population differs greatly from the two earlier phases. A majority of individuals were young, either juveniles or subadults, and a small number were seniors (Table 4.6). The majority of sheep were slaughtered within the first year of life. Five were a half year and five were one year at death. The presence of a high number of lambs indicates that sheep were imported to Bronocice in late spring, early summer.

Twelve individuals had strontium levels lower or greater than the local range indicating that they originated outside the region and were probably obtained from two different sources (Figure 4.10). Most strontium readings were above the mean. Only one individual (B4) had a strontium level lower than the local range. This is the last phase at Bronocice in which sheep were found with values lower than the local range. This may be indicative of a different source from which sheep were no longer procured at Bronocice. However, Niedźwiedż (Phase 4) had one sheep with this signature suggesting that these particular sheep were obtained west of the Bronocice region.

In most cases non-local individuals had higher strontium levels. Within this non-local group there were two distinct subgroups. One subgroup had very high strontium levels (B5, B15, B16, B17, and B34) that fell outside one standard deviation (Figure 4.10). For these individuals strontium levels did not correlate with age at death; they included two seniors, two subadults and a juvenile revealing that herds containing animals of different ages were brought into the village. The other subgroup (B12, B13, B14, B24, B25, B4, and B29) had only slightly higher levels of strontium than the local range. It cannot be ignored that this subgroup may have been local and that the strontium levels reflect local differences in elevations related to seasonal herding patterns. If so, however, the values suggest that they were not herded by people at Bronocice but instead by outlying communities.

Three non-local individuals (B5, B6, B13) were represented by two teeth with similar strontium levels (Table 4.13). The developmental age difference between the teeth (M1 to M3 and M1 to P4) is more than one year. This indicates that these two animals were moved when they were subadults. Three other non-local individuals came from Pit 101A1, each a different age group (B15, B16, and B17). B15, a juvenile, began its life in the same region as B17, a senior. Perhaps these individuals were related to each other.

Three non-local juvenile individuals came out of pit 1A1. Their deciduous teeth overlapped in strontium levels suggesting they belong to the same herd and shared the same life experiences. Four individuals had strontium levels that fell within the local range. Three of these had similar strontium values and originated from pit 33A1, but were of different ages at death. One (BS4) was represented by three teeth which showed variable peak intensities suggesting it also moved during its life but within the local region.

Several patterns are apparent. First and foremost, the majority of sheep were non-local animals imported to Bronocice. This is major shift in population profile and signals the start of sheep intensification. Locally born sheep exhibited signs of limited mobility within the region. Three different locations were indicated by strontium levels in non-local sheep, one of which may be a birthing area based on age at death profiles of immature sheep. Young sheep dominated this sample which may be a bias in sampling, though it may also signal the importation of pregnant ewes. Last, some individuals appear to have been contemporaries since they came from the same pits.

d. Phase 4 (3400-3100 BC) Funnel Beaker Occupation

The settlement at Bronocice expanded during Phase 4 and sheep rearing continued to grow in economic importance. The densest evidence for settlement occupation was found in Areas A1 and B1 (Figure 4.11). At some point, either at the end of this phase or beginning of Phase 5, a larger enclosure was built in Area C. This event points to increasing elite control over livestock trade and exchange. The enclosure represents an ability to command and direct the labor of others and to control access to a protective space within the settlement.

Ten sheep were tested, of which six individuals were represented by two teeth and one individual by three teeth (Table 4.7). A total of 18 teeth were tested. The group consisted of five subadults, four adults and one senior. One subadult was slaughtered due to a cracked molar.

Most of the sheep had strontium values that clustered around the mean which was far greater than the local range. B6, B19, and B32 had strontium levels that feel outside one standard deviation. In the case of B6 strontium levels were much higher than other sheep which indicates it originated from a different location than the other non-local sheep. B19 and B32 however had lower values that fell within the local range. B19 is interesting because the deciduous molars tested had different values, the highest of which fell outside the local range. In cases where sheep were represented by two or more teeth, the most recently developed teeth had lower strontium values indicating movement to the settlement (Figure 4.12). B27 however had a later erupting molar with an increasing strontium value.

Three patterns were apparent. First, two different outside sources of sheep were indicated. Second, most of the sheep came from the same source. And third, some animals may have been to Bronocice and then moved away, returning later to be slaughtered. This sample had a high number of subadults tested. This age at death is more common when animals are kept for meat since they reach maximum weight and require no further investment of resources such as feed and care. Though this is sampling bias it may nonetheless be an indicating that the importation of sheep was regulated differently than earlier.

e. Phase 5 (3100-2900 BC) Funnel Beaker-Baden Occupation

During Phase 5 the settlement at Bronocice reached its greatest size and population density. The faunal assemblage recovered from this phase was also the largest recovered from any phase. A new and much larger enclosure appeared around the beginning of Phase 5 in Area C (Figure 4.13). The main occupation areas were located in Areas A and B. During this period signs of increasing social unrest were suggested by dismembered human remains found in household pits within the settlement, including severed heads and human body parts, and one large grave containing 17 individuals most likely executed. Signs of ritualized behavior also appear in the form of animal burials. Growing Baden influence is apparent on ceramic vessel forms. Until Phase 5 Funnel Beaker settlements were widely dispersed throughout the region. By this phase settlements were concentrated within the vicinity of Bronocice. The local environment became severely degraded as grazing intensified and cattle increased in economic and social importance. The density of household pits, postmolds and other architectural features suggest that house sizes at Bronocice decreased in size and that social differences increased.

Seventeen sheep were tested. All but two sheep were represented by two teeth. This sample population was composed of 50 percent adults, including two seniors (Table 4.8).The great majority of sheep were non-local (Figure 4.14). Four individuals were classified as local based on strontium levels that fell within the local range. An additional sheep may also be local (BS42), the value of its deciduous molar fell just above the local range. Local animals consisted of three juveniles and one adult. It may be the case however that the juveniles were born to non-local females given that the majority of sheep were imported to the settlement. The single local adult on the other hand may have been owned by a local household or obtained from one of the surrounding settlements. In general, strontium levels decreased in the latest developed tooth (Figure 4.14). In the case of local sheep BS47 the reverse was true; the M2 strontium level was above the local range. Cases such as this one may be indicative of sheep from Bronocice being exchanged or traded to other groups within the region that were returned for slaughter. The non-local sheep from Phase 5 fall within two grouping: those that fall within and those that fall outside 1 standard deviation, suggesting two different sources of sheep.

The Phase 5 sheep were composed primarily of non-local sheep. At least two sources of sheep are indicated. There is almost no evidence that sheep were reared at Bronocice.

f. Phase 6 (2900-2700 BC) Funnel Beaker-Baden Occupation

Phase 6 at Bronocice was marked by a decline in population and a decrease in the size of the settlement. The densest occupation was located in Area B (Figure 4.15). A sign of growing social unrest were indicated by the construction of a new fortification ditch and palisade. The reduction in size of the settlement suggests that Bronocice was stressed economically. Baden influences continued to grow during this period (Przybił 2013). Perhaps Bronocice’s trade routes were under threat. During this phase the economic importance of cattle increased while that of sheep decreased. Textile production did not diminish however as there is substantial artifact evidence indicating that textile production continued to be of great importance (Pipes *et al* 2014). Sheep imports continued as well though the volume appears to have decline.

Nine sheep were tested of which four were represented by two teeth (Table 4.9). A total of 14 teeth were tested. The sample was composed an equal number of adults and subadults, and one juvenile. Most strontium values were clustered around the mean. Six sheep were non-local animals. The majority of individuals had strontium values that fell within 1 standard deviation (Figure 4.16). The exceptions were BS50 (M1), BS53 (M2) and BS55 (M2). BS52 was non-local, while the other two were local. Three non-local sheep came from greater distances than the others suggesting that sheep were obtained from different sources. It is unclear if the great enclosure from Phase 5 continued to be used or not. No artifacts dating to this phase were recovered within its perimeter suggesting it was no longer maintained. The general pattern seen in earlier phases of decreasing strontium levels in later erupting teeth was less apparent in Phase 6. This suggests that sheep may have been kept outside the settlement until they were ready for slaughter as opposed to being brought in for trade.

In general, sheep importation continued even though the settlement was in a state of decline. This supports other archaeological evidence that textile production continued to be economically important even though sheep were no longer a major economic focus. Most of the sheep were non-local in origin and at least two sources of sheep were suggested.

2. Żawarża, Phase 3 (3650-3400 BC) Funnel Beaker Occupation

Żawarża was a small settlement measuring 1.5 hectares and consisting of 12 houses arranged around a central space with a well in the center of the common. Ten sheep were tested, most of which represented by two to three teeth. A total of 24 teeth were tested. XRF samples were recovered from three houses, a kiln, the well and a few external pits (Figure 4.17). The group was composed of two juveniles, 3 subadults, three adults and two seniors. One adult and one senior were slaughtered because cracked molars (Z12, Z22).

Most strontium levels were tightly clustered around the mean (Table 4.10, Figure 4.18). Most of the sheep were locally born. One non-local sheep (Z7) was represented by three teeth, the two earliest teeth formed outside the area while the third tooth formed locally. The values of the m3 and M1 are far greater than all other values. This particular individual may in fact have been obtained from Bronocice and was a first generation import. The other individual (Z22) may actually be a local animal because its M2 is similar to that of Z4.However because the M2 formed outside the local range it was classified as non-local.Z4 was born locally but briefly moved outside the local area. Another individual Z5 suggests the same pattern. The low strontium values seen in these three individuals may reflect a particular area within their territory used for grazing sheep during the seasonal cycle. Four of the local individuals were represented by three teeth. In each case two of the teeth had similar strontium levels). Most of the sheep had strontium levels that fell within 1 stand deviation, except for Z7 and Z22 which were non-locally born.

Patterns observed in the sample included a majority of locally born sheep, slight variability in strontium levels among local sheep, two sources of non-local sheep, and limited mobility within the region. The XRF data suggest that most of the sheep were not moved over great distances within the region. Z7 and Z22 originated outside the region. Both had strontium values similar to non-local sheep at Bronocice dating to Phase 3 which suggests similar origins. Z22 was similar to a small number of sheep from Bronocice Phases 1,2 and 3, and one from Niedżwiedż. Though they were infrequent, sheep with lower strontium levels than the local range suggest a different source for the procurement of sheep. Perhaps this settlement traded with other local communities. The one sheep with higher than local strontium levels is very similar to sheep imported to Bronocice and was likely obtained from there.

3. Niedżwiedż, Phase 4 (3400-3100 BC) Funnel Beaker Occupation

The site of Niedżwiedż was a settlement hamlet the size of which is unclear but may have measured about 2 hectares (Burchard and Eker1964). Unlike Żawarża which was a single component site, Niedżwiedż was occupied sequentially by several cultures from the Early to Late Neolithic including Linear Pottery, Funnel Beaker, Corded Ware and Trizciniec groups, though these occupations were not continuous. Excavations of the Funnel Beaker occupation revealed several postmold patterns representing two houses as well as possible pens or stalls (Figure 4.19). XRF samples were drawn from both houses and yard areas. Unfortunately only six sheep were tested by XRF due to a scheduling conflict with the molecular lab in Binghamton. This group was composed of three juveniles, two adults and one subadult. Eleven teeth were tested. The majority of individuals were represented by at least one deciduous molar (Table 4.11). Strontium values were not clustered around the mean. In fact, strontium values ranged considerably suggesting either the sheep were not contemporaries or they came from different herds. Even so, most individuals fell within one standard deviation; N9 was the only sheep that fell clearly outside.

Four individuals were local (Figure 4.20). Two of the local sheep (N7 and N20) exhibited higher strontium values in the latest erupted teeth similar to that of N15, a non-local sheep. In fact, N15 may well be a local sheep born to a ewe from the same flock as N7 and N20. It was killed as a juvenile. Maybe it was a ram. The two non-local sheep (N9 and N15) had very different life histories. Strontium levels from N9 differed greatly while N15 had a strontium level only slightly above the local range. The variability in strontium values overall suggest sheep were obtained from multiple sources. N7, N20 (adults) and N15 (juvenile) were similar. N18 and N22 (juveniles) were similar but had values that fell within the local range. Perhaps the data represent different grazing lands owned by different families. N9 was appears to have been imported to the settlement. The low strontium value obtained for the deciduous molar is reminiscent of individuals seen in Phases 1-3 at Bronocice and at Żawarża. Low strontium values were not seen at Bronocice afterwards.

D. Summary of X-ray Fluorescence Results

The XRF study shows the potential of X-Ray fluorescence as an analytical tool for identifying mobility patterns in livestock populations based on strontium levels in dental enamel. The most informative data was obtained by measuring the earliest and latest erupting teeth within an individual's mouth. The earliest erupting teeth, deciduous and first molars, can indicate point of origin while the latest erupting teeth potentially point to the final destination. Differences in values minimally indicate movement. Slaughter age is an important factor in interpreting data. Animals that are harvested before tooth development is completed are most diagnostic, while older animals are less informative. Culling occurs in livestock for many reasons though they commonly include maintaining sex ratios, health issues, e.g. cracked teeth, and herd size.

Previous studies have discussed the economic intensification in sheep beginning in Phase 3 at Bronocice which was most likely related to wool and textile production (Pipes *et al* 2014, Milisauskas *et al* 2011). The XRF data indicates that the importation of non-local sheep into the settlement intensified at that time. The rate of importation remained high until the end of the settlement as frequencies of local animals never again increased in the Bronocice samples (Figure 4.21). Importation therefore played a major role in first building local sheep herds and in maintaining them over time. Furthermore, during Phase 3, the range in strontium levels expressed the greatest variability in values of all phases which suggests that the initial surge in sheep importation was achieved by acquiring animals from many different sources. Later, less variability appeared in Phases 4-6 suggesting that sheep were acquired from fewer providers.

Table 4.12 summarizes relative frequencies local and non-local sheep by site and phase. The relative frequencies of Phases 1 and 2 at Bronocice are similar to those of Żawarża (Phase 3) and Niedźwiedź (Phase 4), in which the majority of sheep were local and a small percentage were non-local. This corresponds well with earlier studies that indicated sheep rearing was not a major economic focus during the earliest Funnel Beaker settlements in southeastern Poland. The relative frequencies of Phases 3-6 for Bronocice reveal that the majority of sheep were non-local. Sheep intensification had already been documented in earlier studies (Milisauskas *et al* 2012, Pipes *et al* 2009). The main question focused on how that intensification had occurred and what triggered it. The XRF data clearly showed that it was accomplished by importing sheep to the settlement. While intensified sheep rearing was also documented at Żawarża and at Niedźwiedź, the XRF data suggest that it was accomplished in two ways, by localized breeding and by acquisition, most likely with Bronocice.

Another important question that emerged from the XRF study was whether or not sheep were actually raised at Bronocice after Phase 2. Though the overall sample size was small, still 24% of all recovered sheep from Bronocice were sampled. The data suggest that sheep rearing did not occur at Bronocice. Sheep remains found within household deposits most likely resulted from the slaughter of animals for meat in late spring when flocks were brought into the market.

The XRF data revealed other patterns and trends in sheep management strategies. In order to visualize sheep mobility patterns a grid was overlaid on a plan of the Bronocice region upon which Strontium values were plotted. The gridline intervals are arbitrary and serve only to illustrate movement based on regular interval strontium levels across the landscape. In actuality, it is more likely that the distances between strontium values are greater, as well as more variable, given local changes in topography, elevation and geological substrates. Neolithic studies in central Europe have revealed the existence of major trade routes between southeastern Poland, Slovakia, Moravia, and the Hungarian Plain as well as southeast to Ukraine (Czekaj-Zastawny 2011, Furholt *et al* 2008, Pelesiak 2007). Trade in lithics and other goods moved by way of the river gorges. The grid therefore was designed to reflect increasing levels of strontium to the southeast of the region. The values of dental specimens from individual sheep teeth were then plotted on a regional map for each site and occupational phase (Figures 4.22-4.29). Local sheep are indicated by red lines and non-local sheep by blue lines.

Slight variations in strontium levels are evident for Phases 1 (Figure 4.22) and 2 (Figure 4.23. During Phase 1 two local individuals and one non-local individual had strontium levels that were either higher or lower in the latest erupting tooth that fell outside the local range. This pattern occurred in later phases as well and it is thought to reflect seasonal movements of a flock within a territory. When strontium levels of later erupting teeth decreased or increase to that of the local range it is thought to reflect the direct importation of animals. This pattern can be seen especially in the sheep from Żawarża and Niedźwiedź (Figures 4.25 and 4.27). The differences in strontium levels of local sheep however were much greater than that seen in the earliest phases at Bronocice. Perhaps the people in these settlements had larger tracts lands that they exploited. In some instances, such as B34 from Phase 3 Bronocice, the distances a sheep traveled appear to have been great (Figure 4.24). It was generally true that strontium levels in sheep represented by two or more teeth from Bronocice Phases 3 to 6 were lower in later erupting teeth. This was understood to be the result of movement into the settlement. Figures 4.24, 4.26, 4.28, and 4.29 have overlapping strontium levels among some dental specimens from sheep of different ages. This may be reflective of normal flocks in which a range of age groups can be found as opposed to flocks of composed one or generation of the same age. This is significant because it means that sheep were herded to Bronocice which likely included mothers and their offspring as well as their sires. The last pattern observed was an apparent association between strontium levels and specific development ages that overlapped between phases. In several cases individual sheep represented by deciduous teeth, the permanent first molar or later erupting teeth share similar values. The overlap between different ages groups and strontium levels may represent ewes and their lambs and signal birthing locations.

In summary, the XRF results provided information that can be used to distinguish local from non-local animals, identify herding patterns, and document trade in livestock. Furthermore, by linking strontium levels with age-at death information from contemporary animals it may be possible to understand the seasonal movements of flocks within specific territories.

Table 4.1. Comparison of the total number of sheep identified at each site and the number and relative percent of sheep tested.

Phase	Site	Site MNI	# Tested MNI	% Tested MNI
1	Bronocice	23	10	.43
2	Bronocice	21	10	.48
3	Bronocice	38	14	.37
4	Bronocice	74	10	.14
5	Bronocice	108	17	.16
6	Bronocice	29	9	.31
	Total	293	70	.24
3	Żawarża	98	10	.10
4	Niedżwiedż	98	6	.06

Table 4.2. List of potential problems affecting XRF elemental strontium values.

Class of Problem	Specific Concern
Diagenic factors	
	Environmental changes due to heat and moisture
	Soil chemistry
	Groundwater contamination
Biological factors	
	Variable deposition of strontium within teeth
	Variable absorption rate in teeth of different developmental age

Table 4.3. Dental eruption rates in years for sheep indicating the milk or deciduous tooth and its replacement by a (T) permanent tooth (Schmidt 1972).

milk tooth	Permanent Tooth	Sheep
i1		*In utero*
	I1	1.25
i2		*In utero*
	I2	1.75
i3		*In utero*
	I3	2.75
c		*In utero*
	C	3.75
	P1	-
m1		*In utero*
	P2	1.50
m2		*In utero*
	P3	1.75
m3		*In utero*
	P4	2
	M1	.50
	M2	1
	M3	1.75

Table 4.4. Bronocice, Phase 1 XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born (L) or Non-locally born (N).

Unit	Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
						L	N
B6	5-B6	Bs21	Juvenile	m3, M1	9834, 10390	X	-
C1	80-C1	Bs20	Juvenile	m3, M2	17414, 20247	-	X
C2	12-C2	Bs12	Juvenile	M1	16442	X	-
C2	12-C2	Bs13	Adult	M2, M3	12037, 11359	X	-
C2	17-C2	Bs16	Adult	M1, P2	20001, 16263	-	X
C2	17-C2	Bs17	Adult	M1, M3	19204, 12792	-	X
C2	20-C2	Bs11	Subadult	M3	10881	X	-
C2	21-C2	Bs18	Adult[1]	M1, P4	14831, 13770	X	-
C2	40-C2	Bs14	Adult[1]	M1, M3	14831, 8723	X	-
C2	40-C2	Bs15	Adult	M2	12013	X	-
		10 MNI		Mean: 14274		7 MNI	3 MNI

[1]Individual with a cracked tooth at death.

Table 4.5. Bronocice, Phase 2 XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born (L) or Non-locally born (N).

Unit	Pit	Individual	Age Group	Element	Averaged S^r Values	Origin L	Origin N
C2	25-C2	Bs22	Adult	M1	18682	-	X
C2	25-C2	Bs23	Adult	M3	13745	X	-
C2	25-C2	Bs24	Adult	M1	13560	X	-
C2	28-C2	Bs31	Adult	M1,P4	11387, 10133	X	-
C2	29-C2	Bs27	Adult	M3	8567	-	X
C2	29-C2	Bs28	Juvenile	m3, M1	12096, 11498	X	-
C2	30-C2	Bs30	Senior	M1, P4	14832, 13911	X	-
C2	31-C2	Bs29	Adult	P4	11849	X	-
C2	60-C2	Bs25	Adult	M1, P4	15789, 16957	X	
C2	60-C2	Bs26	Subadult	M3	8454	-	X
		10 MNI		Mean: 12961		7 MNI	3 MNI

Table 4.6. Bronocice, Phase 3 (shaded) XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born (L) or Non-locally born (N).

Unit	Pit	Individual	Age Group	Element	Averaged S^r Values	Origin L	Origin N
A1	1-A1	B12	Juvenile	m1/m2	20861	-	X
A1	1-A1	B13	Juvenile	m3, M1	19466, 18583	-	X
A1	1-A1	B14	Juvenile	m3, M1	21266, 24474	-	X
A1	26-A1	B5	Senior	M1, P4	27352, 27227	-	X
A1	30-A1	B24	Adult	P4	16981	-	X
A1	30-A1	B25	Subadult	m1, m3	19238, 17519	-	X
A1	33-A1	B2	Subadult	M1, M2	13240, 13820	X	-
A1	33-A1	B3	Juvenile	m3, M1	13369, 15717	X	-
A1	33-A1	B4	Adult	M1, M2, M3	8710, 10398, 13416	-	X
A1	38-A1	B34	Subadult	m2, M2	19455, 37488	-	X
A1	89-A1	B29	Subadult	m3, P2	17242, 17120	-	X
A1	101-A1	B15	Juvenile	m3, M1	29169, 25143	-	X
A1	101-A1	B16	Subadult	m3	36072	-	X
A1	101-A1	B17	Senior	M2	28962	-	X
		14 MNI		Mean 20492		2 MNI	12 MNI

Table 4.7. Bronocice, Phase 4 XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born or Non-locally born.

Unit	Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
						L	N
A1	21-A1	B6	Senior	M1, M3	31564, 31822	-	X
A1	64-A1	B1	Adult	M1, P4	26437, 18662	-	X
A1	7A1	B23	Adult	M1	21108	-	X
A1	102-A1	B32[1]	Adult	M1	11846	X	-
A1	118-A1	B33	Subadult	m3	19191	-	X
B1	2-B1	B19	Subadult	m1, m3	12840, 17052	X	-
B1	23-B1	B18	Subadult	m3, M1	24319, 21220	-	X
B5	5-B5	B22	Adult	M2, P4	21899, 16864	-	X
B5	5-B5	B27[1]	Subadult	M2, P3	16495, 17887	-	X
B7	2-B7	B21	Subadult	m3, M1, P4	24976, 19153, 18228	-	X
		10 MNI		Mean: 20642		2 MNI	8 MNI

[1]Individual with a cracked tooth at death.

Table 4.8. Bronocice, Phase 5 XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born or Non-locally born.

Unit	Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
						L	N
A1	112A1	BS32	Adult	M1, M3	32560, 29796	-	X
A2	9A2	BS33[1]	Adult	M2, M3	14198, 12061	X	-
A3	12A3	BS35	Juvenile	m3, M1	17455, 18613	-	X
A3	14A3	BS34	Juvenile	m1	18430	-	X
B1	65B1	BS36	Juvenile	m1, M1	26691, 13754	-	X
B1	97B1	BS37	Adult	M1, P4	18501, 18365	-	X
B1	103B1	BS38	Adult	M1, P4	22712, 26242	-	X
B2	6B2	BS39	Subadult	m3, M2	32910, 17861	-	X
B2	6B2	BS40[1]	Senior	M1, P4	27398, 16125	-	X
B6	10B6	BS41	Senior	M1, M3	19588, 16673	-	X
B6	10B6	BS42	Subadult	m3, M1	16309, 12856	-	X
B6	11B6	BS43	Juvenile	m1	14419	X	-
B7	6B7	BS44	Adult	M1, M3	22677, 15797	-	X
B7	6B7	BS45	Adult	M1, M3	22846, 21289	-	X
B8	1B8	BS48	Juvenile	m3	15070	X	-
B8	8B8	BS46	Subadult	m3, P4	25345, 12228	-	X
B8	12B8	BS47	Juvenile	m3, M2	13504, 16919	X	-
		17 MNI		Mean: 19651		4 MNI	13 MNI

[1]Individual with a cracked tooth at death.

Table 4.9. Bronocice, Phase 6 XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born or Non-locally born.

Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
					L	N
11A2	BS49	Adult	M1	18360	-	X
39B1	BS52	Adult	M3	22647	-	X
70B1	BS50	Adult	M1, M3	28727, 18467	-	X
	BS55	Subadult	M2, M3	14009, 18789	-	X
10B5	BS53	Subadult	M2	10124	X	-
4B7	BS54	Juvenile	m1	15705	X	-
	BS56	Subadult	m3, M2	19699, 19643	X	-
8B7	BS51	Subadult	m2	22123	-	X
	BS57	Adult	M1, P4	18598, 17182	-	X
	9 MNI		Mean: 18775		3 MNI	6 MNI

Table 4.10. Żawarża, Phase 3, XRF samples indicating individual and tooth specimen tested, age group, provenience and mobility group: Locally born or Non-locally born.

Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
					L	N
4	Z14	Adult	M1, M2, P4	12827, 12426, 15220	X	-
5	Z6	Subadult	m3, M1	16213, 10907	X	-
5	Z7	Juvenile	m3, M1, M2	19897, 20936, 13951	-	X
17	Z1	Subadult	m3, M1	12182, 12525	X	-
18	Z3	Subadult	m3, M1	14272, 9860	X	-
31	Z4	Juvenile	m3, M1, M2	9800, 9156, 12225	X	-
32	Z5	Adult	m3, M1, M2	14363, 15237, 9614	X	-
37	Z12	Adult[1]	M1, M2, P4	16190, 12977, 10332	X	-
65	Z22	Senior[1]	M2, M3	8725, 10894	-	X
72	Z20	Senior	M3	12660	X	-
	10 MNI		Mean: 13057		8 MNI	2 MNI

[1]Individual with a cracked tooth at death.

Table 4.11. Niedżwiedż, Phase 4 XRF samples indicating individual and tooth specimen tested, age group, pit provenience and mobility group: Locally born or Non-locally born.

Pit	Individual	Age Group	Element	Averaged S^r Values	Origin	
					L	N
20	N7	Adult	P3, P4, M3	14589, 18024, 13554	X	-
29	N9	Subadult	m3, M2	7484, 23265	-	X
61	N15	Juvenile	m3	18377	-	X
67	N20	Adult	P2, P4	13220, 18387	X	-
79	N18	Juvenile	m1, m2	12100, 9702	X	-
101	N22	Juvenile	m1	11205	X	-
	6 MNI		Mean: 14537		4 MNI	2 MNI

Table 4.12. Relative frequencies of local and non-local sheep by phase and site.

Phase	Site	Sheep			
		Local		Non-local	
		#	%	#	%
1	Bronocice	7	.70	3	.30
2	Bronocice	7	.70	3	.30
3	Bronocice	2	.14	12	.86
4	Bronocice	2	.20	8	.80
5	Bronocice	4	.23	13	.77
6	Bronocice	3	.33	6	.67
3	Żawarża	8	.80	2	.20
4	Niedżwiedż	4	.67	2	.33

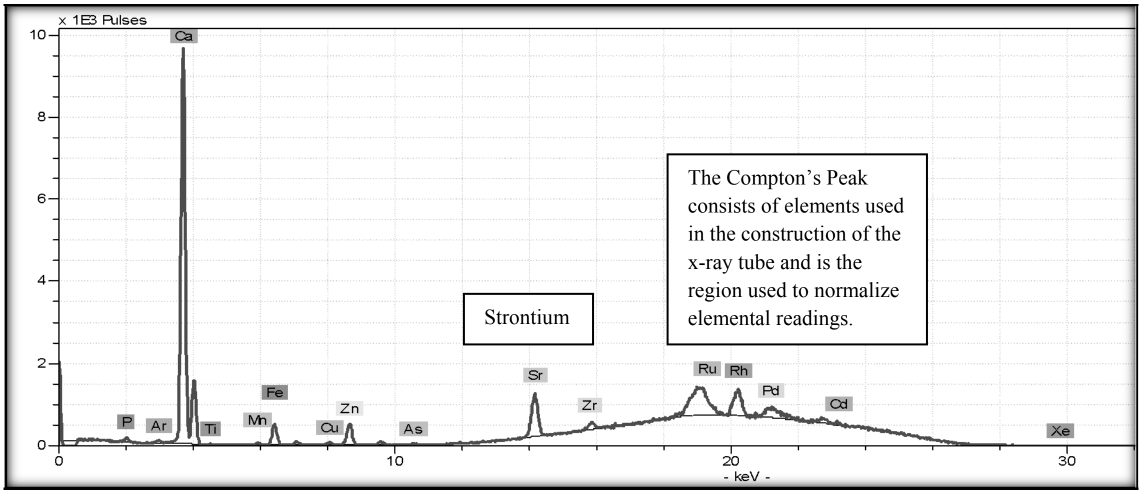


Figure 4.1. Example of XRF a spectral reading. The Y axis indicates the peak intensity of elements while the X axis indicates which elements fluoresce at what voltage.

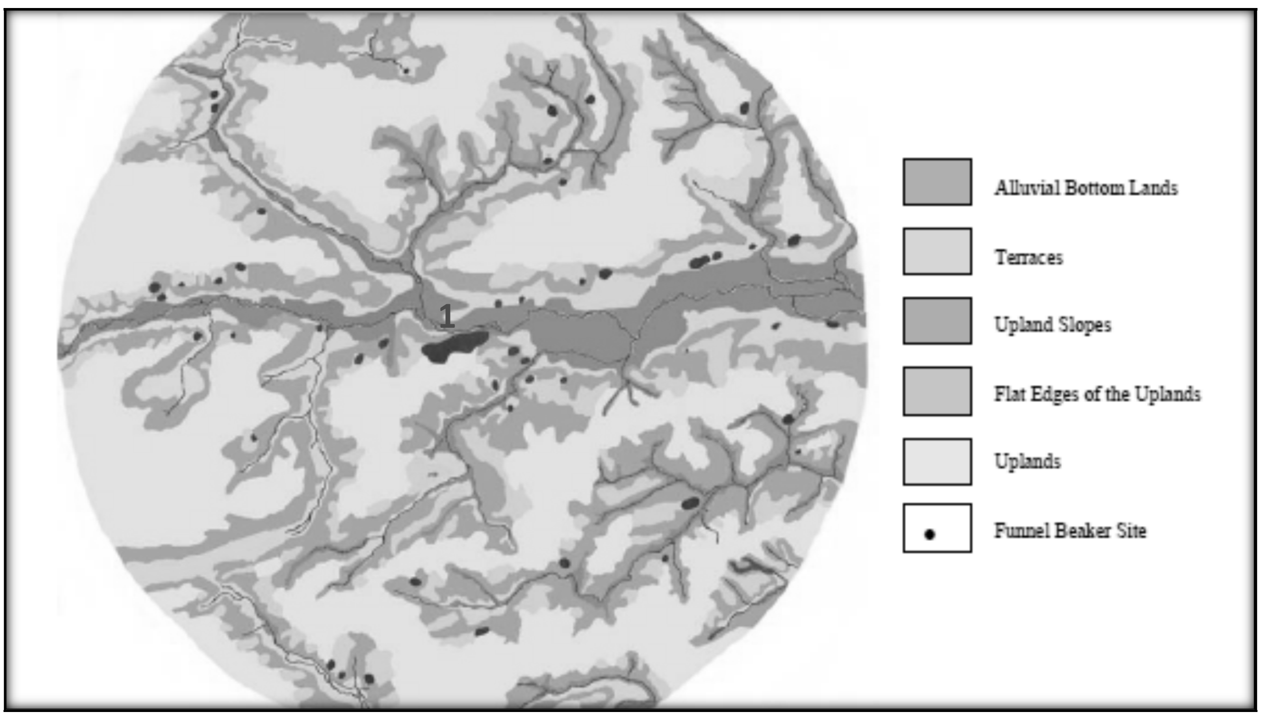


Figure 4.2. Map showing the five major ecological zones in the Bronocice Micro-region and the location of some Funnel Beaker sites including Bronocice (1).

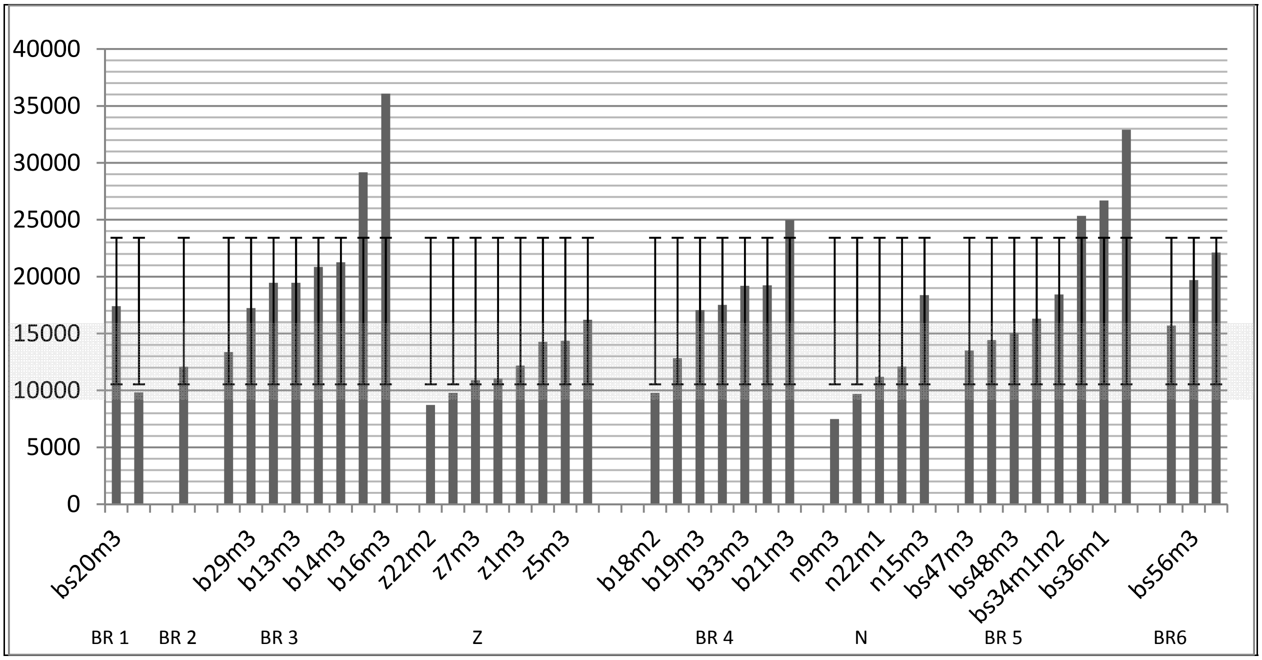


Figure 4.3. Comparison of strontium values in deciduous teeth. Vertical bars = 1 standard deviation for this population. Shaded block indicates the local strontium range.

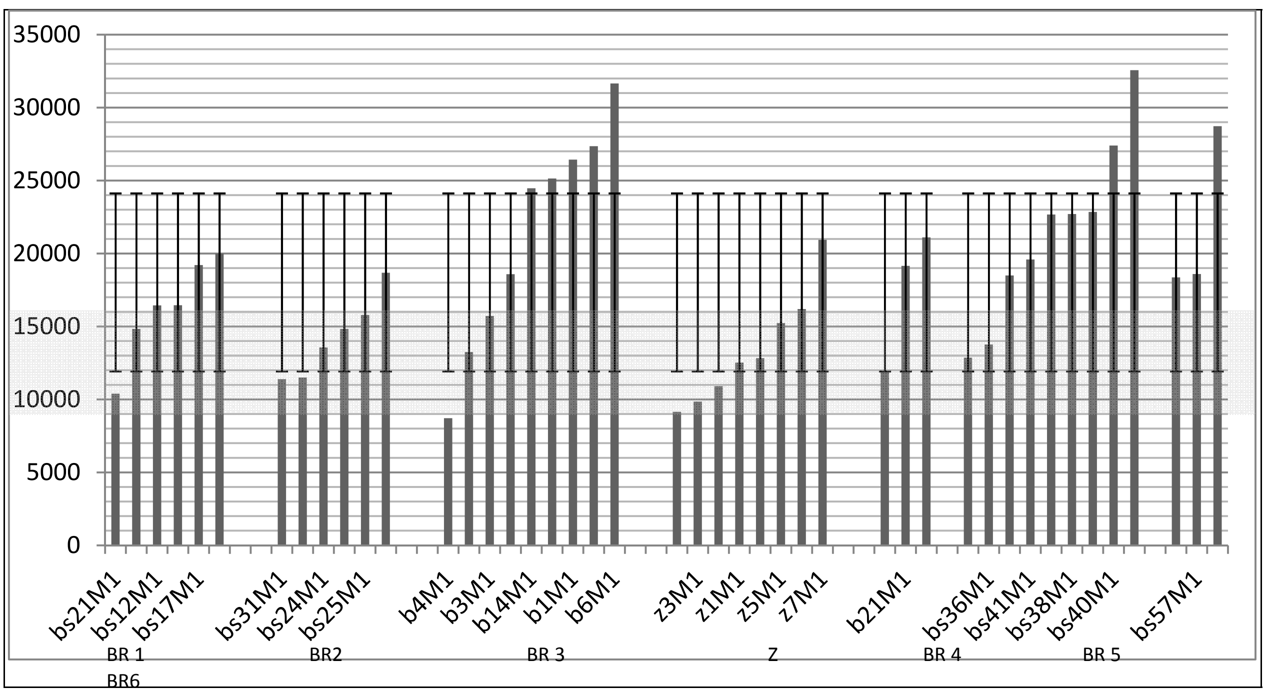


Figure 4.4. Comparison of strontium values in permanent first molars. Vertical bars = 1 standard deviation for this population. Shaded block indicates the local strontium range.

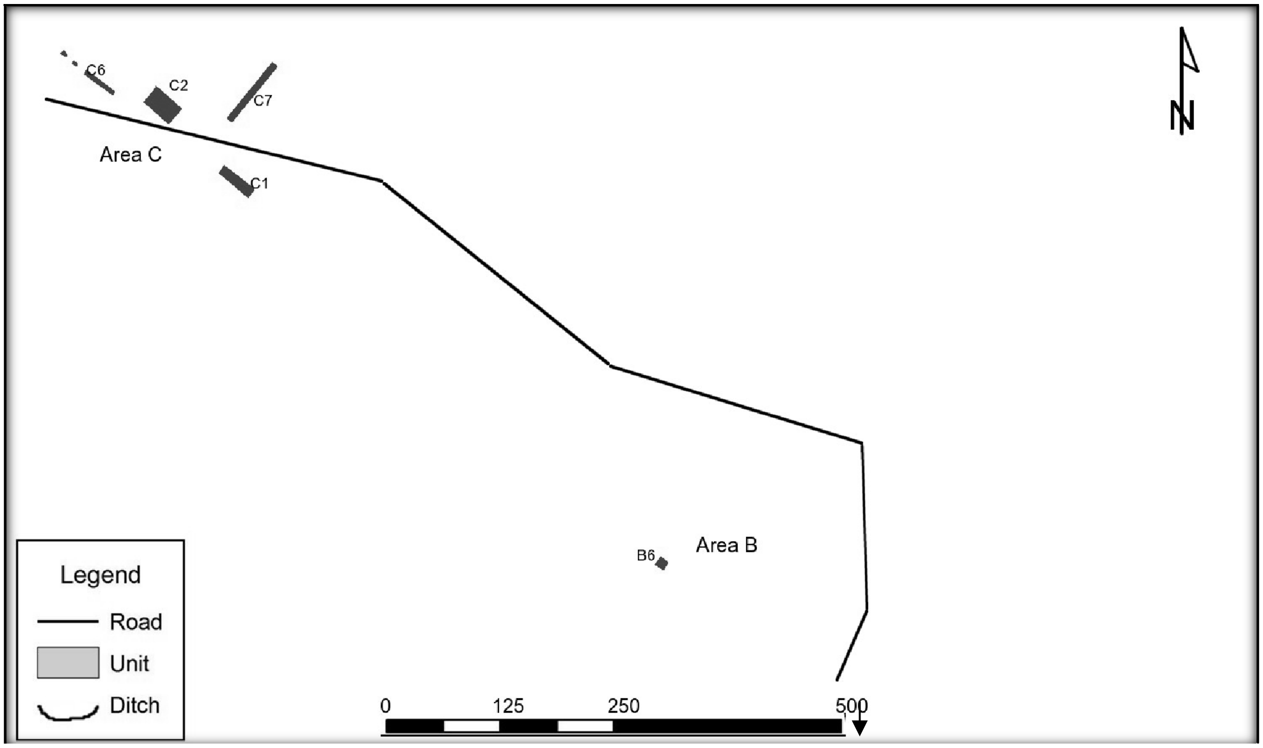


Figure 4.5. Plan of Bronocice showing the extent of the Phase 1 occupation. Sheep XRF samples came mainly from Unit C2 though a couple came from Units B6 and C1.

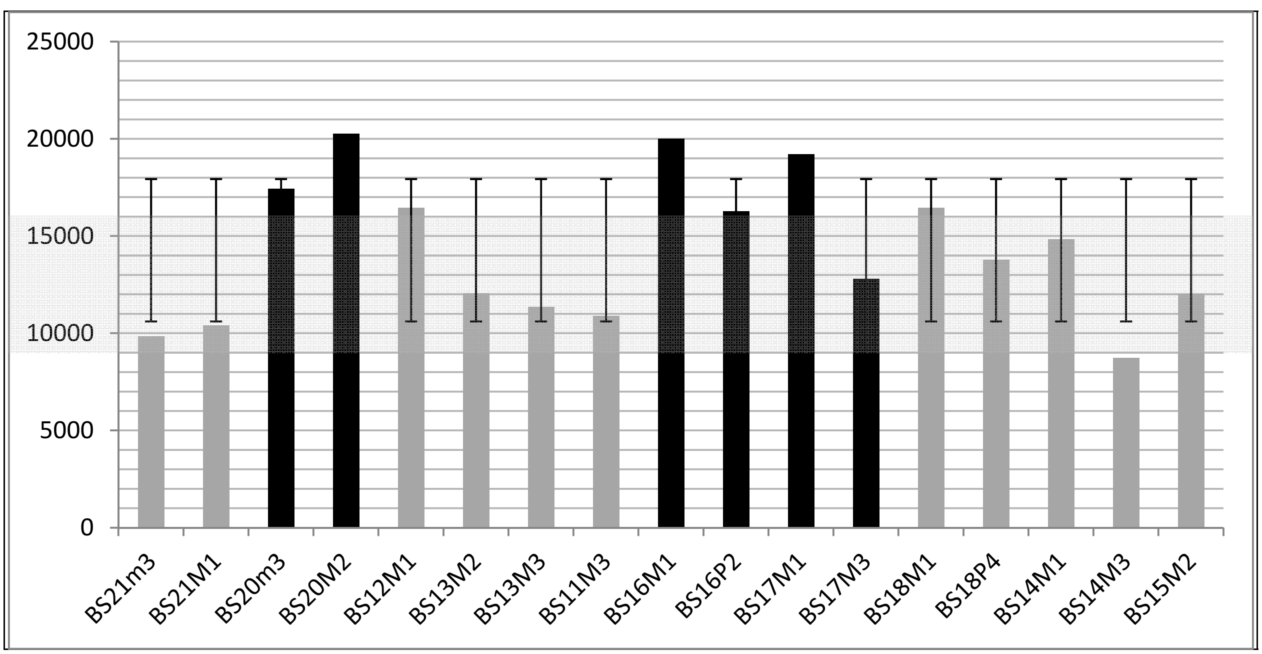


Figure 4.6. Bronocice Phase 1. Vertical bars = 1 StD. Shaded block indicates the local strontium range. Non-local values are indicated in black.

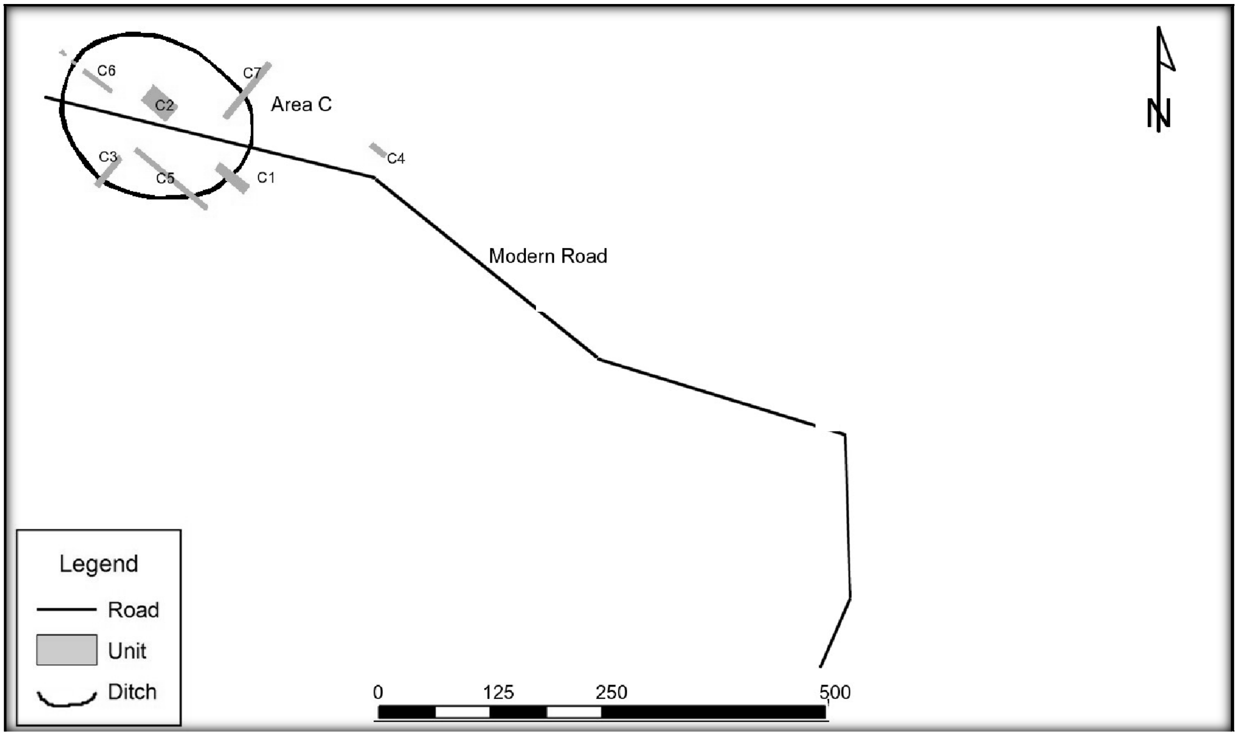


Figure 4.7. Plan of Bronocice showing the extent of the Phase 2 occupation. Sheep XRF samples came from Unit C2.

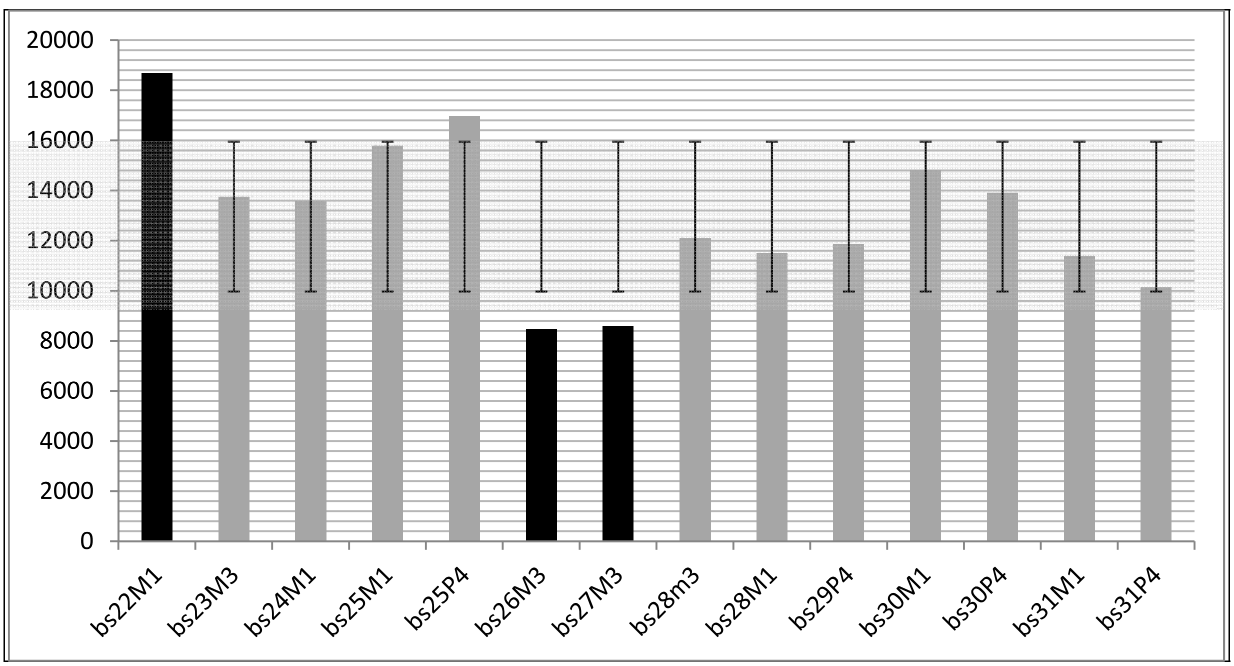


Figure 4.8. Bronocice Phase 2. Vertical bars = 1 StD. Shaded block indicates the local strontium range. Non-local values are indicated in black.

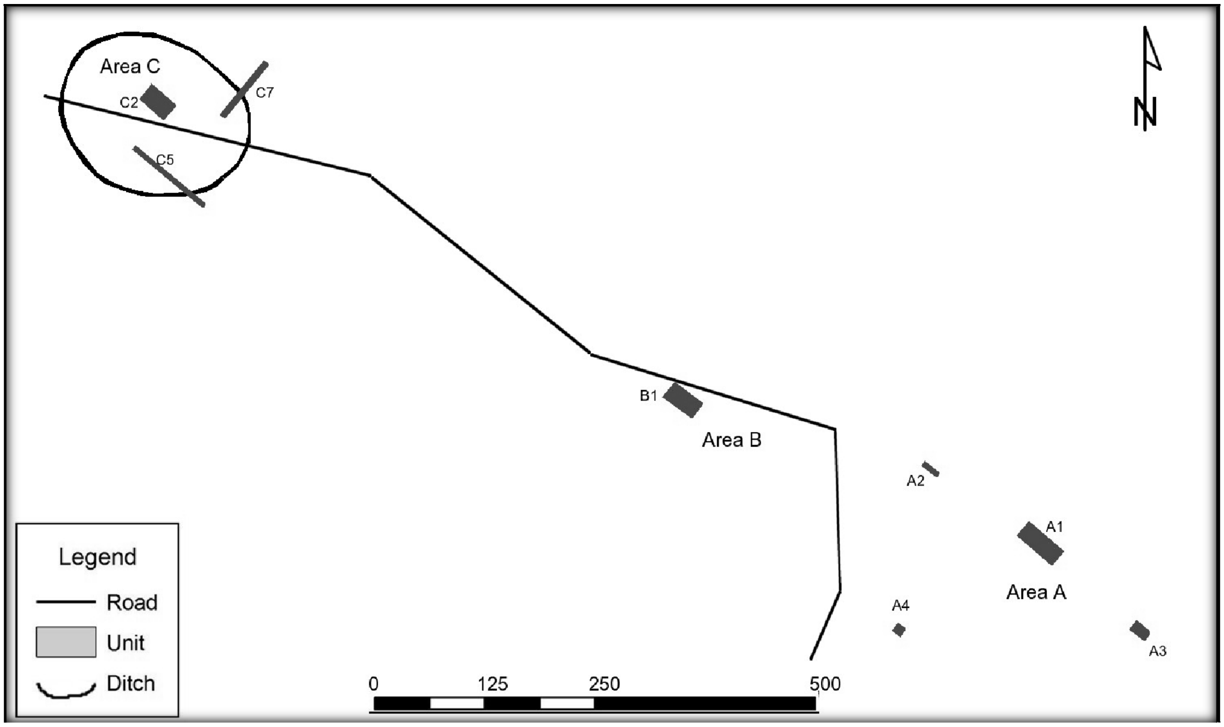


Figure 4.9. Plan of Bronocice showing the extent of the Phase 3 occupation. Sheep XRF samples came from Unit A1. Area C served as a burial ground and enclosure.

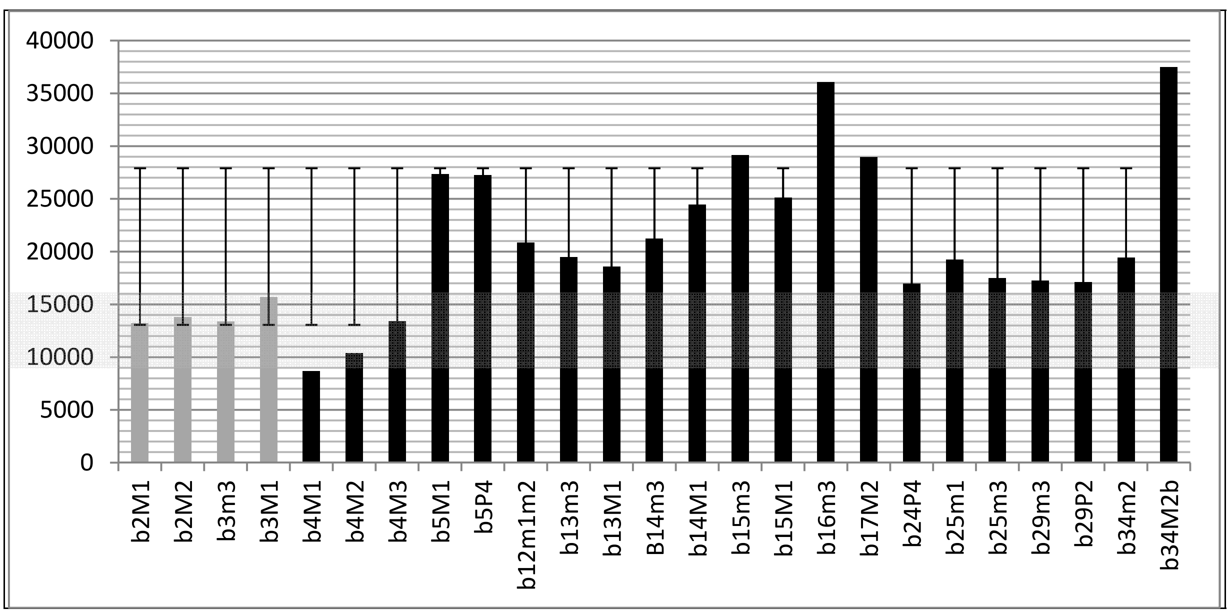


Figure 4.10. Bronocice Phase 3. Vertical bars = 1 StD. Shaded block indicates the local strontium range. Non-local values are indicated in black.

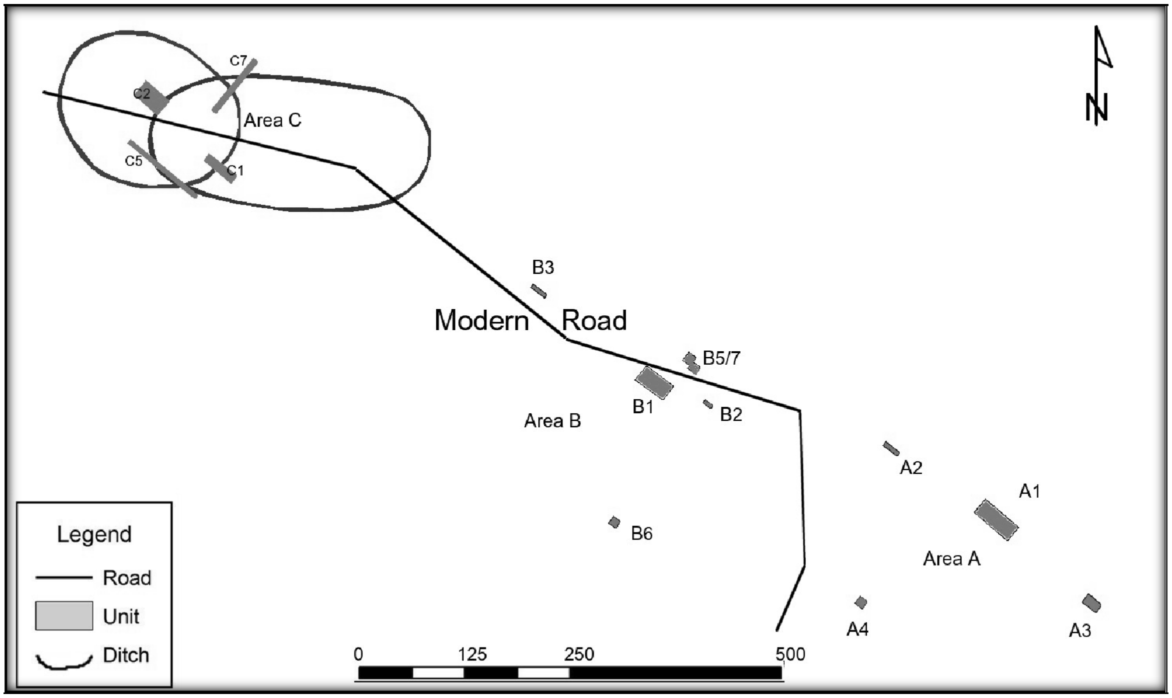


Figure 4.11. Plan of Bronocice showing the extent of the Phase 4 occupations, the old (Area C west) and future (Area C east) enclosure and the continued use of Area C as a cemetery. Sheep XRF samples came mainly from Unit A1 but also from Units B1, B5 and B7.

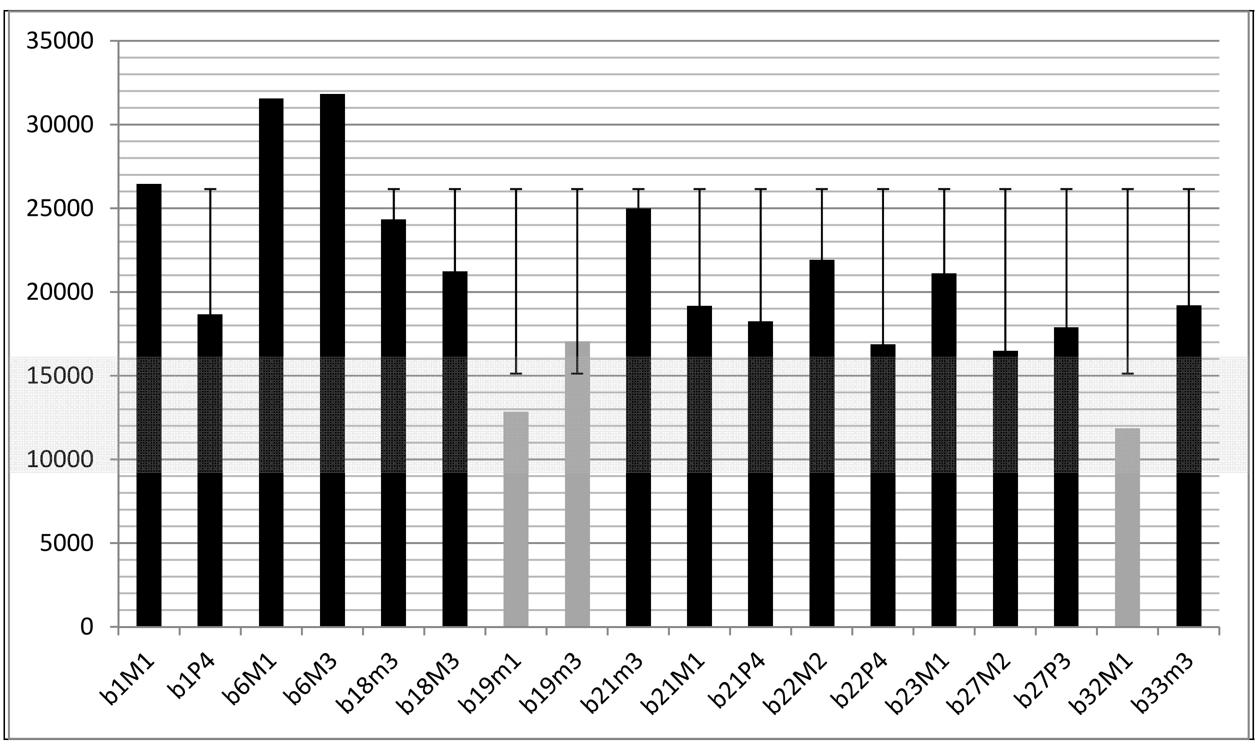


Figure 4.12. Bronocice Phase 4. Vertical bars = 1 StD. Shaded block indicates the local strontium range. Non-local values are indicated in black.

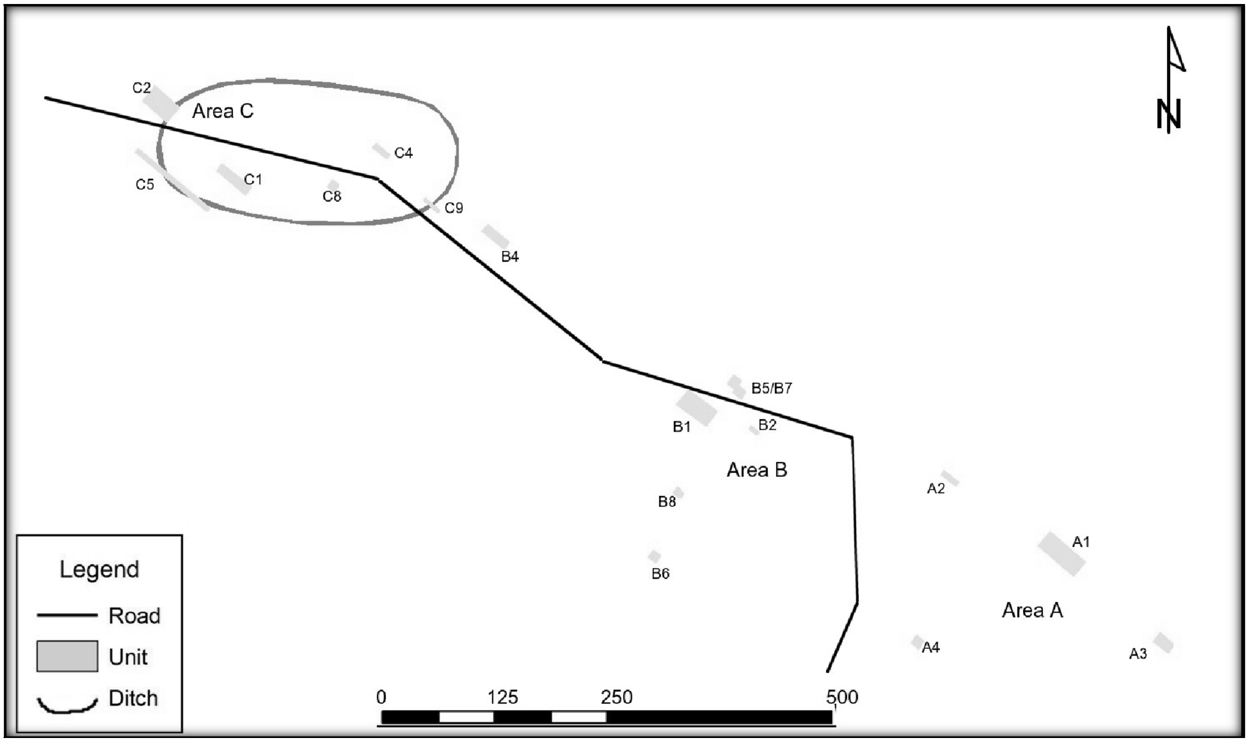


Figure 4.13. Plan of Bronocice showing the extent of the Phase 5 occupation and the new enclosure (Area C). Sheep XRF samples came from Units A1, A3, B1, B2, B6, B7, and B8.

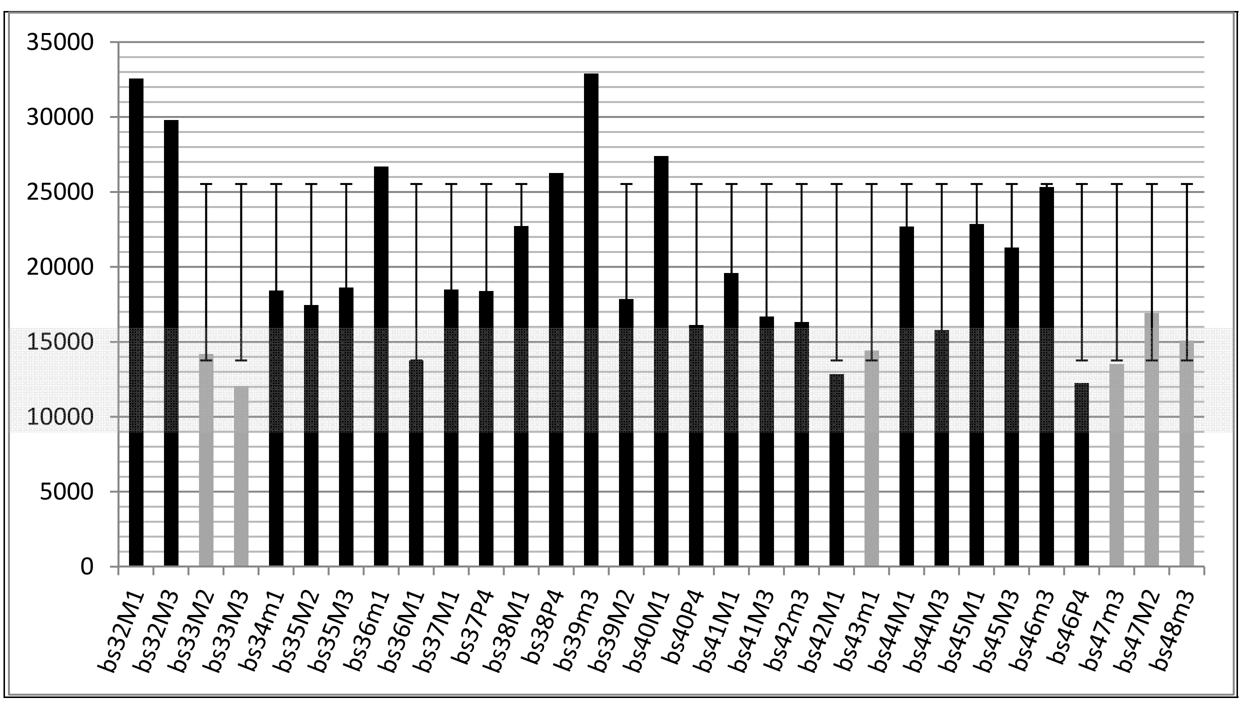


Figure 4.14. Bronocice Phase 5. Vertical bars = 1 Standard Deviation. Shaded block indicates the local strontium range. Non-local values are indicated in black.

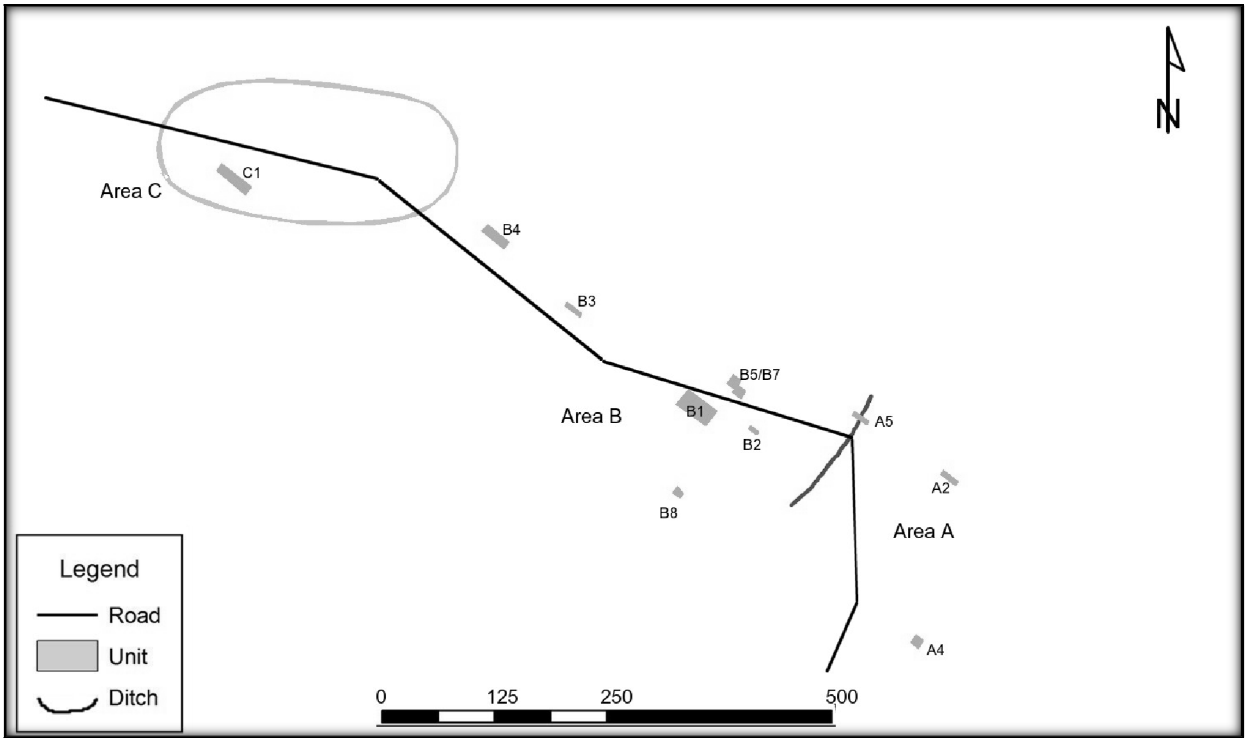


Figure 4.15. Plan of Bronocice showing the extent of the Phase 6 occupation, enclosure around C1, and a new fortification ditch (A5). Sheep XRF samples came from Units A2, B1, B5, and B7.

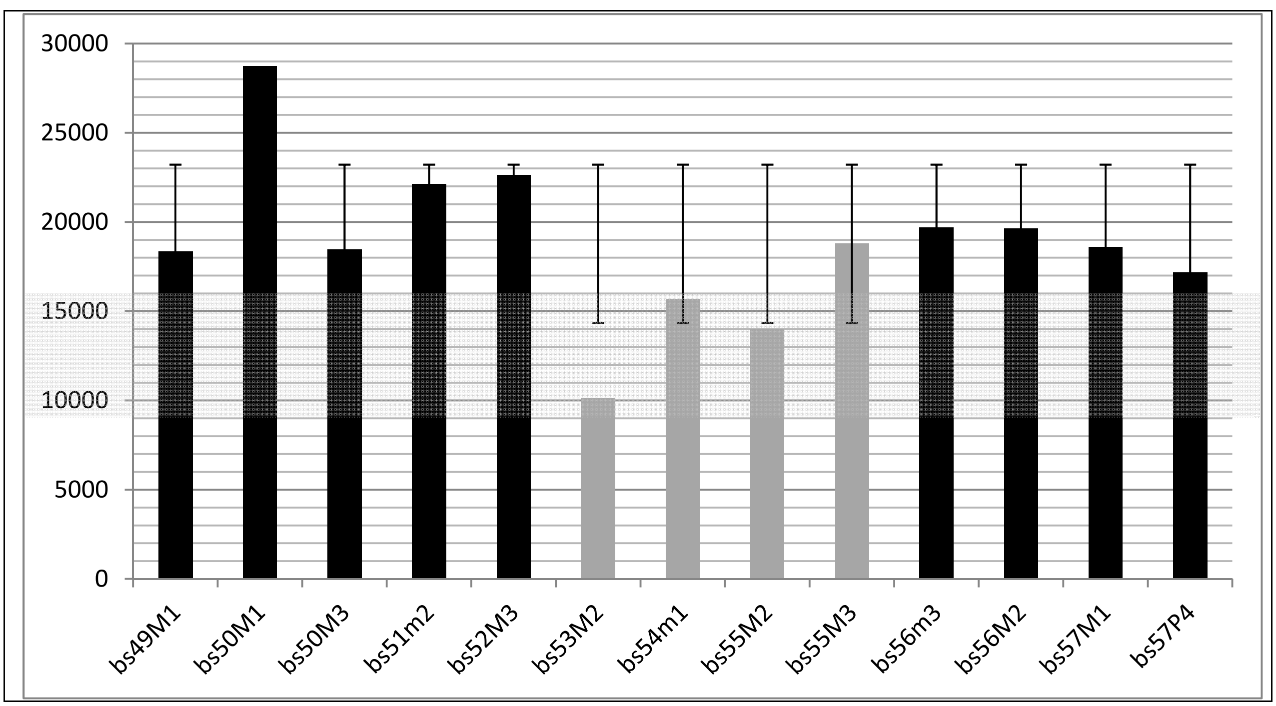


Figure 4.16. Bronocice Phase 6. Vertical bars = 1 Standard Deviation for this population. Shaded block indicates the local strontium range. Non-local values are indicated in black.

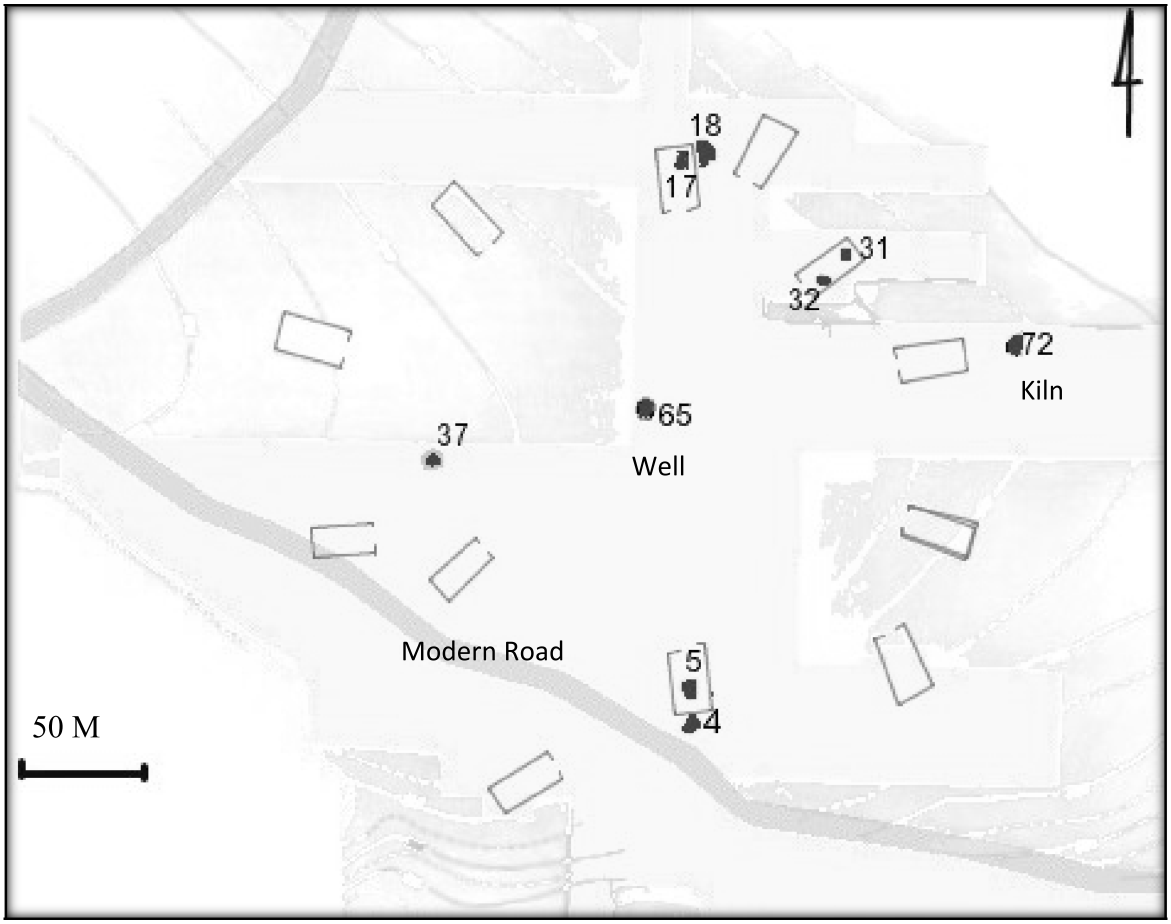


Figure 4.17. Plan of Żawarża showing the extent of the settlement and excavation, and the locations from which XRF samples were drawn.

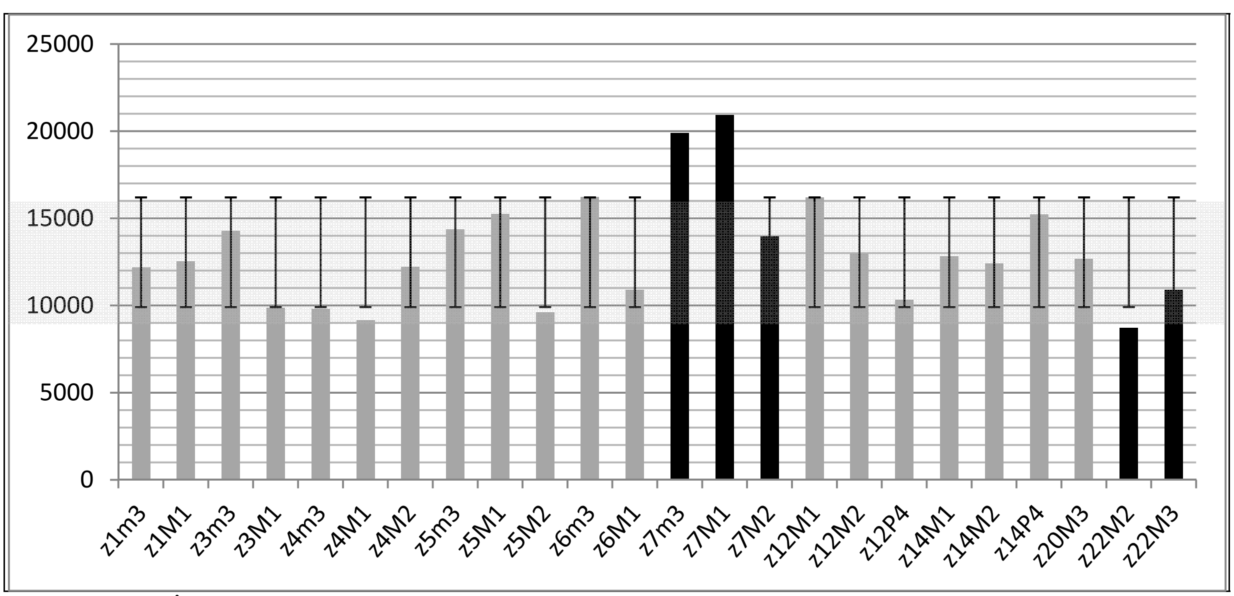


Figure 4.18. Żawarża Phase 3. Vertical bars = 1 StD. Shaded block indicates the local strontium range. Non-local values are indicated in black.

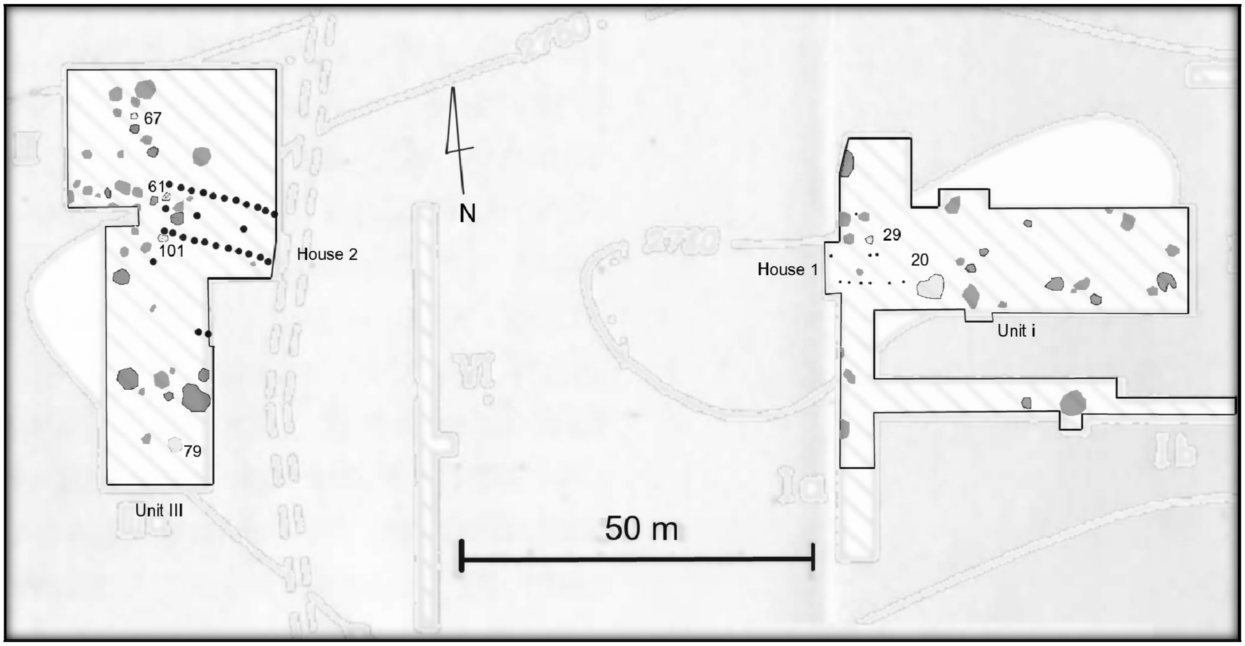


Figure 4.19 Plan of Niedźwiedź, showing the extent of the Phase 4 occupation, postmold structures, and the locations from which XRF samples were drawn.

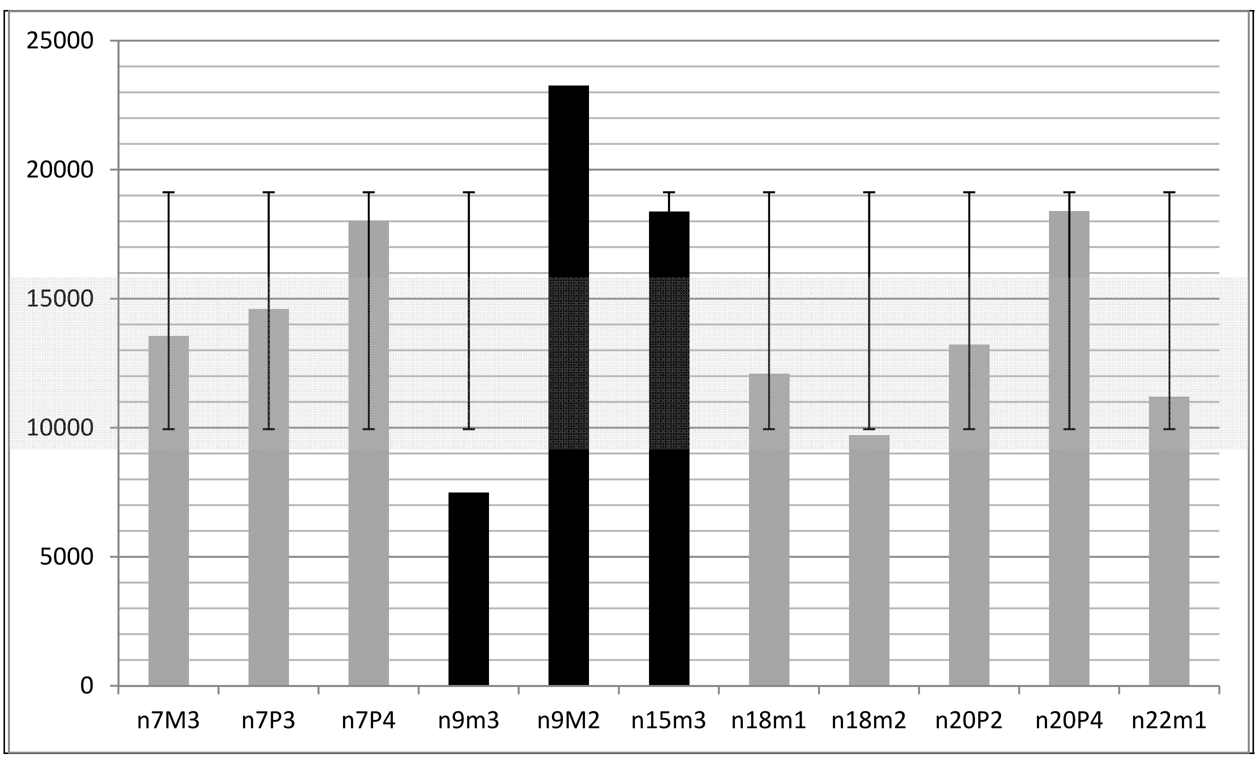


Figure 4.20. Niedźwiedź Phase 4. Vertical bars = 1 Standard Deviation for this population. Shaded block indicates the local strontium range. Non-local values are indicated in black.

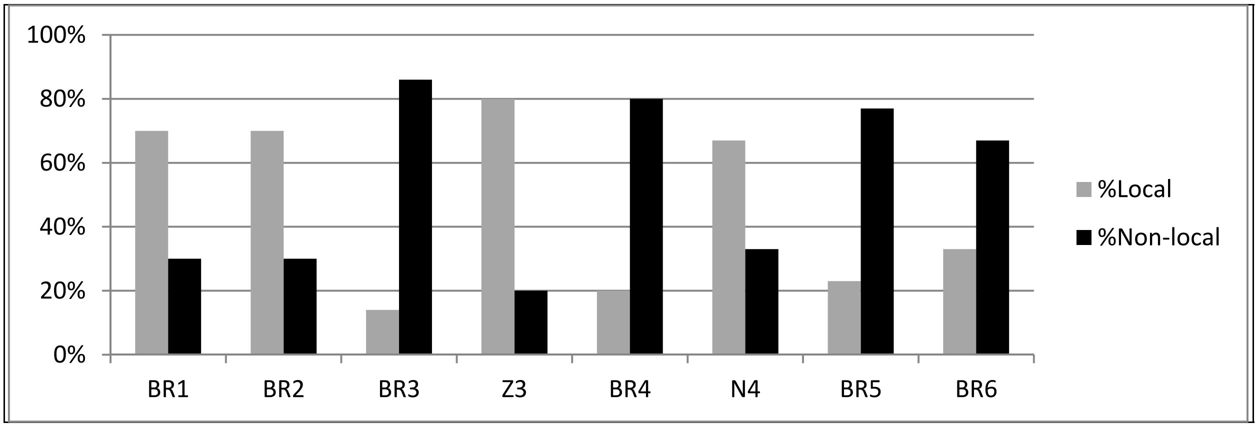


Figure 4.21. Relative frequencies of local and non-local sheep by site and phase.

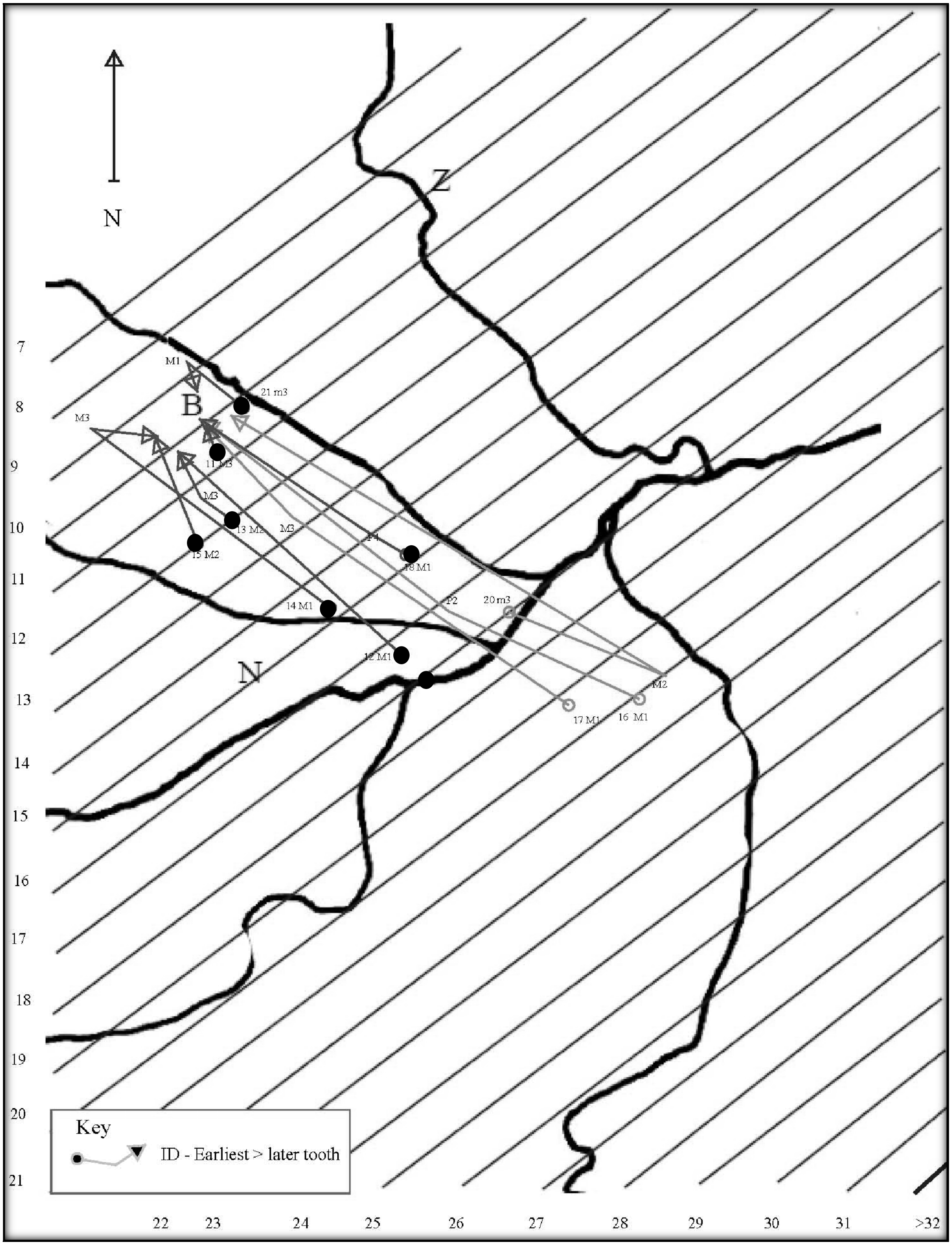


Figure 4.22. Phase 1, Bronocice (3800-3700 BC). Local (●) and non-local (○) sheep mobility patterns.

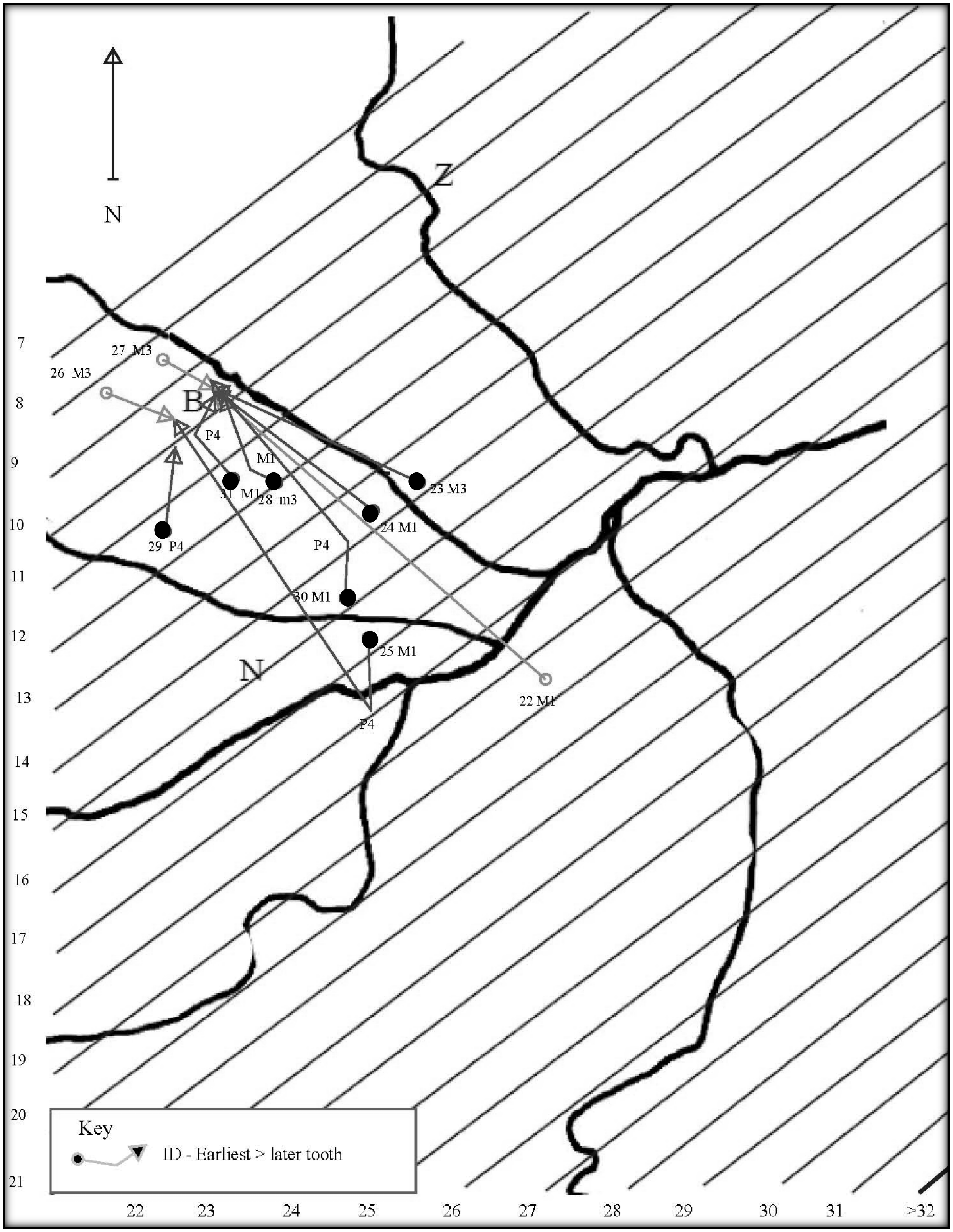


Figure 4.23. Phase 2, Bronocice (3700-3650 BC). Local (●) and non-local (○) sheep mobility patterns.

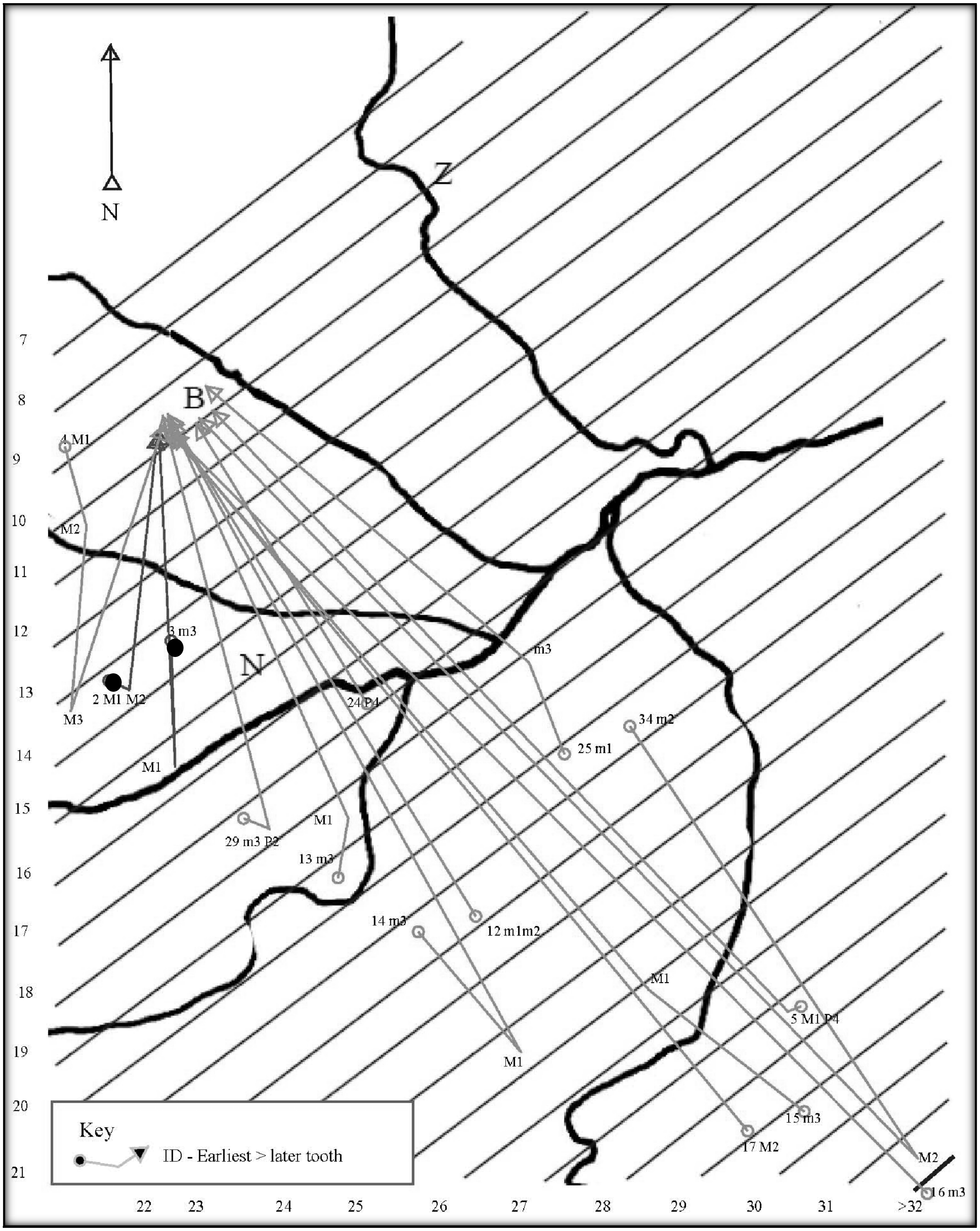


Figure 4.24. Phase 3, Bronocice (3650-3400 BC). Local (●) and non-local (○) sheep mobility patterns.

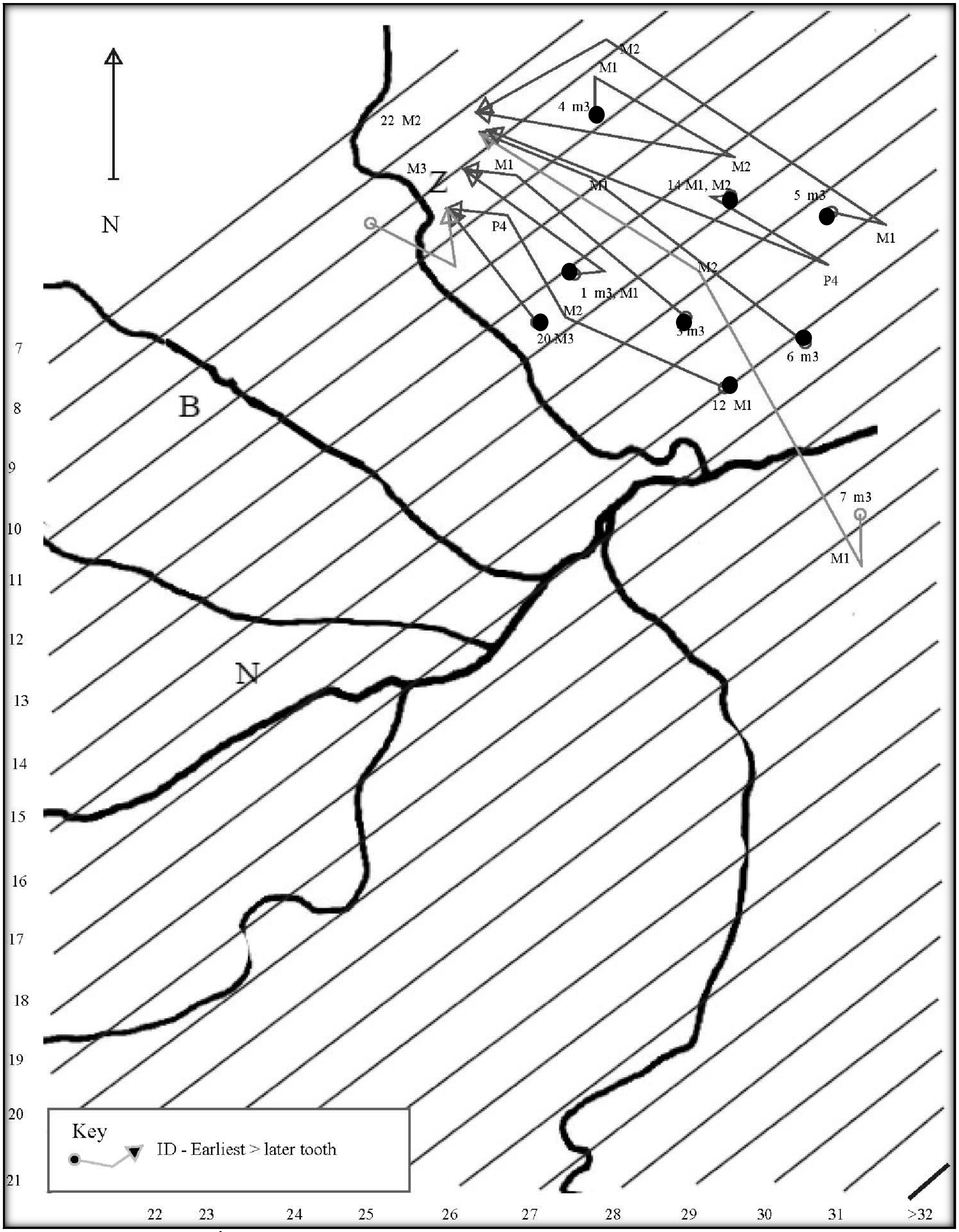


Figure 4.25. Phase 3, Żawarża (3650-3300 BC). Local (●) and non-local (○) sheep mobility patterns.

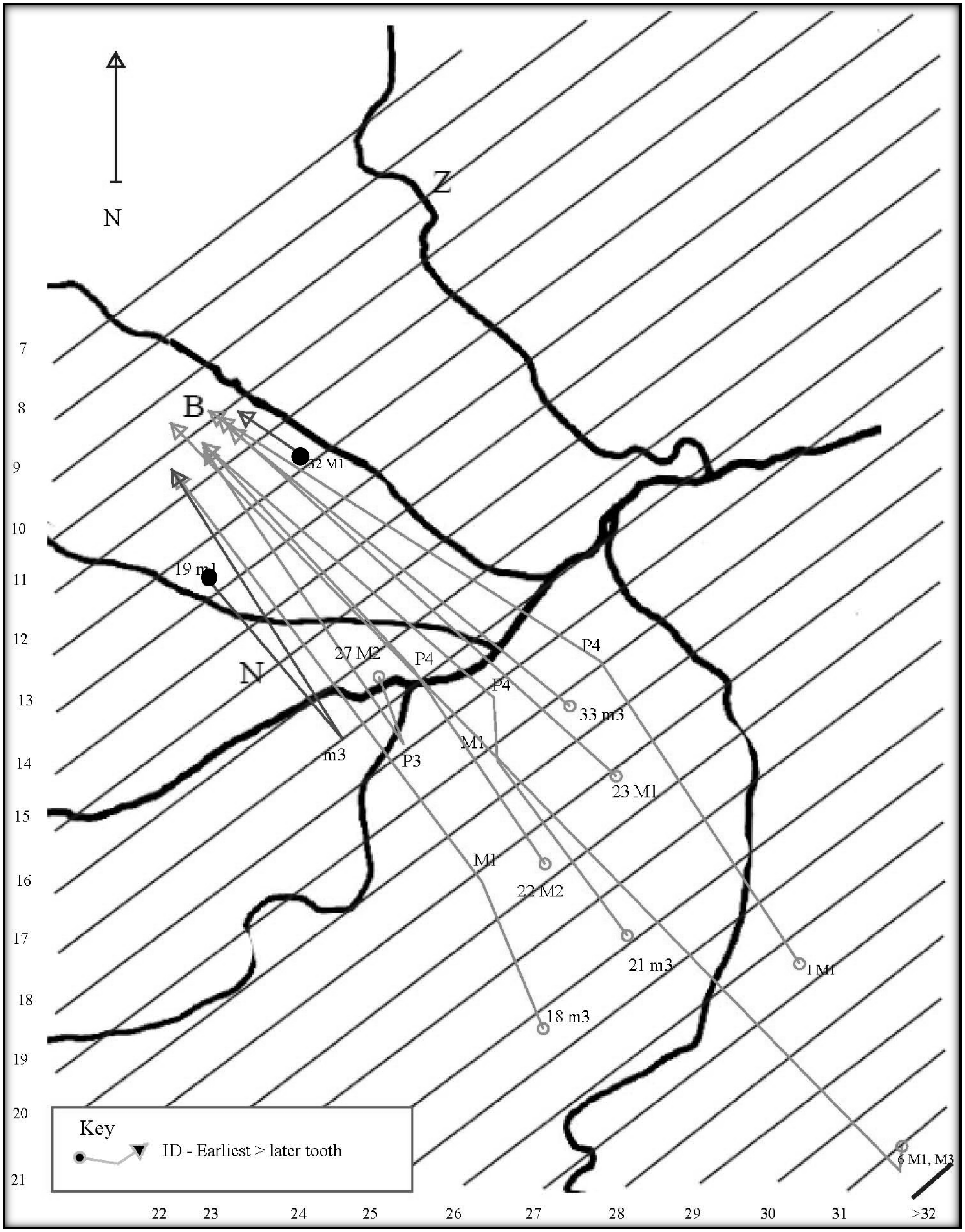


Figure 4.26. Phase 4, Bronocice (3400-3100 BC). Local (●) and non-local (○) sheep mobility patterns.

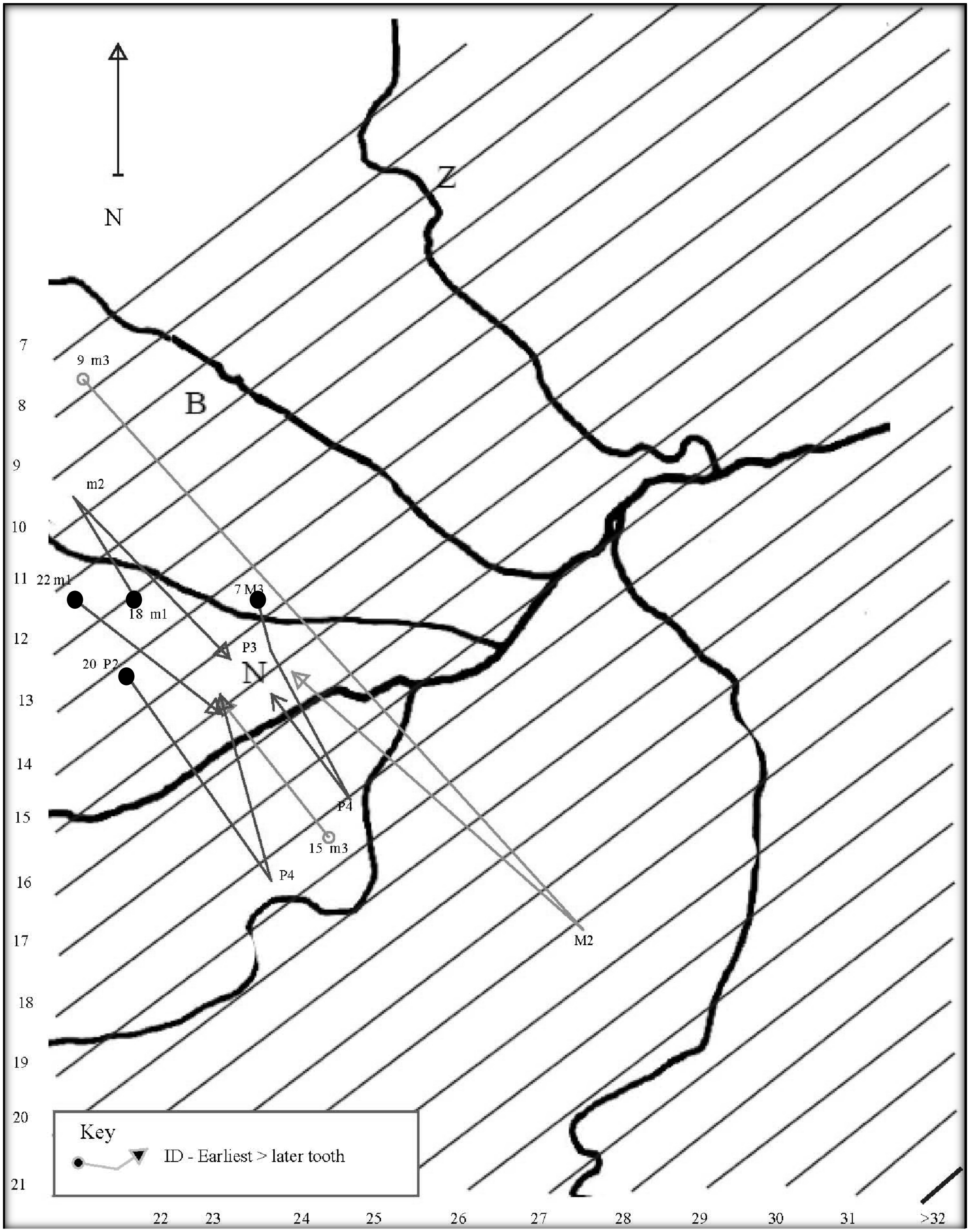


Figure 4.27. Phase 4, Niedźwiedź (3400-3100 BC). Local (●) and non-local (○) sheep mobility patterns.

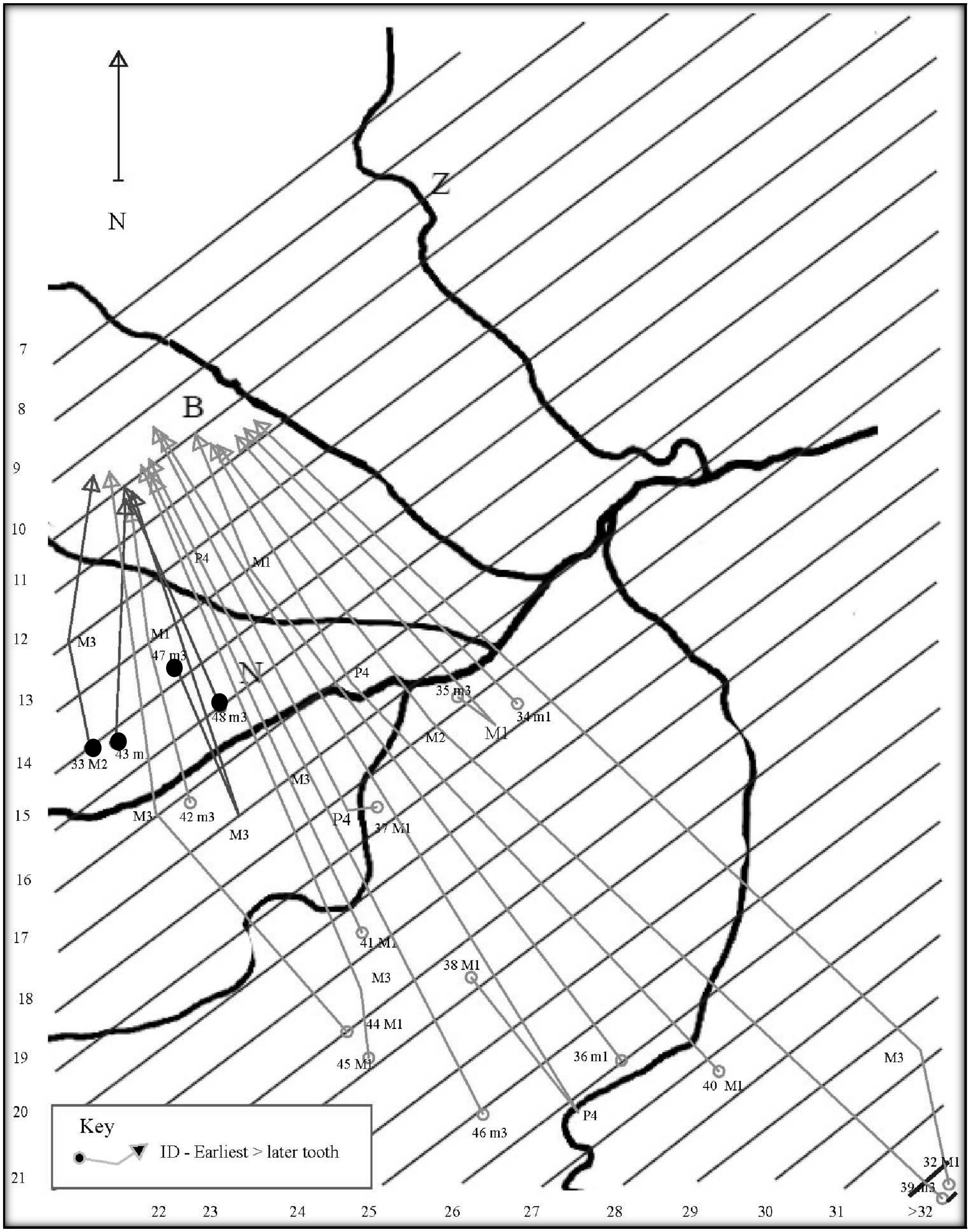


Figure 4.28. Phase 5, Bronocice (3100-2900 BC). Local (●) and non-local (○) sheep mobility patterns.

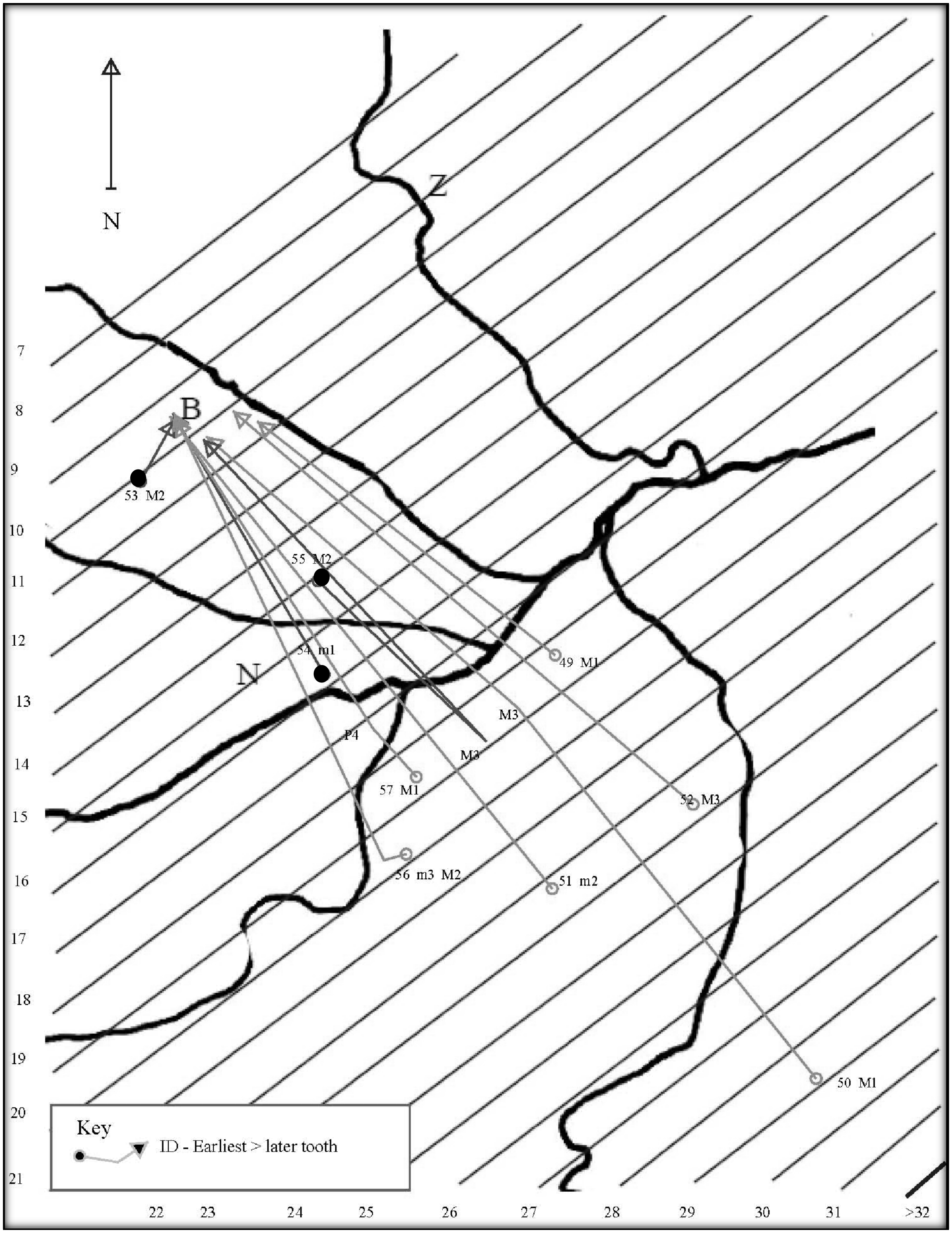


Figure 4.29. Phase 6, Bronocice (2900-2700 BC). Local (●) and non-local (○) sheep mobility patterns.

Chapter 5

Mitochondrial DNA Analysis

Identifying closely related individuals using mitochondrial DNA (mtDNA) within small breeding populations provides insights into the management of livestock, crossbreeding practices and exchange between households and communities (Budowle *et al* 2005, MacHugh *et al* 1999, MacHugh and Bradley 2001). The genetic health of small herds necessitates out-breeding and introduction of unrelated animals. Sheep do not sneak off into the night and have sex. Their reproduction has always been carefully managed by humans since their domestication. Therefore the biological requirement for successful husbandry practices essentially means that people established and maintained social relationships across settlements. The cyclical nature of animal breeding means that these relationships take on a seasonal aspect as well.

A. Mitochondrial DNA

Problems with ancient DNA are abundant and include degradation due to depositional context, environmental degradation and contamination. These issues can impede not only the extraction of DNA but also amplification and sequencing (Pääbo *et al* 2004, Poinar 2003). Still, ancient DNA has been successfully recovered from archaeological faunal materials (Cooper and Poinar 2000, Hummel 2003, Newman *et al* 2002, Willerslev and Cooper 2005).

Mitochondrial DNA (mtDNA) data have been extensively used to examine genetic relationships of varying scales in humans, mammals and other lifeforms. MtDNA is better suited than nuclear DNA (nDNA) to the analysis of ancient remains mainly because it is more abundant. Every living cell contains two copies of nDNA that are located in the nucleus, and

500-2000 copies of mtDNA that are located outside the nucleus. The abundance of mtDNA increases the chances of recovering ancient DNA. MtDNA is transmitted from mother to offspring making it possible to identify maternal relatedness between individuals. Relatedness among individuals can be identified by targeting locations along the hypervariable regions of the D-loop to identify haplotypes or individuals sharing the same base pair sequences (Hummel 2003). Mother and offspring will share the same base pair sequences whereas non-maternally related individuals will not. In human populations the high rate of mutation in mtDNA has been used advantageously to reconstruct maternal lineages over time, to study marriage interactions of different groups, and to document the movement of populations (Epplen and Lubjuhn 1999, Jones 2001). Human mtDNA studies have been used to establish or deny kinship ties in burial contexts between women and children in burial contexts as well as living individuals (Hummel 2003).

In ancient domesticated mammal studies the focus has been mainly on the mobility of livestock, their place of origin, and the process of domestication (Larson *et al* 2007, Scheu *et al* 2008.) In living domesticated mammal species, especially livestock, mtDNA analysis is being used to investigate genetic relatedness and breeding patterns (Budowle *et al* 2005, MacHugh *et al* 1999). MtDNA studies can identify maternal lineages in animal species in the same was as humans by examining the hypervariable regions of the D-loop. These regions express relatively high levels of polymorphisms which allow for the identification of maternal relationships (Hummel 2003). This practice is common among modern breeders. Breeders maintain control over livestock reproduction and use genetic markers, mtDNA haplotypes and polymorphic microsatellites, to identify individuals, maternal relationships and pedigree within domesticated herds (Arruga *et al* 2001, Budowle *et al* 2005, Jamieson 1994, Jamieson and Taylor 1997, Zhao *et al* 2004).

1. Previous DNA research on sheep

DNA studies on archaeological samples of domesticated livestock, cattle, sheep and goat, have documented that Neolithic sites in Europe show an high degree of genetic diversity in all of these species (Cymbron *et al*, 2004, Meadows *et al* 2005, Tapio *et al* 2006). This line of evidence essentially demonstrates that along coastal areas there was a perpetual flow of new genetic stock introduced into breeding populations via long distance trade.

The mtDNA of domesticated sheep has been completely sequenced (Hiendleder *et al* 1998). Initially two major haplotype lineages were identified though now a total of five major lineages are known to exist (Guo *et al* 2005, Meadows *et al* 2007, Tapio *et al* 2006). On a smaller scale however it has been shown that sheep have a complex genetic heritage that resulted from multiple domestication events in southwest Asia (Hiendleder *et al* 2002). Sheep were one of the earliest species domesticated by humans. Studies investigating the mtDNA genetic variability in sheep, comparisons between modern domesticated breeds in Europe and Asia show an overall weak population structure. This has been interpreted as evidence of high introgression of sheep into Europe and Asia and of a wide geographical dispersal (Meadows *et al* 2007, Meadows *et al* 2005, Tapio *et al* 2006). The introduction to sheep throughout Europe was successful in large part because of a continual introduction of new genetic stock due to the lack of wild progenitors in Europe. The same was note true for cattle and pig.

Mitochondrial DNA analysis can be used to identify close genetic relatedness among individuals within and across herds (Budowle *et al* 2005, Hiendleder *et al* 1998). Currently, no ancient DNA studies have focused on breeding practices at the micro level. Instead, genetic studies have been concerned with broader issues of genetic relatedness such as the origins of domestication, process of domestication, the introgression of genetic diversity, and the contribution of wild progenitors with regard to domesticated cattle and pigs (Beja-Pereira *et al* 2006, Guo *et al* 2005 Hiendleder *et al* 2002, Larson *et al* 2007, Meadows *et al* 2005). While these studies provide important information concerning distributions and genetic compositions of modern domesticated animals in various parts of the world, they contribute little to understanding the social mechanisms by which humans managed livestock breeding or maintained the genetic health of herds (Lacy 1997).

2. Relationship between Sheep Rearing and Social Relationships

Breeding practices result from complex decision making processes that include not only husbandry concerns about the health, size, age and sex composition of herds, but also involve social interactions that use livestock for gifts, food for feasting, and as sacrifices for religious ceremonies. Controlled breeding can be achieved in a variety of ways including culling males from the herd, segregating herds by age and sex, castrating males and through the use of leather aprons to impede breeding (Cranstone 1969). In an age when genetics was not understand breeding selection would have been based on phenotype traits, fertility, production of live offspring and, in the case of wooly sheep, quality and abundance of fleece.

Ethnographic studies and historical accounts indicate a wide range of social relationships can exist between communities and households within which livestock exchange and breeding programs play important roles. Common social interactions in which livestock are shifted across settlements and households include marriage, gifting, trading or exchange, and lending or borrowing of males for stud purposes. The XRF data established that large-scale sheep importation into the Bronocice area began around 3650 BC and that smaller communities such as Żawarża and Niedźwiedź did not take part in the larger trade network. Instead they likely obtained new stock through exchange with Bronocice. This suggests the possibility of an annual sheep market taking place in the settlement. Perhaps they were tied to spring fertility rites and the courtship of young people in search of mates. While exactly what form those social relationships took is a matter some of speculation, their existence is not. Those social relationships links were part of the social fabric of the Bronocice micro-region and may in part be observed through establishing genetic links between breeding populations of livestock species. The mtDNA study sought confirmation of genetic relationships between sheep from the three settlements. The transfer of livestock one household to another and from one settlement to would have left a genetic trail reconstructable through mtDNA analysis.

B. Sample selection and methodology

Mitochondrial DNA analysis was used to investigate whether or not there was any close genetic relationship among sheep from the three sites and from Phase 3 to 4. Seventy-five sheep were selected from Phases 3 and 4 (see appendix A). DNA was successfully extracted from all of these sheep, though sequences were obtained from only 34 individuals. Of these, not all of the sequences were sufficient for use in statistical analyses of genetic relatedness and population distances. Sequences of sufficient length were limited to twenty individuals, two which were goats, and which are discussed in this chapter.

In discussion with Professor Andy Merriwether, director of the Ancient DNA and Molecular Anthropology Laboratories at Binghamton University, it was decided that a minimum of 20 sheep individuals per site and phases would serve as representative samples. Each individual would be represented by two DNA samples. Twenty samples were in fact obtained from Żawarża and Niedźwiedź each. However, Bronocice Phase 3 was represented by 16 individuals and Phase 4 by 19 individuals (Appendix A). Samples used for mtDNA analysis were restricted temporally to Phases 3 and 4 (3650-3100 BC). Funding was limited as this part of the project was funded by a National Science Foundation Doctoral Improvement Grant. The high cost of genetic analysis precluded sampling individuals from earlier and later periods. Phases 3 and 4 were targeted because faunal analyses had already marked them as important milestones in the region. Mitochondrial DNA data proved to be more difficult to amplify and sequence than anticipated. Contamination was major problem and severely limited the number of individuals for which results were obtained. Of the 75 sheep from which DNA was extracted from only 20 individuals have to date been successfully sequenced.

For a description of the methodologies used to prepare the samples see Appendix C. Appendix D contains the full genetic report prepared by the lab at Binghamton University and Appendix E contains the mtDNA sequences.

C. Results of the analysis

The discussion below is based on the report provided by Jennifer Luedke (reproduced in its entirety in Appendix D). The mtDNA analysis targeted the mitochondrial loop at positions 15496-00015 using five primer sets (Table 5.1).Within the targeted region, 20 individuals were successfully sequenced for positions 16068-16275. A number of statistical analyses were conducted which included

- a polymorphic sites table that shows base pair changes in sequences and which groups related individuals (Table 5.2)
- a bootstrapped Neighbor-joining tree (Figure 5.1); a table showing degrees of difference based on nucleotide base pair differences (Table 5.3)
- a table showing group distance between the three sites (Table 5.4); and a network analysis (Figure 5.2).
- Other measures of distance can be found in Appendix D however as the focus of this study is on close family relationship those results are not discussed in this chapter.

These tools were used to show relatedness and genetic proximity or distance within and across herds. The discussion that follows first examines sheep within sites and phases that are related and then considers cross site and temporal relationships.

1. Analysis of Family Groupings

All three settlements and both phases were represented by three or more sequenced sheep. They were all related to some degree. However the sheep sequences obtained from Żawarża and Niedźwiedź were more closely related to each other than the sequences from Bronocice were to each other (Table 5.4). That is not surprising since the XRF data already indicated two distinct economies were in operation, one involving local exchange between Bronocice and smaller communities, and the other involving long distance trade between Bronocice and parts unknown. Figure 5.2 illustrates genetic distance between the main group of sheep and the outliers. It reveals that some of the sheep were more distantly related to the main group (N1, B3 and B18), and that others (N4 and N13) were so far removed from the rest of the individuals that they were likely goats. It is indicates the presence two closely related genetic groups.

The polymorphic sites table (Table 5.2) identifies the groups of sheep that were closely related. These are referred to herein as Family 1 and Family 2. Additionally, unrelated individuals have been labeled as Family 3, 4, 5, and 6. Table 5.5 summarizes the provenience information for each of the 20 sheep successfully sequenced providing not only site and phase associations, but identifies the pits from which the samples were obtained.

Sheep from Family 1 were found only at Bronocice but included individuals from Phases 3 and 4. Each of these individuals came from different household pits (Table 5.5). Superficially, the temporal assignments of the pits might preclude immediate relatedness or descent between the individuals. However, pits 101-A1, 33-A1 and 64-A1 are actually transitional in time, Phase 3/4 and may have existed at the same time or overlapped in time. So it is possible that the sheep from some of these pits actually have been directly related to each other as well as to the sheep from 23-B1 (Phase 4).

Family 2 was larger and included 11 sheep from all three sites and both temporal phases (Table 5.5). While it is difficult to know how many generations of sheep are represented in the samples an estimate based on a life expectance of 7-8 years for mature sheep can be used for calculating a minimal number at Żawarża and Niedżwiedż. Each of these sites was occupied for 1 generation by Funnel Beaker people. Assuming one human generation equals 25 years the minimum number of sheep generations would be four at either of these settlements. The occupational lengths at Bronocice for Phases 3 and 4 were unfortunately much longer which precludes any such calculations. However, the degree of proximity between herds from all three sites and phases was statistically great (Table 5.4). Perhaps all of these sheep were temporally close in time.

Four unrelated sheep were also present at Bronocice (Phases 3 and 4) and at Niedżwiedż (Table 5.5). Once again the sheep from Phase 3 came from transitional pits. Therefore they represent sheep that may have been contemporary with those from Families 1 and 2. The sheep from Niedżwiedż (N1) may have been a non-local individual. Unfortunately this individual was represented by a distal humerus which means that no XRF data is available to confirm or deny its point of origin.

2. Sheep Families, Temporal and Spatial Correlations

The spatial locations from which the 18 sheep were obtained may shed some light on social relationships. All Family 1 sheep were found at Bronocice. Three of sheep belonging to Family 1 were found in Unit A1 but two are from Phase 3 (B4, B15) and were non-local animals while the third member (B1) dates to Phase 4 and was a local or descendant animal. The fourth sheep belonging to Family 1 (B19) was also a locally born animal though it was found in Unit B1. Therefore it may concluded that the related sheep from Family 1 were possible associated with multi-generational households.

The related sheep from Family 2 on the other hand were found at the three sites and dated to Phases 3 and 4. As was the case with Family 1 some of the sheep dated to Phase 4 were locally born whereas those dating to Phase 3 were non-local in origin. At Bronocice members of Family 2 were found in three different parts of the site (Units A1, B1 and B7) (Figure 5.3). It may be that several households obtained sheep from the market, as opposed to slaughtering their own animals, which originated from the same flock. The presence of descendants reveals that some of the sheep imported were bred in the region and produced offspring.

At Żawarża, two of the individuals were obtained from a pit associated with a kiln located on the outer edge of the settlement (Z15, Z16, Pit 76). No household association is therefore possible for these two sheep though it is more likely than not that the kiln was owned and operated by single household (Figure 5.4). The third sheep came from inside a house pit (Z8, Pit 5) a fair distance from the kiln area. All three individuals belonged to Family 2.

At Niedżwiedż sheep came three areas at the site. N1 and N10 were associated with the House 1 whereas N19 was found near the House 2, and N18 was found in the south yard of House 2. Except for N1 the three remaining sheep belonged to Family 2.

In four cases there were pits that yielded two individuals, 3 pits at Bronocice (33-A1, 101-A1 and 23-B1) and 1 pit at Żawarża (76). At Bronocice the individuals found in the same pits were unrelated to each other, whereas at Żawarża they were closely related. This indicates a couple things with regard to the sheep from Bronocice. First, Bronocice households obtained sheep from different flocks and perhaps at different times. Second, the sheep found in these pits were not mother and offspring since they had different mtDNA. At this time it is unknown if they might represent father and offspring.

D. Discussion of the Mitochondrial DNA results

The mtDNA analysis provided insights into the genetic relationships among sheep from the three sites and Phases 3 and 4. It revealed the presence of 2 dominant families, one extensive than the other, and four other families. Both Family 1 and 2 were represented in both phases. In nearly every case the sheep from Phase 3 were non-local in origin, whereas their relations from Phase 4 were local in origin. This clearly shows they were descended from imported animals.

The close genetic relationships observed in sheep between the smaller settlements and those at Bronocice are clear indications that Bronocice drew people in where they were able to obtain new stock for their herds. Questions remain concerning social structure, patterns of acquisition and the exchange. The sample size is currently too small to clearly understand the nature of the relationships among Bronocice households and how they acquired sheep. It remains a question whether households at Bronocice raised and slaughtered sheep or if they obtained them as food in the market. Nonetheless the genetic data provides a rich picture of the structure of sheep relatedness within and across the three settlements.

Table 5.1 Primer Conditions.

Primer	Primer Sequence (5'-3')	Annealing Temperature (°C)
15496F 15660R	TTAAACTTGCTAAAACTCCCA AATACTATGTACTCGTTTGCA	53
15944F 16119R	GCCAGCCACCATGAATATTGT GAGCGAGAAGAGGGATCCT	58
16068F 16275R	CCATGCCGCGTGAAACCAAC ACAGTTATGTTAGGCATGGGCT	61
16227F 16444R	GACATCTCGATGGACTAATGAC GCAGATATGTCCTGTGACCATT	61
16399F 00015R	GGTAAGCATGGGCATAATAT TTAAGCTACATTAACTATGCG	53

Table 5.2. Polymorphic sites table of samples for positions 16068-16275. Brono 3 = Bronocice Phase 3, Z = Żawarża (Phase 3), Brono 4 = Bronocice Phase 4, and N = Niedźwiedź (Phase 4).

																					N per site			
Sample	16068	16069	16096	16097	16098	16101	16118	16130	16132	16133	16136	16138	16161	16165	16185	16207	16214	16217	16244	16245	Brono 3	Z	Brono 4	N
REF*	C	C	C	A	G	A	C	A	C	T	G	G	A	G	G	C	T	C	A	T				
B1, B15.2, B4.19.2	.	.	.	.	.	.	T	G	.	.	.	.	.	.	.	.	.	.	.	.	2		1	
B3	.	.	.	.	.	.	T	.	.	.	A	A	.	.	.	.	.	.	G	.	1			
B5, B17, B4.7, B4.9, B4.21.2, Z8, Z15, Z16, N18, N10, N19	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	3	3
B13.2	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	T	.	.	1			
B4.18, B4.18.2	.	.	.	G	A	.	T	G	.	.	.	A	.	.	A	.	.	.	.	.			2	
N4	.	.	T	G	.	G	T	.	T	C	.	.	T	A	.	.	.	T	.	.				1
N13	.	.	T	G	.	G	T	.	.	C	.	.	T	A	.	T	C	T	.	.				1
N1	T	T	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.				1

*Ovis aries reference sequence Genbank AF010406 (Hiendleder *et al.* 1998).

Table 5.3. Pairwise Differences calculated between each individual sample for primer set 16068F/16275R (Tamura 2004)

B1	0.000																				
B3	0.021	0.000																			
B5	0.005	0.016	0.000																		
B17	0.005	0.016	0.000	0.000																	
B13.2	0.011	0.021	0.005	0.005	0.000																
B15.2	0.000	0.021	0.005	0.005	0.011	0.000															
B4.7	0.005	0.016	0.000	0.000	0.005	0.005	0.000														
B4.9	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000													
B4.18	0.021	0.032	0.027	0.027	0.032	0.021	0.027	0.027	0.000												
B4.18.2	0.021	0.032	0.016	0.016	0.021	0.021	0.016	0.016	0.021	0.000											
B4.19.2	0.000	0.021	0.005	0.005	0.011	0.000	0.005	0.005	0.021	0.021	0.000										
B4.21.2	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000									
Z8	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000								
Z15	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000							
Z16	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000						
N4	0.062	0.074	0.056	0.056	0.050	0.062	0.056	0.056	0.074	0.062	0.062	0.056	0.056	0.056	0.056	0.000					
N13	0.068	0.080	0.062	0.062	0.056	0.068	0.062	0.062	0.080	0.069	0.068	0.062	0.062	0.062	0.062	0.016	0.000				
N18	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000			
N1	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000		
N10	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000	0.000	
N19	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000	0.000	0.000

Table 5.4. Between Group Mean Distance.

Bronocice phase 3	0.000		
Bronocice phase 4	0.012	0.000	
Zawarza	0.005	0.008	0.000
Niedzwiedz	0.005	0.007	0.000

Table 5.5. Correlation of provenience information and genetic relationship.

Specimen	Site	Phase	Structure #	Pit	Age-at-Death	Family 1	Family 2	Family 3	Family 4	Family 5	Family 6	No Family
B3	Bronocice	34	A1.11	33-A1	Juvenile	-	-	X	-	-	-	-
B4	Bronocice	34	A1.11	33-A1	Adult	X	-	-	-	-	-	-
B5	Bronocice	3	A1.2	26-A1	Senior	-	X	-	-	-	-	-
B13	Bronocice	3	A1.8	1-A1	Juvenile	-	-	-	X	-	-	-
B15	Bronocice	34	A1.10	101-A1	Juvenile	X	-	-	-	-	-	-
B17	Bronocice	34	A1.10	101-A1	Senior	-	X	-	-	-	-	-
Z8	Żawarża	3	7	5	Adult	-	X	-	-	-	-	-
Z15	Żawarża	3	KILN	76	Adult	-	X	-	-	-	-	-
Z16	Żawarża	3	KILN	76	Adult	-	X	-	-	-	-	-
B1	Bronocice	34	A1.14	64-A1	Adult	X	-	-	-	-	-	-
B7	Bronocice	4	A1.24	68-A1	Adult	-	X	-	-	-	-	-
B9	Bronocice	4	B1.2	23-B1	Adult	-	X	-	-	-	-	-
B18	Bronocice	4	B1.2	23-B1	Subadult	-	-	-	-	X	-	-
B19	Bronocice	4	B1.1	2-B1	Subadult	X	-	-	-	-	-	-
B21	Bronocice	4	B7.2	2-B7	Subadult	-	X	-	-	-	-	-
N1	Niedźwiedź	4	1 YARD	2	Adult	-	-	-	-	-	X	-
N4	Niedźwiedź	4	1 YARD	12	-	-	-	-	-	-	-	Goat
N10	Niedźwiedź	4	1	41	Adult	-	X	-	-	-	-	-
N13	Niedźwiedź	4	1 YARD	43	-	-	-	-	-	-	-	Goat
N18	Niedźwiedź	4	2 YARD	79	Juvenile	-	X	-	-	-	-	-
N19	Niedźwiedź	4	2 YARD	108	Adult	-	X	-	-	-	-	-

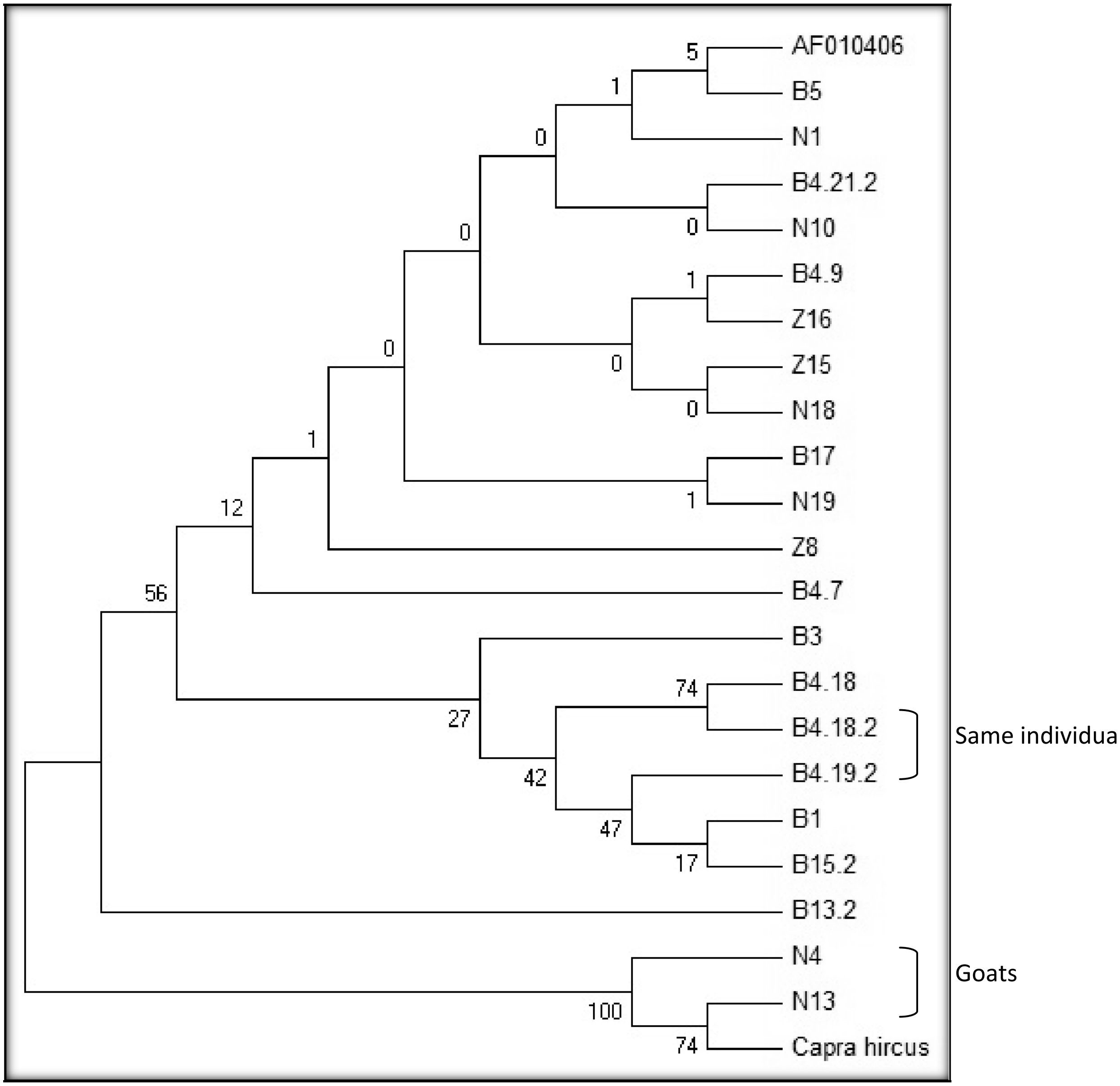


Figure 5.1. Bootstrapped consensus Neighbor Joining Tree (1,000 replicates).

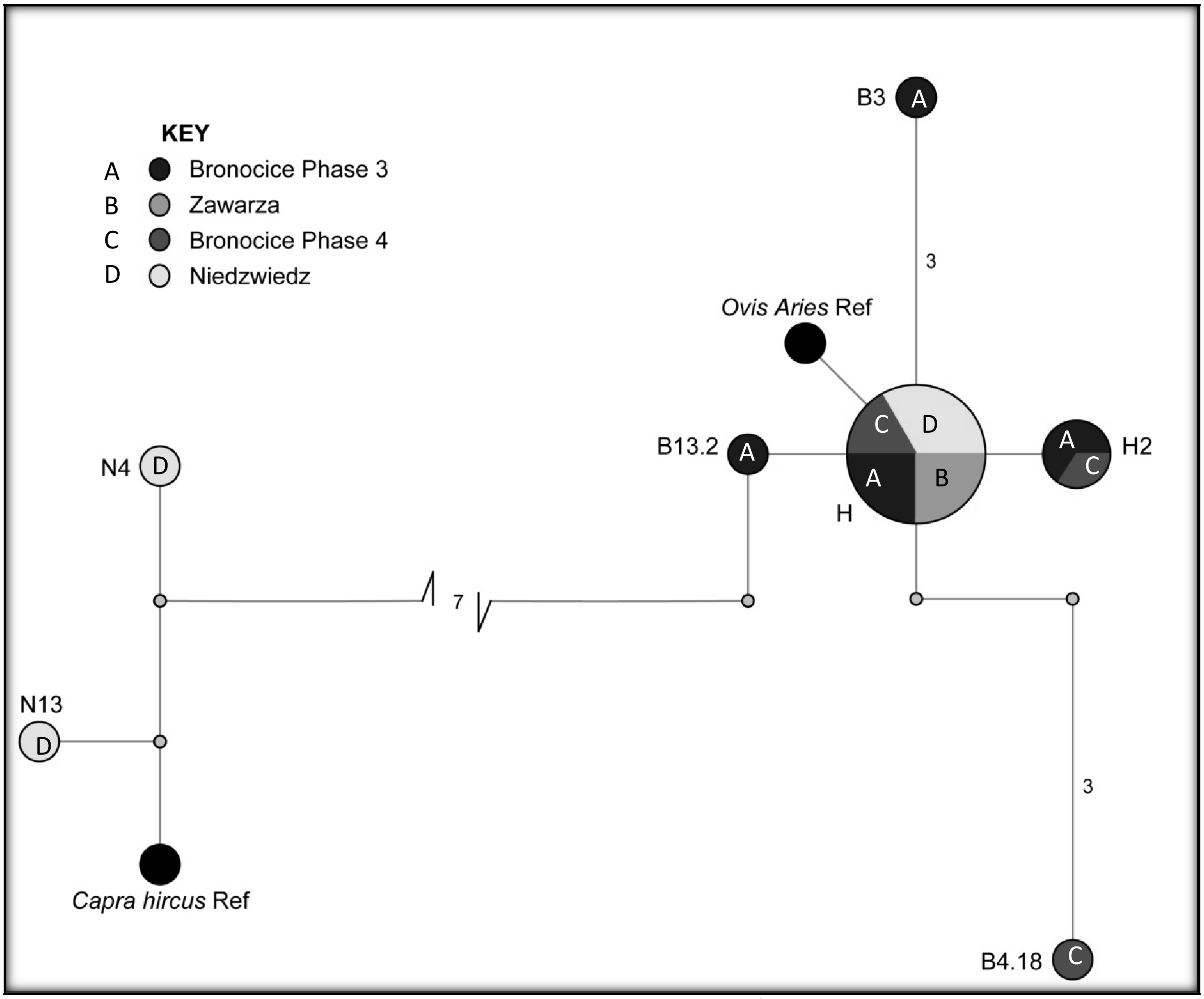


Figure 5.2. Network Analysis where Bronocice Phase 3 = A, Żawarża = B, Bronocice Phase 4 = C and Niedżwiedż = D.

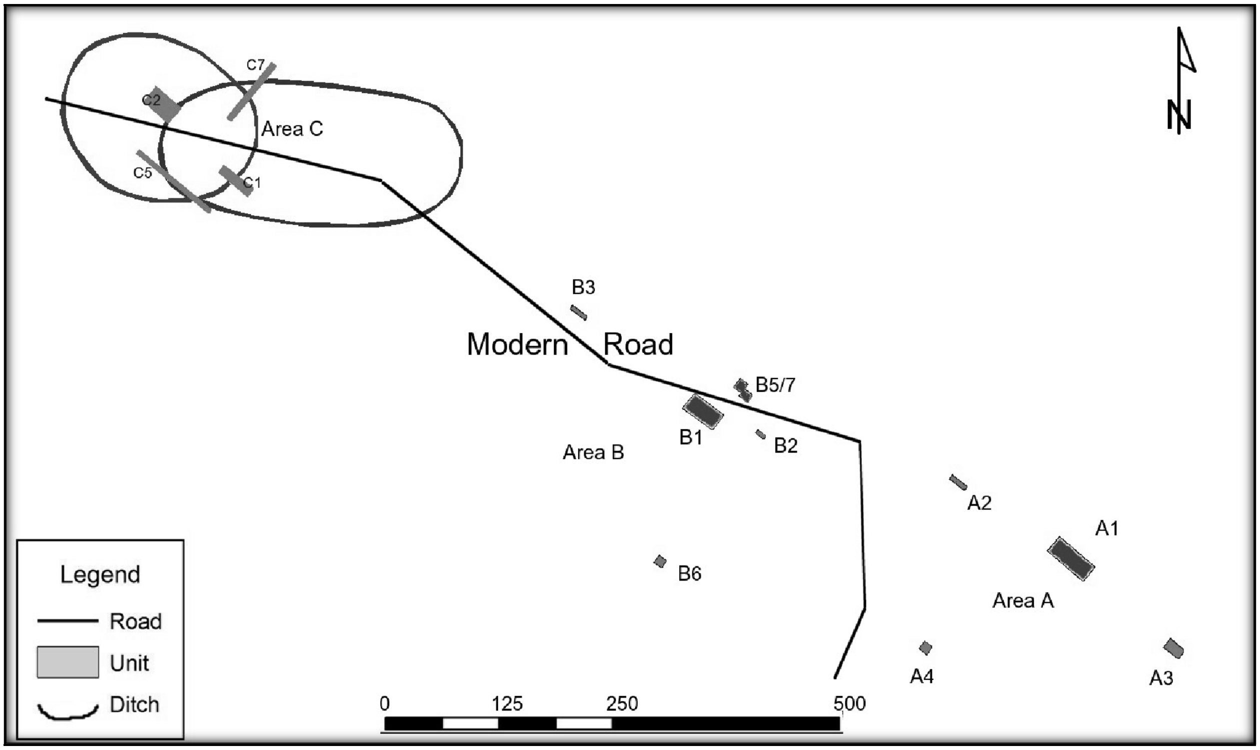


Figure 5.3. Bronocice Phases 3 and 4 locations from which successfully sequences sheep samples were obtained.

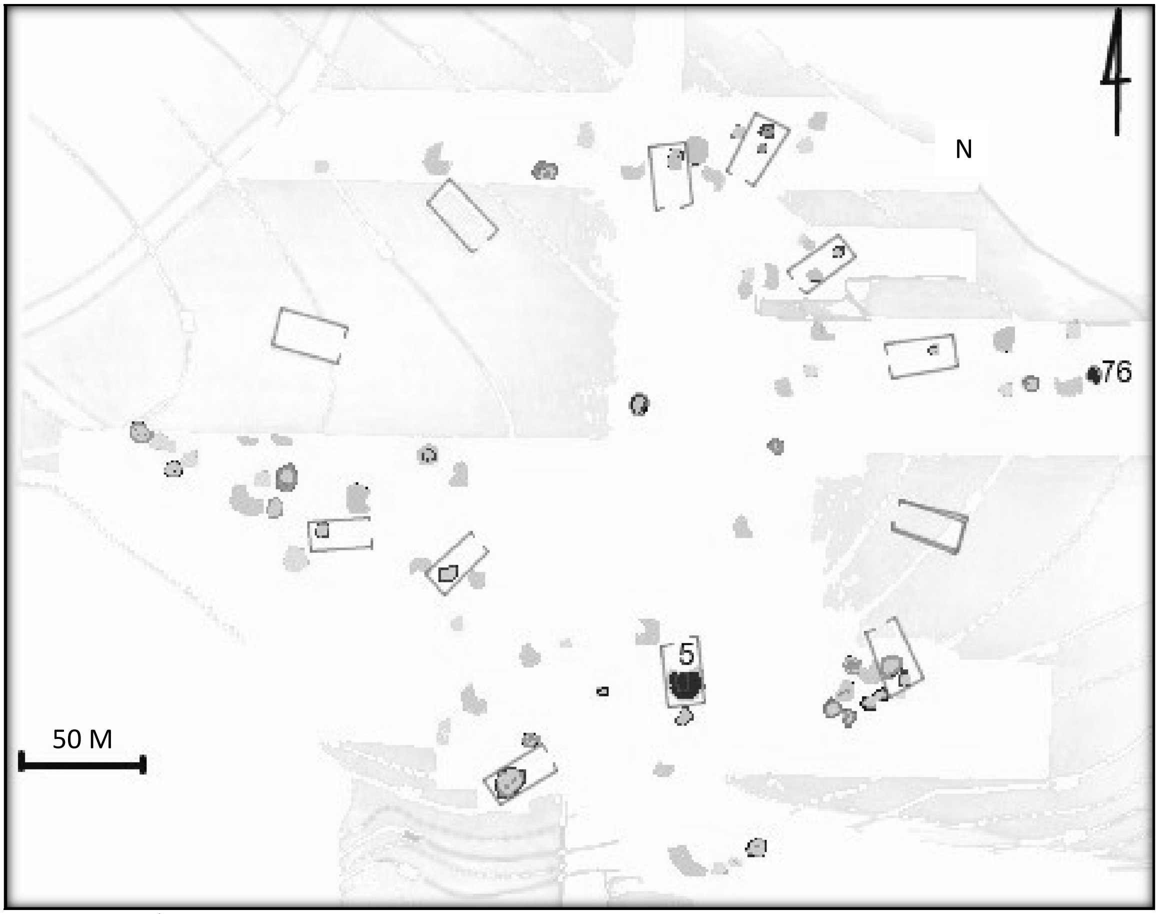


Figure 5.4. Żawarża Phase 3 location from which successfully sequences sheep samples were obtained.

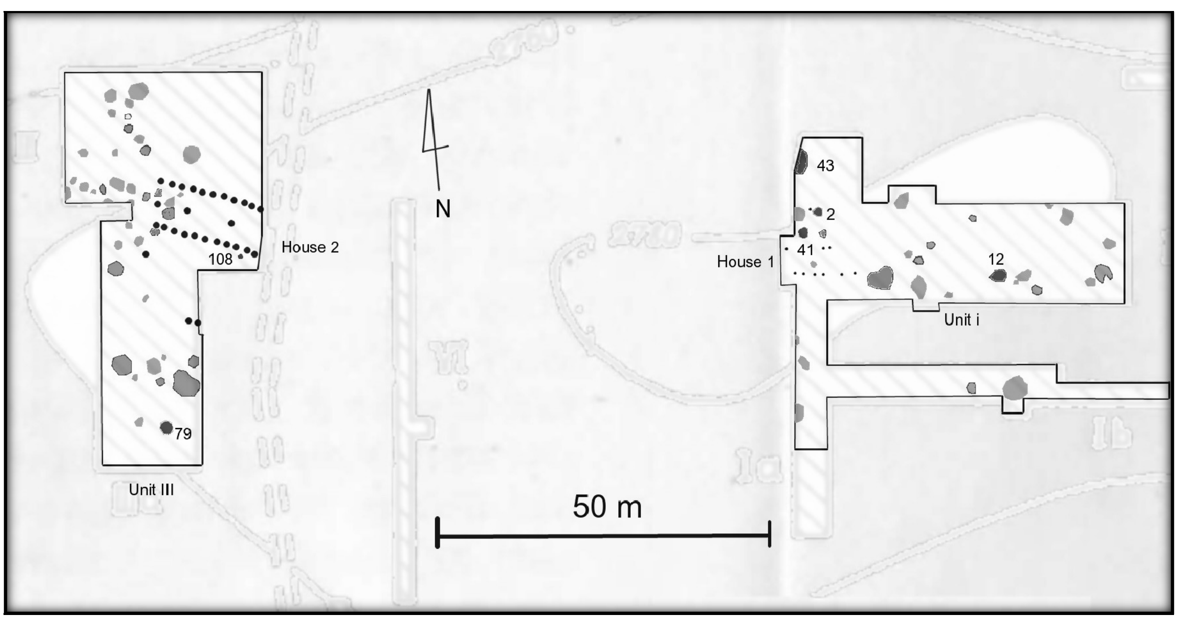


Figure 5.5. Niedźwiedź Phase 4 location from which successfully sequences sheep samples were obtained.

Chapter 6

Interpretation of the Combined XRF and Mitochondrial DNA Data

The results of the XRF and mitochondrial DNA analyses were combined in order to examine sheep management practices including herding, breeding and culling practices. The data were evaluated by comparing the results with dental eruption patterns and age-at-death profiles in order to propose a cyclical calendar of events during which specific activities occurred and which included an annual sheep drive to Bronocice.

The results of the X-ray fluorescence and Mitochondrial DNA analyses complement other sources of evidence concerning trade and exchange between settlements and among households from the 4th to 3rd millennia BC in southeastern Poland. Lithic tools, raw materials and rare objects such as *spondylus* shell jewelry, amber, salt, and copper tools and artifacts have been recovered archaeologically at sites in southern Poland among other places (Cavruc and Harding 2011, Harding 2013, Kowalczyk 1962). These resources were obtained through trade with groups located to the south east, west and north of the region (Czekaj-Zastawny *et al* 2011, Milisauskas 2011, Nowak 2006, Pelesiak 2007). These trade routes were ancient by the time Funnel Beaker people moved into the region having been established early in the Neolithic (Giblin 2009, Neustupńy and Neustupńy 1961). Overland routes must have begun to appear with the clearing of large tracts of land around settlement, initially as agricultural fields and later becoming pasturelands for grazing livestock. Connecting settlements by paths became a necessity with the advent of wheeled vehicles and horseback riding. It was not just the creation of new trade routes that changed in the second half of the 4th millennium BC but also the intensity in trade and the volume of goods and livestock moving across large distances. Some settlements directly exploited local resources, such as Ćmielów, while craft specialists appeared in many larger settlements around this time (Babel *et al* 2005, Gumiński 1989, Lech and Lech 1984, Podkowińska 1962).

Much discussion about the movement of things has appeared in journals through with regard to the Neolithic these tend to be discussed as goods rather than commodities. This is problematic because it avoids the concept of market economy. Small scale transfers of objects may well fit that model. However large scale movement of materials and animals on a regular schedule do not. The more appropriate term for such trade is commodity exchange in a market based economy. The term market implies a regular meeting at a specified location in which commodities are bought and sold though it does not imply coinage. The term goods is also inappropriate for large scale trade because it conveys a sense of gifting and community ownership. Commodities on the other hand imply personal ownership over materials that are traded and a contractual expectation of payment (Clark 2007).

A. Combined Results

The XRF data revealed important changes occurred in the Bronocice region in sheep management practices which involved major stock-building through the importation of non-local sheep. The need for new genetic stock existed long before the period of stock-building began. In earlier times small numbers of non-local animals were added to local sheep herds. The Phase 1 and 2 XRF data indicate 20 percent of animals were non-local. However, a clear reversal in population structure began in Phase 3. Imported animals appeared in very high frequencies at Bronocice, (84%), while very few locally born sheep were found from that time on. Directional herding was suggested by decreasing strontium levels in sheep enamel. Age-at death data suggest and that non-local pastoralist herded their flocks to Bronocice once a year during late spring or early summer. Some of the smaller communities intensified sheep rearing practices but were not involved in long distance trade. Bronocice was one of a few central places in southeastern Poland that engaged in direct trade with extra-regional groups. The intensified sheep rearing observed in faunal assemblages from some small communities points to a specialized economic relationship with Bronocice, likely involving wool production. The mitochondrial DNA data revealed that acquisition of new sheep typically occurred at Bronocice. Descendants of non-local sheep were found in outlying communities and in descendant sheep at Bronocice.

1. Bronocice

XRF data was available for the six occupational phases at Bronocice. Mitochondrial DNA was limited to Phases 3 and 4. XRF data showed that the first two phases were characterized by a low frequency of introgression of non-local individuals. This pattern was reversed permanently beginning in Phase 3 continuing through Phase 6.

Eleven sheep from Bronocice, Żawarża and Niedźwiedź dating to Phases 3 and 4 had overlapping XRF and mtDNA data (Table 6.2). The mtDNA identified descendants of imported sheep in all three settlements (Figure 6.5). Sheep grew in value and a long term trend in animal importations began during Phase 3.Small, local settlements continued to raise sheep as part of their subsistence package which included pig, goat and cattle as well.

The XRF data from the 11 sheep are presented in Figure 6.1. When the strontium levels of the 11 sheep for which mtDNA was available are compared no strong patterning was observed (Figure 6.6). The first six individuals in Figure 6.1 date to Phase 3 Bronocice, the next four are from Phase 4 Bronocice and the last one is from Niedźwiedź. The lack of strong patterning

among potentially contemporary sheep suggests that they represent different flocks in most instances. However, B15 and B17 are similar, and B18 and B21 are also similar (Figure 6.7). In both of these cases it would appear the pairs shared the same migratory histories which indicate that flocks were composed of individuals from different families or that the migratory routes were well established and included established stopping points along the way to Bronocice.
Six individuals dating to Phase 3 were represented by both XRF and mtDNA data. In two cases there were individuals from the same families, while in two other cases sheep were not related to each other at all (Table 6.2). With one exception (B3) all of the sheep were non-local in origin. Four individuals from Phase 4 were also represented by XRF and mtDNA data. One non-local sheep (B1) was from the same family as a local sheep (B19). The other two sheep belonged to different families.

Family 1 was represented by non-local sheep from Phase 3 and Phase 4, and one local sheep. This family was also represented by a local sheep from Niedźwiedź (N18). This pattern shows the presence of descendants from non-local animals. Family 2 was represented by non-local sheep from Bronocice Phase 3and Phase 4. Unfortunately there is no XRF data to indicate whether members of that family found at Żawarża and Niedźwiedź were local or not. The overall XRF patterns from both sites suggest the likelihood that there were descendants. Two unrelated non-local sheep were found for both Phases 3 and 4. No other families were indicated at the smaller sites.

2. Żawarża

Żawarża was a single component site overlapping with Bronocice Phase 3. Sheep samples were taken from several houses and pits (Figure 3.11). Sheep samples were drawn from

13 pits associated with six houses, side yards, a well, and a commons. Twenty individuals were selected of which ten were represented by dental samples of which were tested for strontium levels by XRF. All twenty individuals were processed for DNA analysis, but to date only three have produced useable sequences (Figure 4.4). Though there were only 10 XRF samples they were selected from all six houses, their side yards and the well were represented by a minimum of one individual.

XRF data showed that all of the sheep from Żawarża were born and raised within the local region, with a single exception. One other individual had a single value that fell below one standard deviation. The variability in values from deciduous teeth to late erupting permanent teeth was very small. Among these individuals the strontium values varied only slightly suggesting that the sheep were not herded over great distances. It is evident that Żawarża did not engage in long distance trade for sheep and it is likely that they acquired new sheep from Bronocice.

Three individuals were successfully sequenced. Z8 came from House 7, while Z15 and Z16 came from the kiln are associated with House 4. All three individuals were closely related to some of the sheep from Bronocice and all of the sheep from Niedźwiedź. However, there were small distances between the one from House 7 and the two from the kiln area.

The XRF and DNA data reveal two patterns. First, nine of the ten XRF sheep were raised locally and second, the three DNA sequences reveal that sheep were closely related not only to each other, but also to contemporary (Phase 3) sheep at Bronocice, as well as to sheep from the later occupations at Niedźwiedź and Bronocice Phase 4. Żawarża had a close relationship with Bronocice. It could not have had a direct relationship with Niedźwiedź because the two settlements did not exist at the same time. However, the fact that strong genetic relationships were indicated between these two sites reveals that the sheep from both settlements shared ancestral ties. Also, it shows there existed social interactions existed between Bronocice and other communities for a long period of time within the region.

3. Niedżwiedż

Faunal deposits were found in several pits from which sheep samples were obtained. A total of 20 sheep samples were selected from 12 pits. In five pits multiple individuals are represented. Unfortunately there were fewer XRF and DNA results from Niedżwiedż than the other sites and phases. Poor timing resulted in the transfer of some dental samples to the molecular lab in Binghamton before they could be tested with XRF. Consequently XRF data are limited to six sheep and are ambiguous due to the small sample size. Of these, six sheep it was only possible to obtain an adequate sequence of mtDNA from N18. Two sheep (N9 and N15) had strontium values that fell outside the range established for the area, marking them as non-local, while another two sheep (N18 and N22) had the reverse situation with strontium levels falling within the range marking them as local. The last two sheep (N7 and N20) did not deciduous teeth left, only permanent teeth all of which erupted after the first year and a half of life. In the case of N7 there is a difference in strontium levels over a ¼ year in this animal's life indicating movement. The same is true for N20 which shows great differences over the course of a half year.

Mitochondrial DNA was successfully extracted from all dental specimens. However, only one specimen provided both XRF and DNA information. N18 was found in a pit near House 2. This particular individual was killed at less than ½ year. It is closely related to two other sheep, N10 (House 1) and N19 (yard of House 2) for which there is no XRF data. The two structures were separated by approximately 75 meters which is close enough for these animals to have shared a common history.

The results of the DNA analysis show different degrees of genetic relatedness. N10 (House 1), N18 (House 2) and N19 (House 2 yard) are very closely related animals. They show close relatedness to three sheep from Żawarża, two phase 3 sheep from Bronocice and three phase 4 sheep from Bronocice. Less closely related are the remaining three sheep from Niedźwiedź. In fact N4 and N13 were determined to be goats, not sheep.

B. Cyclical Nature of Sheep Importation in the Bronocice Micro-region

Mobility patterns indicated by the XRF data can be correlated with herding practices. In most cases strontium levels were lower in later erupting teeth. However, there were several instances at all sites and during most phases where strontium levels were higher in later erupting teeth. Those cases in particular likely reflect localized herding patterns. However, because they are different from the patterns seen in the majority of sheep it must also be considered that these individuals may have been acquired from other local Funnel Beaker groups. It is also important to realize that grazing lands changed over time. The landscape around Bronocice was gradually transformed from a heavily forested area to a parkland environment dominated by grasslands and woods. The areas in which sheep grazed therefore expanded. Some of the values seen for sheep in the earlier phases may in fact represent pasturelands that were used for other purposes later, e.g. agriculture.

Figures 6.1-6.3 plot strontium distributions for the earliest erupting teeth: deciduous molars (m1-m3) and permanent first molar (M1), representing birth to ½ year of age; permanent second molar (M2), representing 1 year of age; and permanent premolars (P2-P4) and permanent third molar (M3), representing 1 1/2 to 2 years of age. In each figure five zones are apparent. Zone 2 denotes the established local strontium range. Locally born and raised sheep fall within this zone from all three sites, though at Bronocice the majority are from Phases 1 and 2. Sheep from Zone 1 had much lower levels than the established range while in Zones 3-5 sheep had higher levels. Very few sheep from Niedżwiedż or Żawarża had sheep from Zones 3-5 which further supports a non-local designation for higher strontium levels.

Figures 6.1 to 6.3 reveal gradually decreasing strontium levels nearer to the settlements. The earliest teeth have values far greater, even in the earliest phases. This pattern suggests that lambing occurred outside of Bronocice, not in the settlement. Stopping points along the way are suggested by large concentrations of sheep teeth of the same developmental age that have similar strontium values. The strontium distribution pattern also suggests that sheep were herded to Bronocice over a period of months.

These figures also reveal is that the majority of sheep brought into Bronocice were young, often juveniles and subadults, when they arrived. It is evident that older animals, adults and seniors, were also brought in. It is likely that the older animals were mainly females, probably proven breeders as well as good wool producers. The data suggest that sheep arrived at Bronocice late May early June. By that time the lambs were already sexually mature and the herd ready for wool plucking. Barren females, juvenile males, as well as animals with poor coats were likely culled from the herd at that time. The number of immature animals reflected in the sample populations for each site and phases are evidence of culling.

It can be inferred based on the regularity in strontium values seen in Figures 6.1-6.3 that sheep were herded along a regular route, likely overland as opposed to by boat, with established stopping points for grazing and watering animals as well as a birthing area. There are important cognitive implications that emerge from herding practices. First, local Funnel Beaker people and communities anticipated the annual arrival of new livestock. And second, some people were aware of the locations where shepherds and their flocks were located at specific times of the year. The arrival of livestock and people at Bronocice was an expected event that likely required local preparations.

Another interesting pattern was revealed by combining the XRF and mtDNA data concerning sheep rearing patterns within the micro-region. The XRF samples from Żawarża and Niedźwiedź were dominated by locally sheep. High frequencies of locally born sheep indicate that Funnel Beaker groups successfully bred sheep, requiring periodic introduction non-local animals for various reasons such as invigorating the herd, replacing infertile ewes, poor wool producers and balancing sex ratios. High frequencies of non-local sheep observed at Bronocice from Phases 3 – 6 indicate a low probability that the settlement was engaged in sheep rearing. Furthermore, patterns observed in genetically related sheep when combined with XRF data revealed that sheep from outlying communities were descendants of those at Bronocice. When compared with the data from Żawarża and Niedźwiedź a picture emerges in which sheep rearing occurred in outlying communities though not at Bronocice.

Based on the XRF data from Bronocice there is little evidence for local sheep after Phase 3. The slaughter of large numbers of sheep observed at Bronocice from this time forward is dominated by non-local sheep. These animals, especially juvenile males and subadults as well as diseased and weak individuals, were culled from the herds during the sheep trade at Bronocice, and may have been at feasts. Outlying communities came to Bronocice to get new stock for their herds.

Culling and slaughter patterns revealed some aspects of localized sheep management practices as well. There are many reasons for slaughtering sheep that have nothing to with sex, age or reproduction. These mostly have to do with health concerns such as infections and injuries. In some cases it is evident why the animal was slaughtered in Bronocice and the smaller settlements. For example, Bs14 and Bs18 had cracked molars. Sheep with cracked molars suffer from malnutrition and dental infections. Checking for cracked teeth and culling those individuals from the flock is a long standing husbandry practice. In general, there were few cracked teeth within the XRF sample (n=7). With the exception of BS27 cracked teeth were mainly found in adults. Other reasons for culling are possible such as poor health, poor fleece and ageing stock. A sheep life's expectancy in a well maintained herd today is 10-12 years. Every year a stock herder makes decisions about which animals to remove from the herd. It is assumed that during the Neolithic decisions would have been based on ability to feed animals during the winter as well as health. But other factors such as sex ratios, reproductive success and health likely figured into the decisions as well. Some of these decisions are evident in the sheep used for this study.

The sheep from three sites and all phases of occupation were dominated by adults (Table 6.1, Figure 6.4). The highest proportion of adults was seen during Phase 2 at Bronocice and Phase 4 at Niedżwiedź. Molars from adults showed signs of heavy wear; seniors in particular also exhibited heavy plaque. Most adults were five years or more at death. A few seniors were present within the assemblages. Perhaps these were highly productive rams or females.

Juveniles were also frequent and always outnumbered subadults. The heavy culling of juveniles throughout all phases regardless of origin suggests these were rams. Sheep are born in late winter, January-February. In the annual calendar at Bronocice six months coincided with the arrival of sheep herds from outside the region. The juveniles slaughtered around this time may have been used for feasting during the sheep market.

Subadults were less frequently slaughtered than either juveniles or adults. They varied considerably in exact age from 1 to 2 years at death within the faunal assemblage at Bronocice. It is possible that this group includes animals were culled for reasons other than their sex. Sheep become sexually active within the first year of life. It is possible that these included females that failed to get pregnant.

C. Households, Sheep and Social Relationships

Correlating the results of the XRF and mtDNA data with structures at the sites did not produce encouraging results. This was partly due to the paucity of DNA data as well as the realization that sheep herding most likely did not occur at Bronocice. Still, it is worth examining the physical distribution of sheep remains by structures because it provides insights into variability of households from which sheep remains were recovered and their material wealth.

Excavations at each of the three sites resulted in the discovery of vast numbers of pits, varying in size and configuration. Some of these pits were inside features, such as cellars, storage units, and stairs. Other pits were outside consisting of storage pits and clay extraction pits. Many contained refuse found in the bottom layers of the pits. Groupings of features by structure based on the analysis of field data were used to represent households. It was expected that some correlation between households at Bronocice and the smaller sites might be determined however that proved to be a challenge that could not be met.

1. Bronocice

Bronocice was far more complex than surrounding settlements. A study of the architectural evidence at Bronocice conducted in 2013 (Pipes *et al in press*) resulted in a structural reconstruction of the settlement over time. In some cases identifying structures required little more than a glance at field excavation photos. For example, in Unit B4 there was the clear outline of a longhouse in the north wall of the unit. At one end of the structure there was a set of stairs leading to cellar and at the other end a storage pit (Figure 6.8). In most cases it was more difficult to reconstruct structures due to significant rebuilding episodes, particularly in Units A1 and B1 which were occupied for several hundred years. For example, a phase 3 house consisting of a set of stairs leading to a large cellar was later disturbed by the excavation of a cellar during Phase 4 (Figure 6.9). The locations of the structures from which sheep samples were obtained are identified in Figures 6.10-6.15. The first Funnel Beaker settlement and subsequent occupation by Lublin-Volhynian were small consisting of a core of buildings located in Unit C2 (Figures 6.10-6.11). The second Funnel Beaker occupation in Phase 3, located to the east of Area C was larger and more complex. This settlement was transformed over the next several hundred years a village into a town (Figures 6.12-6.15).

The realization that the Lublin-Volhynian fortification ditch could be used to enclose animals seems the likely catalyst for establishing a sheep market at Bronocice. The creation of a much larger enclosure towards the end of Phase 4 indicates a growing need to accommodate greater numbers of imported livestock. It is worth noting that this massive enclosure did not encircle the settlement (Figure 6.14). In the final phase of occupation (Phase 6) a new fortification ditch was built around a diminished settlement, perhaps this time for protection (Figure 6.15).

Since the end of the 1970s excavations at Bronocice much research has been done on the artifact assemblage. Several studies have been published that address the ceramics, lithics, architectural remains, burials, botanicals, fauna, and environment (Kamphaus *et al* 2013, Kruk *et al* 1996, Kruk and Milisauskas 1981, Milisauskas and Kruk, 1989, 1984, 1977, Milisauskas *et al* 2012, 2004, Pipes *et al* 2014, 2010, 2009, Szostek 2014). Some of these studies have revealed the presence of specialists within the settlement by Phase 3 and areas of special significance. Some of these specialists included weavers, axe and stone tool makers, bakers and builders. Weavers were found by locating pits in which concentrations of fiber and textile production artifacts appeared. Stone tool and axe makers were located in structures having large concentrations of debitage associated with lithic and axe production. One area (Unit A2) in the settlement yielded a series of large ovens that spanned all of Phases 3-5 (3650-2900 BC) (Figure 6.16). Since no other ovens were identified in the settlement it appears this household operated a communal oven and probably baked the bread for the community.

Specialized builders were implicated by changing construction patterns over time and increasing standardization not only of pit sizes, but also internal arrangements and structural features such as tiling of platform surfaces and floors, and the lining of pits with clay. Houses were distinguished from barns based on the size and shape of pits. Over the course 1100 years architectural complexity increased significantly at Bronocice while at the same time construction methods became more consistent (Table 6.3). The presence of a wide range of specialists points to a highly structured society in which it is likely that many households were independent of direct involvement with agropastoral activities. Another notable feature was the decrease in the size of houses over time. As Bronocice became increasingly congested the size diminished, though not all. Some structures outside the main residential in Area B1 appear to have been farmhouses with large barns. In Unit A3 a series of large and barns were found. In the cellar of one structure seven head of cattle had been slaughtered and the structure burned suggesting signs of a raid (Figure. 6.17). This event we now know happened around 3400 BC (3398 ± 87 BC). Two things can be inferred from this event. First, the sudden death of 7 cattle represented a loss of wealth and property. Second, their confinement within a single barn suggests they were owned by a single wealthy household. The isolated location of the farm on the outskirts of town left it vulnerable to attack.

Table 6.4 presents an abbreviated list of structures associated with sheep samples used in this study. It lists only those structures from which sheep samples were obtained and summarizes artifacts contents. (Appendix F contains the entire list of structures, associated pits and plans). In general, house structures yielded greater diversity and volume of artifacts than did barns. The cultural materials recovered from houses represent the discards of daily activities. There are some apparent patterns. For instance, later structures yielded greater volumes of artifacts. Contemporaneous structures were variable which may reflect specialists, e.g. weavers, flintknappers, etc. However, there were no correlations between sheep and fiber and textile production artifacts. The number of households represented in this study was 44. In terms of the composition of sheep by household there was temporal patterning (Table 6.5). Only phase 1 had a higher frequency of households with only local sheep. All other periods had higher frequencies of non-local sheep, even though a few had both.

2. Żawarża

The settlement at Żawarża was considerably less complicated than Bronocice through the circular arrangement of houses was unusual among Funnel Beaker settlements (Figure 6.18). The architectural analysis of Żawarża revealed that most structures were similar in terms of size and shape, pit volume, and location of hearths. The arrangement of structures around a central plaza and the lack of differentiation between them suggest a small community in which most individuals were related by blood or marriage. Very little social differentiation was indicated. A few unique features however do suggest a small degree of social distinction was present. At least one potter and three weavers were indicated by a kiln and loom weights. The presence of non-Funnel Beaker women is suggested by two 'mini axe' loom weights recovered from different households (Figure 6.19).One pit contained a unique 'tulip shaped' pot that signals contact with the Michelsberg culture from northern Bohemia (Kulczyzka-Leciejewiczowa 2002). Two households at Bronocice had similar 'mini axe' loom weights, one from Phase 3 and the other from Phase 5 (Figure 2.35). Perhaps these households were related in some way.

Analysis of flint artifacts from the site indicate that tools were not made at the site. Instead, debitage show retouching and sharpening of tools, suggesting that lithic tools were a commodity obtained through exchange, probably from Bronocice which had lithic specialists. The volume of materials recovered from household deposits indicates a fair degree of similarity. However, in patriarchal societies hamlets are usually led by one family, generally headed by an able bodied male. This person would have been in charge of the community. At Żawarża he would have had oversight the management of several hundred head of livestock including sheep, goat, cattle and pig.

Sheep samples were obtained from inside house deposits as well as yard features. A minimum of five households were represented in this study (Table 6.3). The majority of households had local sheep though a couple had both local and non-local sheep. Unfortunately there was no overlap between XRF and mtDNA data.

3. Niedźwiedź

Niedźwiedź was more difficult to evaluate than Bronocice or Żawarża. Insufficient information exists in publications to evaluate differences among households, although two households were clearly indicated (Figure 6.12). Sheep samples were obtained from the two houses and, as at Żawarża, from yard deposits. The presence of Baden influences on the ceramic assemblage points to direct contact with members of that culture. Furthermore, the location of the settlement near Baden territory increases the likelihood that there was regular interaction. Some of the ceramics recovered at the site show signs of Baden influence (Burchadt1977). A nephrite axe was also found that suggest interactions with areas outside the Bronocice region as the source of this mineral is non-local. Signs of social conflict were indicated by the skull found in Pit 60/61. This was not a Funnel Beaker traditional burial of the dead. Instead, the skull may represent a trophy item. The presence of a copper awl in Pit 38, in the east yard of House 1, suggests a non-Funnel Beaker woman or someone with contact with outsiders resided in the settlement.

Unfortunately erosion and the construction of a road impacted remains between the two houses. The relationship between them is unclear though they share a similar alignment. The mitochondrial DNA results from Niedźwiedź indicated the presence of one family line not found at Bronocice or Żawarża. And the XRF results indicated the presence of sheep with much lower strontium values than the majority of non-local sheep in the entire sample population. Both households had local and non-local sheep (Table 6.5).

D. Discussion

A few clear patterns emerged from combining the results of both types of analysis. Relatedness in sheep was not tied to origin, site or phase. Some related sheep were local in origin and others were non-local. For example, B19 at Bronocice was local whereas the other three members of Family1 were non-local in origin. B19 dated to Phase 4 so its temporal affiliation indicated it was descended from a non-local sheep. Another example is N18, a locally born sheep from Phase 4 Niedżwiedż, which was related to two sheep from Phase 3 and one from Phase 4 at Bronocice. Within the mtDNA sample the majority of related sheep were non-local in origin. Members of Family 1 and Family 2 were represented during both phases 3 and 4. Members of Family 2 were found represented during all phases and at all sites. Based on contextual evidence from the XRF results, it is highly likely related sheep found at Żawarża and at Niedżwiedż, (for which no XRF data was available except N18) were local animals, whereas those from Bronocice, Phases 3 and 4, were non-local animals. Related non-local sheep from Bronocice represent flocks imported to the settlement during Phases 3 and 4. The multi-generational relationships observed among sheep indicate a long tradition of importing sheep from two main. The non-related sheep of which there were four were present in lower frequencies and may indicate acquisition from non-traditional sources as well.

Another sheep management pattern may be inferred based on these data. The people who took the flocks to Bronocice differed from those who herded them within the region. Local sheep herders lived in small settlements such as Żawarża and Niedżwiedż. Their movements were seasonal, limited in range, and likely territorial. On the other hand, non-local sheep herders were specialized pastoralists who moved sheep from point A to point B for the express purpose of selling them on an annual basis.

The strontium data from non-local sheep suggest unidirectional movement of sheep in most cases towards Bronocice. It may be concluded that once a year sheep were gathered there was a sheep market at Bronocice which would have been preceded by certain events. Local sheep however had variably strontium levels which was likely due to seasonal movements within the local area. It is impossible to determine whether specialized pastoralists owned and traded the sheep or were hired to do so by someone else. The earliest forms of writing found in southwest Asia are clay balls containing tokens. They date from 8000-1500 BC, dropping in frequency after 3000 BC (Robinson 1995). The tokens were counters that served as inventories of commodities such as grains and livestock and were in the conveyance from one trading party to another. Determining whether specialized pastoralists arriving at Bronocice owned the livestock or herded them on someone else's behalf is beyond the scope of this study. However, they presumably whatever they obtained in trade, other commodities such as textiles, in the opposite direction.

Assuming that wool production was indeed the reason for intensified sheep rearing, a network of economic relationships must have existed between sheep herders, traders, and local elites, involving the redistribution of sheep, reproduction of sheep, the harvesting of wool and the production of thread and cloth.

Table 6.1. Age groups of Sheep by age groups for Bronocice, Żawarża and Niedżwiedż, total site Minimum Number of Individuals (MNI) and relative percent (%).

Site	Phase	Juvenile		Subadult		Adult		Senior		Unknown		TOTAL	%
		MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	MNI	
Bronocice	BR1	8	.38	3	.14	10	.48	-	-	-	-	21	1.00
	BR2	3	.15	2	.10	12	.60	1	.05	2	.10	20	1.00
	BR3	11	.26	9	.21	17	.41	2	.05	3	.07	42	1.00
Bronocice	BR4	21	.28	13	.18	31	.42	1	.01	8	.11	74	1.00
Bronocice	BR5	35	.33	24	.23	38	.36	1	.01	8	.08	106	1.00
	BR6	7	.23	8	.27	14	.47	-	-	1	.03	30	1.00
Żawarża[1]	Z3	30	.33	21	.23	40	.43	1	.01	-	-	92	1.00
Niedżwiedż[2]	N4	18	.19	21	.21	58.	.59	1	.01	-	-	98	1.00

Kulczycka-Leciejeviczowa[1], Makowicz-Poliszot[2]

Table 6.2. List of sheep indicating origins (XRF) and/or family relationships (mtDNA).

Site	Phase	House	Pit	Specimen	Age Group	Local	Non-local	Family 1	Family 2	Unrelated
Bronocice	3	A1.2	26-A1	B5	Senior	-	X	-	X	-
		"	38-A1	B34	Subadult	-	X	-	-	-
		A1.8	1-A1	B13	Juvenile	-	X	-	-	X
			"	B12	Juvenile	-	X	-	-	-
			"	B14	Juvenile	-	X	-	-	-
		A1.10	101-A1	B15	Juvenile	-	X	X	-	-
		"	"	B17	Senior	-	X	-	X	-
		"	"	B16	Subadult	-	X	-	-	-
		A1.11	33-A1	B3	Juvenile	X	-	-	-	X
		"	"	B4	Adult	-	X	X	-	-
		"	"	B2	Subadult	X	-	-	-	-
		A1.13	89-A1	B29	Subadult	-	X	-	-	-
		A1.16	30-A1	B24	Adult	-	X	-	-	-
		"	"	B25	Subadult	-	X	-	-	-
				Total		2	12	2	2	2
Żawarża	3	1	17	Z1	Subadult	X	-	-	-	-
		"	18	Z3	Subadult	X	-	-	-	-
		3	31	Z4	Juvenile	X	-	-	-	-
		"	32	Z5	Adult	X	-	-	-	-
		Yard house 4	72	Z20	Senior	X	-	-	-	-
		Kiln house 4	76	Z15	Adult	-	-	-	X	-
		"	76	Z16	Adult	-	-	-	X	-
		7	4	Z14	Adult	X	-	-	-	-
		"	5	Z8	Adult	-	-	-	X	-
		"	"	Z6	Subadult	X	-	-	-	-
		"	"	Z7	Juvenile	-	X	-	-	-
		Yard house 10	37	Z12	Adult	X	-	-	-	-
		Well	65	Z22	Senior	-	X	-	-	-
				Total		8	2	-	3	-
Bronocice	4	A1.9	21-A1	B6	Senior	-	X	-	-	-
		A1.14	64-A1	B1	Adult	-	X	X	-	-
		A1.15	118-A1	B33	Subadult	-	X	-	-	-
		A1.24	68A1	B7	Adult	-	-	-	X	-
		"	7-A1	B23	Adult	-	X	-	-	-
		A1.34	102-A1	B32	Adult	X	-	-	-	-
		B1.1	2-B1	B19	Subadult	X	-	X	-	-
		B1.2	23-B1	B18	Subadult	-	X	-	-	X
		"	"	B9	Adult	-	-	-	X	-
		B5/7.1	5-B5	B22	Adult	-	X	-	-	-
		B5/7.2	2-B7	B21	Subadult	-	X	-	X	-
		"	"	B27	Subadult	-	X	-	-	-
				Total		2	8	2	3	1
Niedźwiedż	4	1	29	N9	Subadult	-	X	-	-	-
		1	41	N10	Adult	-	-	-	X	-
		Yard house 1	2	N1	Adult	-	-	X	-	-
		Yard house 1	20	N7	Adult	X	-	-	-	-
		2	61	N15	Juvenile	-	X	-	-	-
		2	101	N22	Juvenile	X	-	-	-	-
		2	108	N19	Adult	-	-	-	X	-
		Yard house 2	67	N20	Adult	X	-	-	-	-
		Yard house 2	79	N18	Juvenile	X	-	-	X	-
				Total		4	2	1	4	-

Table 6.3. Summary of architectural features by occupational phase and cultural affiliation at Bronocice.

EU	Phase 1 Funnel Beaker	Phase 2 Lublin Volhynian	Phase 3 Funnel Beaker	Phase 3/4 Funnel Beaker	Phase 4 Funnel Beaker	Phase 5 Funnel Beaker-Baden	Phase 6 Funnel Beaker-Baden
Internal Features							
Cellar pit	X	X	X	X	X	X	X
Cellar floor, tiled	-	-	-	-	-	X	X
Cellar with stairs	X	X	-	-	-	X	-
Cellar with ledge/shelf	-	X	X	X	X	X	X
Cellar pit with tiled shelf/ledge	-	-	-	-	X	X	X
Cellar with oven	-	-	-	X	-	X	X
Cellar with hearth	-	-	-	-	X	X	X
Cellar pit, entry to ditch	-	X	-	-	-	-	-
Storage pit	X	X	X	X	X	X	X
Postmold	X	X	X	X	X	X	X
Exterior Feature							
Fortification ditch	-	X	-	-	X	-	X
Palisade	X	X	-	-	X	-	X
Animal enclosure	-	-	X	X	X	X	-
Animal pen	X	-	-	-	-	-	-
Stone ramp	-	-	X	-	-	-	-
Possible freestanding oven	-	-	-	-	X	X	-
Exterior pit	X	X	X	X	X	X	X
Structure Type							
Small Houses	X	-	-	-	-	X	-
Medium Houses	X	X	X	X	X	X	X
Large Houses	-	X	-	X	X	X	X
Sheds	-	-	-	X	X	X	X
Small Barns	X	-	X	X	X	X	X
Large Barns	X	X	X	X	X	X	X
Other Feature							
Animal burial, interior pit	X	X	X	X	X	X	-

Table 6.4. Summary of Bronocice artifact classes recovered from structures in which sheep samples were taken and composition of sheep by origin (L)local, (N)non-local or (B) both.

PH	Structure #	Structure Type	Sheep ID	Vessels	Sherds	Lithic Tools	Faunal	Floral	Textile	Bone Tools	L/NL/B
1	B6.1	Small House	BS21	-	40	4	31	9	7	1	L
	C1.1	Medium House	BS20	-	20	4	32	6	-	-	N
	C2.1	Medium House?	BS12, BS13	2	431	5	69	2	1	-	L
	C2.2	Small Barn	BS16, BS17, BS11, BS18	-	260	10	88	-	5	1	B
	C2.8	Large Barn	BS14, BS15	-	135	3	49	25	-	1	L
2	C2.11	Medium House	BS22, BS23, BS24, BS31, BS27, BS28, BS30, BS29, BS25, BS26	-	869	18	220	1	5	2	B
3	A1.2	Large Barn	B5, B34	-	176	3	162	-	3	-	N
	A1.8	Medium House	B12, B13, B14	3	609	9	125	2	10	8	N
	A1.10	Medium House	B15, B16, B17	-	383	-	78	3	4	6	N
	A1.11	Small Barn	B2, B3, B4	-	179	-	39	-	1	1	N
	A1.13	Large House	B29	1	374	-	41	18	2	-	L
	A1.16	Medium House	B24, B25	8	1220	8	52	11	5	11	N
4	A1.9	Large House	B6, B23	1	1225	29	76	137	12	12	N
	A1.14	Medium House	B1	1	350	-	76	7	5	4	N
	A1.15	Medium House	B33	4	214	6	29	-	3	2	N
	A1.24	Medium House	B7	1	1202	6	118	7	2	2	N
	A1.34	House burial	B32	-	144	-	23	-	1	-	L
	B1.1	Medium House	B19	-	610	-	-	-	-	-	L
	B1.2	Medium House	B18, B9	-	1211	28	259	8	8	5	N
	B5/7.1	Medium House	B22, B27	5	1148	30	160	15	21	4	N
	B5.7.2	Medium House	B21	8	1220	25	271	-	4	1	N
5	A1.29	Small House	BS32	-	395	5	36	-	2	5	N
	A2.2	Large House	BS33	-	1140	32	33	29	23	4	L
	A3.9	Medium House	BS34, BS35	-	295	5	100	38	4	1	N
	B1.15	Large House	BS37	1	911	28	110	-	16	13	N
	B1.21	Medium House	BS36, BS38	2	665	17	159	8	4	3	N
	B2.2	Medium House	BS39, BS40	-	176	2	39	-	1	2	N
	B5/7.5	Small House	BS44, BS45	1	853	39	226	-	3	2	N
	B6.4	Large House	BS41, BS42, BS43	4	1228	14	77	18	5	4	B
	B8.1	Large House	BS48	2	1084	63	242	-	12	4	L
	B8.2	Large House	BS46, BS47	1	892	27	101	-	20	1	B
6	A2.4	Large House	BS49	-	813	18	15	-	5	6	N
	B1.22	Medium House	BS50, BS55	1	1628	8	33	19	4	-	N
	B1.24	Large House	BS52	-	1567	22	265	4	33	7	N
	B5/7.7	Large House	BS51, BS57	4	1025	18	34	-	28	1	N
	B5/7.8	Large House	BS53	2	527	21	56	2	27	3	L
	B5/7.9	Small Barn	BS54, BS56	-	87	7	80	-	1	1	L

Table 6.5. Minimum number of households represented by XRF samples, with local, non-local sheep or both local and non-local sheep.

Site	Phase	Local		Non Local		Both		Total Households	
		#	%	#	%	#	%	#	%
Bronocice	1	3	.60	1	.20	1	.20	5	1.00
Bronocice	2	-	-	-	-	1	1.00	1	1.00
Bronocice	3	-	-	5	.83	1	.17	6	1.00
Bronocice	4	2	.22	7	.78	-	-	9	1.00
Bronocice	5	2	.20	6	.60	2	.20	10	1.00
Bronocice	6	2	.33	4	.67	-	-	6	1.00
Żawarża	3	3	.60	-	-	2	.40	5	1.00
Niedżwiedż	4	-	-	-	-	2	1.00	2	1.00

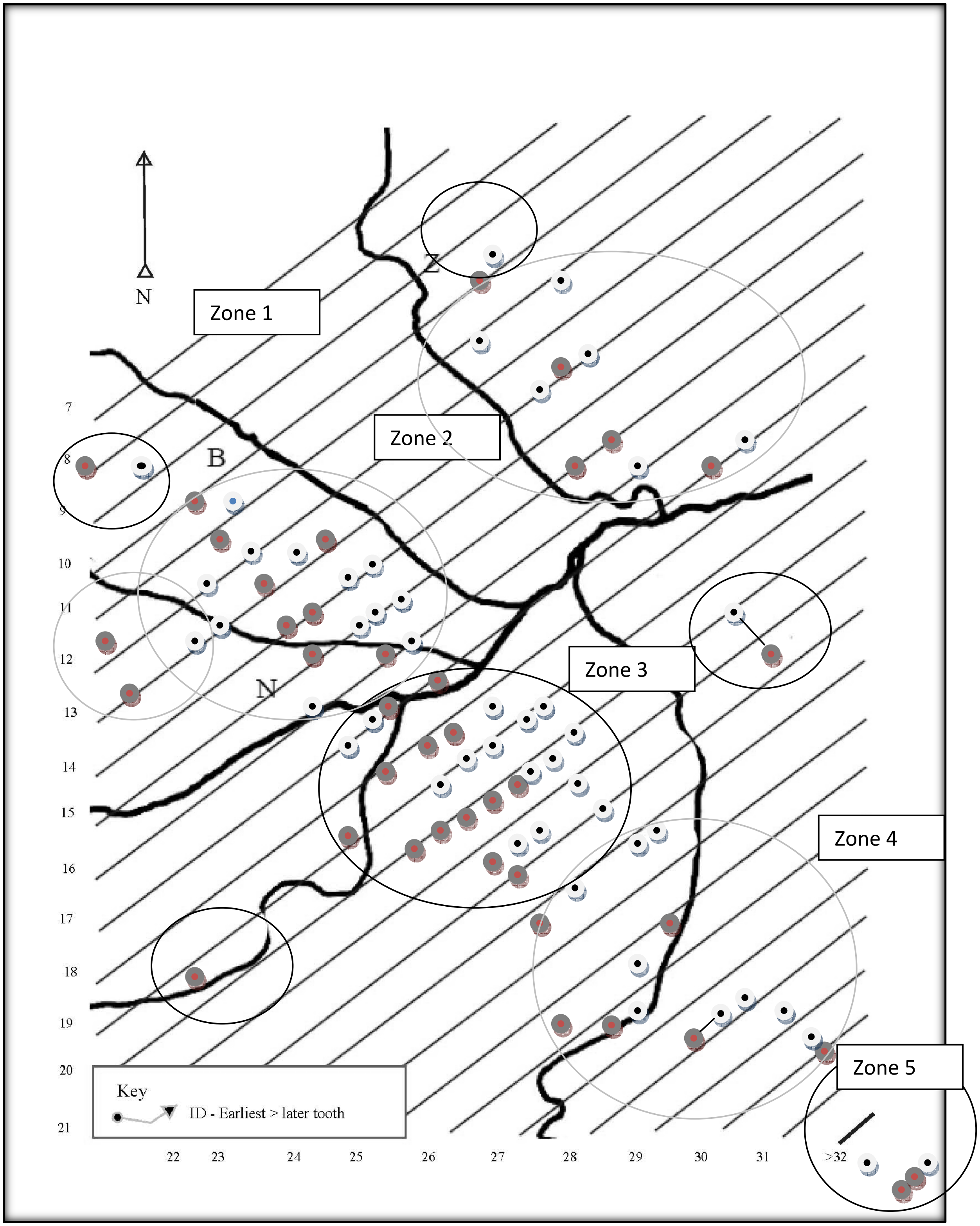


Figure 6.1. Plot of all deciduous teeth m1-m3 (●) and permanent first molar M1 (◉) - birth to ½ year of age.

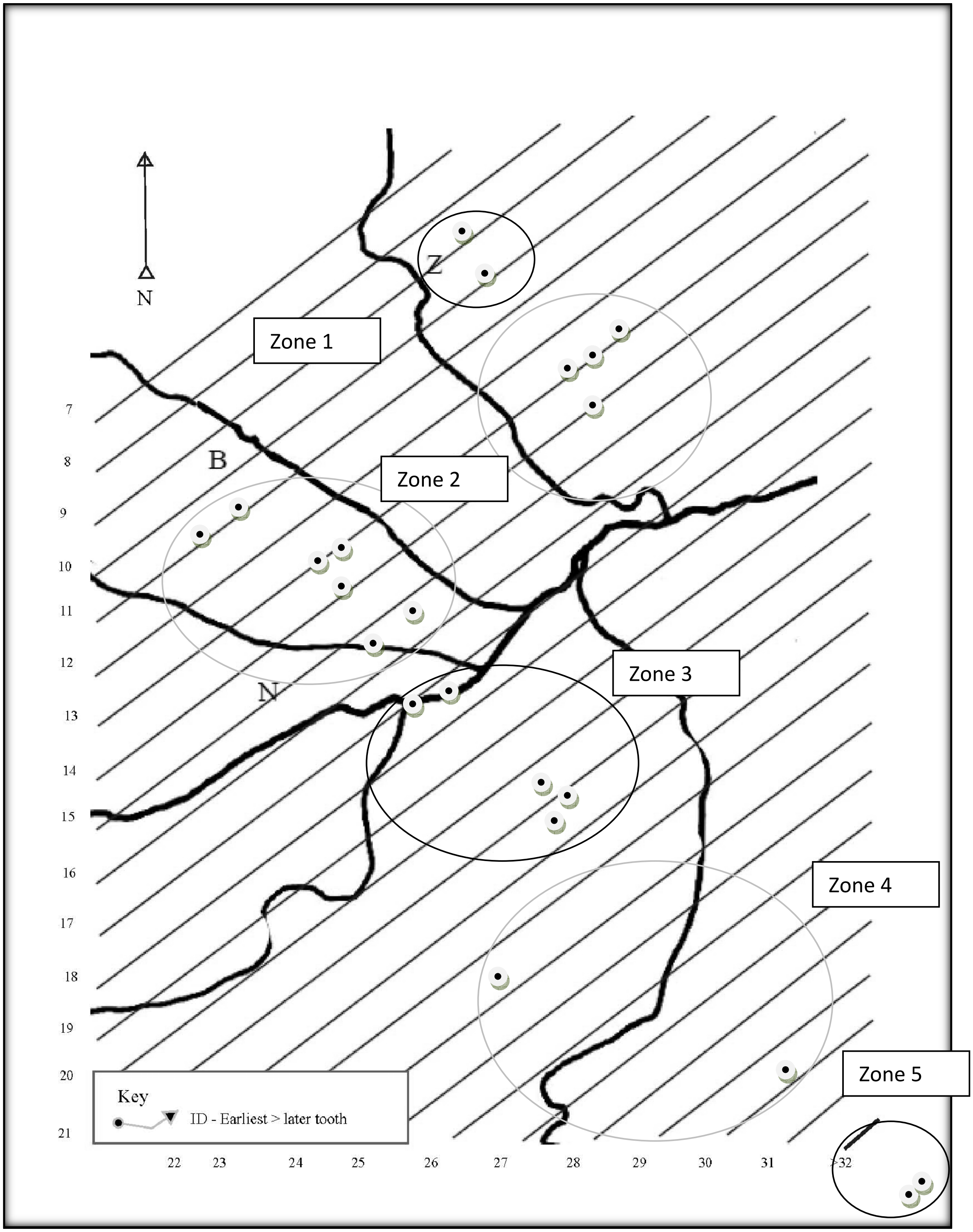


Figure 6.2. Plot of all permanent second molars M2 - 1 year of age.

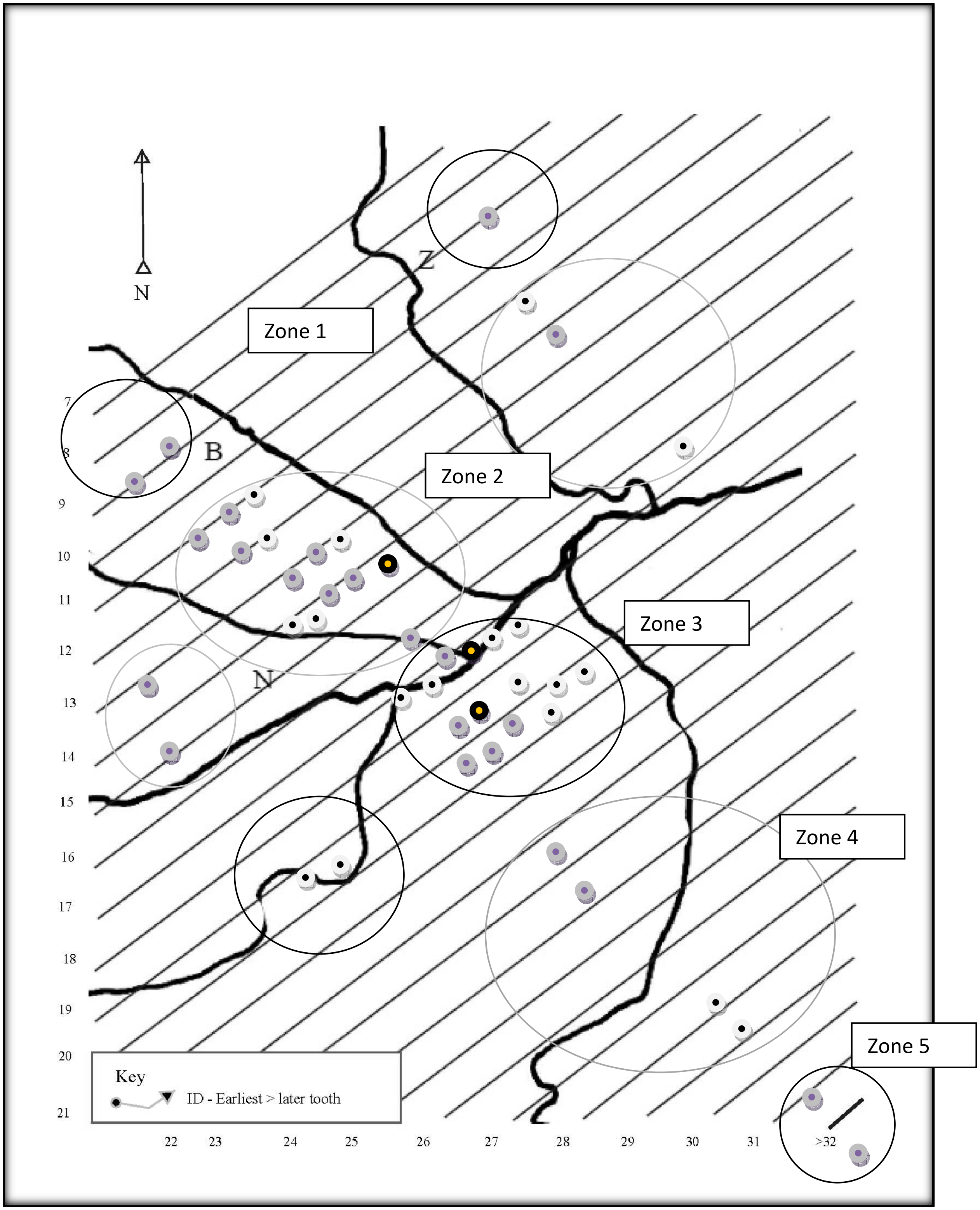


Figure 6.3. Plot of all permanent premolars, P2 - 1 ½ years of age ( ), P3 and M3 – 1 3/4 years of age ( ), and P4 ( ) - 2 years of age.

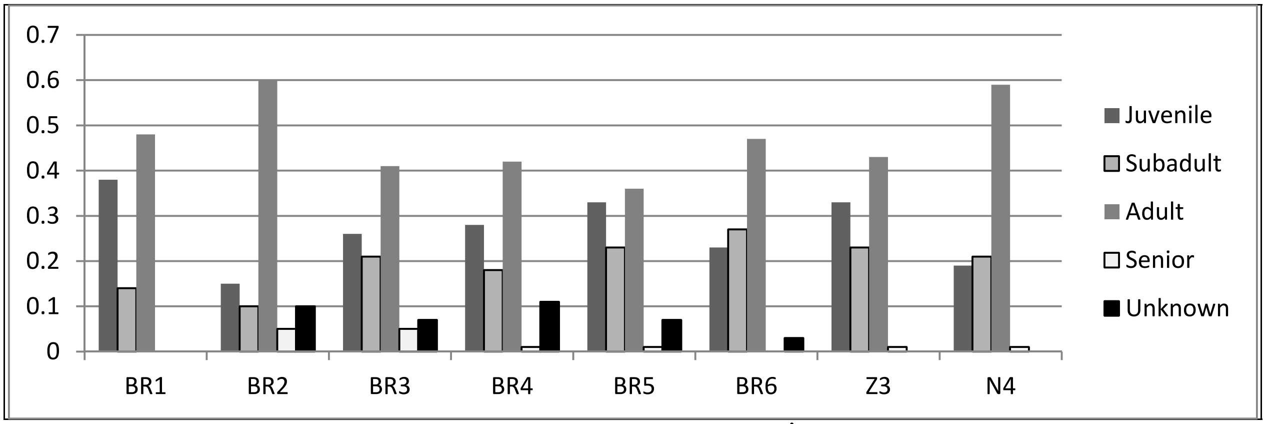


Figure 6.4. Relative frequencies of age groups at Bronocice, Żawarża and Niedźwiedź, by phase, relative percent (%) based on Minimum Number of Individuals.

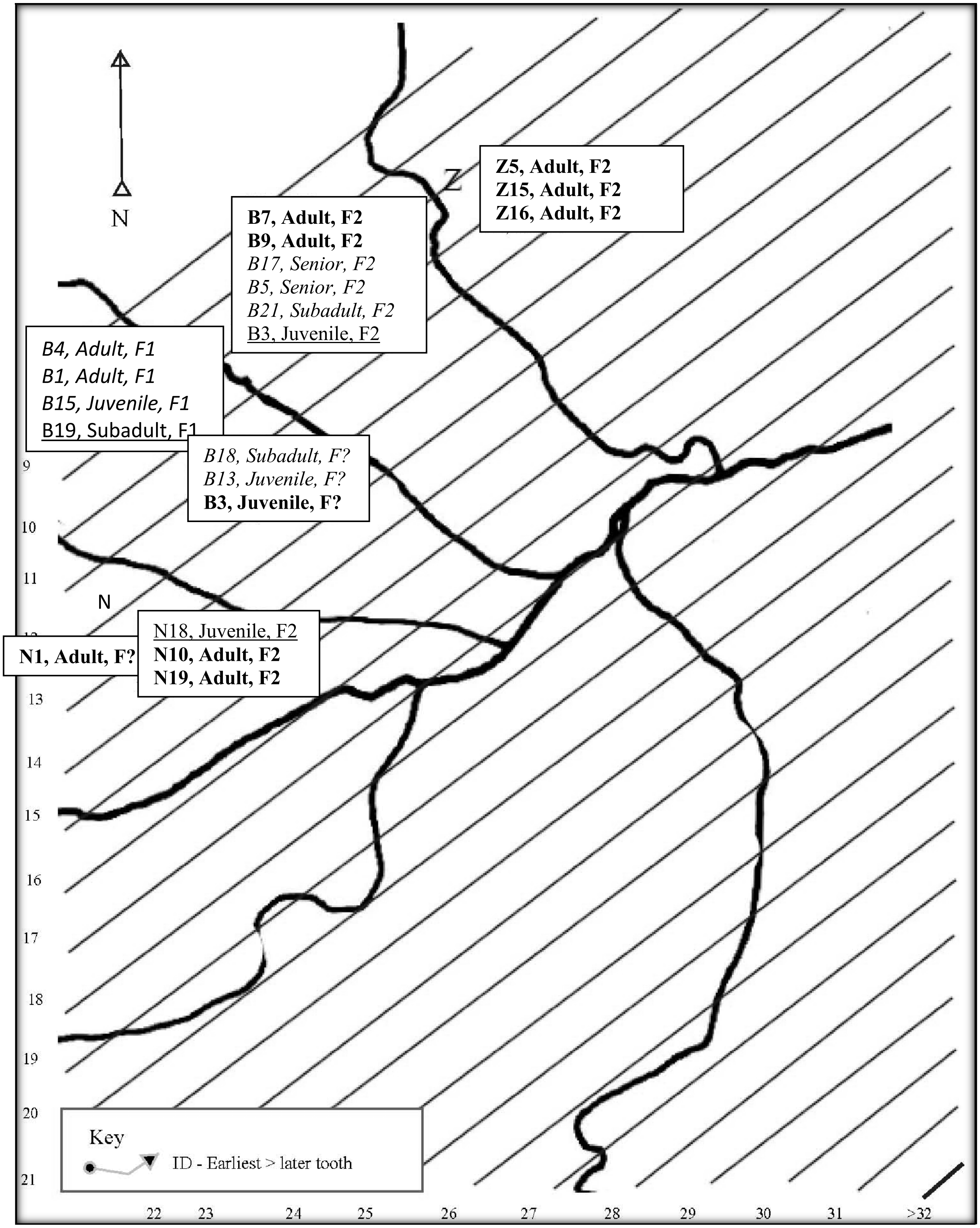


Figure 6.5. Plan indicating sheep groups by site, local (underlined), non-local (italics), and unknown origins (bolded), and by genetic Family (F#).

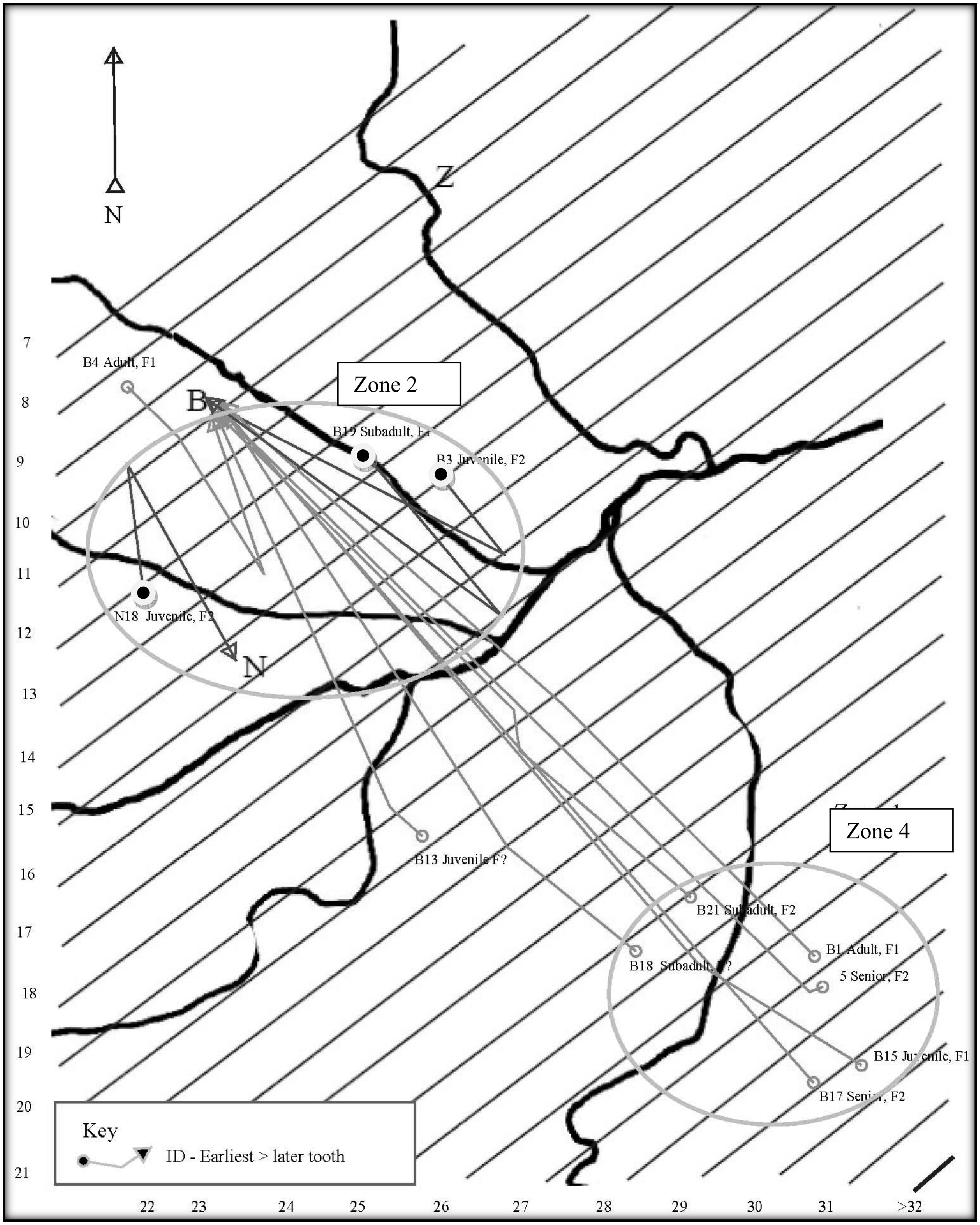


Figure 6.6. Plan indicating all movement of all sheep for which XRF and mtDNA was available. Color coded by local (●), non-local (◉), and genetic Family (F#).

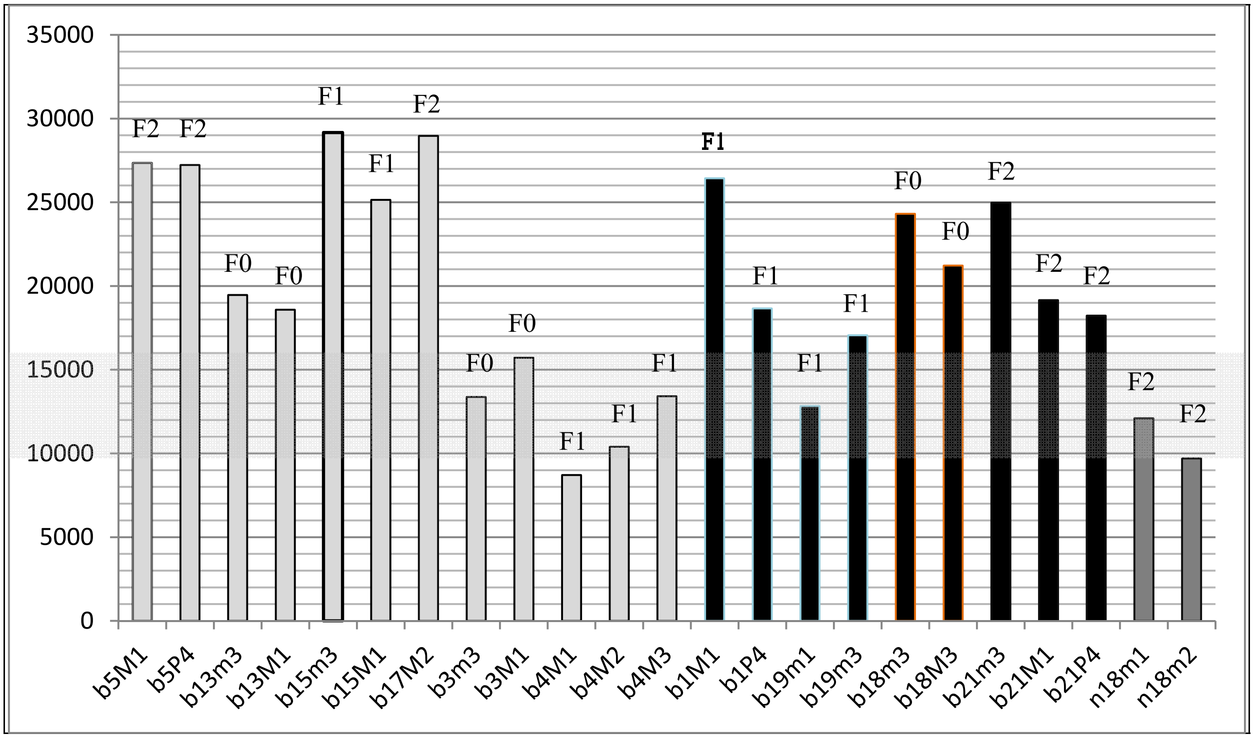


Figure 6.7. Strontium distributions of sheep for which mtDNA data is available: Bronocice, Phase 3 light grey, Bronocice Phase 4 black, Niedżwiedż dark grey. Family 1 – F1, Family 2 – F2, Unrelated Individuals – F0.

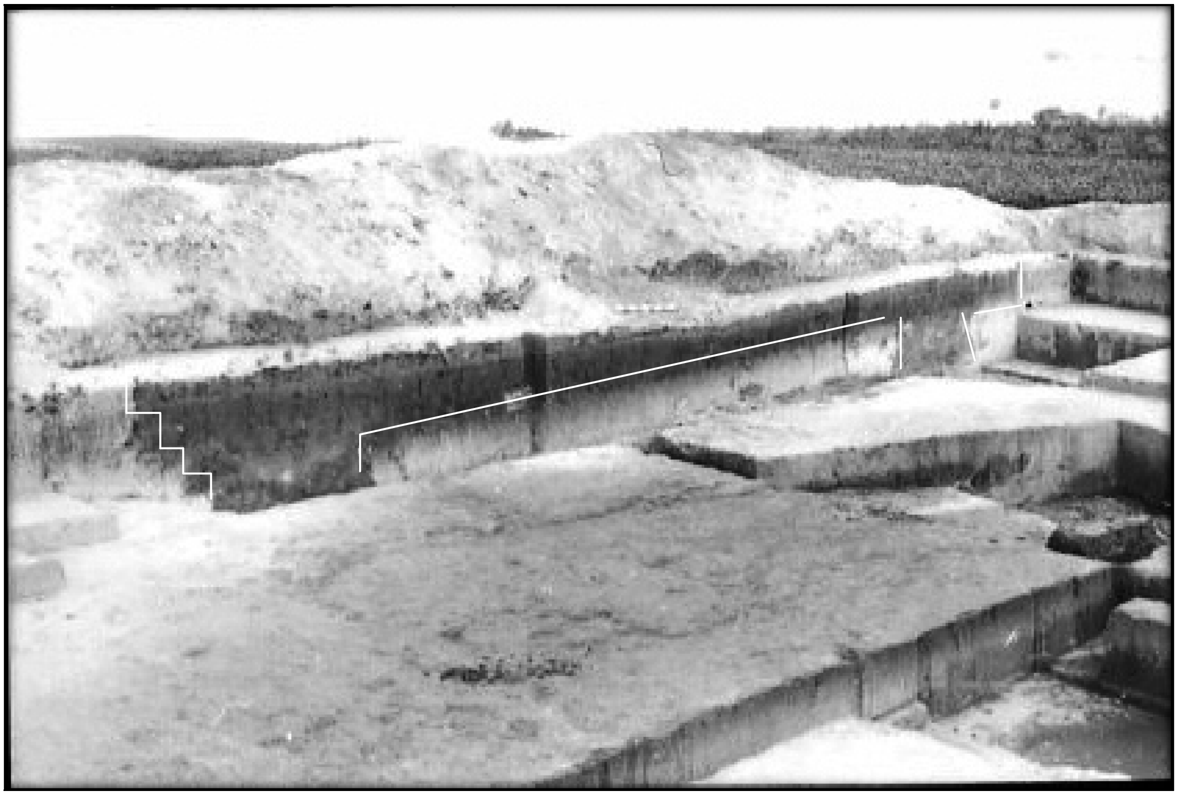


Figure 6.8. Outline of a longhouse, stairs into cellar, and storage pit. North wall of Unit B4.

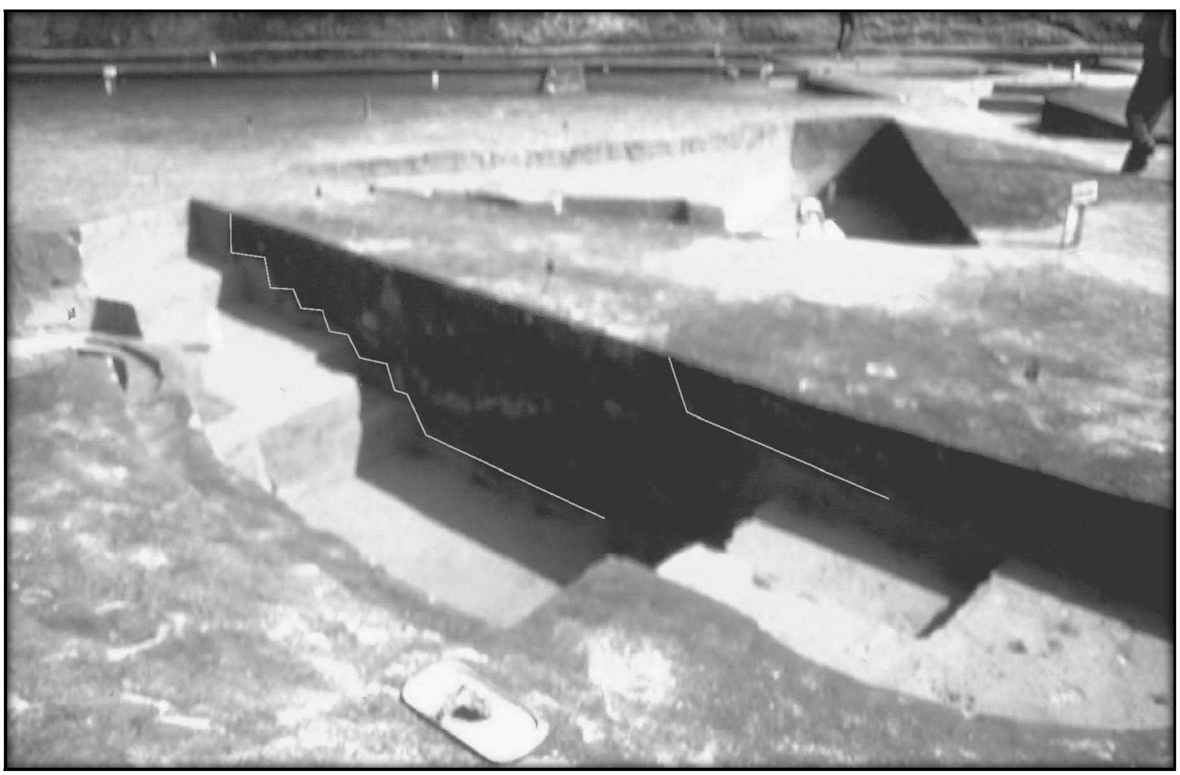


Figure 6.9. House with stairs, cellar and storage pit, Pit 49-A1 Phase 3 (left), impacted by later construction of Pit 50, which is a floor for a Phase 4 house (right).

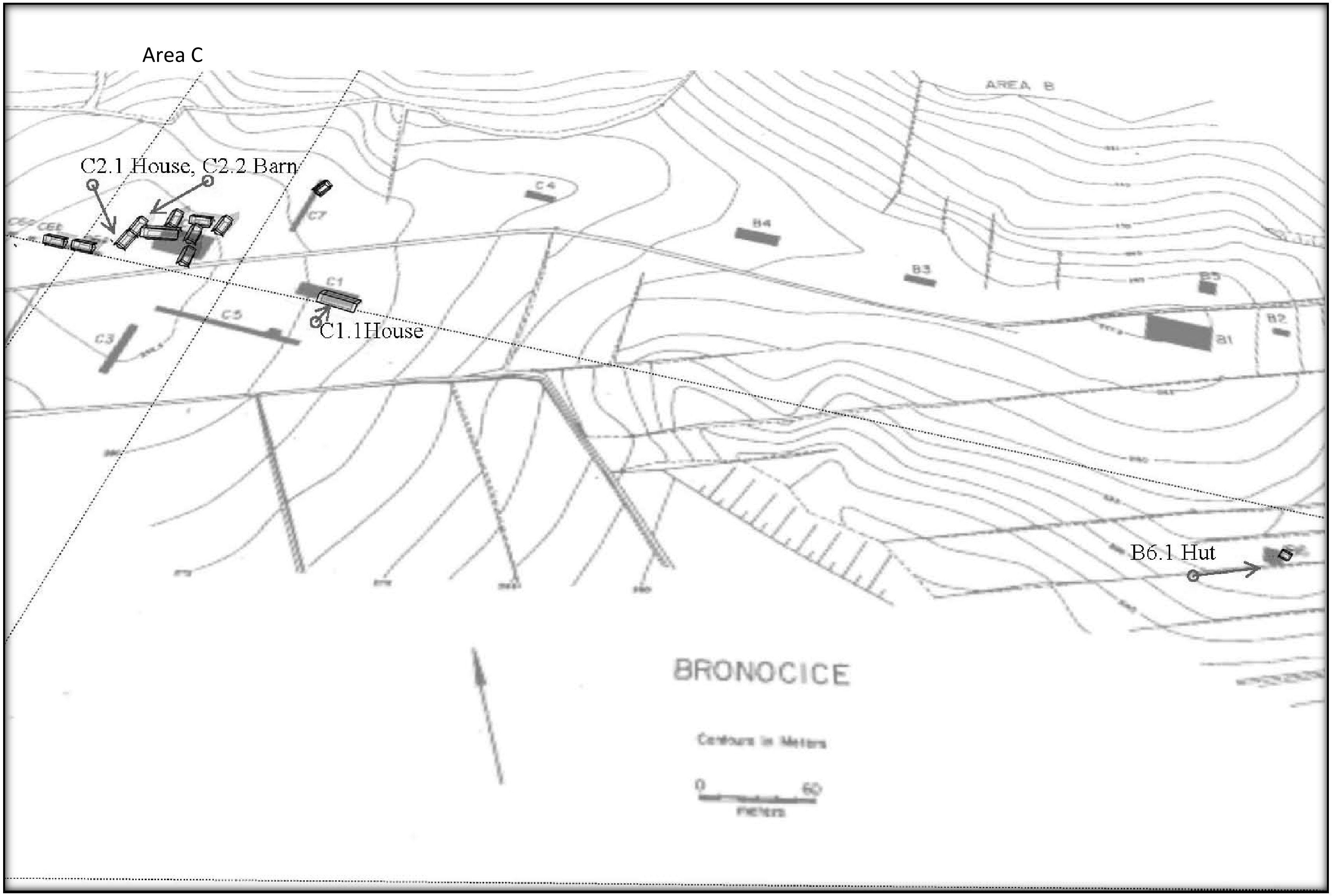


Figure 6.10. Bronocice, layout of the settlement locations of Phase 1 houses (analytical units) from which sampled sheep were obtained.

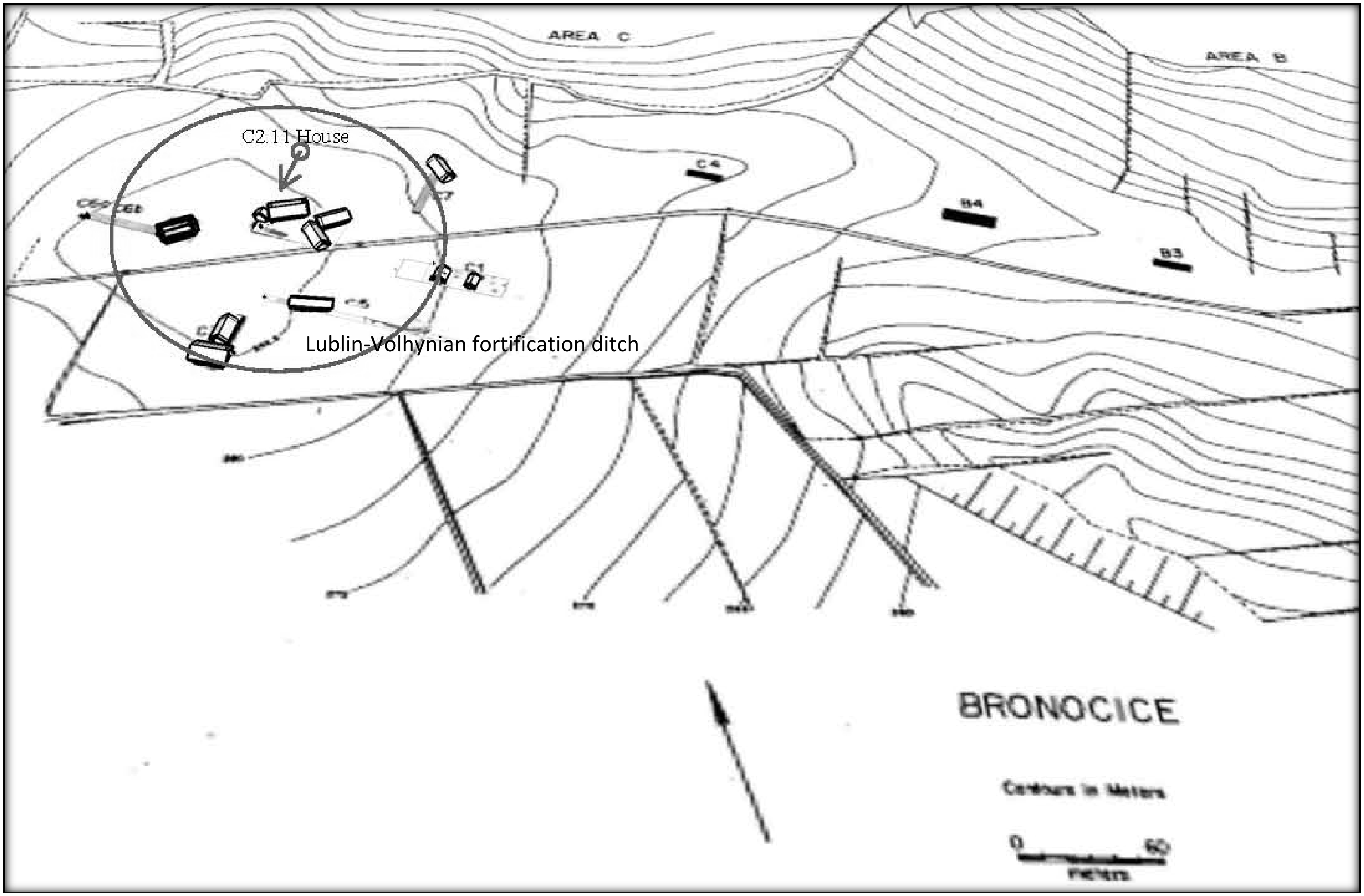


Figure 6.11. Bronocice, layout of the settlement and locations of Phase 2 houses (analytical units) from which sampled sheep were obtained.

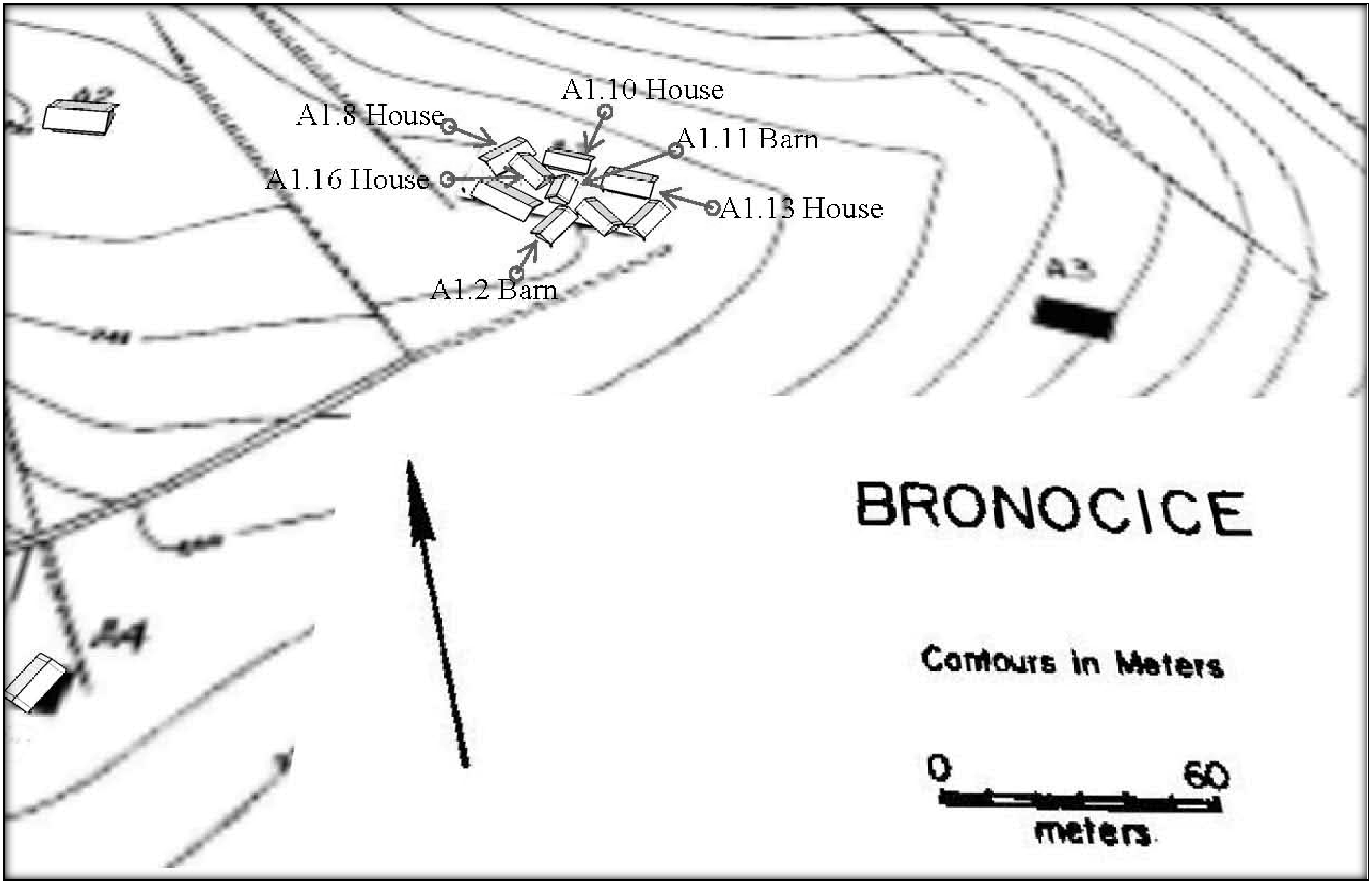


Figure 6.12. Bronocice, layout of the settlement and locations of Phase 3 houses (analytical units) from which sampled sheep were obtained. The Lublin-Volhynian ditch/enclosure is located to the west.

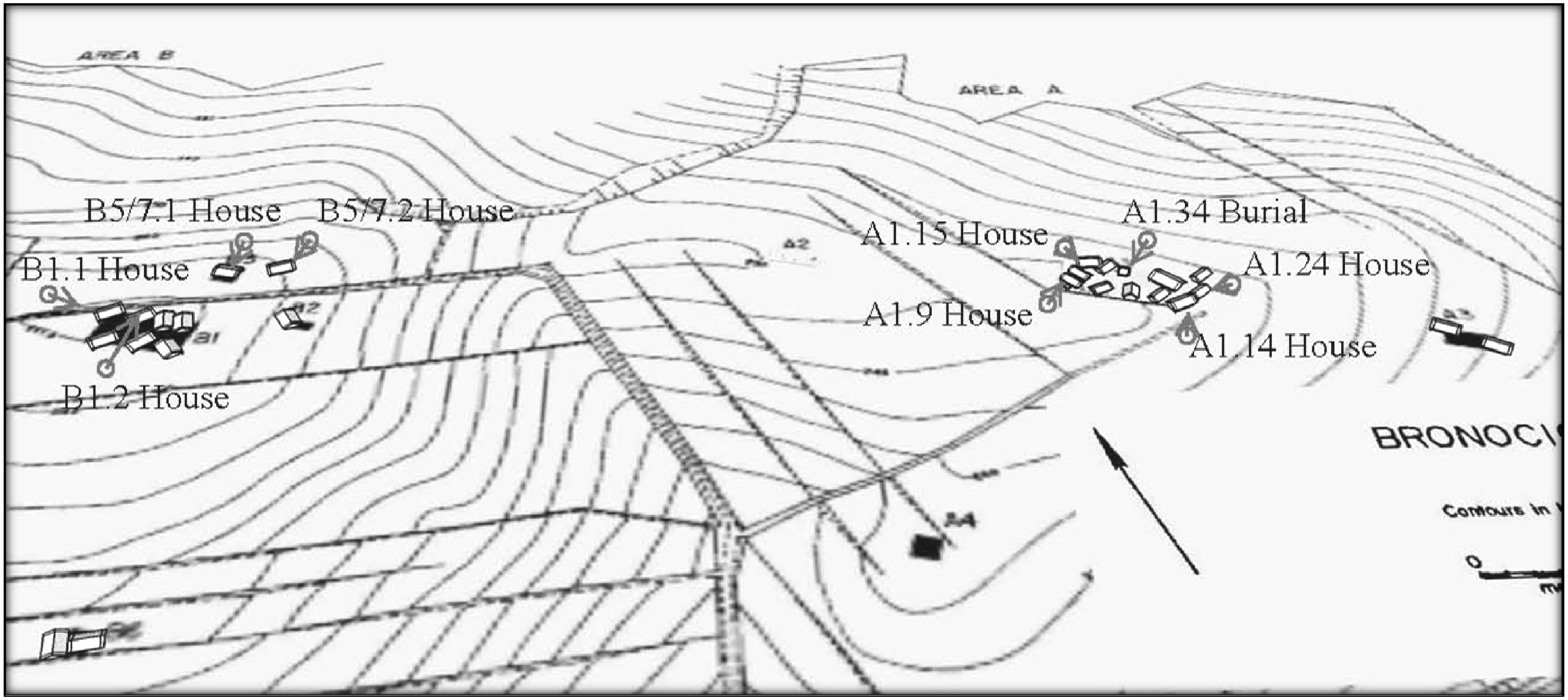


Figure 6.13. Bronocice, layout of the settlement and locations of Phase 4 houses (analytical units) from which sampled sheep were obtained.

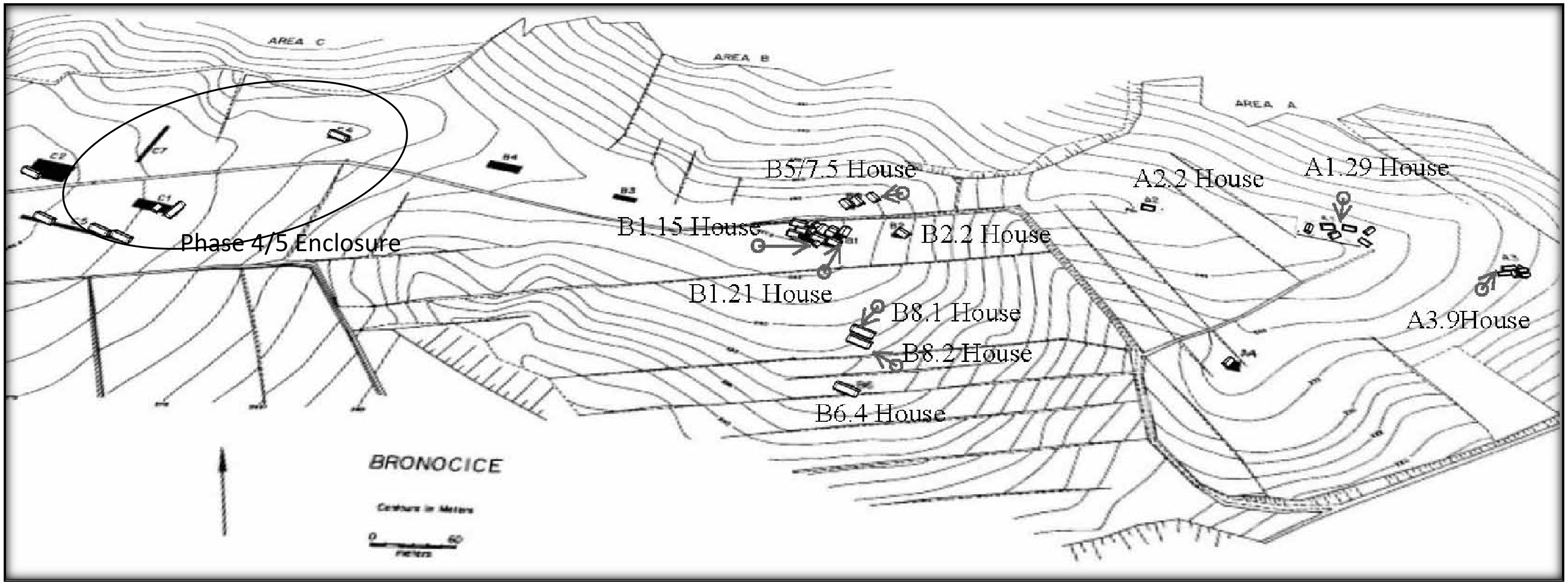


Figure 6.14. Bronocice, layout of the settlement and locations of Phase 5 houses (analytical units) from which sampled sheep were obtained.

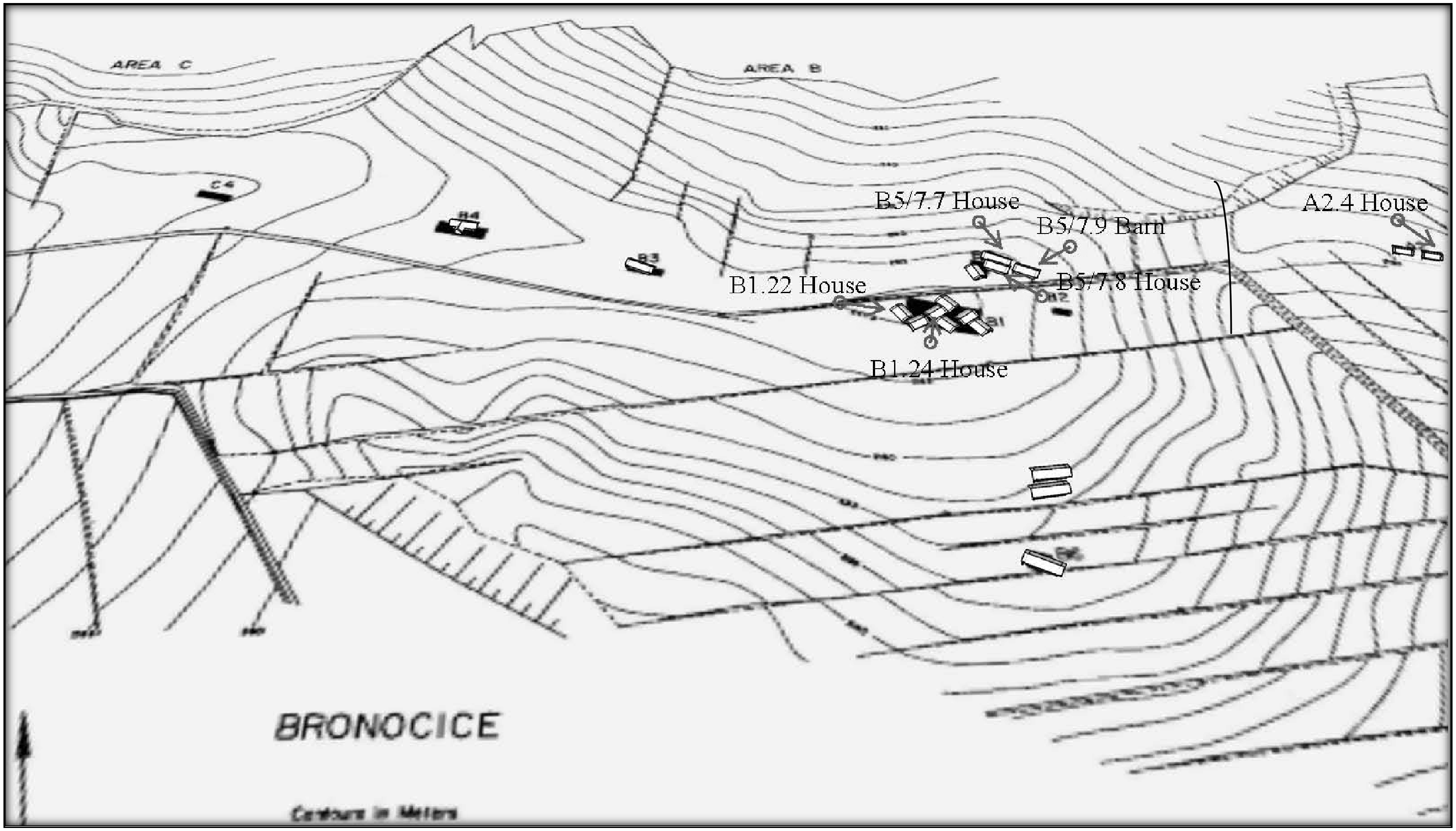


Figure 6.15. Bronocice, layout of the settlement and locations of Phase 6 houses (analytical units) from which sampled sheep were obtained.

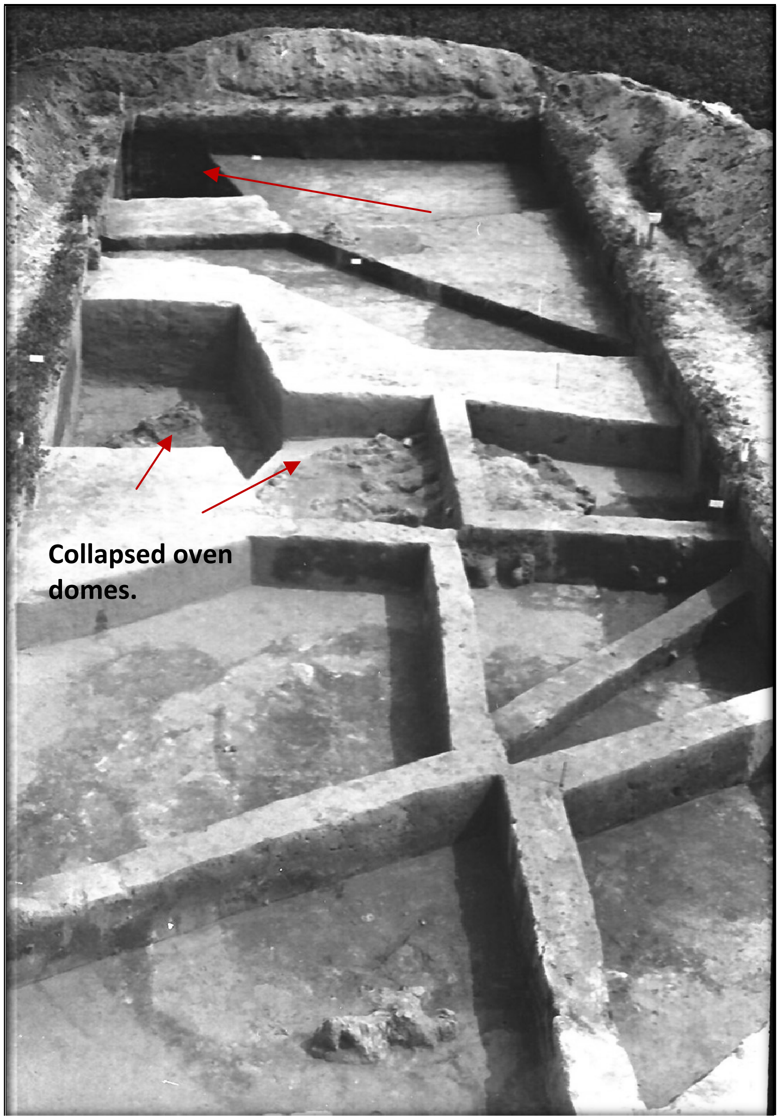


Figure 6.16. Ovens in Unit A2.


Figure 6.17. Slaughtered cattle in 21-A3.

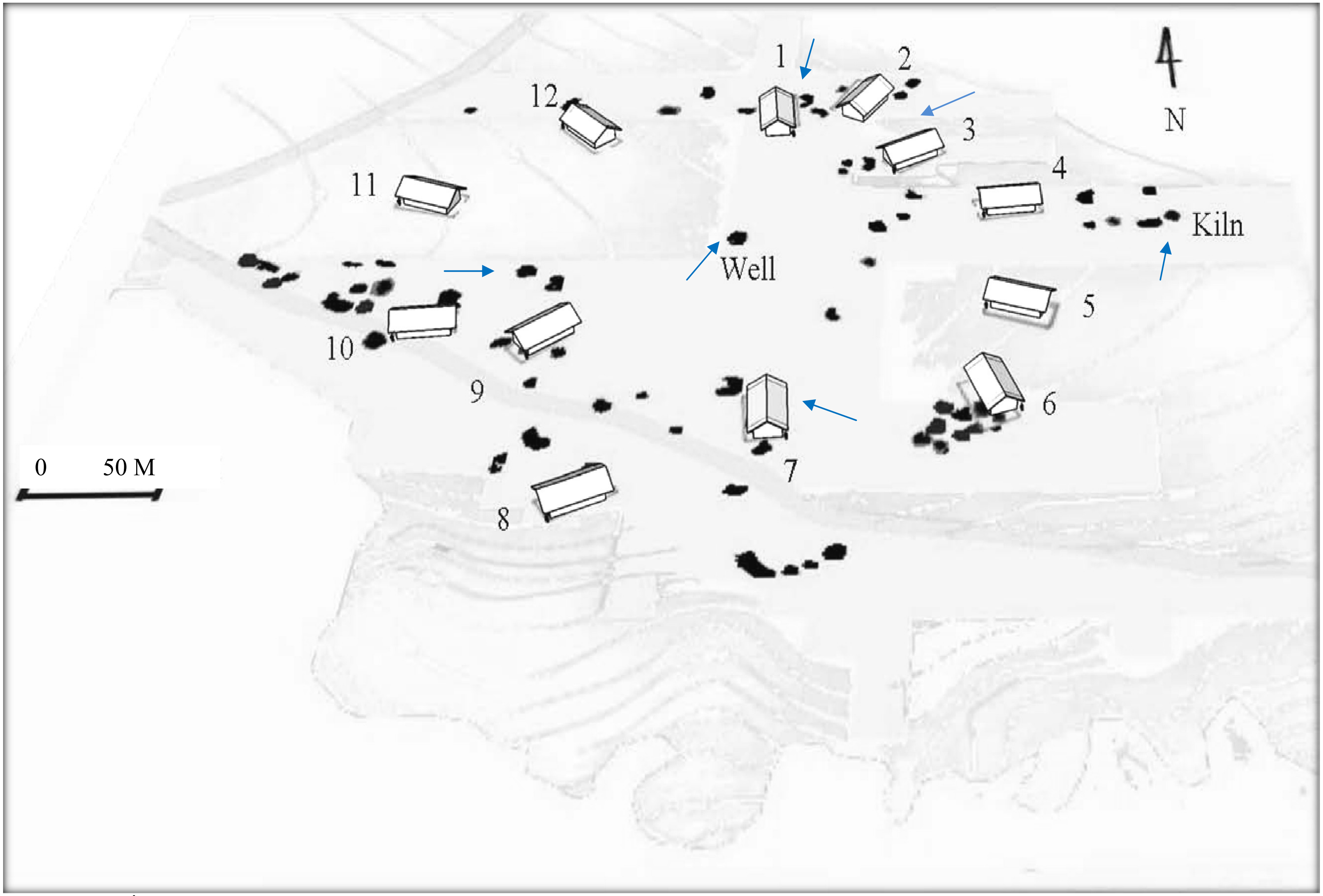


Figure 6.18. Żawarża, layout of the settlement and Phase 3 houses (analytical units) from which sheep samples were obtained.

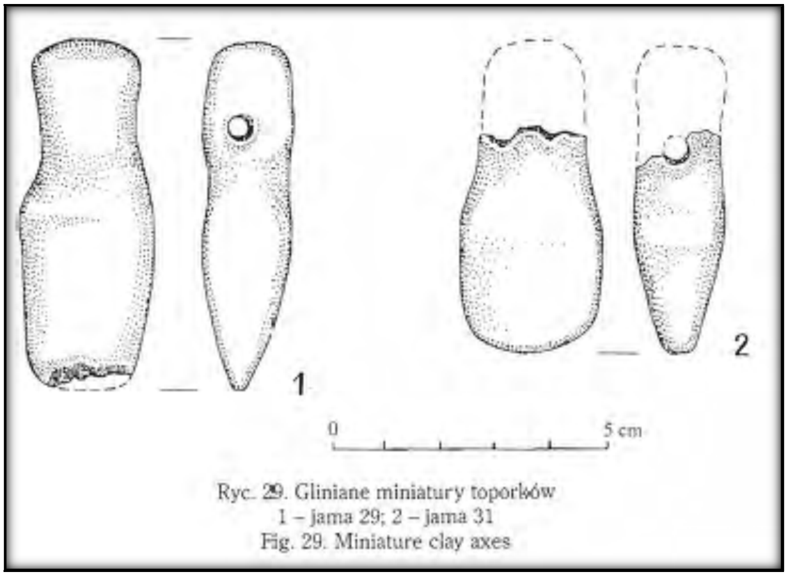


Figure 6.19. 'Mini axe' loom weights from Żawarża.

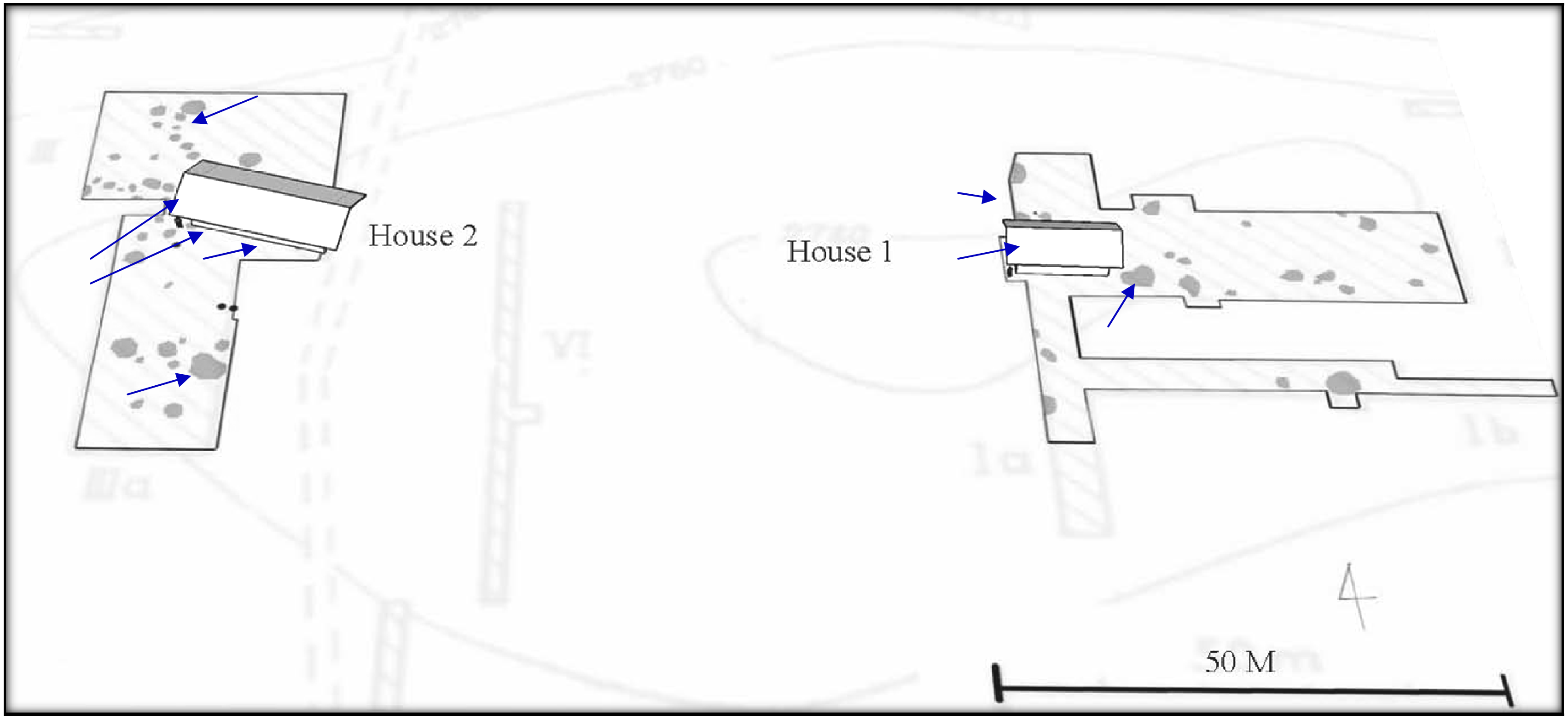


Figure 6.20. Niedźwiedź, layout of the settlement and Phase 4 houses (analytical units) from which sheep samples were obtained.

Chapter 7

The Business of Sheep at Bronocice

A. Introduction

This study began with the simple premise that an examination of sheep mobility patterns and genetic relationships can shed light on social relationships involving the management of sheep within and across settlements. A model was proposed involving long distance trade and local exchange of sheep in the Bronocice micro-region.

- The model

During the middle late Neolithic in southeastern Poland complex central place settlements obtained sheep from outside the region through long distance trade and that surrounding small subsistence farming communities obtained sheep from central places through localized exchange. Trade occurred between unrelated groups of individuals and involved negotiating the transfer of valued goods, materials and livestock by elites. Local exchange occurred between elites in central place communities and households from surrounding communities and was based on social close ties, possibly between extended families and business partners.

- Hypothesis 1

The surge in sheep frequencies beginning in 3650 BC in southeastern Poland resulted from stock-building through the importation of sheep. Variability and patterning seen in elemental strontium of sheep dental enamel can be used to segregate livestock into groups of local and non-local animals. The presence of high frequencies of non-local individuals *within an assemblage represents stock-building is an indication of sheep importation via long distance trade.*

- Hypothesis 2

Close genetic ties can be detected through mitochondrial DNA (mtDNA) analysis. In a tiered economic system small subsistence farming communities obtained sheep from the larger community. Their sheep will show genetic greater proximity to those from the central place. Whereas imported sheep found in central places will be less closely related genetically because they represent imported animals.

The x-ray fluorescence (XRF) and mitochondrial DNA (mtDNA) data supported both hypotheses and provided important insights into the management of sheep. The XRF results revealed that sheep intensification noted in previous studies began ca 3650 BC (Phase 3) at Bronocice (Milisauskas *et al* 2012, Pipes *et al* 2014) and was accomplished by importing sheep from other cultures outside the region. The data indicated that intensification in smaller surrounding communities was accomplished by obtaining sheep through exchange with Bronocice. The non-local sheep at Bronocice were shown to be genetically related to local sheep at Bronocice, Żawarża and Niedżwiedż. The results of these studies provide a foundation for examining 1) the structure of trade and exchange at Bronocice and the groups involved, 2) explaining why sheep became important economically with the region, and 3) considering what Bronocice offered in exchange for sheep.

B. The Structure of Trade and Exchange and the Groups Involved

Trade and exchange involve swapping material goods, people and services, all of which are economic activities made possible through social interactions during which values are agreed upon and terms of equivalent exchange negotiated. Trade and exchange imply different scales of economic activities as well as distinct groups. Trade in prehistory is said to involve elites who managed the traffic in goods or commodities between local and non-local entities through which they acquired rare and valued items. Exchange occurs between local groups, such as households, craft specialists, farmers, pastoralists, and self-interested individuals and is smaller in scale and often times focused on food and other necessities.

The terms trade and exchange have been used extensively in the archaeological literature to describe the movement of raw materials, products, services, animals and people in the past in the Neolithic (Bogucki 2007, Bogucki 1988, Czekaj-Zastawny *et al* 2011, Greenfield 2005, 2014, Milisauskas 2011, Milisauskas and Kruk 1989, Neustupný and Neustupný 1961, Nowak 2006, Parkinson *et al* 2013, Renfrew and Bahn 2004, Sherratt 1997, Sosna 2007, Videiko 1999). Most introductory archaeology textbooks discuss the terms 'trade, exchange and reciprocity' as increasing levels of economic activities and with implicit political orientation (Renfrew and Bahn 2004). With regard to the Neolithic period, trade is thought to have been handled by elites especially interested in prestige items such as copper axes, amber, and spondylus shell (Milisauskas 2011). The accumulation of personal wealth by elites is often detected in burials, for these individuals were laid to rest with their precious items (Pawn 2012). There is great emphasis the role that elites play in establishment control over labor and trade and exchange, all of which are considerations but perhaps ignore the importance of smaller players (Webster *et al* 1990). There are a few issues that are often given little attention. First, it is an assumption that prestige items were an important component of long distance trade. Obtaining a copper axe or beads may have been part of a transaction but their acquisition happened rarely, perhaps once in an individual elite's life. Second, a wide range of commodities were traded constantly, such as stone axes, lithic tools, salt, and livestock, and more valuable and more important to most people. In age of starvation and where death lurked behind every infection and broken bone, prestige was not something most people had foremost in their minds. Elites may have marked themselves visually but their interest would have been on meeting the economic needs of the people they lived with.

Craft specialization and specific trades provided commodities that were involved in long distance trade. Perhaps the easiest examples of craft specialization seen throughout Europe are lithic extraction and tool manufacturing industries. The size of production, limited range of products, and distances over which they were distributed point to fulltime specialists early in Neolithic. It has been estimated that 2.5 million flint axes were produced at Rijckholt in the Netherlands (Renfrew and Bahn 2004). The mine at Grimes Graves, England, is estimated to have produced 28 million flint axes. The size of flint mines is impressive. Grimes Graves measures 37 hectares (approximately 91 acres). In southeastern Poland the earliest commodities were flint varieties and the production of tools, especially axes and stone blades. The mine at Krzemionki, Poland and measures 78.5 hectares (approximately 194 acres) and was exploited from ca 3900-1600 BC. Banded axes were distributed up 600 kilometers away to the north, south, east and west (Czekaj-Zastwany *et al* 2011).

Another issue revolves around the structure of trading. Politics and economies are inevitably intertwined. As such social and political hierarchies tend be linked with specific kinds of economies. The political structure in southeastern Poland has been described as similar to Big Men, in which powerful individuals asserted control over trade in the region (Milisauskas and Kruk 1984, 1989). This type of political and economic structure entails the use of feasting and gift giving between elites and their entourages, as well as staged events to facilitate negotiation.

This structure is based in part on Pacific island models of Big Men and Big Women who control the flow of trade, especially prestige items, and in which social obligations may be embedded, such as political alliances forged on the backs of unequal gift exchange (Mauss 1950, Malinowski 1922, Weiner 1976). In my opinion these models are incorrect because they derive from island economies in which population movements are constrained and because they involve commodities that are extracted or produced in significantly different ways. Application of island models compresses the stages involved in the creation, distribution and consumption of commodities.

Europe is a vast continent over which people moved by land and by water. The range of commodities of commodities extracted, produced, grown and raised far outstrips island models. Discussions about Neolithic and Copper Age long distance trade and exchange in central Europe typically ignore the possibility that markets systems were already in existence in the Neolithic. A market is simply a scheduled gathering of people for the exchanging provisions, livestock, and other commodities through a variety of systems based on bartering or money. The most common market is based on agro pastoral commodities.

Neolithic farmers were among the first to generate large surpluses for ‘redistribution’, or exchange. What did they want in exchange? Likely candidates include livestock, salt, flint tools, stone axes, and dogs. Salt was especially important to stockherders. Salt is an essential mineral needed when raising large herds of cattle and sheep (Mathis and Ross 1996, NSW Agriculture 2003). Evidence of salt production dates back to the early Neolithic in the Wieliczka area near Krakow where over 400 sites have been identified associated with Lengyel, Funnel Beaker and Baden cultures (Harding 2013). Salt was a highly valued commodity during prehistory and later historic times.

There is a tendency is to discuss commodity exchange as if only two entities were in involved in regulating trade. That simplification denies the scale at which these exchanges occurred and ignores the transactions of many other types of commodities, currently invisible to the archaeological eye. There is an abundance of archaeological data indicating that livestock intensification was common throughout many regions in central Europe by the mid 4th millennium BC (Parkinson et al 2004). Previous studies have revealed the involvement of settlements, households, pastoralists, craft specialists, and elites in trade and exchange within the Bronocice region and with other cultures, especially those to south and east, during the 4th millennium BC (Aino 2006, Barber 1991, Czekaj-Zastawny *et al* 2011, Gumiński 1989, Podkowińska1962, Séfériadès 2009). Furthermore, studies have shown that economic specialization in animal production also occurred at this time throughout central Europe (Glass 1991, Greenfield 2005, Hoekman-Sites 2011, Marti-Grädel *et al* 2004, Milisauskas and Kruk 1991, Parkinson *et al* 2004, Pipes *et al* 2014). Intensified production is an indication of the increasing importance of livestock as a form of wealth, not just among elite households in central places, but also in small subsistence farming communities. Genetic studies have also revealed human population movements. Funnel Beaker people moved on a north/south access in central Europe (Brandt *et al* 2013). Genetic patterns also reveal a high degree of heterogeneity within Funnel Beaker populations indicating mixing with localized Mesolithic groups (Brandt *et al* 2013). There is also evidence that people from the Great Hungarian moved considerably within that region resulting in homogeneity (Pawn 2012)) while in Ukraine the presence of eastern Eurasian immigrants is found (Deguilloux *et al* 2012, Nikitin *et al* 2012). It appears that several migrations of people occurred over millennia into Europe (Khar'kov *et al* 2004). Ceramic assemblages reflect the admixture of non-local people at many regional sites (Gumiński 1989, Podkowińska and Rauhut 1960).

The nature of trade and exchange were extremely complex and involved many groups of local and non-local people, who had distinct roles and agendas, and not just the last in the line, e.g providers and consumers. This study revealed that the timing of trade and exchange, at least of sheep, were scheduled and arranged events. Scheduling can be predicted because of multiple factors affecting the timing of acquisition and transmission of goods, such as seasonal weather patterns, agricultural activities including planting, harvesting and field preparation, and livestock practices such as gathering fodder, grazing, birthing, and mating of livestock.

None of the current economic models used to explain trade and exchange in southeastern Poland during the second half of the 4^{th} millennium BC can accommodate the volume or intricacies indicated by the archaeological record, or the implications of an annual migration of large herds of sheep, and most likely of other livestock species. A more sophisticated model of trade and exchange, based likely on a market system, is required to understand who and how trade and exchange were controlled and regulated. Focusing on elites, who are the easiest and most obvious actors in the past, results not only in a compression of the roles different groups played in economic interactions but also in a reduction of the range of activities that resulted in those events.

The logistics involved in sheep intensification within southeastern Poland required the presence of subgroups including households and craft specialists as well as specialized pastoralists. The latter may have moved the herds on someone else's behalf. Perhaps other groups were involved in transporting exchanged goods back to their settlements. One can envision many scenarios. Sheep herds numbering in the hundreds or even thousands would have been moved across land. But goods and materials received in exchange may have been moved by water or even frozen waterways. Other considerations include stopping points and accommodations as well as rights of access or permissions to move across territories already contested by distinct cultural groups. It remains an open question where sheep were imported from. There are lots of indications of extensive trade between southeastern Poland and cultural groups from modern day Slovakia, Czech Republic, Hungary, Ukraine and Germany (Apel and Knutson 2006, Brandt *et al* 2013, Deguilloux *et al* 2012, Dzbynski 2008, Pelesiak 2007, Sosna 2007, Videiko 1999). This part of Central Europe was a large interactive zone through which commodities and people moved and blended cultures over thousands of years (Figure 7.1).

1. Households, Settlements and Cultures

Within the Bronocice region a settlement hierarchy emerged with the reappearance of Funnel Beaker people in Area A ca 3650 BC (Milisauskas and Kruk 1984). This settlement differed from others in the region in terms of size, layout, and complexity. The physical layout of Bronocice from that time on was structurally more like a complex village. Unlike hamlets where most individuals are related by blood and marriage ties, villages and towns are more diverse in composition and include different lineages and households that are unrelated. At Bronocice for example there were a number of lithic workshops, a pattern seen at other sites such as Gródek Nadbużny and at Ćmielów (Gumiński 1989, Podkowińska 1962), one of which specialized in flint axe production. It may be that a specialist came from Ćmielów with his family and settled Bronocice but maintained his access to the Krzemionki mine. Unusual artifacts point to the presence of non-local people at Bronocice. The rare occurrence of drums points to interaction between those households and people in Moravia or Bohemia (Gabałówna 1962). Other indications of contact with outside cultures are seen in flint types, ceramic vessels and fiber and textile production artifacts showing influences from Michelsberg, Stroke-ornamented and Triploye cultures (Chmielewski 2009, Pelesiak 2007, Videiko 1999, Zastawny 2008).

Surrounding settlements in the Bronocice region varied in size and internal arrangement. A study in small settlement variability might find a correlation between these two variables, location, and subsistence practices. Żawarża and Niedżwiedż were similar in size but differed in internal arrangement. Perhaps variable internal arrangements correspond with social differences as well. In any case, these small settlements appear to have been hamlets, settlements in which most, if not all, households and their members were related genetically by marriage.

The basic organizing principle in the Neolithic was the same as it is today, the household. Household identity binds those who live and work together whether they share blood lines or not. The clearest example of unrelated household members are married couples or life partners, in which two individuals from different lines commit to live together and work cooperatively towards common goals such as survival and reproduction. The blood tie is more important when things are going well and less important when adversity strikes and members of a community are mowed down by disease, conflict, accidents and old age. While a physical structure may reinforce a sense of identify with pace it is unnecessary. Households are people who share a common understanding of their role and place in society and a sense of purpose and need. The sharing of activities and group behavior create their culture and give them identity. Whether they live houses, caves or tents, people who live and work together share a common bond, even if personal goals and agenda may not benefit the group.

Funnel Beaker household structure is thought to have been based on patrilineal patrilocal marriage patterns. In large part this is based on anthropological theory of family and social organization as well as ethnographic observations of marriage and residential patterns associated with specific forms of subsistence practices. Subsistence agricultural societies are among the most heavily studied groups by anthropologists in many parts of the world. These societies are generally patriarchal in structure (Apostolou 201), Mies 1986, Moghadam 2004). Women marry into their husbands families and reside in their communities. The Funnel Beaker settlements selected for this study were part of a broad cultural system based on subsistence agriculture and livestock herding.

The majority of settlements within the Bronocice region were composed mainly of Funnel Beaker households. Presumably they were patriarchal and married women (or spousal partners) were found in other communities. The ceramic assemblages and burial patterns found at Funnel Beaker sites indicate that the majority of women were Funnel Beaker in origin. In the past there has some reluctance to accept pots as evidence of people from other cultures. Nonetheless, they are expressions of cultural identify. They are not produced in a vacuum but embody typical styles based on one's culture and are accepted as indicators of non-local individuals. Signs of non-Funnel Beaker women have been observed at many sites in southeastern Poland not only through ceramic styles and decorations, but also decorated fiber and textile related artifacts, the presence of jewelry, and burials patterns atypical of Funnel Beaker practices (Chmielewski 2009, Gabałówna 1962, Gumiński 1989, Kulczyzka-Leciejewiczowa 2002, Pelesiak 2007, Pipes *et al* 2009, Podkowińska 1962, Videiko 1999, Zastawny 2008). Had these material culture patterns been unique at each site they might easily be dismissed as idiosyncratic, the result of a unique individual's creative expression. However the stylistic elements and the artifacts themselves are highly patterned and can be linked to the similar artifacts from other cultures. For these reasons, where they occur at sites like Bronocice they are considered to be the discards of non-Funnel Beaker people, probably women, residing in Funnel Beaker communities (Pipes *et al* 2014).

2. Pastoralists

Pastoralists were especially important to this study because of their role in herding sheep. There were two distinct types of pastoralists identified in this study, local pastoralists who lived in hamlets such as Żawarża and Niedżwiedż, and non-local specialized pastoralists were involved in long distance trading of sheep and who came to Bronocice once a year.

Pastoralism is a specialized type of animal husbandry practice associated with mobile or nomadic lifestyles and intensified rearing of domesticated livestock. Modern pastoralists keep large herds, are product oriented and manage the feeding and reproduction of the herds to meet certain needs (Halstead 1996). There are two basic types of pastoralism often discussed in the literature: nomadic and transhumance. Nomadic pastoralists move their herds in search of pastureland typically within defined territories. Transhumance on the other hand involves the seasonal movement of animals between elevations. In either case, the movement of animals is prompted by inadequate local food resources and an inability to raise enough grain or gather enough fodder to support them in one area throughout the year.

It has been suggested that pastoralism developed out of competition over available grazing land with agriculturalists (Lees and Bates 1973). It has also been suggested that it resulted from the adoption of domesticated animals by hunters and gatherers already practicing a mobile lifestyle and used to following herds. However, pastoralism is also an adaptive strategy relating to changing environmental conditions and the adoption of a less sedentary life possibly emulating the behaviors of other people.

Pastoralism developed in dry, arid regions, not in forested areas. It is a Neolithic specialization in stock breeding and originated with farmers (Ryder 1987). This idea derives from the fact that 1) domesticated animals are only recovered in agricultural settlements and 2) pastoral lands are always located on the borders of agricultural settlements. Pastoralists rely heavily on animal products though some grow crops, while some agriculturalists keep smaller numbers of animals. The essential difference between nomadic pastoralism and static pastoralism is the use of a 'fixed abode' for part of the year by the latter. Typically the herd is shifted vertically not horizontally. The winter home is generally the permanent one. The small settlements in the Bronocice region may have been static pastoralists. The complexity seen in the layout of Bronocice as well as the presence of specialists within the settlement for several hundred years suggests that seasonal rotation of sheep was unlikely. Instead it is more likely that farmers in the settlement kept small numbers of livestock.

According to Eric Wolf, pastoralists have complex relationships with agriculturalists (Wolfe 1997). Pastoralists tend to have well defined grazing lands and often trade their products for grain. Historically conflicts arise between agriculturalist and pastoralists over access to cultivated lands. Formerly accessible areas converted to farmland by agriculturalists lead to disagreements over grazing rights. Often times symbiotic relationships form because agriculturalists want sheep to graze their cropped fields in winter and manure them. There is evidence to support the grazing of crops fields during the Neolithic (Bogaard 2004). In Europe, Davies identified two types of transhumance: Mediterranean resulting from a need to find pasturage and Alpine resulting from the need to vacate agricultural fields during the growing season. Transhumance is not an intermediate form between agricultural and pastoral lifestyles. Instead it is in-between nomadic and static pastoralism (Ryder 1987). Nomadism is a specialized response to areas with poor pasturage, soils and access to water. In many places nomadism is haphazard. In some places transhumance is a specialized form of nomadism in which animals are shifted between pasturelands from summer to winter.

In the past, agriculture was responsible for major changes in forested landscapes that extended over most of Europe, and brought with it significant changes in social relationships and behaviors (Redman 1999). In addition to bringing about sedentism, permanent community life, and commitment to place, crops and animals, it also created new relationships within the family unit as it became the main of unit production. We know little about Neolithic family structures from central Europe currently. But the longhouse is interpreted as a reflection of the family, consisting of two or three generations, and it is assumed that they shared tasks and worked to varying degrees cooperatively managing fields, livestock and other responsibilities (Bogucki 1988).

With regard to Pastoralism, there is some evidence from Germany, southern France and Hungary. Transhumance has been indicated for the early Neolithic at Vaihingen, Germany where strontium analyses of human and cattle teeth have shown migratory movement of herds to higher elevations and of people from outside the area (Bentley and Knipper 2005.) Settlement and faunal data from the Aude Valley in France show that transhumance of sheep and goat developed during the middle Neolithic in response to changes in the environment (Geddes 1983). Through the examination of dung samples recovered from sites on the Great Hungarian Plain it appears that cattle and sheep were moved seasonally during the Early Neolithic (Bogaard 2004).

3. Specialists and Elites

Craft specialists and other specialists existed within the settlement at Bronocice. Craft specialists are indicated by different kinds of workshops, most especially those producing lithic tools, textiles, and bread. Other specialists, less easily recognized individually, include farmers and shepherds, salt producers, and ritual specialists. Specialists require the support of others who remain invisible archaeologically. They include providers of raw materials and labor, and possibly facilitate other needs (Brumfiel and Earle 1987). The economic structure of sheep rearing observed in the Bronocice micro-region points to the presence of elites. These individuals were responsible for organizing and directing the construction, maintenance and management of the enclosures. They also controlled access to and use of the enclosures and probably regulated the sheep market. The large enclosure at Bronocice dating 3400 – 2900 BC (Phases 4-5) fit neither the static pastoralist nor nomadic pastoralist model. From the start the number of animals potentially enclosed at Bronocice would have ranged from a few hundred eventually reaching over a thousand by Phase 5. The enclosures served as a gathering place for sheep herds being traded and exchanged in the micro-region. The market occurred once a year in late spring. Based in age at death data, it appears to have been a scheduled annual event.

So far no signs of Funnel Beaker elites have been found in burials, though the Funnel Beaker cemetery detected in Area C remains essentially unexcavated. Instead a collective grave was found in Pit 36B1 containing 17 individuals most of whom were wearing jewelry and who were outfitted with grave goods and food. These were non-Funnel Beaker people who were executed. We know that because Funnel Beaker people did not adorn themselves with jewelry. It is conspicuously absent not only from all Funnel Beaker burials at Bronocice but also from Funnel Beaker household pits. Out of 600 plus pits at Bronocice less than 10 yielded 1 piece of jewelry making it fairly certain that these indicate the presence of non-Funnel Beaker people (Pipes 2010). The group of individuals in the mass grave is of great interest to this study. The wealth represented by the jewelry alone indicates not only that they were non-local people but also that they were elites. One individual had 301 shell beads, another 79. Some individuals had far fewer shell beads, still others had pierced animal teeth and worked bone pendants. It seems a strong possibility that they were executed and that their death caused serious political and economic difficulties for Bronocice and its surrounding communities. It is hard to ignore the decline of Bronocice at some point after their deaths.

Whatever visual signals Funnel Beaker people used to signal differences in status they remain invisible. However, the intensity of textile production may hold the answer. Perhaps clothing served as social markers. It is an interesting fact that Ötzi was found wearing leather and fur but no cloth (Schlumbaum *et al* 2010).

C. The Economic Significance of Sheep Intensification

The value of sheep rose in the mid 4th millennium BC not only in southeastern Poland but throughout much of Central Europe. Sheep increased not only in economic value but also in social value. Images of sheep have been found dating to this period, such as embossed rams head handles and sheep figurines, suggesting they were appreciated as fit objects of artistic reproduction (Dzierżanowska *et al* 2011). Although the evidence remains circumstantial, it is likely that the increased value in sheep was due to the start of wool production. Sherratt's Secondary Products Revolution (SPR) theory proposed that wooly sheep did not appear before the Bronze Age (Sherratt 1983). According to Sherratt's SPR theory, the primary reason for keeping livestock was as meat-on-the-hoof. In recent years the SPR theory has been increasingly challenged (Greenfield 2014). Specialized analyses have shown that dairying, once considered a Bronze Age development, occurred earlier in time. The inventions of the ard (plow) and cart should probably be pushed earlier in time. The famous Bronocice pot (Figure 2.15) dating to the Phase 3 suggests an earlier date is more likely. It has already proposed that the development of wooly sheep occurred in the mid 4th millennium BC (Greenfield and Fowler 2005). Many Polish archaeologists working in southern Poland assume that wool production was in operation beginning in the mid fourth millennium BC partly because of an abundance of fiber and textile production artifacts recovered from sites with large sheep assemblages, and partly ceramic pots appeared bearing images of sheep (Gumiński 1989, Kulczyzka-Leciejewiczowa 1999).

The social and economic importance of sheep can be further evaluated by looking at written records dating to the early Bronze Age and extrapolating back in time a few hundred years (Barber 1991, Lumb 2013, Randborg 2011). Livestock ownership and control over the production of cloth, especially wool, was an important source economic power among elites starting with the Bronze Age (Sherratt 1997, 1983, 1981, Ryder 1983). Wealth accumulation is not easily documented in this region during the middle late Neolithic. However, in cultures located to southeast material manifestations of wealth are more clearly expressed.

Supply and demand are two key features of commodity exchange. The need for wool and textiles may have led large cultural centers like Bronocice to encourage smaller communities to focus on raising sheep, especially wooly sheep. The material evidence for the production of thread and textiles at Bronocice shows that fabric was an important product and probably a highly valued trade commodity. The large numbers of sheep required for wool production were found in communities that specialized in sheep rearing within the region such as Żawarża and Niedźwiedź. These communities may have had special relationships to weaving families within

Bronocice. Their social interactions were likely based in part on providing raw wool and spun thread Bronocice weavers. But it may also be that they were extended families and formed a broader network of inter-related tasks.

It has been suggested that before irons shears were invented wool was plucked (Barber 1992). Of course in the same way that sickle blades were invented and used to harvest grains it is possible that some lithic blades were used to shear sheep. It is an assumption that wool was plucked. The size of sheep herds arriving at Bronocice was probably totaled over 1000 head of sheep each year. Shearing/plucking of wool would have happened in the late spring, May to June. Sheep cannot have their wool removed earlier as they need the warmth to survive cold weather. So it is a warm weather practice which must be completed early enough in the year so that the fleece can have time too regrow before cold weather returns.

Wool must be cleaned and combed or carded before being spun. It is dyed before spinning which adds another time consuming step. Studies of Navajo weavers show that the winter is the time for processing wool into thread or yarn (M'Closkey 2002). Weaving is done outdoors during warmer weather. If these activities are thought of with production of textiles in mind then a system of set of protocols can be suggested at Bronocice. It is likely that the trade in sheep coincided with the trade in woven textiles. Sheep were brought and textiles were moved out. Timing was an essential component in the successful trade of commodities and livestock. There had to have been an annual cycle within which sheep rearing activities were scheduled as well as events involving the trade and exchange of livestock. A major component of the cycle was annual market in sheep and their associated products, namely wool, thread and cloth.

Some data are available for fiber and textile production artifacts from Bronocice and Żawarża (Tables 2.3 and 5.3). Figure 7.13 presents the relative frequencies of households that had fiber and/or textile production for each phase at Bronocice and at Żawarża. Most households at Bronocice were involved in spinning fibers during every phase except for Phase 3. At Żawarża all households were involved in textile production. Weaving households were fewer at Bronocice during Phases 1 and 2. The production of textiles begins in earnest during Phase 3 and remained high until the end of the settlement. At Bronocice the rate of households involved in both fiber and textile production from Phases 3-6 points to the economic significance of this product and its social value.

1. The Trade in Sheep

The term trade as it is used here references the exchange of sheep between Bronocice and outside traders. There are no written records to support the idea of an annual sheep market involving the trade and exchange of sheep, wool, thread or cloth. However, written records begin to appear in the Bronze Age and continue throughout all ages concerning sheep and their products in many parts of the Old World. Sources include biblical texts, royal texts and tax records covering the medieval period and bills of sales. They often share many common descriptions such as herd size, breeding information, health and disease, movement and management of flocks, volume of wool production, sale of wool, and volume of wool needed to produce textiles. They also mention different breeds of sheep, the kinds of wool they produced, and the uses to which they were put. It is a fact, that knowledge about raising sheep and wool production is ancient. Sheep that failed to breed, to produce quality wool, or that were sick, injured, damaged or old, were killed and eaten. Written sources also reveal that sheep were highly valued and that wool was a source of great wealth and consequently power to elites in larger communities and that it was common for smaller communities to raise sheep in order to supply larger markets. In medieval times written documents from England, the Netherlands and Italy show that wool was sold on contract in advance of production sometimes years in advance (Power 1941). While that may not have been the case during the Neolithic it can be assumed that some form of understanding existed between trading partners.

It is unlikely that middlemen existed during the middle late Neolithic and that trade in livestock occurred between sheep farmers and outside traders. Did sheep traders spend their lives moving back and forth along trade routes without settling down? Or, did they belong to specific communities at one of the route and if so which ones? It must be pointed out that the people who herded sheep to Bronocice each year were specialists who not only the route but also how to successfully feed, water and manage hundreds of animals each sheep.

The XRF data, combined with dental eruption rates and age-at-death profiles indicated that sheep farmers obtained new sheep from the traders on an annual basis. It is presumed that sheep traders obtained woolen cloth in exchange.

An annual market would have drawn together large numbers of people to Bronocice including traders, local shepherds and farmers, weavers, and wool shearers/pluckers. Non-residents would have needed shelter or areas in which to camp, as well as access to food and water. Nothing is known about the existence of inns during the Neolithic but given that long distance trade had already existed for over a millennium throughout in central Europe it is likely they were present. Perhaps they were based on fictive memberships such as clans and lineages. Maybe they were based on extended family relationships in which daughters were married into communities precisely to facilitate the movement of traders across the trade route. On a local level, people coming to Bronocice to acquire sheep may have had extended family with which to stay.

The annual market would have required use of the enclosure. The massive enclosure measuring 4.6 hectares is testament to the presence of an elite household at Bronocice. The construction and maintenance as well as control over access are evidence of that household's power and strength in the community. Enclosing imported sheep was probably not without cost.

The annual market provided an opportunity for people to gather, acquire mates, and celebrate. Large gathering are the key ingredient for celebrations. The event would have begun with the arrival of sheep for trade and exchange as well as people from surrounding settlements who would have brought in their thread/wool for exchange. Weavers would have been their primary market though it begs the question what weavers gave in return, perhaps cloth or perhaps sheep. Unlike the smaller settlement Bronocice had an ever growing number of weavers from 3650 BC until the settlement ceased to exist, a testament to the importance of cloth produced there.

2. Exchange between Local Communities

Changes in sheep management strategies, documented by XRF data and supplemented by mtDNA data indicated the existence of an increasingly complex economy that was dependent on outside importation sheep and their redistribution to regional settlements. The co-occurrence of increasing fiber and textile production artifacts at Bronocice beginning with the rise in sheep imports points to the start of a wool textile industry, probably for export. The need for thread would have been greater than could be supplied by sheep raised at Bronocice. Smaller communities that intensified their sheep rearing efforts were few compared to the majority of settlements which emphasized cattle rearing. Settlements such as Żawarża and Niedźwiedź may have established partnerships with weavers at Bronocice to supply them with wool and/or spun thread. MtDNA data showed that sheep from these settlements were descended from those imported to Bronocice. These settlements they may have benefitted by gaining better access to wool bearing sheep through social ties.

Control and access are two aspects of social interactions at Bronocice. The enclosures at Bronocice provided control over sheep imports. The enclosures themselves are evidence of social hierarchy at the settlement because they indicate control over labor. Trade in sheep probably rested in the hands of a few wealthy households. These households then redistribution sheep to other Funnel Beaker households, most of whom resided in other settlements. Payment for sheep would have been in the form of wool and spun thread. Since money did not exist the agreed value would have been through a barter system. The value of sheep can be considered by considering the age at death profiles. The value of a sheep was equal to its productivity. An older animal represents a longer investment in care and therefore equates with greater value than an animal that was slaughtered as a juvenile or subadult which was consumed within the first or two year of life. The households that controlled the trade and exchange of sheep at Bronocice were most likely the weavers. Beginning in the Bronze Age written documents provide ample evidence that wool was a highly valued commodity as was woolen textiles. Sheep owners were wealthy and as elite members of society had control over production of wool and cloth production, and often at the state level (Barber 1991, McCorriston 1997, Ransborg 2011).

Figure 7.2 summarizes the relative frequencies of local and non-local sheep by site and phase which point to several important economic trends in the Bronocice region that occurred around 3650 BC. First, sheep imports soared at Bronocice, most likely driven by an incipient wool industry. However, Żawarża and Niedźwiedź did not take part in the importation of sheep. Instead they intensified sheep rearing indicating the likelihood that they produced wool for the

Bronocice textile market. Sheep livestock management practices in the Bronocice micro-region evolved over time as a consequence of livestock intensification made possibly by the use of enclosures, breeding practices, livestock importation and environmental transformations. Intensification is a directed effort intended to augment the number of sheep. It is assumed that the need for greater numbers of sheep was related to wool production and the production of textiles for trade. The transformation of Bronocice from a small Funnel Beaker community to one of increasing size, population and economic status in the region is linked to the use of enclosures. Enclosures were necessary as a result of increasing herd size. The changes also indicate an increase in knowledge about trade, breeding practices, care and nurture of livestock. The ability to control the movements of animal in and out of the settlement made it possible to protect livestock from predators, raids, and climate, as well as to house newly arrived herds. Enclosures indicate the type of stockherding practiced at Bronocice was stationary husbandry. In a stationary husbandry system animals go out of the enclosure during the day and return in the evening (Ryder 1983).

Second, sheep importation continued to be important until the settlement ended around 2700 BC even though environmental and social circumstances had changed drastically. Sheep importation therefore was important on many levels. Reproductive issues and health concerns were likely drivers in the importation of new stock animals. But there were also likely social, economic and political reasons as to why the trade in sheep continued. The social relationships between communities, both local and non-local, were maintained because they were important to individuals and families.

Third, the trade in sheep and other livestock was likely managed by a select few at Bronocice who also controlled the use of the enclosure. Smaller settlements like Niedźwiedź and

Żawarża had no obvious signs of enclosures suggesting that they either did not enclose livestock or used simple kraal type corrals or pens which left no trace. Folding serves to contain and protect livestock but it also facilitates the collection of manure for use in fertilizing fields. Certainly the settlement pattern at Żawarża, where the houses were placed around a central common, lends support to this idea.

In addition to sheep, cattle, pigs, goats and dogs were also raised. Livestock grazing requirements may have necessitated a pastoral type management practice. It has been suggested that these smaller settlements may have been winter camps (Kulczyzka-Leciejewiczowa 1999). However, botanical remains from both Niedżwiedż and Żawarża indicate that these communities practiced agriculture. It seems a substantial investment in labor to build permanent houses for a relatively short winter occupation. Perhaps by 3650 BC a division of tasks was already in place in smaller communities, in which animals were herded on a daily basis returning at night while some members of the community engaged in farming.

It is an archaeological bias to assume that any community is made up of able bodied members, a remnant of earlier narrow ideas in which they past was constituted only by men. At any moment a community is composed of multiple age groups as well as individuals in varying states of health. It is likely all of these communities had people who stayed behind even if the majority left. It is also likely that younger people were chosen to be shepherds rather than older ones. Spindle whorls have been found at temporary camps located on sandy soils unfit for agriculture (Kulczyzka-Leciejewiczowa 1999). In these cases it seems likely that women were present and that these camps were not settlements.

D. Conclusions

This dissertation focused on explaining how and why sheep intensification occurred during the mid 4th millennium BC. The period 3650-3100 BC was especially dynamic in southeastern Poland and marked by technological and social changes that contributed to the formation of Bronze Age cultures. As such, the development of a sheep and wool market economy was significant. It offers an explanation as to why Bronocice elites built the enclosures as well as insights into the structure of the market and the accumulation of private wealth in the form livestock.

Neolithic trade and exchange have been documented throughout Europe by tracing the provenience of exotic materials and finished goods made of non-local materials, such as axes, obsidian, amber, metals, and *spondylus* shell artifacts (Bogucki 1988, Bradley and Edmonds 1993, Milisauskas 2011). The success of agricultural practices in generating surpluses on an annual basis is credited with freeing some segments of societies from farming in order that they might engage in other activities on a fulltime basis. In doing so, multiple social transformations occurred some of which include craft and labor specialization, as well as social differentiation based on the accumulation of personal wealth, control over resources, trade secrets, and alliance formation. In southeastern Poland, specialization has been documented in the extraction, production and control over flint mines at villages like Cmielow and other flints mines in the Holy Cross Mountains (Kadrow 2010, Lech and Lech 1984, Podkowińska 1962). Linear Pottery, Lublin-Volhynian, Funnel Beaker and Baden cultural groups, each in turn controlled trade and exchange of lithic commodities.

This study demonstrated that sheep intensification observed southeastern Poland beginning around 3650 BC was achieved by large scale importation of livestock. It also showed that sheep imports continued until ca. 2900 BC. By correlation strontium levels with dental eruption rates and age at death profiles it also revealed that imports occurred at a specific time of year, late May to early June. The results of this analysis suggest that sheep rearing was not a primary occupation at Bronocice. Instead it appears that outlying communities raised sheep and exchanged their wool products at Bronocice. These communities obtained new breeding stock from the market at Bronocice. The relationship between Bronocice and outlying communities such as Żawarża and Niedźwiedż was connected to fiber and textile and production. Though it is unknown what households in Bronocice gave in exchange for wool/thread/textiles it may in fact have been sheep. The production of thread and textiles at Bronocice was great and increased over time. That is seen through the large of number of households involved in spinning and weaving.

The theory that trade and exchange in the Neolithic was limited to elites within larger communities is suggested by elaborated burials in which individuals, usually males, were equipped with valuable objects (). This study suggests that trade and exchange involved many different groups, that these events were schedules and occurred on a much large scale than could have been negotiated by small numbers of elites. The sampling of sheep herds dating from 3800 BC-2700 BC revealed that by 3650 BC a major escalation of livestock trade occurred in southeastern Poland. This annual event likely involved the movement of hundreds, possibly even thousands, of sheep to Bronocice where it is likely that textiles were in turn one of the commodities swapped. The control over all aspects of trade and exchange seems unlikely given the volume of sheep and probably of cattle, pigs and goats as well. Elite control over goods works well on a small scale. But as the scale increases it forcibly requires the ability to maintain control which typically involves brute force. There are no indications of special groups existed that served to force cooperation among the settlements. Instead, it is more likely that elites managed the trade but did not directly control it by organizing when and where trade occurred and exacting some form of payment for access to the enclosures. The XRF data indicated that during the initial surge multiple sources were used to build the local herds. Later, the variability diminished suggesting increasing control and regulation by elites may have achieved through trade agreements. Additionally, the exchange of sheep to outlying communities occurred either during the same period or shortly after the spring market. The annual sheep market was probably linked with social festivities. The market was an event at which people gathered.

The difference between the middle late Neolithic and the early Bronze Age in this region is not the establishment of a market system but the shift to fulltime pastoralism. Wealth accumulation became an investment in livestock. Trade with other regions shifted from production of textiles and other material goods to livestock. The Early Bronze Age cultures which evolved within this region, Corded Ware and Globular Amphora, may have resulted from changing attitudes towards wealth and prestige.

The production of textiles continued unabated until the end of settlement at Bronocice. It has been assumed that environmental degradation and cultural tensions were responsible for the abandonment of the settlement. However, the early Bronze Age saw the appearance of small city states along the Mediterranean in southeastern Europe and larger scale states in southwest Asia. Written sources indicate that textile production was highly regulated and controlled at the state level. It may be that textile production at Bronocice was no longer a viable trade commodity due to competition in other markets.

In conclusion, multiple sources of information reveal the existence of a well regulated and organized market structure dependent in large part on social interactions between different cultural groups and local communities. Mitochondrial DNA and XRF data indicate social relationships between outlying communities and Bronocice were long lasting. Furthermore, they point to an economic system in which an incipient wool and textile industry was supported by social ties between craft specialists and local herders. Last, seasonality data based on sheep dental patterns indicate an annual sheep market occurred during late spring which was controlled and facilitated by the enclosures at Bronocice.

Table 7.1. Simplified chronology in southeastern Poland and surrounding areas.

B.C.	Southeastern Poland	Western Ukraine	Slovakia	Northeast Hungary	Eastern Czech Republic
2700					
	Corded Ware	Pit Grave	Corded Ware	Corded Ware	Corded Ware
	Globular Amphora	Globular Amphora	Globular Amphora		
3100	Funnel Beaker-Baden				
			Baden	Baden	Baden
3800	Funnel Beaker				Funnel Beaker
			Tiszapolgár	Bodrogkerestúr	
			Jordanov, Retz-Bajc		
4200	Lengyel-Polgar				Lengyel-Polgar
		Triploye	Bükk	Tiszapolgár	
5400	Linear Pottery			Tisza	Linear Pottery

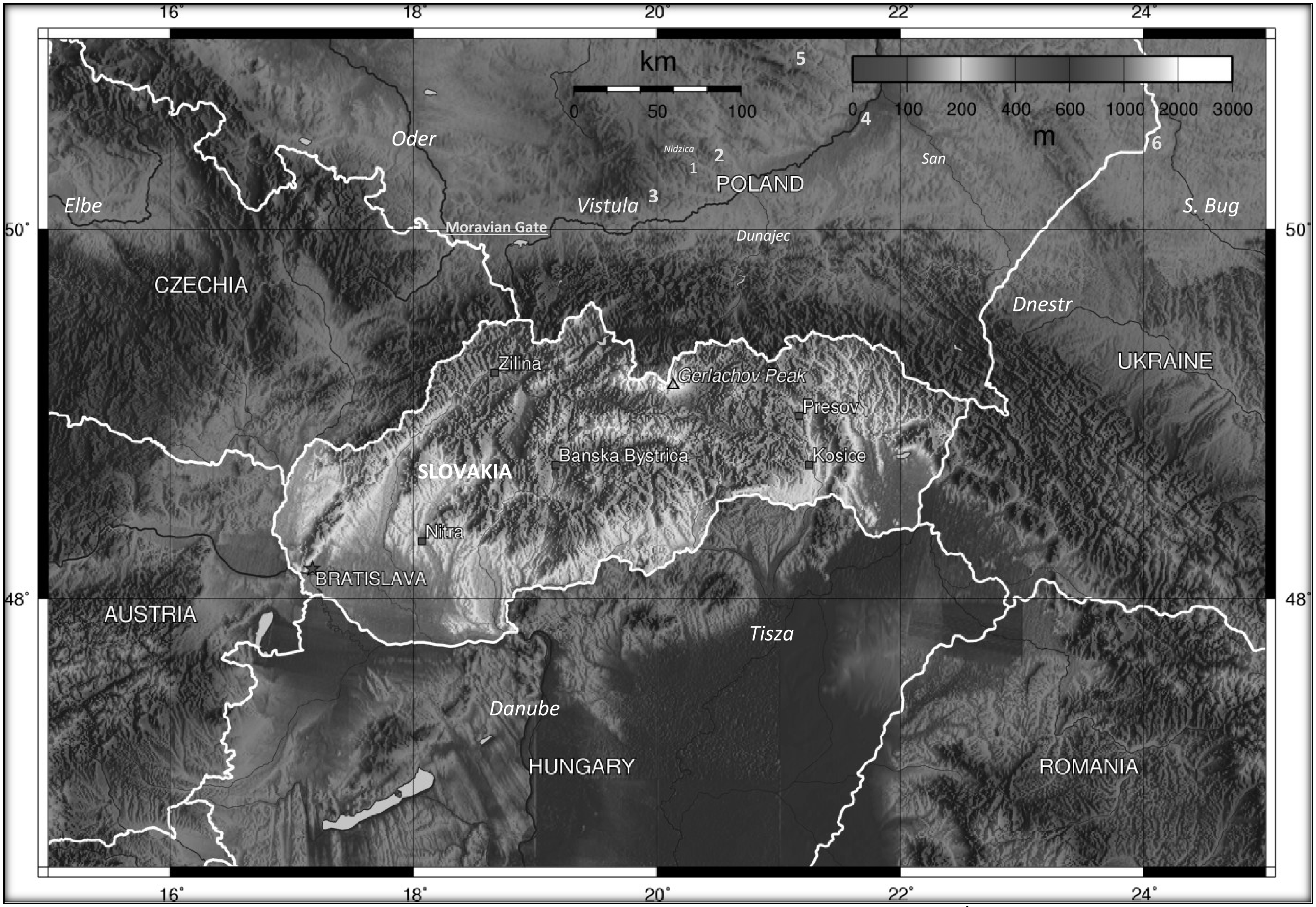


Figure 7.1 . Map of the southeastern interactive area of Central Europe. Key sites: 1 Bronocice, 2 Żawarża, 3 Niedźwiedź, 4 Złota, 5 Ćmielów, 6 Gródek Nadbużny. Source: Modifed from http://en.wikipedia.org/wiki/Slovakia.

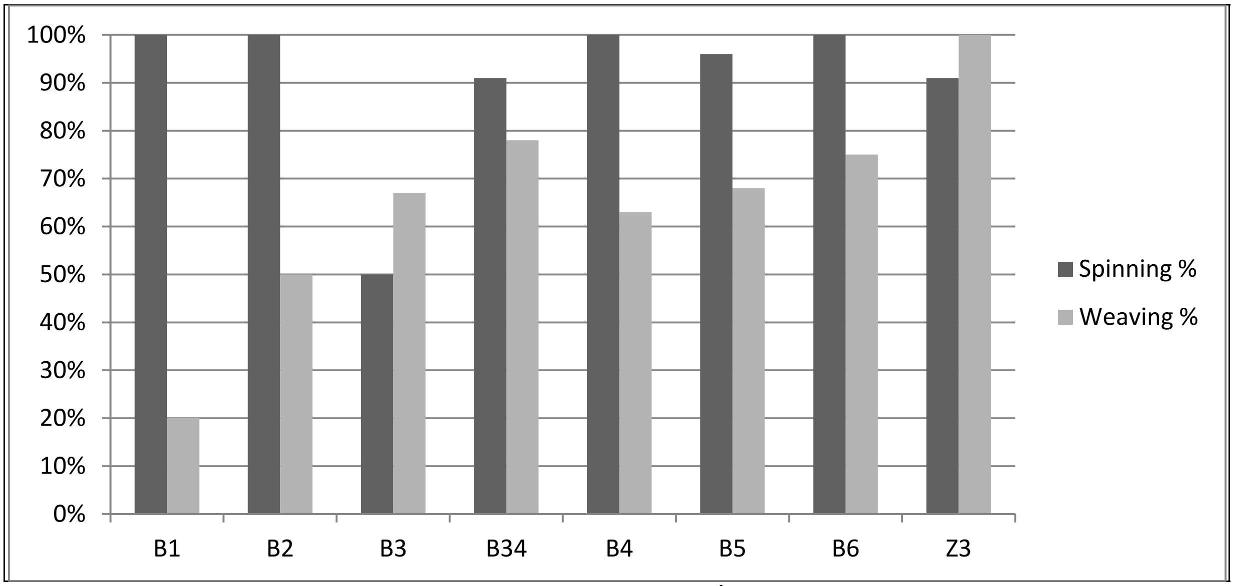


Figure 7.2. Percentage of households at Bronocice and Żawarża with textile and fiber production artifacts engaged in fiber production and textile production.

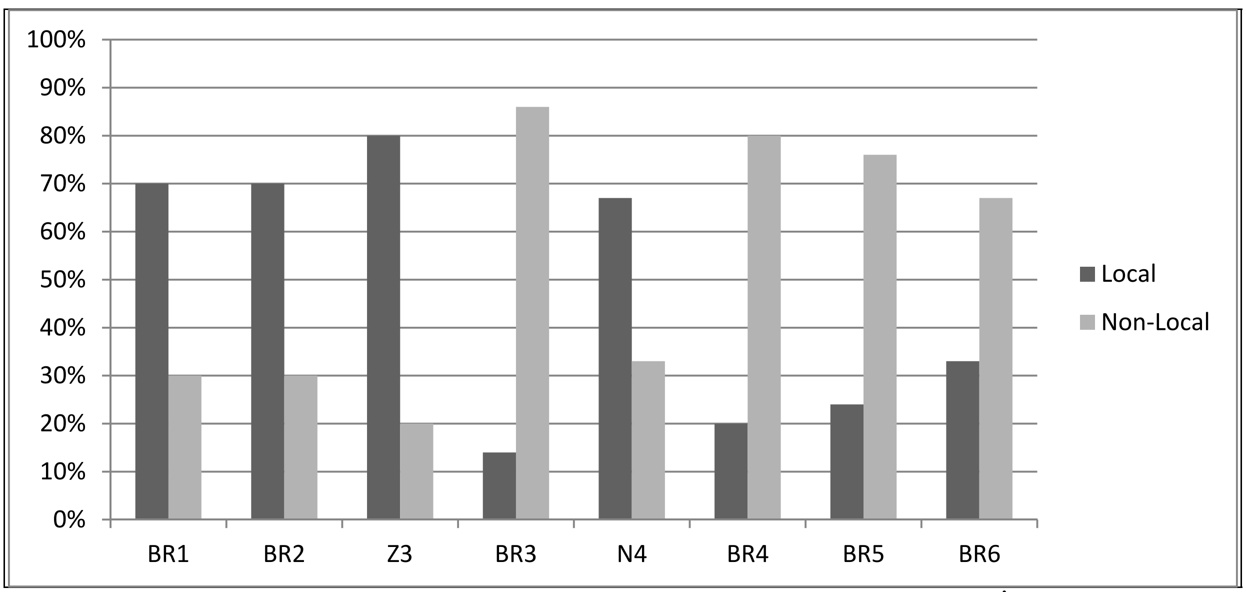


Figure 7.3. Relative frequencies of Local and Non-local sheep at Bronocice, Żawarża and Niedźwiedź.

Epilogue

The main goal of this dissertation was to investigate the surge in sheep remains from Bronocice that began around 3650 BC. The methods used included portable x-ray fluorescence and mitochondrial DNA. This study demonstrated the effectiveness of using this inexpensive method to study livestock mobility patterns of study herd animals. XRF would not be an appropriate method for studying solitary animals. Herd animal have shared pathways and lifeways. For that reason observable patterns are more reliable as they reflect the mobility of a population of animals rather than the idiosyncratic movements of individuals. Combining mtDNA with XRF made it possible to trace descent in closely related animals. The methods enhanced the ability to link social groups together.

Another main goal of this dissertation was to demonstrate the complex nature of animal husbandry practices in order to underline the importance of agents and social interactions within and beyond communities. Archaeological interpretations tend to flatten and generalize the lives and actions of ancient people. Patterning is privileged over variability and yet variability can plays an important role serving to highlight ephemeral traces lost over time. Markets are never mentioned in discussions about Neolithic economic trade practices. The term is too sophisticated for that period and is loaded with expectations about rules regulating not only commodities bought and sold but also concepts of fairness and schedules and value. However, it is evident from this study that an annual market occurred at Bronocice involving sheep and other commodities, likely other livestock as well.

There were of course some disappointments during this study. The first was the overall paucity of mitochondrial DNA data. The effort to generate more results continues as I write and may eventually yield more data and potentially require revision of some of my conclusions. The second was the inability to tie specific households at Bronocice with those at Żawarża and Niedźwiedź. That was due to a couple of factors which included the realization that households at Bronocice were divorced from shepherding and that butchered sheep were obtained from animals culled from imported herds. As such, there was no correlation other than the fact that sheep from all three settlements belonged to the same sheep communities. Regardless, the butchering of sheep in late spring early summer likely signals festivities in which meat would have been important food. The arrival shepherds and probably other traders would have provided opportunities for friend, extended family and business partners to celebrate and catch up on the news of the past year.

Did this study contribute any contribute anything new to the study of middle late Neolithic studies? Yes and no. Milisauskas and Kruk already demonstrated the existence of a low-level two-tier social hierarchy. And the surge in sheep numbers that occurred around 3650 BC was already documented in a number of studies. This study refined those discoveries. By demonstrating the genetic and spatial relationships among the sheep from the selected sites, this study confirmed the economic dominance of Bronocice over the surrounding settlements. It explained that the surge in sheep occurred as a result of importing livestock in large numbers to the region and it supports the hypothesis that textile production was a major trade commodity.

APPENDIX A
List of XRF AND aDNA SAMPLES

Highlighted rows indicate sequenced mtDNA samples. All remaining mtDNA samples either failed to produce DNA or to amplify.

Site	Phase	Individual	Pit/Area	pXRF	Element(s)	mtDNA	Element(s)	Age Group
Bronocice	1	BS11	20-C2	X	M3	-	-	Subadult
		BS12	12-C2	X	M1	-	-	Juvenile
		BS13	12-C2	X	M2, M3	-	-	Adult
		BS14	40-C2	X	M1, M3	-	-	Adult
		BS15	40-C2	X	M2	-	-	Adult
		BS16	17-C2	X	M1, P2	-	-	Adult
		BS17	17-C2	X	M1, M3	-	-	Adult
		BS18	21-C2	X	M1, P4	-	-	Adult
		BS20	80-C1	X	m3, M2	-	-	Subadult
	(Phase 4?)	BS21	5-B6	X	m3, M1	-	-	Juvenile
N=10								
Bronocice	2	BS22	25-C2	X	M1	-	-	Adult
		BS23	25-C2	X	M3	-	-	Adult
		BS24	25-C2	X	M1	-	-	Adult
		BS25	60-C2	X	M1, P4	-	-	Adult
		BS26	60-C2	X	M3	-	-	Subadult
		BS27	29-C2	X	M3	-	-	Adult
		BS28	29-C2	X	m3, M1	-	-	Juvenile
		BS29	31-C2	X	P4	-	-	Adult
		BS30	30-C2	X	M1, P4	-	-	Senior
		BS31	28-C2	X	M1, P4	-	-	Adult
N = 10								
Bronocice	3	B2	33-A1	X	M1, M2	X	M1, M2	Subadult
		B3	33-A1	X	m3, M1	X	m3, M1	Juvenile
		B4	33-A1	X	M1, M2, M3	X	M1, M2	Adult

Site	Phase	Individual	Pit/Area	pXRF	Element(s)	mtDNA	Element(s)	Age Group
Bronocice	3cont.	B5	26-A1	X	M1, P4	X	P4, M2	Senile
		B12	1-A1	X	m1, m2	X	m1, m2, mandible	Juvenile
		B13	1-A1	X	m3, M1	X	m3, M1	Juvenile
		B14	1-A1	X	m3, M1	X	m3, M1	Juvenile
		B15	101-A1	X	m3, M1	X	m3, M1	Juvenile
		B16	101-A1	X	m3	X	m3	Subadult
		B17	101-A1	X	M2	X	M2	Senior
		B24	30-A1	X	P4	X	P4	Adult
		B25	30-A1	X	m1, m3	X	m1, m3	Subadult
		B28	1-A1	-	-	X	Prox. Phalange	-
		B29	89-A1	X	m3, P2	X	m3	Subadult
		B34	38-A1	X	m2, M2	X	Mandible	Subadult
		B35	98-A1	-	-	X	Dist. humerus	-
N = 16								
Bronocice	4	B1	64-A1	X	M1, P4	X	P4, M1	Adult
		B6	21-A1	X	M1, M3	-	M1, M2	Senior
		B23	7-A1	X	M1	-	-	Adult
		B30	64-A1	-	-	X	Scapula	-
		B31	64-A1	-	-	X	Femur	-
		B7	68-A1	-	-	X	Prox. phalange	
		B8	68-A1	-		X	Prox. phalange	
		B9	23-B1	-		X	Hoof	
		B10	23-B1	-		X	Mid Phalange	
		B11	115-A1	-		X	Hoof	
		B18	23-B1	X	m3, M1	X	m3	Subadult
		B19	2-B1	X	m1, m3	X	m3	Subadult
		B20	20-A1	-		X	Mandible	
	.	B21	2-B7	X	m3, M1, P4	X	m3	Subadult
		B22	5-B5	X	M2, P4	X	P4	Adult

Site	Phase	Individual	Pit/Area	pXRF	Element(s)	mtDNA	Element(s)	Age Group
Bronocice	4cont.	B26	5-B5	-	-	X	Mandible	
		B27	5-B5	X	M2, P3	X	P4	Subadult
		B32	102-A1	X	M1	X	M1	Adult
		B33	118-A1	X	m3	X	m3	Subadult
N = 19								
Bronocice	5	BS32	112-A1	X	M1, M3	-	-	Adult
		BS33	9-A2	X	M2, M3	-	-	Adult
		BS34	14-A3	X	m1, m2	-	-	Neonate
		BS35	12-A3	X	m3, M1	-	-	Subadult
		BS36	65-B1	X	m1, M1	-	-	Juvenile
		BS37	97-B1	X	M1, P4	-	-	Adult
		BS38	103-B1	X	M1, P4	-	-	Adult
		BS39	6-B2	X	m3, M2	-	-	Subadult
		BS40	6-B2	X	M1, P4	-	-	Senior
		BS41	10-B6	X	M1, M3	-	-	Senior
		BS42	10-B6	X	m3, M1	-	-	Subadult
		BS43	11-B6	X	m1	-	-	Juvenile
		BS44	6-B7	X	M1, M3	-	-	Adult
		BS45	6-B7	X	M1, M3	-	-	Adult
		BS46	8-B8	X	m3,P4	-	-	Subadult
		BS47	12-B8	X	m3, M2	-	-	Juvenile
		BS48	1-B8	X	m3	-	-	Juvenile
N = 17								
Bronocice	6	BS49	11-A2	X	M1	-	-	Adult
		BS50	70-B1	X	M1, M3	-	-	Adult
		BS51	8-B7	X	m1	-	-	Subadult
		BS52	39-B1	X	M3	-	-	Adult
		BS53	10-B5	X	M2	-	-	Subadult
		BS54	4-B7	X	m1	-	-	Juvenile

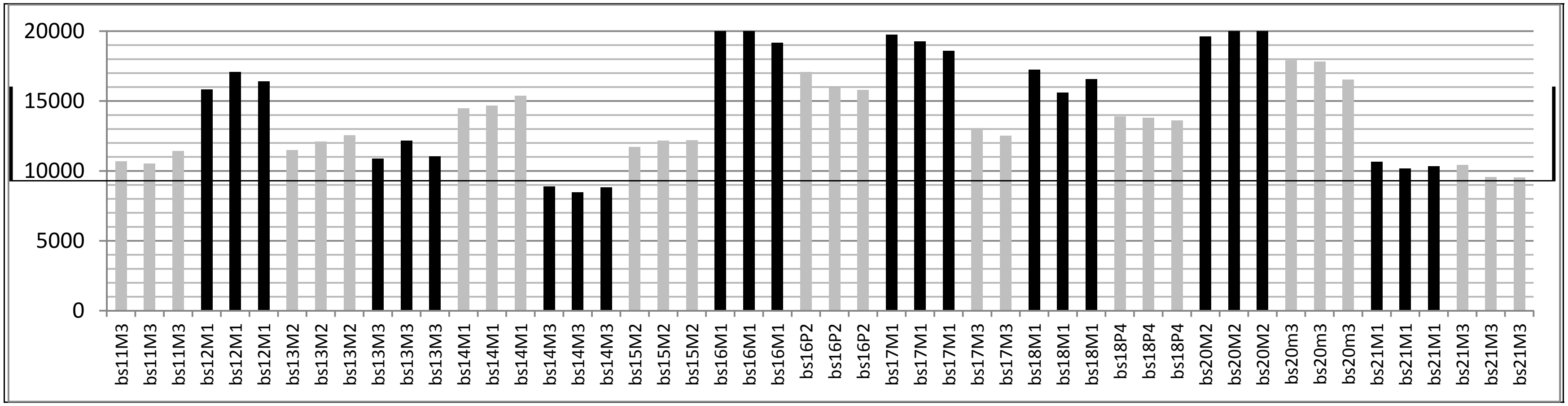
Site	Phase	Individual	Pit/Area	pXRF	Element(s)	mtDNA	Element(s)	Age Group
Bronocice	6cont.	BS55	70-B1	X	M2, M3	-	-	Subadult
		BS56	4-B7	X	m3, M2	-	-	Subadult
		BS57	8-B7	X	M1, P4	-	-	Adult
N = 9								
Zawarża	3	Z1	17	X	m3, M1	X	m3, M1	Subadult
		Z2	“	-	-	X	Dist. humerus	-
		Z3	18	X	m3, M1	X	m3, M1	Subadult
		Z4	31	X	m3, M1, M2	X	m3, M1	Juvenile
		Z5	32	X	m3, M1, M2	X	m3, M1	Adult
		Z6	5	X	m3, M1	X	m3, M1	Subadult
		Z7	5	X	m3, M1, M2	X	m3, M1	Juvenile
		Z8	“	-	-	X	Dist. humerus	-
		Z9	2	-	-	X	Calcaneus	-
		Z11	76	-	-	X	Atlas	-
		Z12	37	X	M1, M2, P4	X	P4, M2	Adult
		Z14	4	X	M1, M2, P4	X	P4, M2	Adult
		Z15	76	-	-	X	Calcaneus	-
		Z16	“	-	-	X	Scapula	-
		Z18	41	-	-	X	Scapula	-
		Z19	76	-	-	X	Scapula	-
		Z20	72	X	M3	X	Ramus, M3	Senior
		Z21	67	-	-	X	Metacarpus	-
		Z22	65	X	M2, M3	X	M2, M3	Senior
		Z23	41	-	-	X	Radius	-
N = 20								
Niedźwiedź	4	N1	2	-	-	X	Dist. Humerus	-
		N2	9	-	-	X	Innominate	-
		N3	7	-	-	X	M1 (split)	-
		N4	12	-	-	X	M3	-

Site	Phase	Individual	Pit/Area	pXRF	Element(s)	mtDNA	Element(s)	Age Group
Niedżwiedż	4	N5	12	-	-	X	Metacarpus	-
		N7	20	X	P3, P4, M3	X	P4	Adult
		N8	29	-	-	X	Scapula	-
		N9	29	X	m3, M2	X	m3	Subadult
		N10	41	-	-	X	Radius	-
		N11	39	-	-	X	M1	-
		N12	53	-	-	X	Prox. Phalange	-
		N13	43	-	-	X	M3	-
		N15	61	X	m3	X	m3	Juvenile
		N16	60,61	-	-	X	Innominate	-
		N17	75	-	-	X	Dist. Humerus	-
		N18	79	X	m1, m3	X	m2	Juvenile
		N19	108	-	-	X	Innominate	-
		N20	67	X	P2, P4	X	P2, P4	Adult
		N21	83	-	-	X	M1	-
		N22	101	X	m1	X	m1	Juvenile
N = 20								

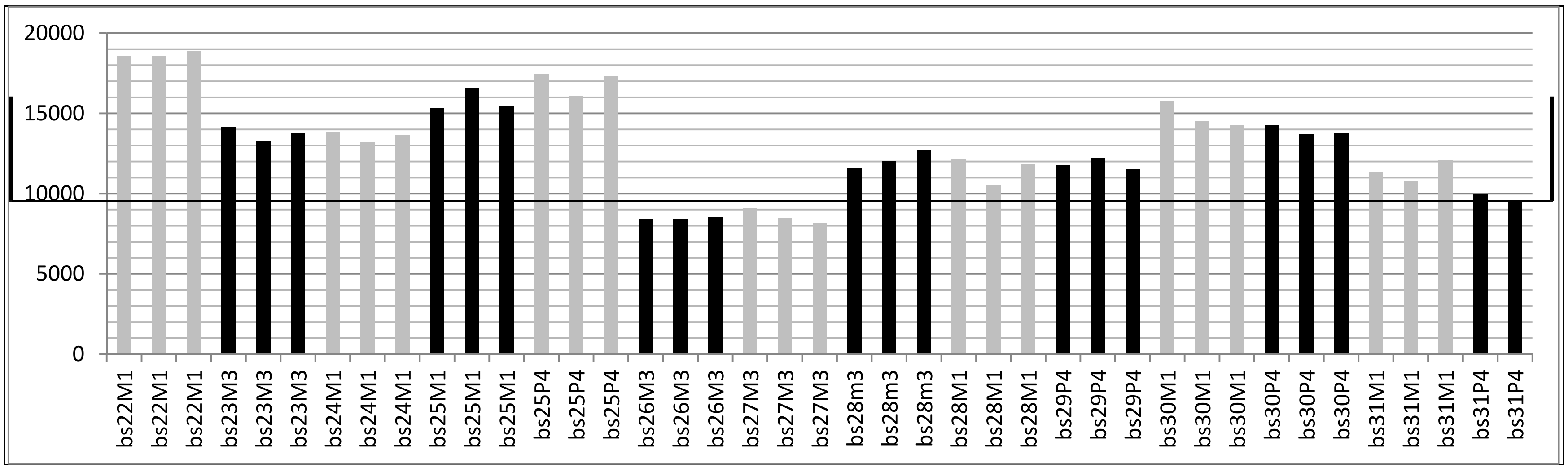
Appendix B
XRF Records

Lingual, buccal and occlusal readings from Bronocice Phases1-6, Żawarża Phase 3 and Niedżwiedż Phase 4.

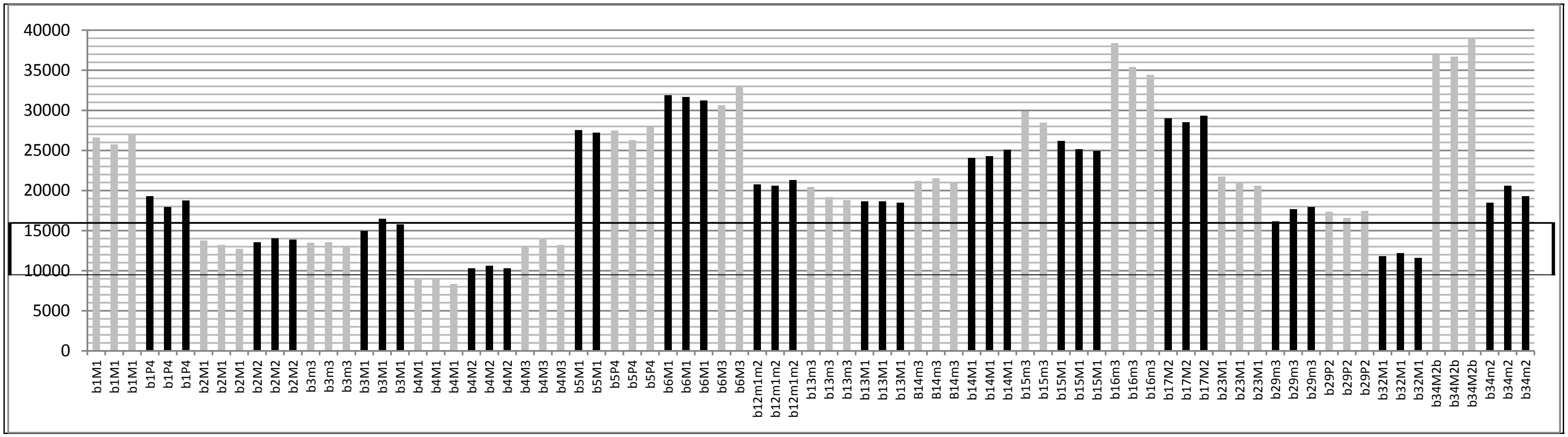
Test Series 1



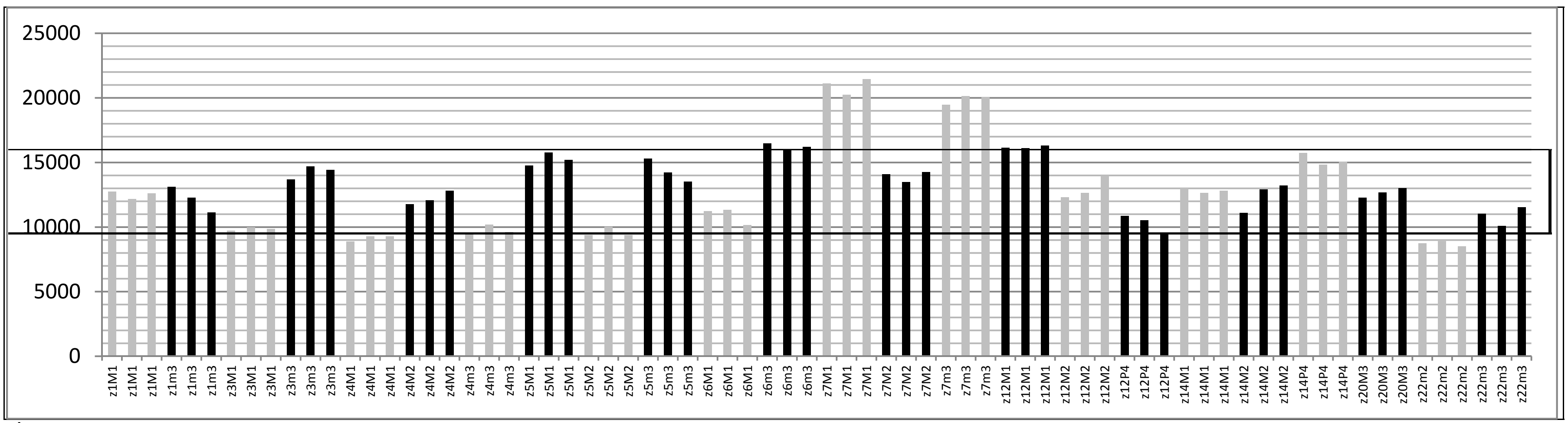
Bronocice Phase 1: Lingual, buccal and occlusal dental enamel readings of individual sheep.



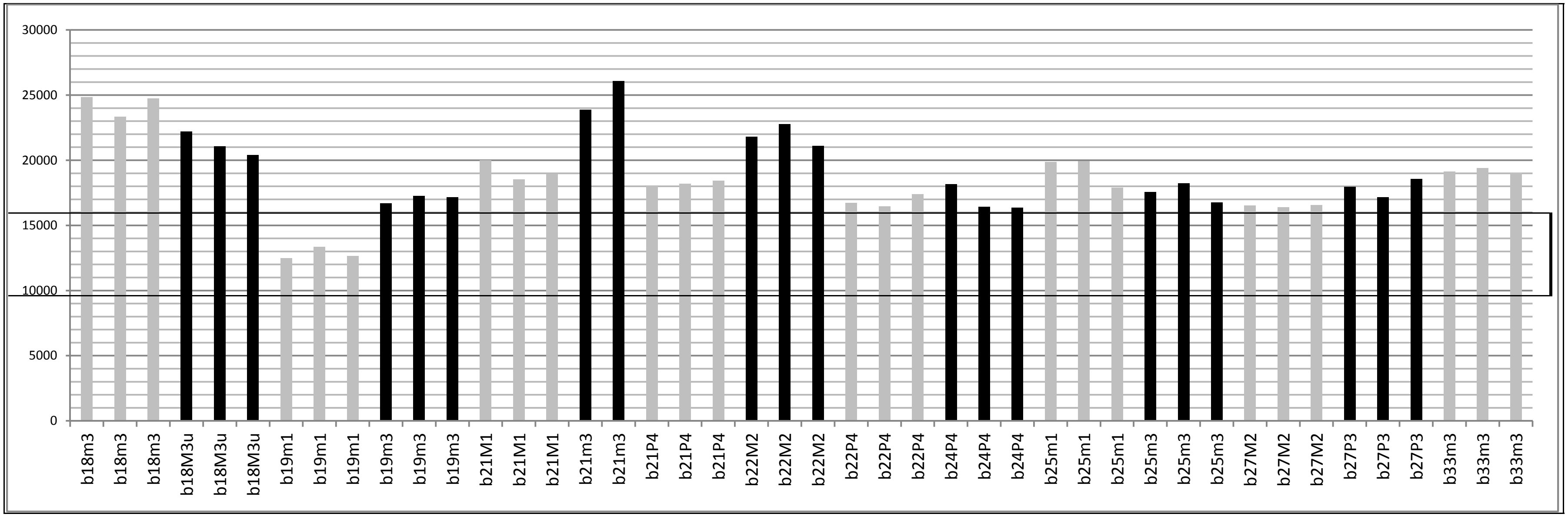
Bronocice Phase 2: Lingual, buccal and occlusal dental enamel readings of individual sheep .



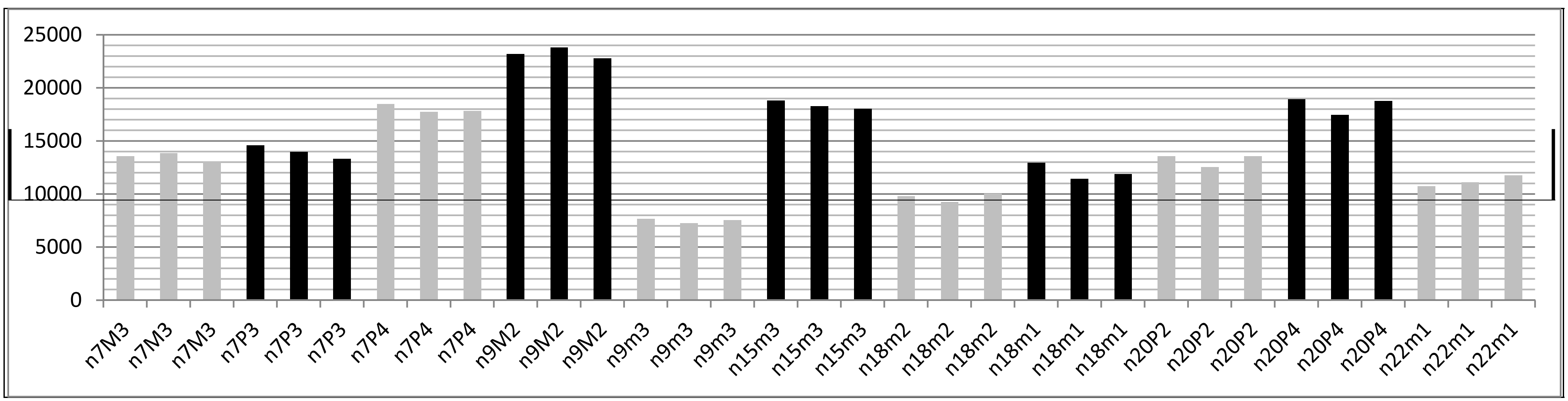
Bronocice Phase 3: Lingual, buccal and occlusal dental enamel readings of individual sheep.



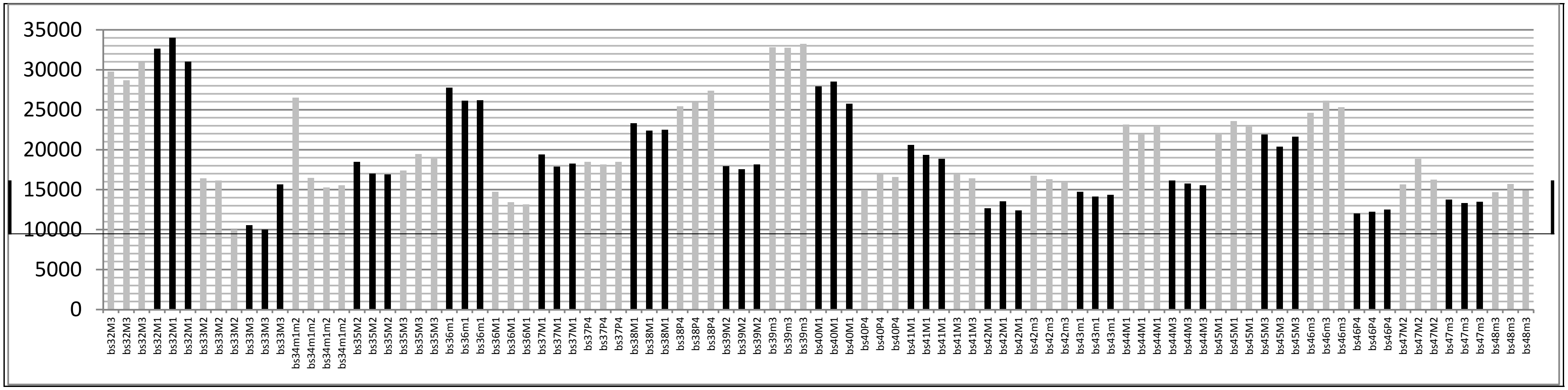
Żawarża Phase 3: Lingual, buccal and occlusal dental enamel readings of individual sheep.



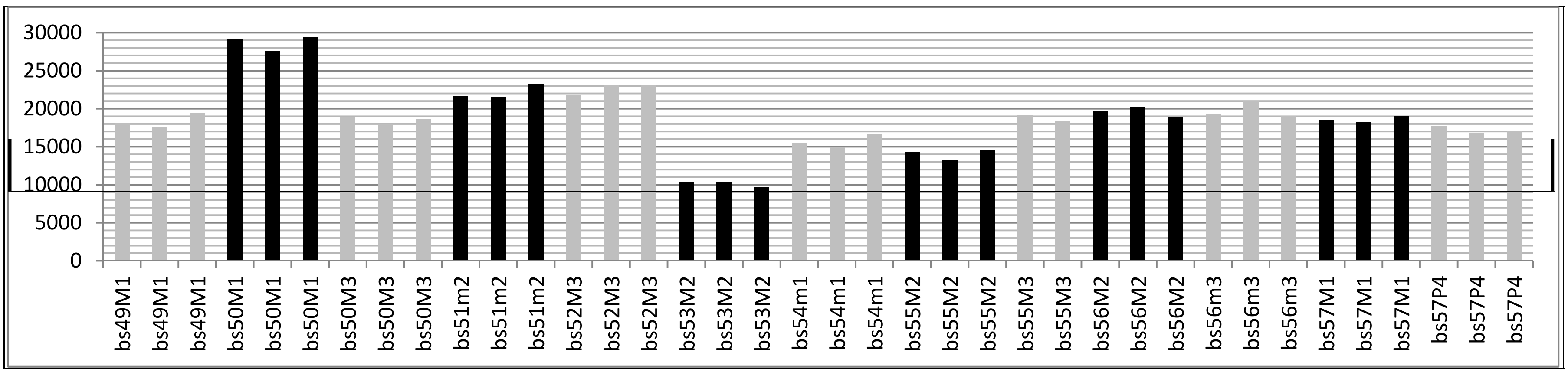
Bronocice Phase 4: Lingual, buccal and occlusal dental enamel readings of individual sheep.



Niedżwiedż Phase 4: Lingual, buccal and occlusal dental enamel readings of individual sheep.



Bronocice Phase 5: Lingual, buccal and occlusal dental enamel readings of individual sheep.



Bronocice Phase 6: Lingual, buccal and occlusal dental enamel readings of individual sheep.

Appendix C

Mitochondrial DNA Methodology

Prepared by Jennifer G. Luedke

A total of 75 faunal specimens were chosen from the sites of Bronocice (N=16 from temporal Phase 3 and N=19 from temporal Phase 4), Zawarża (Phase 3), (warza (N=20 consistent with temporal Phase 3) and Niedźwiedź (N=20 consistent with temporal Phase 4). The samples were collected by the excavators and placed within separate labeled plastic bags and brought to the D. A. Merriwether dedicated ancient DNA laboratory. The samples comprised of the second and third molars from each archaeologically established specimen taken from the same maxilla when available providing a total of 150 total samples. In the absence of an intact tooth, other skeletal elements such as long bones were used.

The samples were prepared for extraction by washing the outer surface of each skeletal element with a 20% bleach solution and subjecting them to a DNA stratalinker. This was done to further address potential handling and site contamination. The interior of each molar was drilled to produce approximately 0.1 g of fine white bone powder under strident sterile positive pressure conditions. Samples were drilled in sets of five and always included an extraction negative control. After drilling, the bone powder was decalcified in 2 ml of 0.5M of EDTA solution at room temperature for a minimum of 4 days at slow rotation. After rotation, 500 µl of Proteinase K and 1.5 ml of dH2O were added. The samples were then incubated at 40 °C for two days while rotating at approximately 25 rpm (Lee *et al.* 2009). The DNA samples were then extracted utilizing a modified version of the Yang *et al.* (1998) protocol. Centricon® Ultracel YM-30 (Millipore, Billerica MA) centrifugal concentration columns were used to reduce 2 ml of the Proteinase K and sample solution to approximately 30 µl by spinning at 5100 rpm for 30 minutes. After reduction the samples were transferred to the QIAamp Spin Column and 750 µl of Qiagen PB buffer was added. Columns were centrifuged at 12,500 rpm for 1 minute. The samples were then washed with 750 µl of Qiagen PE buffer and centrifuged again at 12,500 rpm for 1 minute. The columns were then transferred to 2 ml screw top storage tubes and the DNA finally eluted with 200 µl of Tris-EDTA buffer with a pH of 8, centrifuged at 6,000 rpm for 1 minute. The final products were then stored at -80°C until PCR was performed. Extractions were completed twice for every specimen, once per tooth.

Efforts to amplify the extracts by PCR (Saiki *et al.* 1988) with Platinum Taq Polymerase (Invitrogen) were accomplished using five primer sets targeting the sheep mitochondrial region between positions 15496 through 00015 (see Chart 1.1) based upon Cai *et al.* (2007). Each reaction contained 1 µl of extracted sample, 1.5 µl of 25 µM $MgSO_4$, 2.5 µl of 10X PCR buffer, 0.25 µl of 20 µM concentration of each primer, 0.5 µl of 10 µM dNTPs, 17.87 µl of dH_2O and 0.13 µl of Taq for a total reaction mixture of 25 µl. A touchdown PCR (-0.1) was completed with the conditions set at 94ºC denaturing temperature for 10 sec. followed by each specified annealing temperature for each primer for 45 sec. and an elongation temperature of 72ºC for 1 min. This amplification was verified by electrophoresis using 1% ethidium bromide stained agarose gels.

Samples that proved difficult to amplify with 1 µl of extraction product were assumed to lack enough template to amplify and were attempted again at 3 µl and 6 µl. If this failed to yield results the samples were assumed to be inhibited. This was tested by a PCR reaction containing a positive control that was added to each extraction. If the sample was inhibited by soil conditions, the positive control would also be affected yielding no PCR results. However, if the results were positive, the extraction was deemed a failure since there was nothing in the extraction to inhibit the positive from reacting. These samples were eliminated from the subsequent processing. In the cases where nothing amplified, indicating inhibition, the samples were then subjected to a series of dilutions in order to dilute the inhibiting substances so that the reaction could potentially amplify the existing DNA. The samples were serially diluted to the following concentrations: 1:5, 1:10, 1:20, 1:50, 1:100, 1:150, 1:200, and 1:360. Even with dilutions samples often refused to amplify for all or some of the primer sets and were withdrawn from the following procedures.

Due to time constraints and the lengthy methodology not all extracts went through this entire process. Some were tested for only one primer set at full concentration of 1 μl (these are noted on in the Bronocice Sheep Sample Progress Table at the end of this section) and if no positive results were recorded they were removed from the study. Further work is needed to submit these samples to inhibition testing, dilution and PCR amplification processes.

Successfully amplified samples were then purified and prepared for sequencing by size exclusion filtration with a Millipore plate that retains DNA with a molecular weight greater than 100,000 to remove contaminates but retaining PCR product greater than 100 bp (Millipore, Billerica MA). The samples were then confirmed on a 2% ethidium bromide stained agarose gel to ensure purity and presence. The samples were prepared and sequenced in the Merriwether lab under the standard lab protocols described in Merriwether et al. (1999). Therefore one μl of this purified product was used in a cycle sequencing reaction with 1.5 μl of Big Dye solution from the Dydeoxy™ terminator cycle sequencing kit (Applied Biosystems) along with 1 μl of dH_2O and primers. The amount of primer used was 0.1 μl of a 20 μM solution of each, using all previous primer sequences mentioned for PCR to ensure adequate sequencing coverage (Refer to

Chart 1.1 for primer sequences). This was then direct cycle sequenced using an ABI 3730XL automated sequencer in the Koji Lum Laboratory at Binghamton University (Applied Biosystems, Inc.).

Sequences were analyzed with Sequencer 4.10.1 (Gene Codes, Inc.). They were then aligned with MUSCLE and Neighbor-joining trees were constructed using MEGA 5.1 (Tamura *et al*. 2011). Populations statistics were calculated in MEGA 5.1 (Tamura *et al.* 2011) and Arlequin 3.5 (Excoffier *et al*. 2010). Median-joining networks were constructed with the Network 4.1.1.1 program (http://www.fluxus-engineering.com).

Chart 1.1 Primer Conditions

Primer	Primer Sequence (5'-3')	Annealing Temperature (°C)
15496F	TTAAACTTGCTAAAACTCCCA	53
15660R	AATACTATGTACTCGTTTGCA	
15944F	GCCAGCCACCATGAATATTGT	58
16119R	GAGCGAGAAGAGGGATCCT	
16068F	CCATGCCGCGTGAAACCAAC	61
16275R	ACAGTTATGTTAGGCATGGGCT	
16227F	GACATCTCGATGGACTAATGAC	61
16444R	GCAGATATGTCCTGTGACCATT	
16399F	GGTAAGCATGGGCATAATAT	53
00015R	TTAAGCTACATTAACTATGCG	

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Bronocice Sheep Sample Progress Table. A (+) denotes successful completion of a process while a (-) indicates negative results. The numbers in parentheses show the number of attempts for each reaction. A blank space indicates a reaction that has not yet been attempted while an X shows samples that repeatedly were negative and have been removed from the dataset.

			Amplification Reactions						
Sample	**Extraction 1**	**Extraction 2**	**15496F/ 15660R**	**15944F/ 16119R**	**16068F/ 16275R**	**16227F/ 16444R**	**16399F/ 00015R**	**Purified**	**Sequenced**
B1	+	+	+	+	+	+	+	+	+
B2	+	+	+	+	- (5)	- (4)	- (4)	+	+
B3	+	+	+	+	+	- (4)	- (4)	+	+
B4	+	+	+	+	+	- (4)	- (4)	+	+
B5	+	+	+	+	+	+	+	+	+
B6	+	+	+	+	+	+	+	+	+
B12	+	+	- (3)	- (3)	- (3)	X	X		
B13	+	+	+	- (3)	+	+	+	+	+
B14	+	+	+	+	+	+	+	+	+
B15	+	+	+	- (3)	+	+	+	+	+
B16	+	+	+	- (3)	- (3)	- (3)	+	+	+
B17	+	+	+	+	+	- (3)	- (3)	+	+
B28	+	+	- (3)	- (3)	- (3)	X	X		
B29	+	+	- (3)	- (3)	- (3)	- (3)	X		
B30	+	+	- (3)	+	- (3)	- (3)	- (3)	+	+
B31	+	+	- (5)	- (5)	- (5)	- (5)	- (5)		
B34	+	+	- (5)	- (5)	- (5)	- (5)	- (5)		
B35	+	+	- (5)	- (5)	- (5)	- (5)	- (5)		
B4.7	+	+	- (5)	- (5)	- (5)	- (5)	- (5)		
B4.8	+	+	- (5)	- (5)	- (5)	- (5)	- (5)		
B4.9	+	+	- (3)	- (3)	- (3)	X	X		
B4.10	+	+	- (3)	- (3)	- (3)	X	X		
B4.11	+	+	- (3)	- (3)	- (3)	X	X		

			Amplification Reactions						
Sample	**Extraction 1**	**Extraction 2**	**15496F/ 15660R**	**15944F/ 16119R**	**16068F/ 16275R**	**16227F/ 16444R**	**16399F/ 00015R**	**Purified**	**Sequenced**
B4.18	+	+	+	- (3)	+	+	- (4)	+	+
B4.19	+	+	+	- (3)	+	+	- (4)	+	+
B4.20	+	+	+	- (3)	+	- (4)	- (4)	+	+
B4.21	+	+	+	- (3)	- (3)	+	+	+	+
B4.22	+	+	- (3)	- (3)	- (3)	- (3)	+	+	+
B4.23	+	+	- (3)	- (3)	- (3)	X	X		
B4.24	+	+	+	+	- (3)	- (3)	- (3)	+	+
B4.25	+	+	- (3)	+	- (3)	- (3)	- (3)	+	+
B4.26	+	+	- (3)	+	- (3)	+	- (3)	+	+
B4.27	+	+	- (1)						
B4.32	+	+	- (1)						
B4.33	+	+	- (1)						
N1	+	+	- (4)	- (4)	+	- (4)	- (4)	+	+
N2	+	+	- (3)	- (3)	- (3)	X	X		
N3	+	+	- (3)	- (3)	- (3)	X	X		
N4	+	+	+	- (3)	+	+	- (3)	+	+
N5	+	+	- (3)	- (3)	- (3)	X	X		
N7	+	+	- (3)	- (3)	- (3)	X	X		
N8	+	+	- (3)	- (3)	- (3)	X	X		
N9	+	+	- (1)						
N10	+	+	+	+	+	+	+	+	+
N11	+	+	- (3)	- (3)	- (3)	X	X		
N12	+	+	- (3)	- (3)	- (3)	X	X		
N13	+	+	+	- (3)	+	+	- (3)	+	+
N15	+	+	- (3)	- (3)	- (3)	X	X		
N16	+	+	- (3)	- (3)	- (3)	X	X		

			Amplification Reactions						
Sample	Extraction 1	Extraction 2	15496F/ 15660R	15944F/ 16119R	16068F/ 16275R	16227F/ 16444R	16399F/ 00015R	Purified	Sequenced
N17	+	+	- (3)	- (3)	- (3)	X	X		
N18	+	+	+	+	+	+	+	+	+
N19	+	+	+	+	+	+	+	+	+
N20	+	+	+	+	+	- (3)	- (3)	+	+
N21	+	+	- (3)	- (3)	- (3)	X	X		
N22	+	+	- (3)	- (3)	- (3)	X	X		
Z1	+	+	- (3)	- (3)	- (3)	X	X		
Z2	+	+	- (2)	- (2)	- (2)	X	X		
Z3	+	+	- (3)	- (3)	- (3)	X	X		
Z4	+	+	- (3)	- (3)	- (3)	X	X		
Z5	+	+	- (3)	- (3)	- (3)	X	X		
Z6	+	+	- (3)	+	+	- (3)	- (3)	+	+
Z7	+	+	- (1)						
Z8	+	+	+	+	+	+	+	+	+
Z9	+	+	+	- (3)	- (3)	+	- (3)	+	+
Z11	+	+	- (3)	- (3)	- (3)	X	X		
Z12	+	+	- (1)	+	- (3)	- (3)	- (3)	+	+
Z14	+	+	- (1)						
Z15	+	+	+	+	+	- (4)	- (4)	+	+
Z16	+	+	- (4)	- (4)	+	+	- (4)	+	+
Z18	+	+	- (1)						
Z19	+	+	- (1)						
Z20	+	+	- (1)						
Z21	+	+	- (1)						
Z22	+	+	- (1)						
Z23	+	+	- (1)						

Appendix D

The report from the Molecular Lab at Binghamton University is reproduced in its entirety.

Mitochondrial DNA Report

By Jennifer Luedke MA, ABD

Binghamton University

a. Mitochondrial DNA Methodology

A total of 75 faunal sheep were chosen from the sites of Bronocice, Zawarża and Niedzwiedz (Appendix A). These samples were retrieved from storage facility of the Polish Academy of Sciences and shipped to the State University at Buffalo. They were placed within separate labeled plastic bags and brought to the D. A. Merriwether dedicated ancient DNA laboratory. The samples comprised a mix of dental specimens, generally molars, as well as postcranial elements providing a total of 150 total samples.

The samples were prepared for extraction by washing the outer surface of each skeletal element with a 20% bleach solution and subjecting them to a DNA stratalinker. This was done to further address potential handling and site contamination. The interior of each molar was drilled to produce approximately 0.1 g of fine white bone powder under strident sterile positive pressure conditions. Samples were drilled in sets of five and always included an extraction negative control. After drilling, the bone powder was decalcified in 2 ml of 0.5M of EDTA solution at room temperature for a minimum of 4 days at slow rotation. After rotation, 500 µl of Proteinase K and 1.5 ml of dH2O were added. The samples were then incubated at 40 °C for two days while rotating at approximately 25 rpm (Lee et al 2009). The DNA samples were then extracted utilizing a modified version of the Yang et al (1998) protocol. Centricon® Ultracel YM-30 (Millipore, Billerica MA) centrifugal concentration columns were used to reduce 2 ml of the Proteinase K and sample solution to approximately 30 µl by spinning at 5100 rpm for 30 minutes. After reduction the samples were transferred to the QIAamp Spin Column and 750 µl of Qiagen PB buffer was added. Columns were centrifuged at 12,500 rpm for 1 minute. The samples were then washed with 750 µl of Qiagen PE buffer and centrifuged again at 12,500 rpm for 1 minute. The columns were then transferred to 2 ml screw top storage tubes and the DNA finally eluted with 200 µl of Tris-EDTA buffer with a pH of 8, centrifuged at 6,000 rpm for 1 minute. The final products were then stored at -80°C until PCR was performed. Extractions were completed twice for every specimen, once per tooth.

Efforts to amplify the extracts by PCR (Saiki et al 1988) with Platinum Taq Polymerase (Invitrogen) were accomplished using five primer sets targeting the sheep mitochondrial region between positions 15496 through 00015 (see Chart 1.1) based upon Cai et al (2007). Each reaction contained 1 µl of extracted sample, 1.5 µl of 25 µM $MgSO_4$, 2.5 µl of 10X PCR buffer, 0.25 µl of 20 µM concentration of each primer, 0.5 µl of 10 µM dNTPs, 17.87 µl of dH_2O and 0.13 µl of Taq for a total reaction mixture of 25 µl. A touchdown PCR (-0.1) was completed with the conditions set at 94ºC denaturing temperature for 10 sec. followed by each specified annealing temperature for each primer for 45 sec. and an elongation temperature of 72ºC for 1 min. This amplification was verified by electrophoresis using 1% ethidium bromide stained agarose gels.

Samples that proved difficult to amplify with 1 µl of extraction product were assumed to lack enough template to amplify and were attempted again at 3 µl and 6 µl. If this failed to yield results the samples were assumed to be inhibited. This was tested by a PCR reaction containing a positive control that was added to each extraction. If the sample was inhibited by soil conditions, the positive control would also be affected yielding no PCR results. However, if the results were positive, the extraction was deemed a failure since there was nothing in the extraction to inhibit the positive from reacting. These samples were eliminated from the subsequent processing. In the cases where nothing amplified, indicating inhibition, the samples were then subjected to a series of dilutions in order to dilute the inhibiting substances so that the reaction could potentially amplify the existing DNA. The samples were serially diluted to the following concentrations: 1:5, 1:10, 1:20, 1:50, 1:100, 1:150, 1:200, and 1:360. Even with dilutions samples often refused to amplify for all or some of the primer sets and were withdrawn from the following procedures.

Due to time constraints and the lengthy methodology not all extracts went through this entire process. Some were tested for only one primer set at full concentration of 1 µl (these are noted on in the Bronocice Sheep Sample Progress Table at the end of this section) and if no positive results were recorded they were removed from the study. Further work is needed to submit these samples to inhibition testing, dilution and PCR amplification processes.

Chart 1. Primer Conditions

Primer	Primer Sequence (5'-3')	Annealing Temperature (°C)
15496F	TTAAACTTGCTAAAACTCCCA	53
15660R	AATACTATGTACTCGTTTGCA	
15944F	GCCAGCCACCATGAATATTGT	58
16119R	GAGCGAGAAGAGGGATCCT	
16068F	CCATGCCGCGTGAAACCAAC	61
16275R	ACAGTTATGTTAGGCATGGGCT	
16227F	GACATCTCGATGGACTAATGAC	61
16444R	GCAGATATGTCCTGTGACCATT	
16399F	GGTAAGCATGGGCATAATAT	53
00015R	TTAAGCTACATTAACTATGCG	

Successfully amplified samples were then purified and prepared for sequencing by size exclusion filtration with a Millipore plate that retains DNA with a molecular weight greater than

100,000 to remove contaminates but retaining PCR product greater than 100 bp (Millipore, Billerica MA). The samples were then confirmed on a 2% ethidium bromide stained agarose gel to ensure purity and presence. The samples were prepared and sequenced in the Merriwether lab under the standard lab protocols described in Merriwether et al (1999). Therefore one µl of this purified product was used in a cycle sequencing reaction with 1.5 µl of Big Dye solution from the Dydeoxy™ terminator cycle sequencing kit (Applied Biosystems) along with 1 µl of dH_2O and primers. The amount of primer used was 0.1 µl of a 20 µM solution of each, using all previous primer sequences mentioned for PCR to ensure adequate sequencing coverage (Refer to Chart 1.1 for primer sequences). This was then direct cycle sequenced using an ABI 3730XL automated sequencer in the Koji Lum Laboratory at Binghamton University (Applied Biosystems, Inc.).

Sequences were analyzed with Sequencer 4.10.1 (Gene Codes, Inc.). They were then aligned with MUSCLE and Neighbor-joining trees were constructed using MEGA 5.1 (Tamura et al 2011). Population statistics were calculated in MEGA 5.1 (Tamura et al 2011) and Arlequin 3.5 (Excoffier et al 2010). Median-joining networks were constructed with the Network 4.1.1.1 program (http://www.fluxus-engineering.com). Sequences may be found in Appendix C.

b. Mitochondrial DNA Results

From the initial 150 extractions, 41 to date have successfully produced amplifiable product (a success rate of approximately 26%). All sequences obtained from these products are provided in FASTA format at the end of this report. Of these products, 21 samples (representing 20 individuals) were successfully sequenced for positions 16068 through 16275. In order to have the greatest number of representatives from each site only the products from positions 16068-16275 were used in the final analysis. Efforts to amplify further samples and regions are ongoing and will provide improved data resolution in the future.

i. Analysis of the Experimental Population

A polymorphic sites table was constructed showing the base pair changes of each of the successful 21 experimental samples representing 20 individuals (Table 5). These changes appear to be consistent with a European origin as expected (Cai et al 2007). Individuals that share the exact same sequence, which indicates a direct familial relationship, are combined within the table with population sizes (N) from each site indicated on the left. *Samples B4.18 and B4.18.2 are from the same individual.* They appear to be identical and therefore verify the ancient sequence results.

Table 5. Polymorphic sites table of samples for positions 16068-16275. Brono 3 = Bronocice Phase 3, Z = Zawarża (Phase 3), Brono 4 = Bronocice Phase 4, and N = Niedzwiedz (Phase 4).

																					N per site			
Sample	16068	16069	16096	16097	16098	16101	16118	16130	16132	16133	16136	16138	16161	16165	16185	16207	16214	16217	16244	16245	Brono 3	Z	Brono 4	N
REF*	C	C	C	A	G	A	C	A	C	T	G	G	A	G	G	C	T	C	A	T				
B1, B15.2, B4.19.2	.	.	.	.	.	.	T	G	.	.	.	.	.	.	.	.	.	.	.	.	2		1	
B3	.	.	.	.	.	.	T	.	.	.	A	A	.	.	.	.	.	.	G	.	1			
B5, B17, B4.7, B4.9, B4.21.2, Z8, Z15, Z16, N18, N10, N19	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	3	3
B13.2	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	T	.	.	1			
B4.18, B4.18.2	.	.	.	G	A	.	T	G	.	.	.	A	.	.	A	.	.	.	.	.			2	
N4	.	.	T	G	.	G	T	.	T	C	.	.	T	A	.	.	.	T	.	.				1
N13	.	.	T	G	.	G	T	.	.	C	.	.	T	A	.	T	C	T	.	.				1
N1	T	T	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.				1

*Ovis aries reference sequence Genbank AF010406 (Hiendleder *et al.* 1998).

A bootstrapped Neighbor-joining tree (Figure 15) was constructed of the 21 samples containing both the reference sequence (Genbank AF010406) (Hiendleder et al 1998) as well as a *Capra hircus* (goat) sequence obtained from Genbank as the out group (Tamura 2011). One thousand replicates were analyzed and the percentage of how many times each taxa was found to branch together is shown next to the branches. Within the tree two samples appear to be more closely related to the out group goat. This indicates that the zooarchaeological samples were misidentified as sheep, a common problem due to the similarity in size and skeletal structure between goats and sheep. The bootstrapping values are relatively low due to the short sequence length making it difficult to discern a clearer structure within the tree.

The genetic distance between each of the 20 individuals was determined using the Maximum Composite Likelihood model (Tamura 2004) conducted in MEGA 5 (Tamura 2011). The aligned sequences were placed into a matrix of pairwise differences or distances between each other (Table 6). In other words each sequence is given a distance between itself and every other sequence within the data set based upon the number of nucleotide basepair differences between them. All positions that contained missing data or gaps were eliminated from the analysis. Those that are directly related are highlighted in blue and substantiate the previous polymorphic sites Table 5.

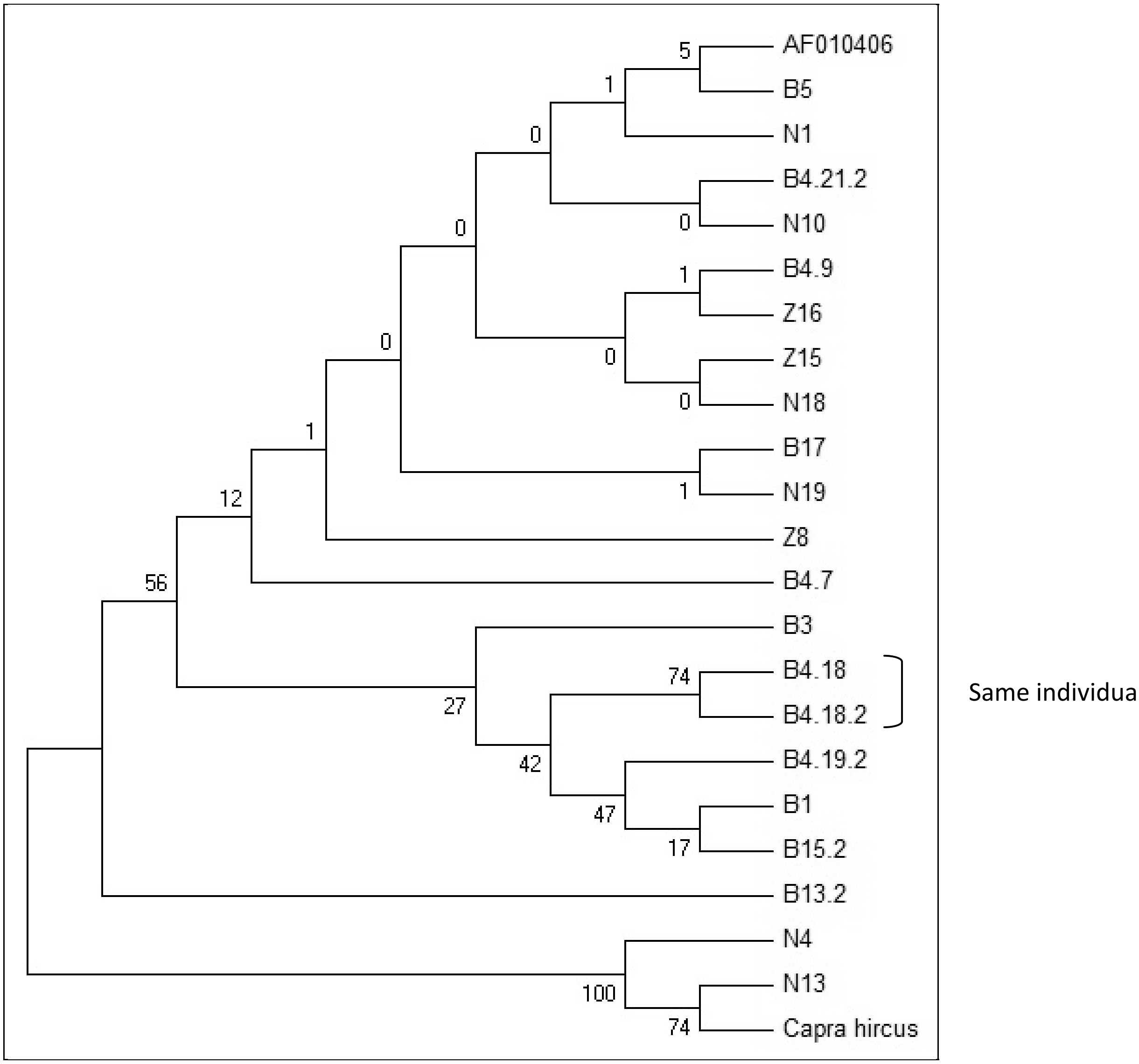

Figure 15. Bootstrapped consensus Neighbor Joining Tree (1,000 replicates).

B1	0.000																				
B3	0.021	0.000																			
B5	0.005	0.016	0.000																		
B17	0.005	0.016	0.000	0.000																	
B13.2	0.011	0.021	0.005	0.005	0.000																
B15.2	0.000	0.021	0.005	0.005	0.011	0.000															
B4.7	0.005	0.016	0.000	0.000	0.005	0.005	0.000														
B4.9	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000													
B4.18	0.021	0.032	0.027	0.027	0.032	0.021	0.027	0.027	0.000												
B4.18.2	0.021	0.032	0.016	0.016	0.021	0.021	0.016	0.016	0.021	0.000											
B4.19.2	0.000	0.021	0.005	0.005	0.011	0.000	0.005	0.005	0.021	0.021	0.000										
B4.21.2	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000									
Z8	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000								
Z15	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000							
Z16	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000						
N4	0.062	0.074	0.056	0.056	0.050	0.062	0.056	0.056	0.074	0.062	0.062	0.056	0.056	0.056	0.056	0.000					
N13	0.068	0.080	0.062	0.062	0.056	0.068	0.062	0.062	0.080	0.069	0.068	0.062	0.062	0.062	0.062	0.016	0.000				
N18	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000			
N1	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000		
N10	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000	0.000	
N19	0.005	0.016	0.000	0.000	0.005	0.005	0.000	0.000	0.027	0.016	0.005	0.000	0.000	0.000	0.000	0.056	0.062	0.000	0.000	0.000	0.000

Table 6. Pairwise Differences calculated between each individual sample for primer set 16068F/16275R (Tamura 2004)

Since samples N4 and N13 appear to be more closely related to goat (*Capra hircus*) they were eliminated from the population statistical calculations. If they had been included they would have created a false impression of the genetic distance between the site of Niedzwiedz and the other sites. For statistical analysis in MEGA5, the genetic data was grouped according to each site and time period, providing four distinct populations within the statistical analysis (Tamura 2011). When the between group mean distance was calculated (see Table 7) it depicts a greater genetic distance between the two time phases of Bronocice (see highlighted value) than it does between this site and any other. The amount of genetic distance calculated between Niedzwiedz and Zawarża appears to be zero denoting a direct genetic relationship between the sheep at these sites. While they are equally distant from Bronocice they date to different phases. The genetic distance between them is small, which is a clear indicator that local herders crossbred their sheep, perhaps sharing rams or exchanging ewes.

Table 7. Between Group Mean Distance.

Bronocice phase 3	0.000		
Bronocice phase 4	0.012	0.000	
Zawarza	0.005	0.008	0.000
Niedzwiedz	0.005	0.007	0.000

The Network analysis (Figure 16) provides a visual depiction of the relationships between the samples (Bandelt 1999). Samples that had the same sequence are denoted by a single node label. Node H represents samples B5, B17, B4.7, B4.9, B4.21.2, Z8, Z15, Z16, N18, N10 and N19. Node H2 represents samples B1, B15.2 and B4.19.2. Sample B4.18 is only represented as one individual within the Network. Analysis shows that within node H, 3 samples, Z8, Z15 and Z16, from the site of Zawarża exist within the same central node as the majority of those samples from the site of Bronocice. Within this assemblage they show no genetic divergence from the ancestral node of Bronocice. This scenario would be consistent with the inhabitants of Zawarża obtaining their breeding stock from the larger site of Bronocice. Also present with the central node are three samples from Niedzwiedz, N18, N10 and N19. This again points to a relationship between the sites however Niedzwiedz has one sample removed from the central node indicating a unique mitochondrial lineage not found at the site of Bronocice. Further results may cause a re-evaluation of this interpretation.

Both the Neighbor-joining tree and Network indicate that two samples from Niedzwiedz, N4 and N13, are genetic outliers from an otherwise homogenous population. The potential is that these are actually goat skeletal remains rather than sheep. Further sequencing results should resolve this question.

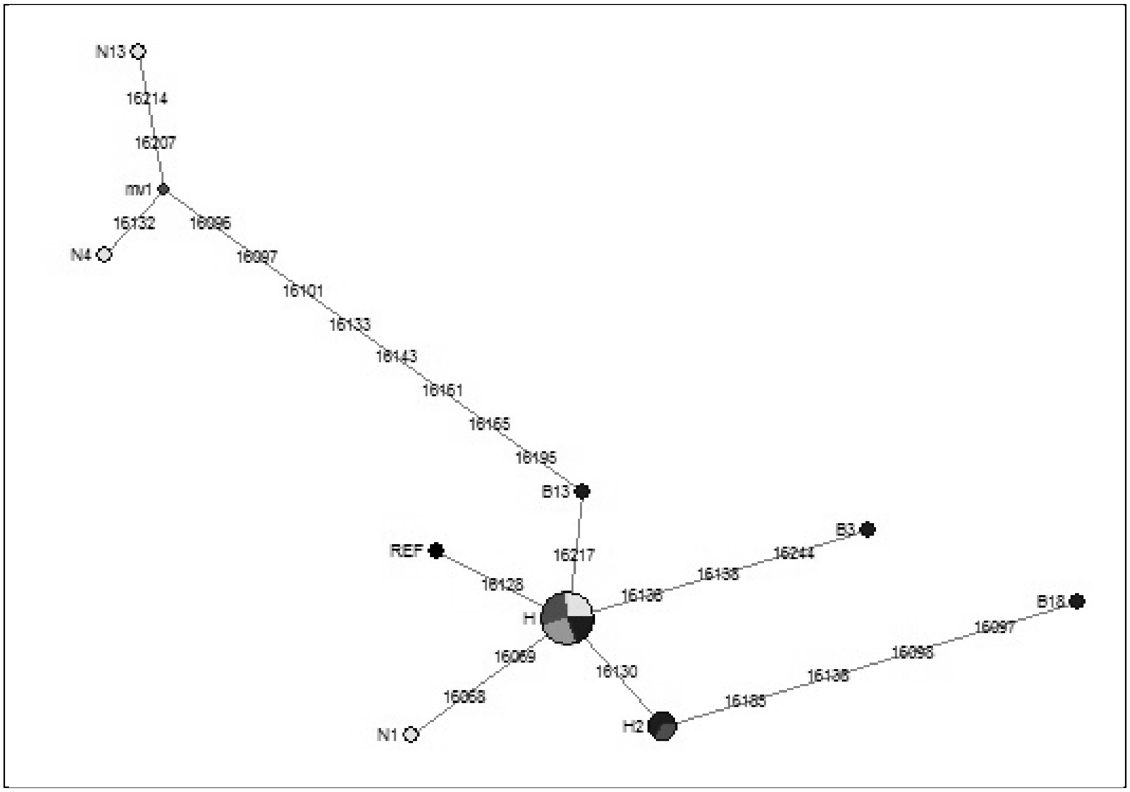

Figure 16. Network Analysis where Bronocice Phase 3 = blue, Zawarża = green, Bronocice Phase 4 = red and Niedzwiedz = yellow.

ii. Analysis of the Experimental Population in Comparison with Modern Populations

A Neighbor-joining tree (Figure 17) was constructed using sheep sequences obtained on Genbank from three major geographic areas, East Asia (dark blue), West Asia (teal), and Europe (red) using MEGA5 (see Cai et al 2007 and Tapio et al 2006 for accession numbers; Tamura 2011). The experimental samples are denoted on the tree by purple text. Some samples from New Zealand were included in the European data set. The experimental samples appear to branch with those of the European samples as expected. However, due to the short sequence length no clear structure is apparent within the tree. These same groups were used to calculate the population statistics in Tables 8 and 9.

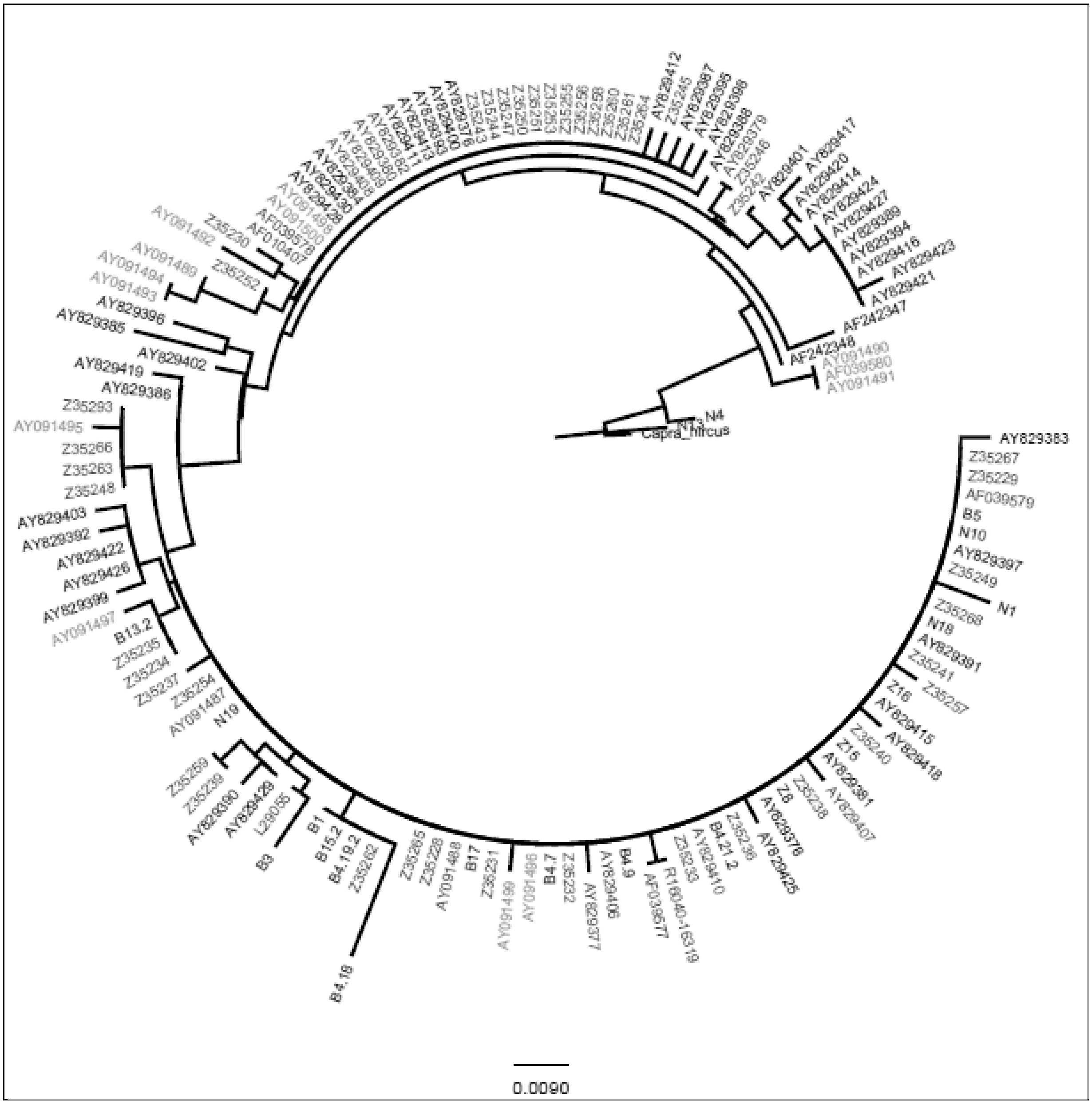

Figure 17. Neighbor Joining Tree (Formatted in FigTree v1.4, Rambaut 2012)

The mean number of pairwise differences and nucleotide diversity both show a level of variation intermediate between Europe and East Asia (Table 8). This is not surprising based on the work of others that has shown that genetic variability in sheep as well as cattle and goats is due to a constant influx of animals into Europe (Meadows et al 2005). This could be due to the impact of selective breeding over the past five thousand years. Neutrality tests indicated that the ancient samples were subject to selection, in other words they were not selectively neutral. This is a reasonable conclusion since these sheep were domesticated and therefore subject to human selection processes. The Slatkin's linearized Fst values (Slatkin 1995) show that there is the least amount of genetic distance between the experimental samples and those from Europe as opposed to any other grouping as expected (highlighted in blue in Table 9).

Table 8. Arlequin Intrapopulational Tests (Excoffier et al 2010).

	Genetic Diversity	Mean # of Pairwise Diff.	Nucleotide Diversity
Experimental	0.6947 +/-0.108	3.489 +/-1.856	0.0170 +/-0.010
Europe	0.7962 +/-0.037	2.746 +/-1.476	0.0134 +/-0.008
East Asia	0.9503 +/-0.021	4.539 +/-2.275	0.0221 +/-0.012
West Asia	0.9359 +/-0.051	5.897 +/-3.011	0.0288 +/-0.017

Table 9. Slatkin's linearized Fst values (Slatkin 1995).

	Experimental	Europe	East Asia	West Asia
Experimental	0.00000			
Europe	0.13465	0.00000		
East Asia	0.30114	0.11579	0.00000	
West Asia	0.31437	0.18400	0.03420	0.00000

The genetic results confirm that the inhabitants of Bronocice impacted the breeding and movement of sheep between themselves and the individuals at Zawarża and Niedzwiedz. As more sequencing results are analyzed better resolution should allow for additional conclusions concerning how sheep were used as a means of exchange and social contact between settlements and people of southern Poland during the Neolithic.

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Appendix E

Chapter 5: aDNA Sequences

Sample	15943	15944	15945	15946	15947	15948	15949	15950	15951	15952	15953	15954	15955	15956	15957	15958	15959	15960	15961	15962	15963	15964	15965	15966	15967	15968	15969	15970	15971	15972	15973	15974	15975	15976	15977	15978	15979	15980	15981	15982	15983	15984	15985	15986	15987	15988	15989	15990	15991	15992	15993	15994	15995	15996	15997	15998	15999	16000	16001	16002	16003	16004	16005	16006	16007	16008	16009	16010	16010	16011	16012	16013	16014	16015	16016	16017	16018	16019
AF010406	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B1	-	-	-	-	-	-	-	-	-	-	-	-	C	C	A	C	G	T	C	A	C	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	T	C	G	T	A	C	A	T	G	A	G	C	G	T	C	A	T	A	T	A	C
B2	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B3	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4	-	-	-	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B5	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B6.2	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B13.2	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	-	-	-	-	-	-	-	-	-
B14.2	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B15.2	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B17	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	T	A	C	A	T	A	G	T	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	T	A	C	A	T	A	G	T	A	T	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	C	A	T	G	A	G	-	-	-	-	-	-	-	-	-	-
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18.2	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4.19.2	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4.20.2	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4.21.2	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	T	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4.24	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N1	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	T	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
N4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N10	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
N13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N18	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
N19	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	T	A	C	A	T	A	G	T	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	T	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
Z8	-	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
Z9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z12	-	-	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
Z15	A	A	G	C	A	T	G	T	A	C	A	T	T	T	G	T	T	T	C	A	C	T	G	A	A	G	C	A	T	G	T	A	G	G	G	T	A	T	T	A	A	A	C	T	G	C	T	T	G	A	C	C	G	T	A	C	A	T	A	G	T	A	C	A	T	G	A	A	-	G	T	C	A	A	A	T	C	C
Z16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	T	A	C	A	T	A	G	T	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample	16020	16021	16022	16023	16024	16025	16026	16027	16028	16029	16030	16031	16032	16033	16034	16035	16036	16037	16038	16039	16040	16041	16042	16043	16044	16045	16046	16047	16048	16049	16050	16051	16052	16053	16054	16055	16056	16057	16058	16059	16060	16061	16062	16063	16064	16065	16066	16067	16068	16069	16070	16071	16072	16073	16074	16075	16076	16077	16078	16079	16080	16081	16082	16083	16084	16085	16086	16087	16088	16089	16090	16091	16092	16093	16094	16095	16096	16097
AF010406	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B1	G	C	A	A	C	A	T	A	T	C	T	T	A	T	G	T	C	T	G	T	C	T	T	A	T	C	A	T	G	C	A	A	A	C	G	A	G	T	A	C	A	T	A	G	T	A	G	T	A	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	G
B3	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B5	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	C	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B6.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B13.2	-	-	-	-	-	-	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B14.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B15.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B17	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	G
B4.18.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	G
B4.19.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4.20.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4.21.2	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
B4.24	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	T	A	A	C	C	C	G	C	T	C	A
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N1	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	T	T	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
N4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	T	G
N10	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
N13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	T	G
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N18	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
N19	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
Z8	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
Z9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z12	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	T	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
Z15	A	T	T	C	T	A	G	T	C	A	A	C	A	T	G	C	G	T	A	T	C	C	T	G	T	C	C	A	T	T	A	G	A	T	C	A	C	G	A	G	C	T	T	G	T	T	C	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A
Z16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	T	A	A	C	C	A	T	G	C	C	G	C	G	T	G	A	A	A	C	C	A	A	C	A	A	C	C	C	G	C	T	C	A

Sample	16098	16099	16100	16101	16102	16103	16104	16105	16106	16107	16108	16109	16110	16111	16112	16113	16114	16115	16116	16117	16118	16119	16120	16121	16122	16123	16124	16125	16126	16127	16128	16129	16130	16131	16132	16133	16134	16135	16136
AF010406	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	C	T	A	A	C	T	G	T	G
B1	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	G	A	C	T	G	T	G
B2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	A
B4	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B6.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B13.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B14.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B15.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	G	A	C	T	G	T	G
B17	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	T	G	T	G
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B4.9.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B4.18	A	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	G	A	C	T	G	T	G
B4.18.2	A	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B4.19.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	G	A	C	T	G	T	G
B4.20.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B4.21.2	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
B4.24	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N1	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
N4	G	C	A	G	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	T	C	G	T	G
N10	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
N13	G	C	A	G	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	C	G	T	G
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N18	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
N19	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
Z9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z12	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G
Z16	G	C	A	A	G	G	A	T	C	C	C	T	C	T	T	C	T	C	G	C	T	C	C	G	G	G	C	C	C	A	T	T	A	A	C	T	G	T	G

Sample	16137	16138	16139	16140	16141	16142	16143	16144	16145	16146	16147	16148	16149	16150	16151	16152	16153	16154	16155	16156	16157	16158	16159	16160	16161	16162	16163	16164	16165	16166	16167	16168	16169	16170	16171	16172	16173	16174	16175
AF010406	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B1	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B2	-	-	-	-	-	-	-	-	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B3	G	A	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B6.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B13.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B14.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B15.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B17	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B30.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.9.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.18	G	A	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.18.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.19.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.20.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.21.2	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N1	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
N4	G	G	G	G	T	A	G	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	T	C	A	G	A	C	A	T	C	T	G	G	T	T	C
N10	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
N13	G	G	G	G	T	A	G	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	T	C	A	G	A	C	A	T	C	T	G	G	T	T	C
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N18	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
N19	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
Z9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C
Z16	G	G	G	G	T	A	A	C	T	A	T	T	T	T	A	A	T	G	A	A	C	T	T	T	A	A	C	A	G	G	C	A	T	C	T	G	G	T	T	C

Sample	16176	16177	16178	16179	16180	16181	16182	16183	16184	16185	16186	16187	16188	16189	16190	16191	16192	16193	16194	16195	16196	16197	16198	16199	16200	16201	16202	16203	16204	16205	16206	16207	16208	16209	16210	16211	16212	16213	16214
AF010406	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B1	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B3	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B6.2	T	T	T	C	T	T	C	A	G	G	A	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B13.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B14.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B15.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B17	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B30.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.9.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.18	T	T	T	C	T	T	C	A	G	A	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.18.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.19.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.20.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.21.2	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N1	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
N4	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	C	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
N10	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
N13	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	C	C	T	A	A	A	A	T	C	G	C	C	T	A	C	T	C	T	T	C
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N18	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
N19	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
Z9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T
Z16	T	T	T	C	T	T	C	A	G	G	G	C	C	A	T	C	T	C	A	T	C	T	A	A	A	A	T	C	G	C	C	C	A	C	T	C	T	T	T

Sample	16215	16216	16217	16218	16219	16220	16221	16222	16223	16224	16225	16226	16227	16228	16229	16230	16231	16232	16233	16234	16235	16236	16237	16238	16239	16240	16241	16242	16243	16244	16245	16246	16247	16248	16249	16250	16251	16252	16253
AF010406	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B1	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B3	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	G	T	G	A	C	T	A	A	T	C
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B6.2	C	C	C	C	T	T	-	A	C	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B13.2	C	C	T	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B14.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	G	T	G	A	C	T	A	A	T	C
B15.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B17	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B30.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.9.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.18	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.18.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	A	G	A	C	T	A	A	T	C
B4.19.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.20.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	A	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.21.2	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N1	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N4	C	C	T	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N10	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N13	C	C	T	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N15	-	-	-	-	-	-	-	-	-	-	-	-	-	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N18	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N19	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
Z9	-	-	-	-	-	-	-	-	-	-	-	-	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C
Z16	C	C	C	C	T	T	A	A	A	T	A	A	G	A	C	A	T	C	T	C	G	A	T	G	G	A	C	T	A	A	T	G	A	C	T	A	A	T	C

Sample	16254	16255	16256	16257	16258	16259	16260	16261	16262	16263	16264	16265	16265	16266	16267	16268	16269	16270	16271	16272	16273	16274	16275	16276	16277	16278	16279	16280	16281	16282	16283	16284	16285	16286	16287	16288	16289	16290	16291
AF010406	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B1	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B13.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B14.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B15.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B17	A	G	C	C	C	A	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B4.9.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
B4.18.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.19.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.20.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.21.2	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
N1	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N4	A	G	C	C	C	A	T	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	G	T	C	A	T	A	C	A	T	T	T	G	G
N10	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
N13	A	G	C	C	C	A	T	G	C	T	C	A	-	A	C	A	T	A	A	C	T	G	T	G	C	T	G	T	C	A	T	A	C	A	T	T	T	G	G
N15	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
N18	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
N19	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
N20	-	-	-	-	-	-	-	-	-	T	T	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G
Z9	A	G	C	C	C	A	T	G	C	T	C	A	C	A	C	A	T	A	A	C	T	G	T	G	C	T	G	T	C	A	T	A	C	A	T	T	T	G	G
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z16	A	G	C	C	C	A	T	G	C	C	T	A	-	A	C	A	T	A	A	C	T	G	T	G	G	T	G	T	C	A	T	G	C	A	T	T	T	G	G

Sample	16292	16293	16294	16295	16296	16297	16298	16299	16300	16301	16302	16303	16304	16305	16306	16307	16308	16309	16310	16311	16312	16313	16314	16315	16316	16317	16318	16319	16320	16321	16322	16323	16324	16325	16326	16327	16328	16329	16330
AF010406	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B13.2	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B14.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B15.2	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
B4.18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.20.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N4	T	A	T	T	T	T	T	T	A	A	T	T	T	T	C	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N10	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N13	T	A	T	T	T	T	T	T	A	A	T	T	T	T	C	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N15	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N18	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N19	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
Z9	T	A	T	T	T	T	T	T	A	A	T	T	T	T	C	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z16	T	A	T	T	T	T	T	T	A	A	T	T	T	T	T	G	G	G	G	A	T	G	C	T	T	G	G	A	C	T	C	A	G	C	T	A	T	G	G

Sample	16331	16332	16333	16334	16335	16336	16337	16338	16339	16340	16340	16341	16342	16343	16344	16345	16346	16347	16348	16349	16350	16351	16352	16353	16354	16355	16356	16357	16358	16359	16360	16361	16362	16363	16364	16365	16366	16367	16368	16369	16370	16371	16372	16373	16374	16375	16376	16377	16378	16379	16380	16381	16382	16383	16384	16385	16386	16387	16388	16389	16390	16391	16392	16393	16394	16395	16396	16397	16398	16399	16400	16401	16402	16403	16404	16405	16406	16407
AF010406	C	C	G	T	C	T	G	A	G	G	-	C	C	T	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B13.2	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B14.2	-	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B15.2	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
B4.18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.20.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	G	G	T	A	A	G	C	A	T
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
N1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N4	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	A	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	C	C	A	T	A	A	T	G	G	T	A	G	G	C	A	T
N10	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
N13	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	A	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	C	C	A	T	A	A	T	G	G	T	A	G	G	C	A	T
N15	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
N18	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
N19	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	G	G	T	A	A	G	C	A	T
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T
Z9	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	A	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	C	C	A	T	A	A	T	G	G	T	A	G	G	C	A	T
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z16	C	C	G	T	C	T	G	A	G	G	C	C	C	C	G	A	C	C	C	G	G	A	G	C	A	T	G	A	A	T	T	G	T	A	G	C	T	G	G	A	C	T	T	A	A	C	T	G	C	A	T	C	T	T	G	A	G	C	A	T	C	C	T	C	A	T	A	A	T	G	G	T	A	A	G	C	A	T

Sample	16408	16409	16410	16411	16412	16413	16414	16415	16416	16417	16418	16419	16420	16421	16422	16423	16424	16425	16426	16427	16428	16429	16430	16431	16432	16433	16434	16435	16436	16437	16438	16439	16440	16441	16442	16443	16444	16445	16446
AF010406	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	T	G
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	T	G
B13.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	-	-	-	-
B14.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	-	-	-	-
B15.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	T	G
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	-	-
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	-	-	-	-	-	-	-
B4.18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.20.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.21.2	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	T	G
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	-	-	-
N1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N4	G	G	G	C	A	T	A	A	T	G	C	A	G	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	-	-	-
N10	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	-	-	-	-
N13	G	G	G	C	A	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N15	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	-	-	-	-	-
N18	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	-	-	-	-	-	-	-
N19	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	C	T	G
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	-	-	-
Z9	G	G	G	C	A	T	A	A	T	G	C	A	G	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	G	-	-	-
Z12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z16	G	G	G	C	A	T	A	A	T	A	T	A	A	T	T	A	A	T	G	G	T	C	A	C	A	G	G	A	C	A	T	A	T	C	T	-	-	-	-

Sample	16447	16448	16449	16450	16451	16452	16453	16454	16455	16456	16457	16458	16459	16460	16461	16462	16463	16464	16465	16466	16467	16468	16469	16470	16471	16472	16473	16474	16475	16476	16477	16478	16479	16480	16481	16482	16483	16484	16485
AF010406	T	A	T	C	G	T	G	C	A	T	T	T	A	T	A	T	A	T	T	C	T	T	T	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	T	A	T	C	G	T	G	C	A	T	T	T	A	T	A	T	A	T	T	C	T	T	-	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B13.2	-	-	-	-	-	-	-	-	-	-	T	T	A	T	A	T	A	T	T	C	T	T	-	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B14.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B15.2	T	A	T	C	G	T	G	C	A	T	T	T	A	T	A	T	A	T	T	C	T	T	-	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B4.7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B4.19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.20.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.21.2	T	A	T	C	G	T	G	C	A	T	T	T	A	T	A	T	A	T	T	C	T	T	-	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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N19	T	A	T	C	G	T	G	C	A	T	T	T	A	T	A	T	A	T	T	C	T	T	T	T	T	T	C	C	C	C	C	C	T	T	C	C	C	C	T
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Sample	16486	16487	16488	16489	16490	16491	16492	16493	16494	16495	16496	16497	16498	16499	16500	16501	16502	16503	16504	16505	16506	16507	16508	16509	16510	16511	16512	16513	16514	16515	16516	16517	16518	16519	16520	16521	16522	16523	16524	16525	16526	16527	16528	16529	16530	16531	16532	16533	16534	16535	16536	16537	16538	16539	16540	16541	16542	16543	16544	16545	16546	16547	16548	16549	16549.1	16550	16551	16552	16553	16554	16555	16556	16557	16558	16559	16560	16561
AF010406	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B6.2	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
B13.2	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
B14.2	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
B15.2	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B4.21.2	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	T	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	T	T	C	A	A	A	T
B4.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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N10	T	A	A	A	T	A	W	T	T	A	T	C	A	C	C	A	T	T	T	W	T	A	A	C	A	C	G	S	T	T	C	C	C	C	C	T	A	G	A	W	A	T	T	A	A	T	A	W	A	A	A	T	W	T	A	T	C	C	C	G	S	C	C	T	G	C	M	A	T	A	C	T	C	C	A	A	T
N13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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N19	T	A	A	A	T	A	T	T	T	A	T	C	A	C	C	A	T	T	T	T	T	A	A	C	A	C	G	C	T	T	C	C	C	C	C	T	A	G	A	T	A	T	T	A	A	T	A	T	A	A	A	T	T	T	A	T	C	C	C	G	C	C	C	T	-	C	A	A	T	A	C	T	C	A	A	A	T
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Z8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Z15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Sample	16563	16564	16565	16566	16567	16568	16569	16570	16571	16572	16573	16574	16575	16576	16577	16578	16579	16580	16581	16582	16583	16584	16585	16586	16587	16588	16589	16590	16591	16592	16593	16594	16595	16596	16597	16598	16599	16600	16601	16602	16603	16604	16605	16606	16607	16608	16609	16610	16611	16612	16613	16614	16615	16616
AF010406	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6.2	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
B13.2	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
B14.2	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
B15.2	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
B17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B30.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B4.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4.18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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B4.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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N19	C	A	T	A	C	T	C	C	A	A	C	C	G	A	A	G	T	A	A	A	T	A	T	A	T	A	G	G	C	A	C	C	T	G	G	G	T	C	A	C	A	T	A	C	A	T	A	A	C	G	C	A	T	A
N20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Appendix F
Summary of Bronocice Analytical Units, Plans of Excavation Units and Structures by Phase

Table F1. Phase 1 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure#	Structure Type	Pits	Shape	Top Dia. (M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
B6	B6.1a	Small House	5	TR	?	1.50	?	?	Pit house	Associated with postmolds, probable an animal pen. Rebuilt upon Phase 5
C1	C1.1	Medium House	76	TR	.75	1.40	1.40	5.23	Cellar	Later impacted by Phase 5 by double burial of a woman and infant suggesting an awareness of the earlier building
			80	H	1.72	.90	.90	3.61	Storage pit with steps	
			81	H	.70	1.44	1.44	1.85	Postmold	
C2	C2.1	Medium House?	12	TR	.80	1.15	1.26	5.30	Cellar	Impacted by later Phase 2 pit construction
	C2.2	Small Barn	17	TR	.72	1.25	.55	1.25	Postmold	
			20	R	.86	.86	1.23	2.85	Storage pit	
			21	TR	.70	.70	.86	1.42	Postmold	
	C2.3	Small Barn	35	R	.57	.57	.63	.64	Postmold	
			36	TR	.61	.74	.79	1.13	Storage pit	
	C2.4	Medium House	45	TR	.53	1.10	1.31	2.84	Storage pit	Pits 46 and 49 contained human remains so the house was built on top of burials. This suggest a lack of awareness of the burials
			46	H	.45	.45	.63	.12	Postmold	
			49	TR/P	3 x 2.40	1.15, .44	1.85	5.54	Cellar	
	C2.5	Complex House	42/43/44	TR/Sr	1.60	?	1.05	8.44	Large cellar with steps	
	C2.6	Medium House?	59	TR	.55	1.04	1.15	6.10	Large cellar	
	C2.7	House	61	TR	1.57	2.60	1.30	4.38	Storage pit	Construction of the house disturbed a human burial
	C2.8	Large Barn Granary?	24	H	.90	.90	.57	.72	Postmold	
			32	H	.74	.74	.57	.56	Postmold	
			33	H	1.20	1.20	.71	1.52	Postmold	
			40	B	.95	.95	1.51	1.36	Storage pit	Lots of cereals in Pit 40
C6	C6.1	Small Barn	9	TR	.75	.80	.70	1.32	Unclear	
	C6.2	Small Barn	2/	R	.87	.87	.94	2.23	Storage pit	Eroded. Unsure if these represent a structure
			3	H	1.10	1.10	.52	.78		
C7	C7.1	Barn	1	H	?	?	?	.70	Postmold	Possibly associated with 2 postmolds.
			2	R	?	?	?	1.62	Storage pit	
			4	B	?	?	?	.11	Postmold	

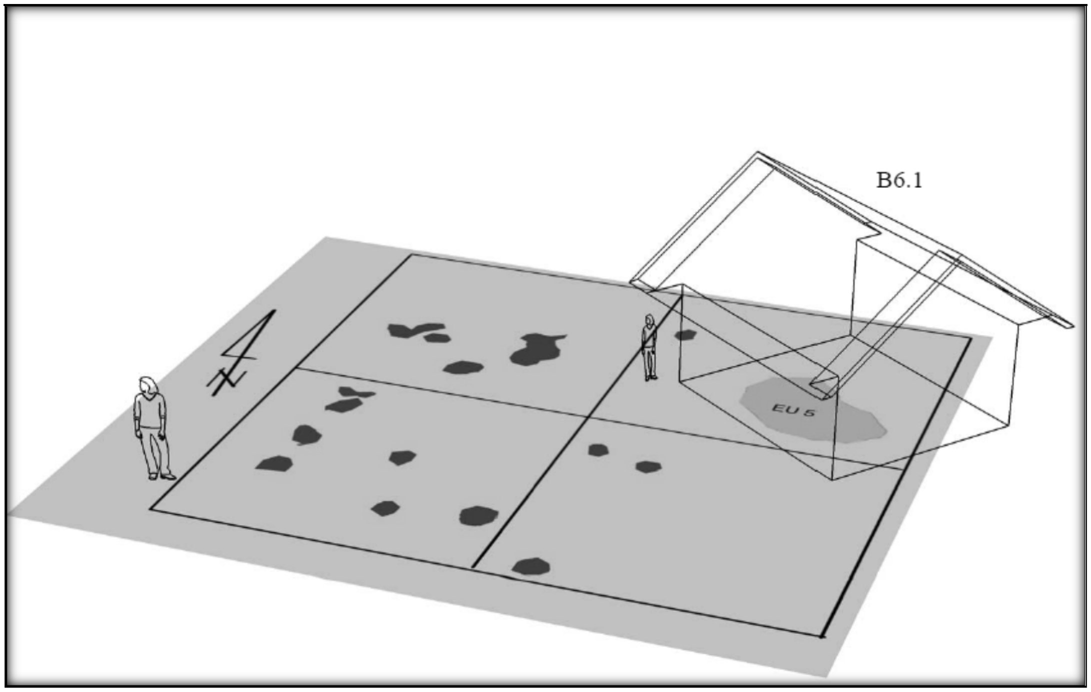

Figure F1. Unit B6 Phase 1 Structure.

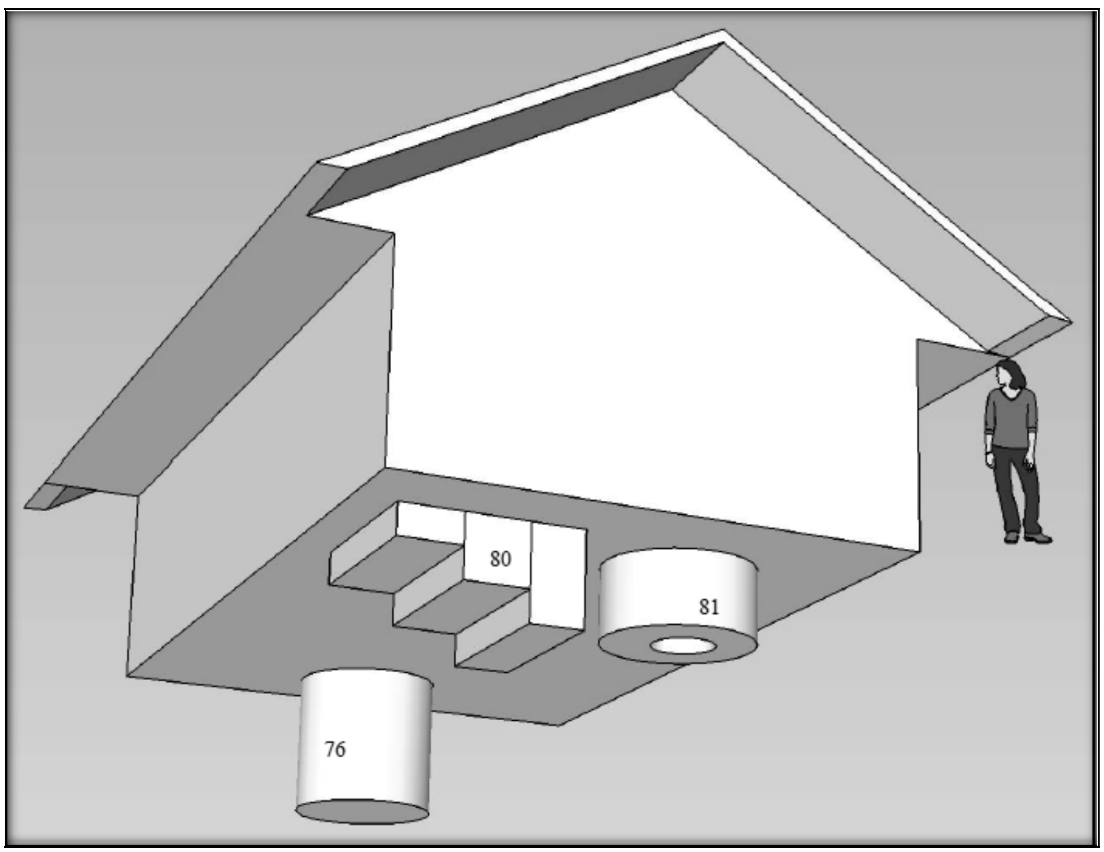

Figure F2. Unit C1 Phase 1, Structure.

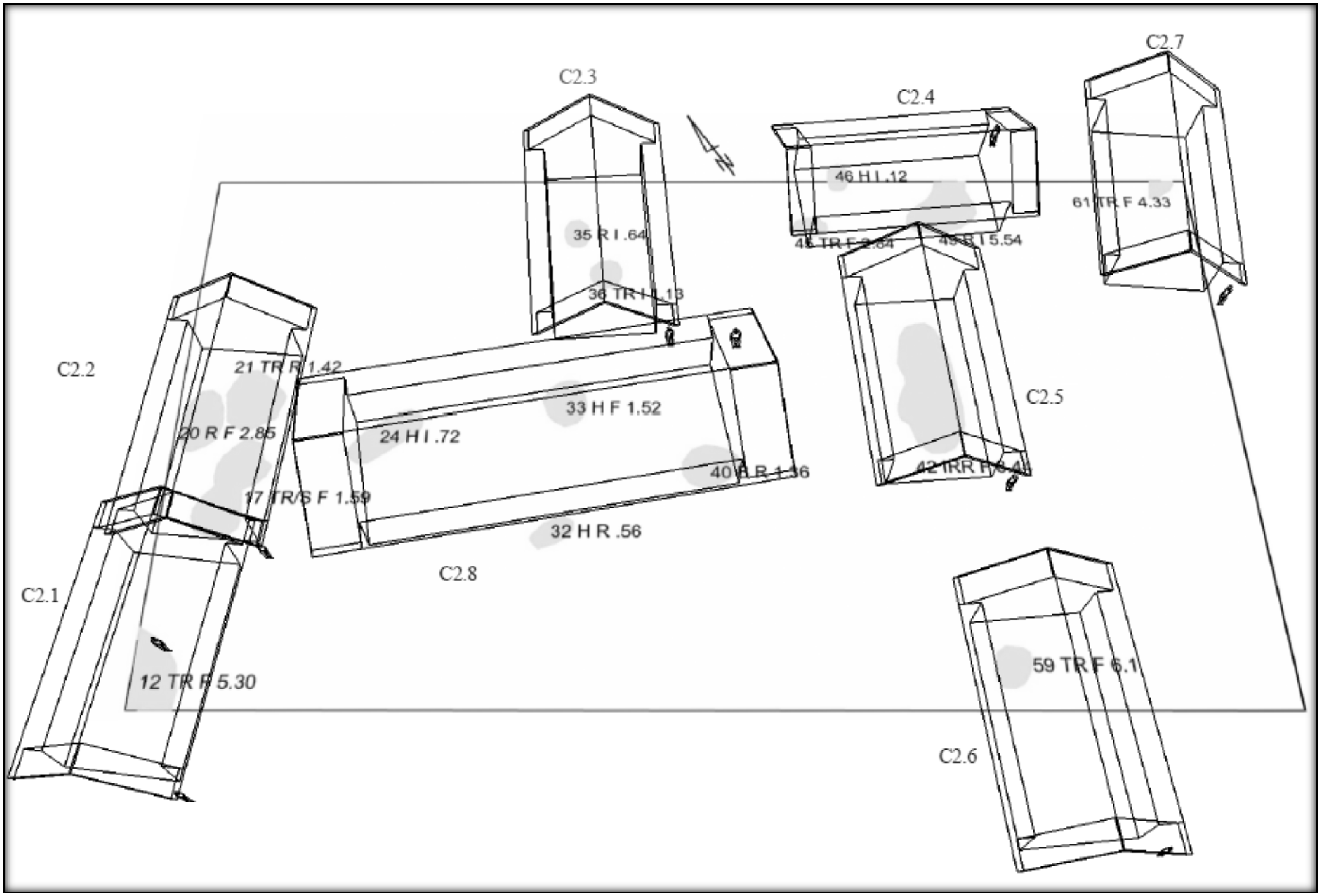

Figure F3. Unit C2 Phase 1 Structures.

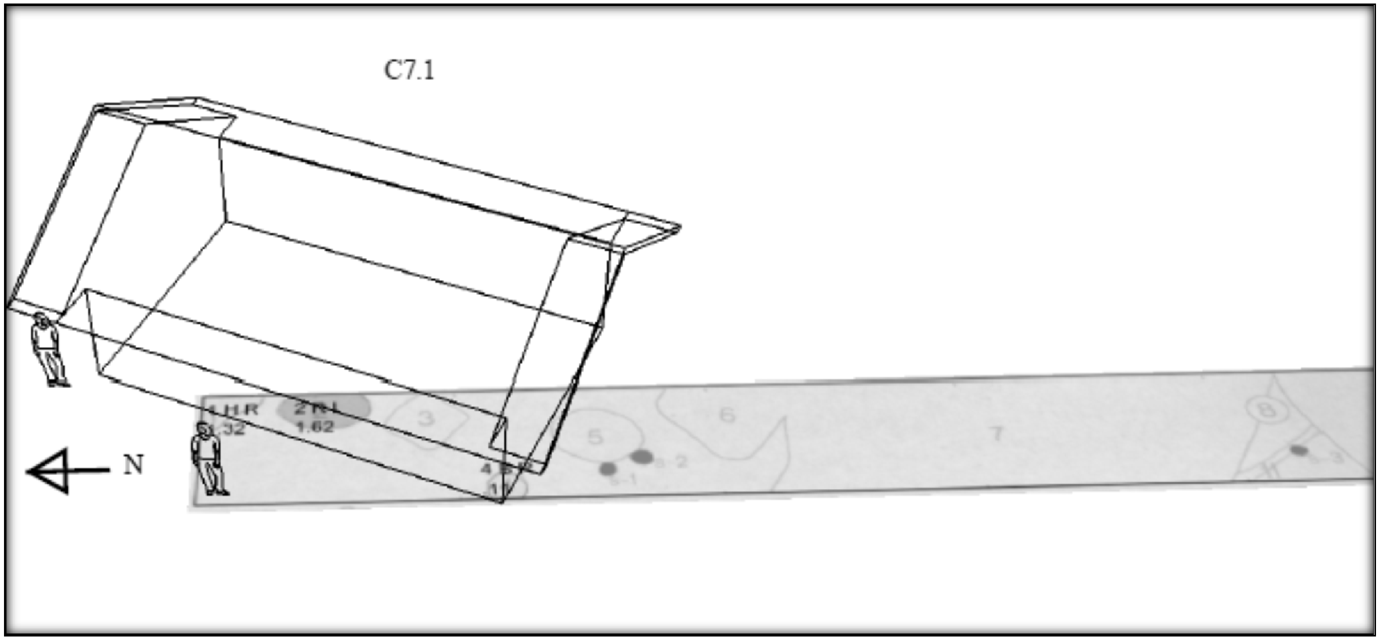

Figure F4. Unit C7 Phase 1 Structure.

Table F2. Phase 2 structures and dimensions (M meters) and function, by excavation unit.

Structure #	Structure Type	Associated Pit(s)	Pit Shape	Top Dia. (M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
C1.2	Medium House	71	R	.62	.62	.70	.84	Postmold	Appears to sit over the Phase 2 ditch. There may have an access to the ditch from here. / Postmold bottom center of b6C1.
		73	TR	.70	1.20	1.70	4.82	Cellar with shelf	
		86	TR	1.10	1.25	.90	2.99	Storage pit with ledge	
C1.3	Medium House	78	TR/R	1.76	.95	1.30	6.44	Cellar with shelf	
		79	H	1.96	1.92	.90	4.22	Cellar with stairs	Postmold in center bottom
		82	TR	.95	1.10	1.10	3.63	Storage pit	
C2.9	Large House	12a	?	?		?	?	Postmold	
		13	IR	.90	.90	.85	.68	Steps	
		14/15	TR	1.65	1.95	1.59	16.30	Cellar	Human remains
		16	TR	.50	.60	.75	.71	Postmold	
C2.11	Large House	22	H	.86	.86	.57	.68	Postmold	C2.11 may be single large house with multiple storage rooms
		23	TR	.47	.72	1.03	1.16	Postmold	
		25	TR	1.40	1.82	1.49	12.10	Cellar with ledge	
		26	H	1.00	1.00	.55	.77	Daub pit?	
		27	TR	.65	.92	1.05	2.05	Postmold	
		28/29	TR	1.70	1.72	1.29	5.61	Cellar	Human remains
		30	TR	.88	.88	.95	2.31	Storage pit	
		29a	TR	.50	.73	1.15	1.38	Postmold	
		37	TR	.55	.85	.89	1.39	Storage pit	
		38	H	.84	.84	.67	.86	Postmold	
C2.12	Large House	50	R	.42	.42	.71	.39	Postmold	
		51	IR	.88	.88	.51	1.24	Daub pit?	
		52	H	2.06	2.06	.83	3.85	Storage pit with steps	
		63	R	.70	.70	.95	1.48	Postmold	
C2.13	Large House	41	TR	.55	.80	.75	1.08	Storage pit	
		55	H	.90	.90	.51	.59	Postmold	
		58	R	.70	.70	.59	.90	Postmold	
		60	TR	.85	1.85	1.55	5.99	Cellar	
C3.1	Medium House	9a	TR	.90	.98	.80	1.01	Storage pit with shelf	Adjacent to Phase 2 ditch and associated with it. The ditch has a ledge or standing platform at this location.
		9	R	.70	.70	.82	1.26	Storage pit	
		10	?	1.40	2.96	1	12.46	Cellar with shelf	
		11	?	3.10	3.10	.70	4.68	Stairs	

Table F2 continued. Phase 2 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Associated Pits	Pit Shape	Top Dia. (M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
	C3.2	Small House	1a	B	.95	.95	1.16	1.04	Postmold	Perpendicular to palisade
			1b	-	?	?	?	?	Floor	Barn floor
			2	?	.40	.40	.20	?	Postmold	
			3	H	.50	.50	.20	?	Postmold	
			4	R	1.92	1.92	.54	6.25	Cellar	
			5	H	.80	.80	.48	.46	Postmold	
			6	H	1.02	1.02	.50	.66	Postmold	
C5	C5.1	Large Barn	2	TR	.80	1.051	.90	2.43	Storage pit	
			5	TR	.94	1.12	.47	1.50	Storage pit	Associated with a postmold
			6	H	1.44	1.44	.35	.50	Daub pit?	
C6	C6.3	Medium House	6	TR	.70	.81	.88	1.57	Storage pit	
			7	H	2.40	2.40	.80	4.28	Cellar	
			8	TR	.70	1.05	.80	1.94	Storage pit	
C7	C7.2	Medium House	3	TR	?		?	2.95	Storage pit	Adjacent to Phase 2 ditch
			5	TR	?		?	6.06	Cellar	Associated with 2 postmolds
			6	TR	?		?	3.59	Storage pit	

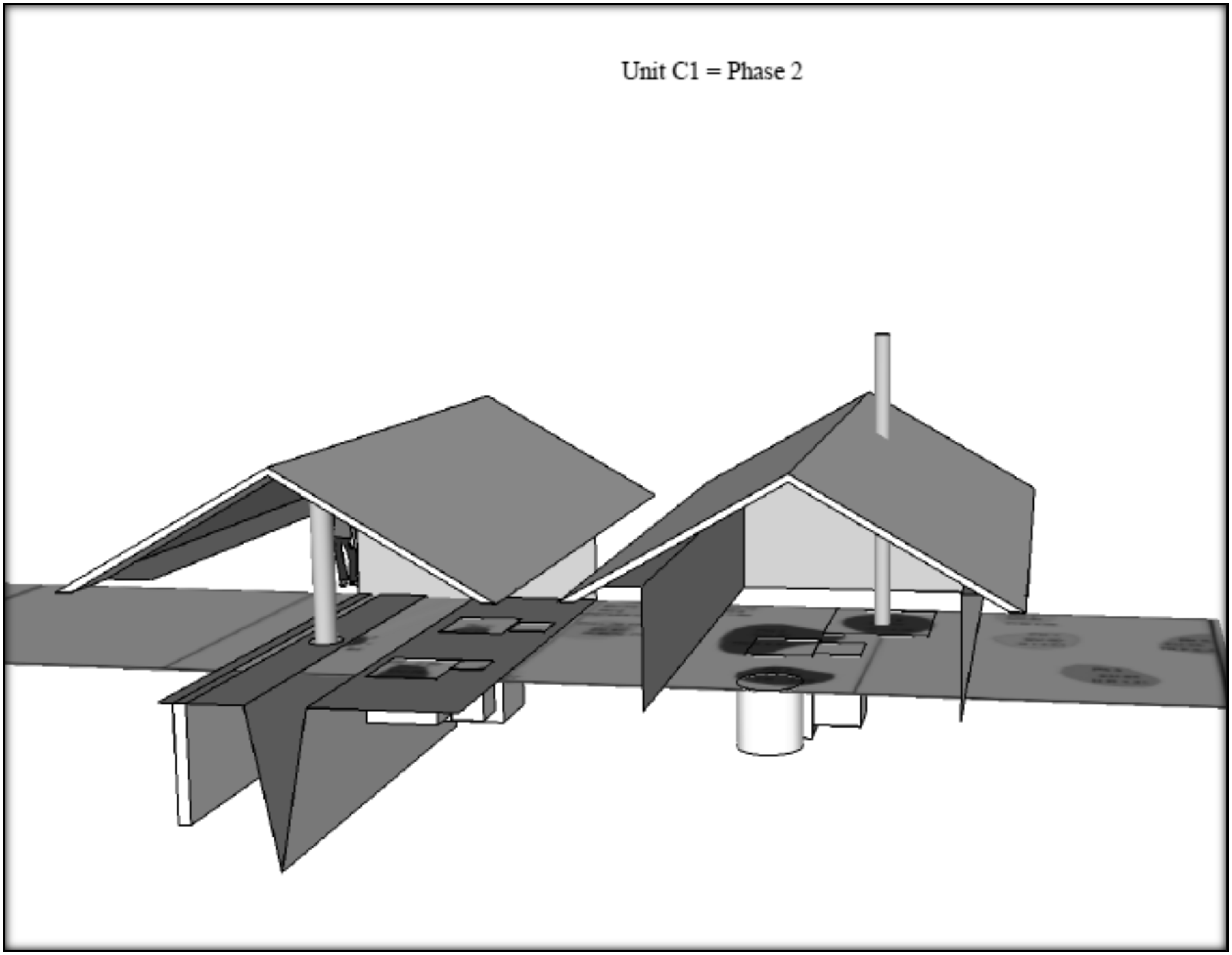

Figure F5. Unit C1 Phase 2 Structures.

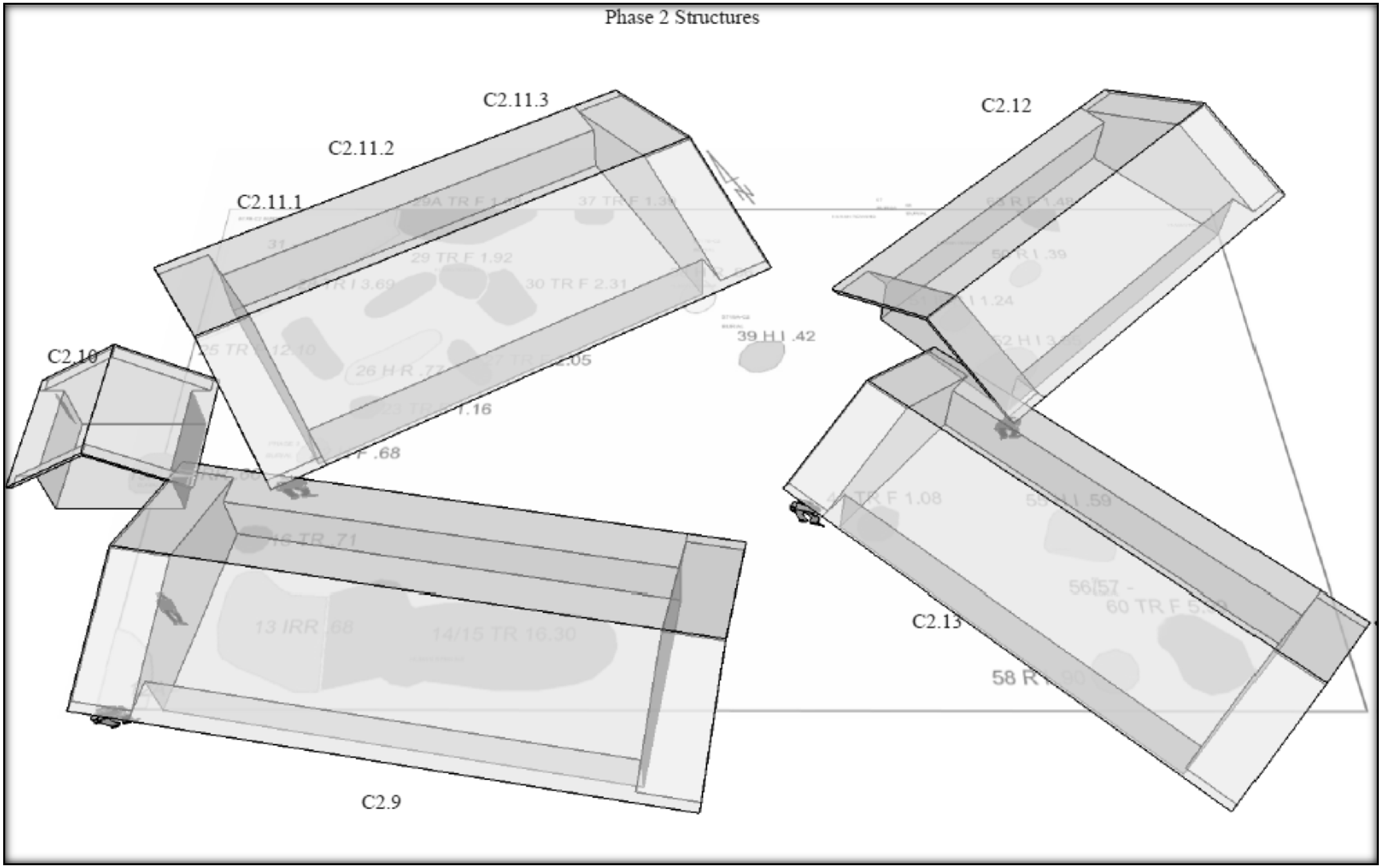

Figure F6. Unit C2 Phase 2 Structures. (C2.9 is probably Phase 3)

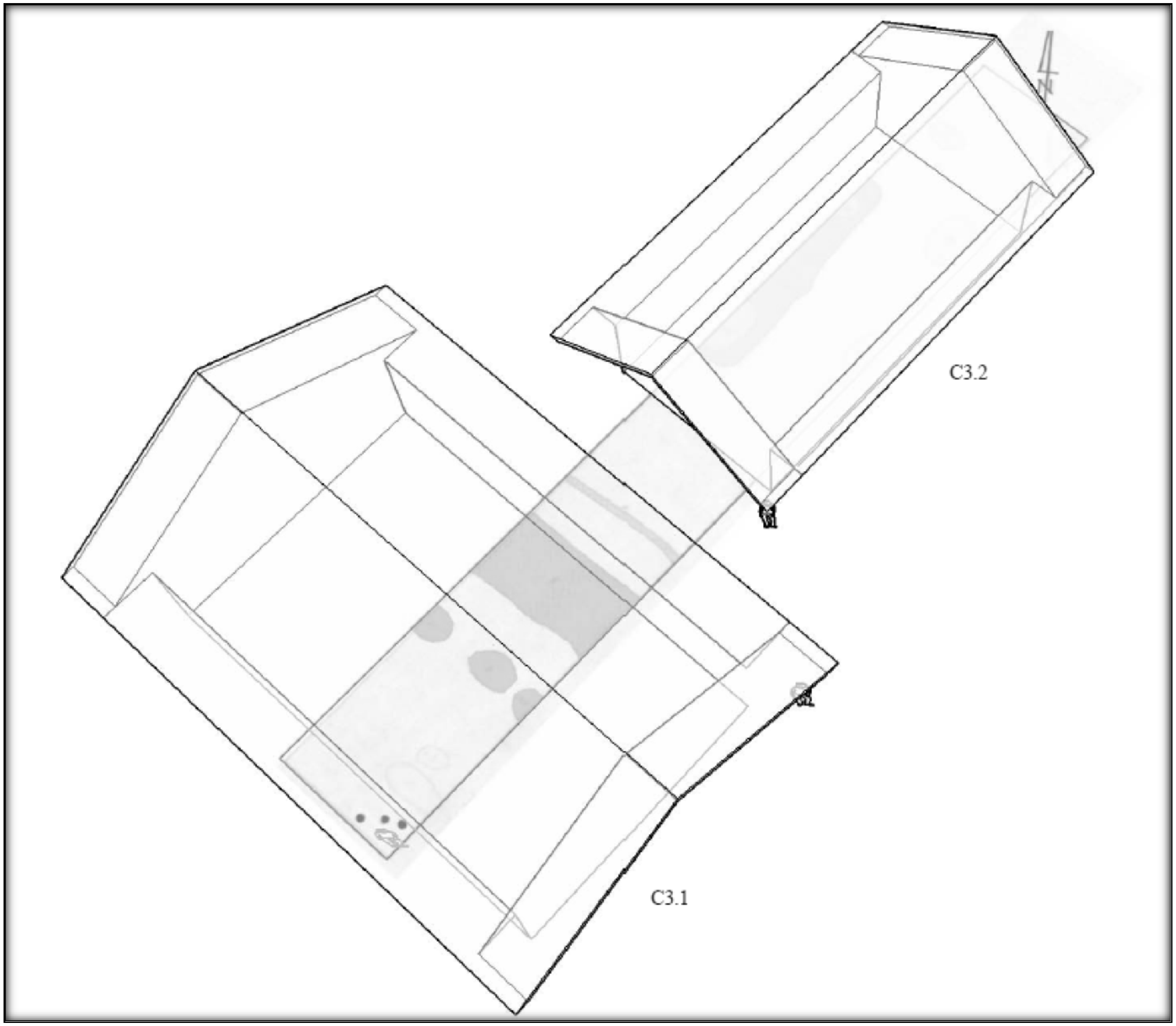

Figure F7. Unit C3 Phase 2 Structures.

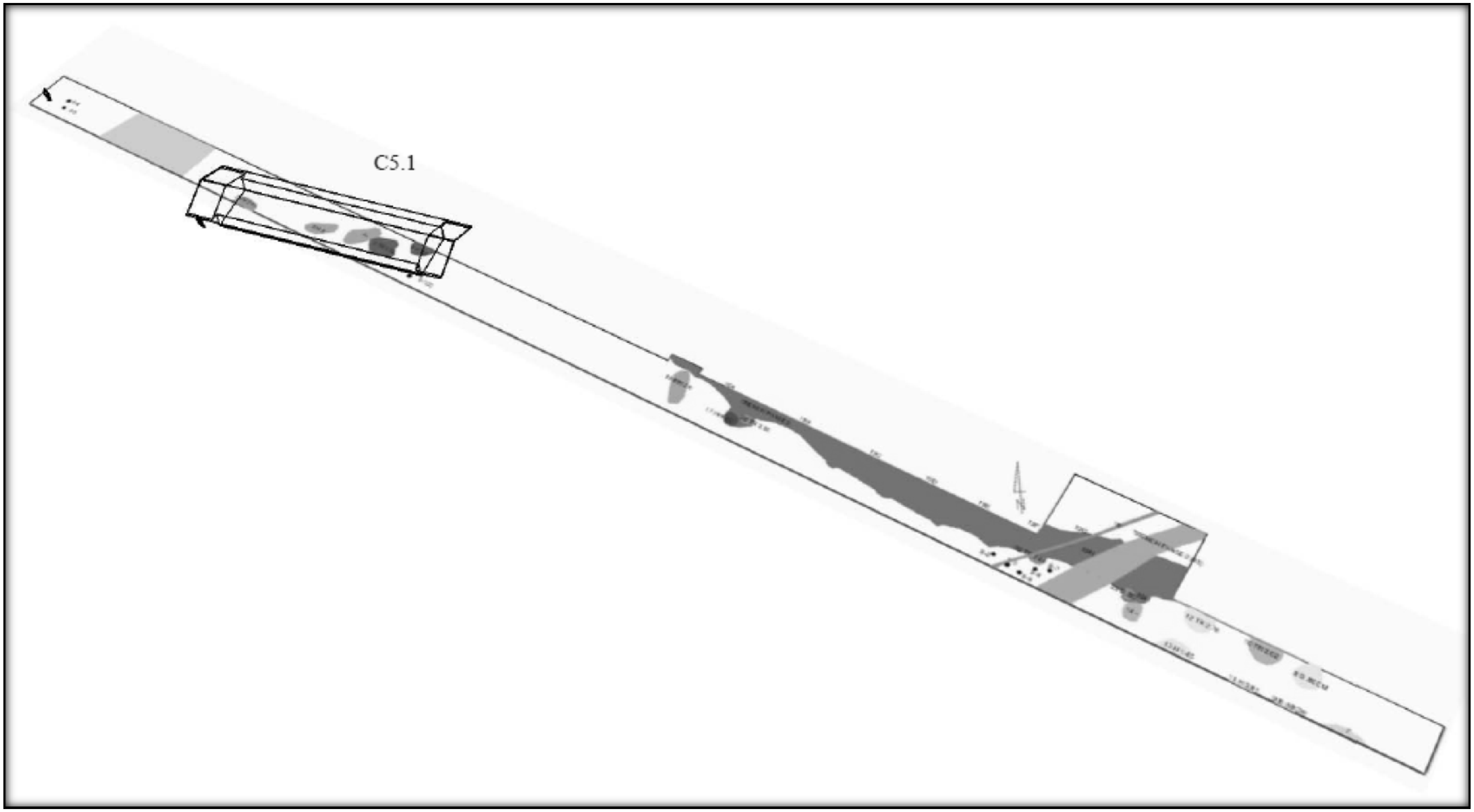

Figure F8. Unit C5 Phase 2 Structures.

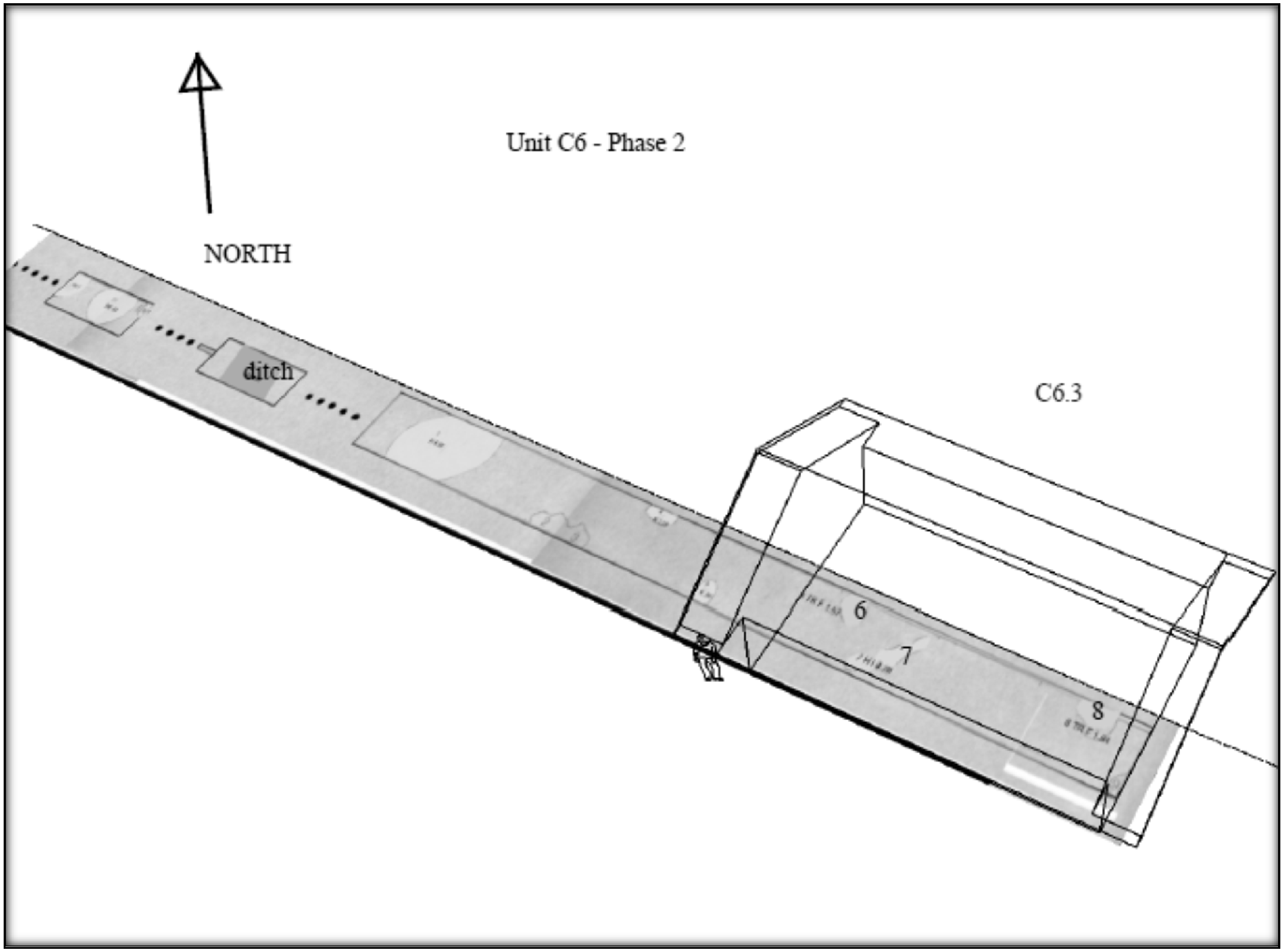

Figure F9. Unit C6 Phase 2 Structure.

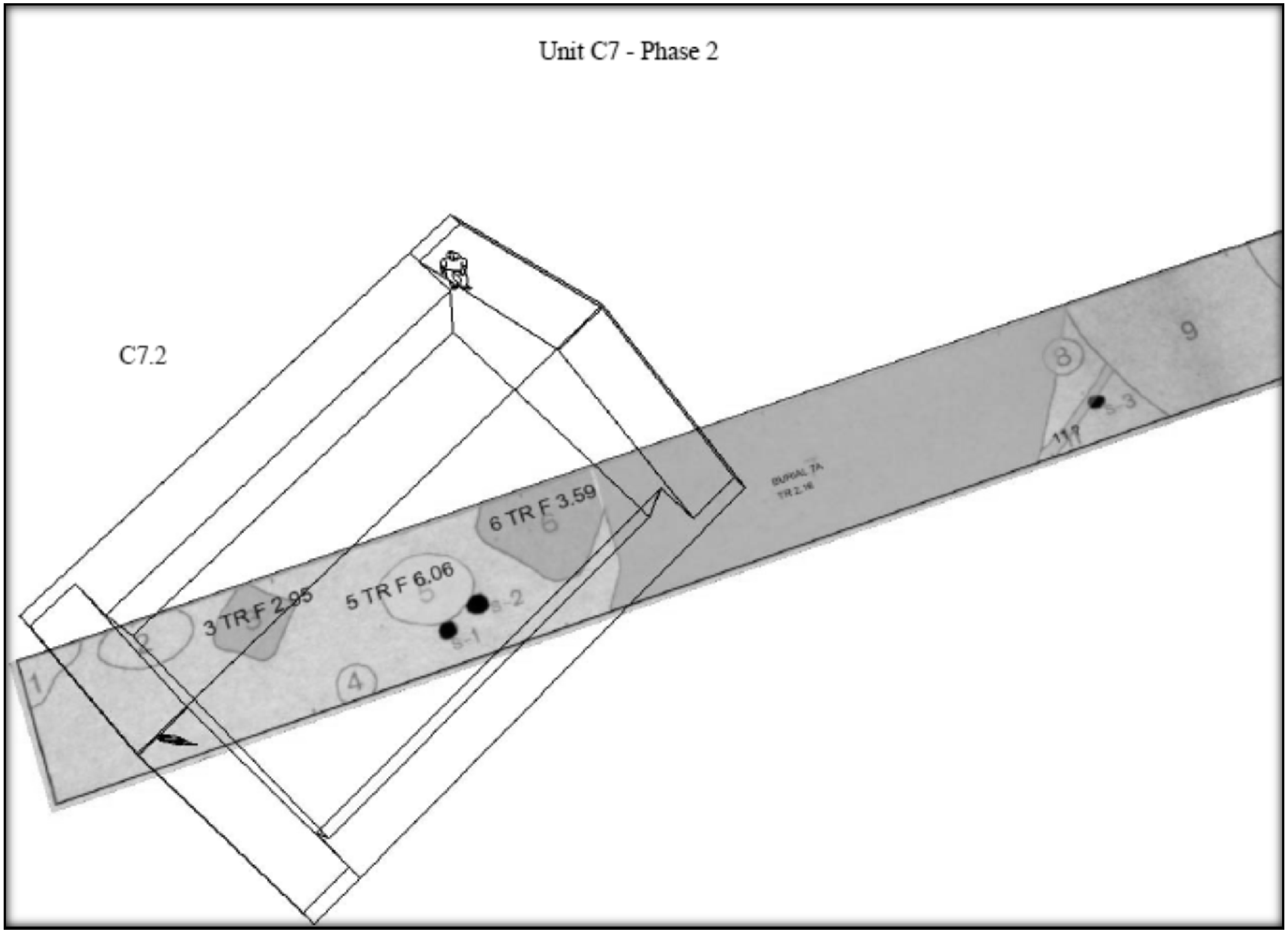

Figure F10. Unit C7 Phase 2 Structure.

Table F3 . Phase 3 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Related Pits	Pit Shape	Top Dia.	Bottom Dia. (M)	Depth	Cubic Vol.	Pit Function	Comment
A1	A1.1	Large Barn	6	TR	1.80 X .80		.72	.66	Floor	See field notebook
			15	?	.50		1.26	.72	Postmold	Impacted by later construction
			121	TR	1.20	.57	1.04	.44	Storage pit	
	A1.2	Large Barn	26	H	1.54	1.10	.58	1.42	Daub pit?	
			28	H	1.56	1.56	.70	2.04	Storage pit	
			37	H	.90	.90	.58	.74	Postmold	
			38	TR	.93	1.00	.70	2.04	Storage pit	Postmold in bottom
	A1.3	Medium House	78	TR	2.70 x 2.10	1.70	1.53	9.83	Cellar with shelf	
			44/45/47	TR/S	1.65	1.12	1.38	4.71	Cellar with shelf	
	A1.4	Medium House	98	TR	1.17	1.17	1.80	6.16	Cellar with shelf	
			51	TR	3.30	1.54	1.38	6.10	Cellar	
			52	?	1.10 x .60	?	.35	?	Postmold	
	A1.5	Medium House?	124	TS/S	1.10	1.10	1.16	4.40	Cellar with shelf	
	A1.6	Small Barn	67	H	1.00	1.00	.60	.90	Postmold	
			73	TR	.50	.66	.86	.91	Postmold	
			75	H	.70	.70	.64	.62	Postmold	
			76/116	TR	1.95	1.40	1.76	3.80	Storage pit with ledge	
			79	H	.44	.44	.56	.21	Postmold	
	A1.7	Small Barn?	62	TR	.90	1.25	.80	3.29	Storage pit	
A3	A3.1	Medium House	3	H	.64	.64	.32	.17	Postmold	
			4	B	.85	.85	.80	.57	Postmold	
			6	TR	.90	1.25	1.50	5.49	Cellar with ledge	
			7	TR/S	2.13	1.15	1.43	6.31	Cellar with shelf	
	A3.2	Small Barn	24	R	.55	.55	.60	.56	Postmold	
			27	?	?	?	?	?	Postmold	
			28	TR	1.10	1.42	.68	3.40	Storage pit	

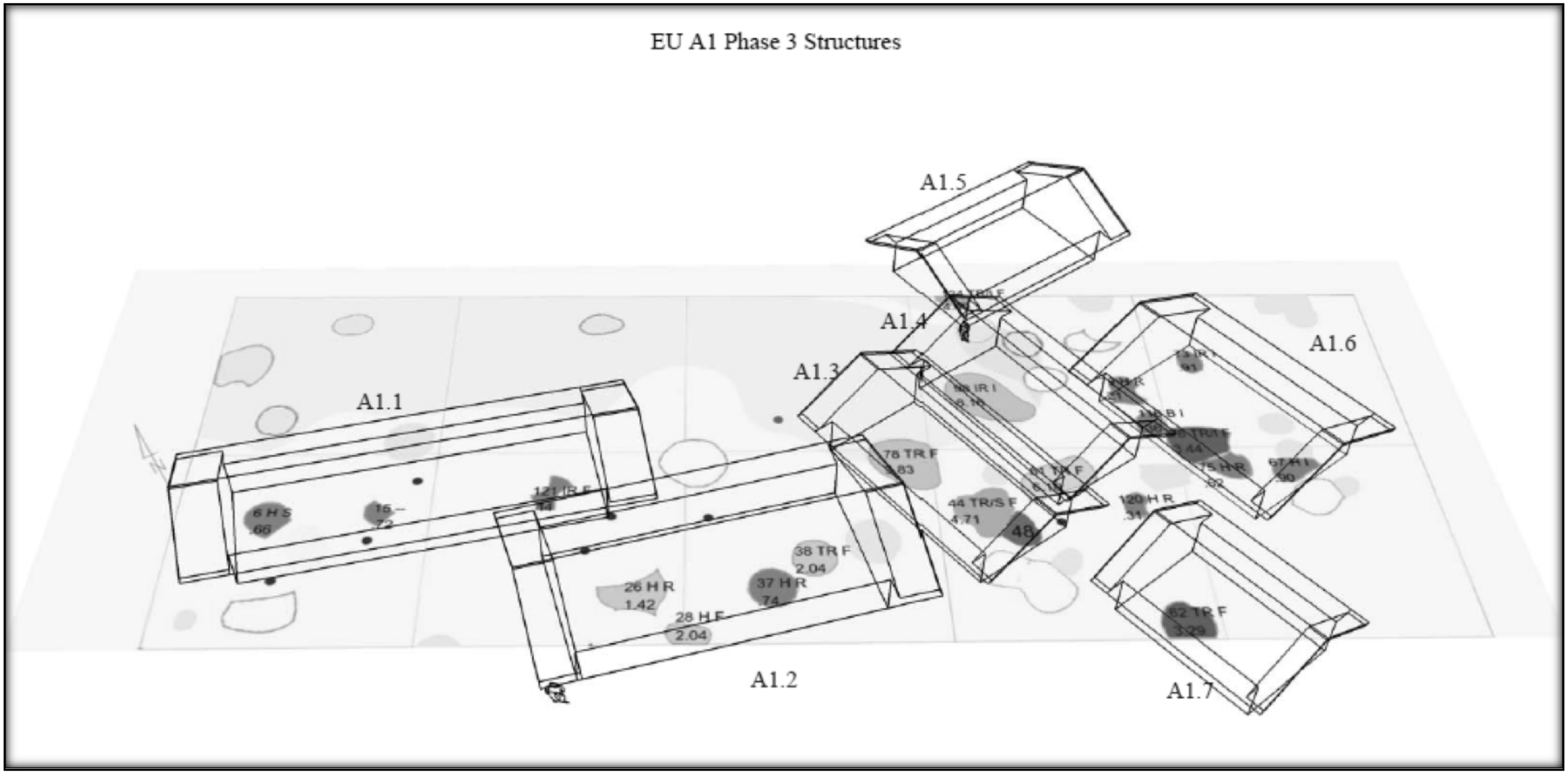

Figure F11.Unit A1 Phase 3 Structures.

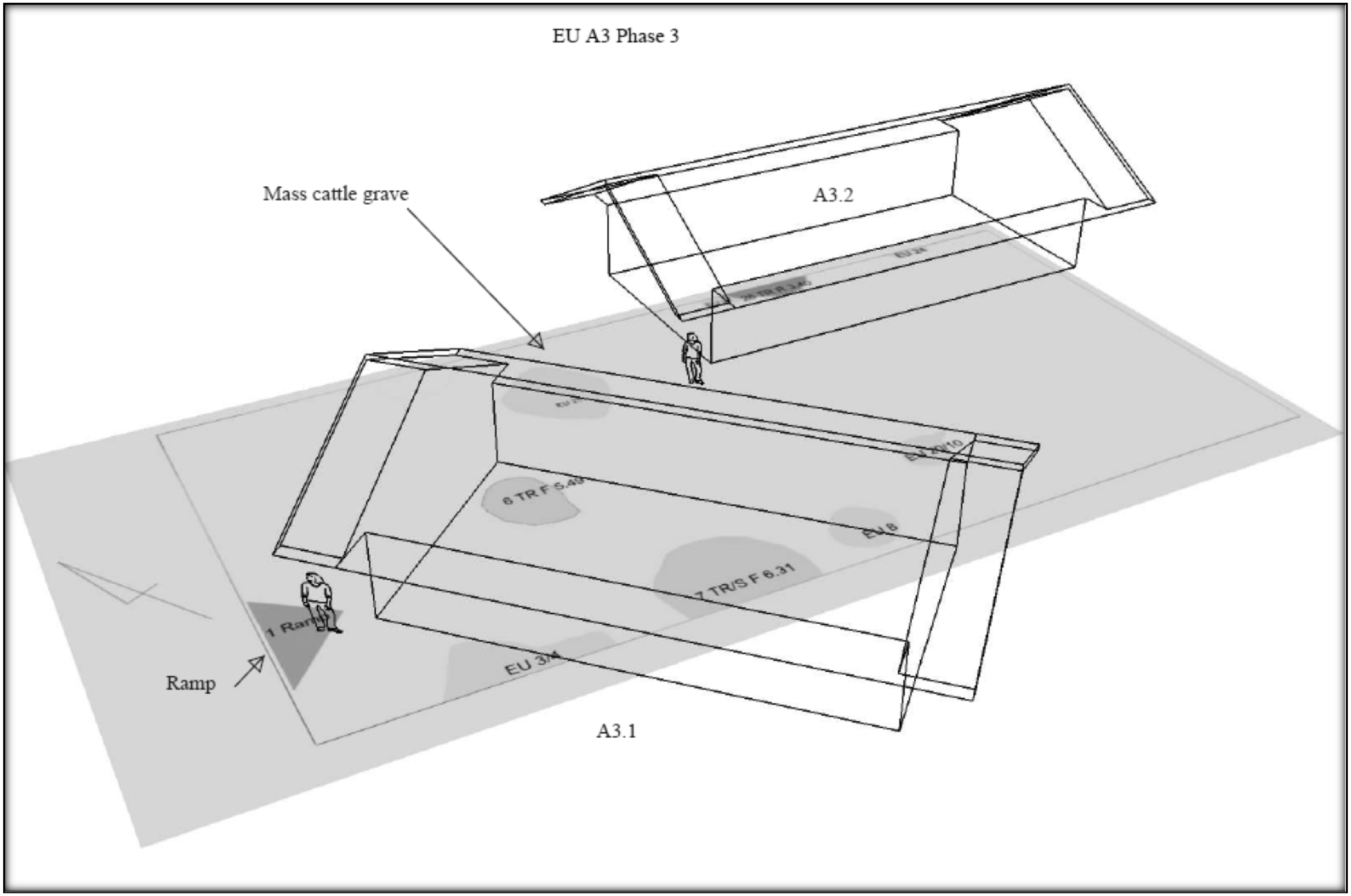

Figure F12. Unit A3 Phase 3 Structures. The ramp descends in front of A3.1 and heads towards the pit containing the mass burial of cattle.

Table F4. Phase 3/4 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Related Pit	Pit Shape	Top Dia. (M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
A1	A1.8	Medium House	117	R	1.32	1.32	1.94	10.60	Cellar	
			125	R	.90	.90	.96	2.44	Burial	
			1	TR	1.20 x 1.50	3.25	1.91	11.02	Cellar	
			126	TR/P	.85	1.05	2.30	6.54	Cellar	
	A1.9	Large House	7,111	TR	2.80 x 2.20	.2.50	1.90	13.86	Cellar	
			8	H	1.10	1.10	1.90	2.29	Storage	
			9	H	1.80	1.80	.70	2.40	House floor	
			21	TR	1	1.45	1.70	8.10	Cellar	
	A1.10	Medium House	101	TR/S	1.55	2.46	2.65	14.68	Cellar	Unusual pit shape. Looks like it was re-dug.
			102	Burial	1.80 x 1.55	-	.75	1.20	Burial	Face down position
	A1.11	Small Barn	33	IR	2.60	1.90	.94	4.40	Storage pit	PM in center and on edge
			35	H	1.60	1.60	.86	3.05	Floor	
	A1.12	Medium House	42	B	1.10	1.10	1.40	1.69	Cellar	
			43	?	.65	.65	1.30	1.43	Postmold	
			46	TR	.80	.92	.90	2.09	Cellar steps	
			49	TR	1.64	1.64	.70	2.16	Cellar	
	A1.13	Large House	89	TR	.64	1.25	1.34	3.88	Storage pit	
			99	TR	.50	.78	.80	.35	Shelf	
			100	B	.60	.60	.80	.28	Postmold	
			96	TR	.50	.60	.84	.80	Shelf	
			110	R	1.24	1.24	1.78	8.59	Cellar	
	A1.14	Medium House	64	B	1.05	1.05	1.30	1.43	Storage pit	
			65	B	.60	.60	.70	.25	Storage pit	
			66	TR/S	2.20	.90	1.67	5.15	Cellar with floor	
			72	B	.15	.15	.80	.011	Postmold	
A2	A2.1	Large House	3	R	.30	.60	.85	1.00	Postmold	
			4	TR	.20	1.20	.75	1.18	Storage pit	
			10/13	TR/S	.1.40	2.15	2.00	13.25	Cellar with shelf	
			14	TR	.100	1.10	1.80	2.17	Storage pit	

Table F4 continued. Phase 3/4 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Related Pit	Pit Shape	Top Dia. (M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
A4	A4.1	Large Barn	4	H	.7	.7	.5	.86	Daub pit?	Two phase 3 pits included with the house.
			5	H	1.6	1.6	.8	2.92	Storage pit	
			6	H	.8	.8	1.2	.76	Postmold	
			8	H	1.24	1.24	.4	.5	Daub pit?	
			10	R	.65	.65	.42	.55	Postmold	

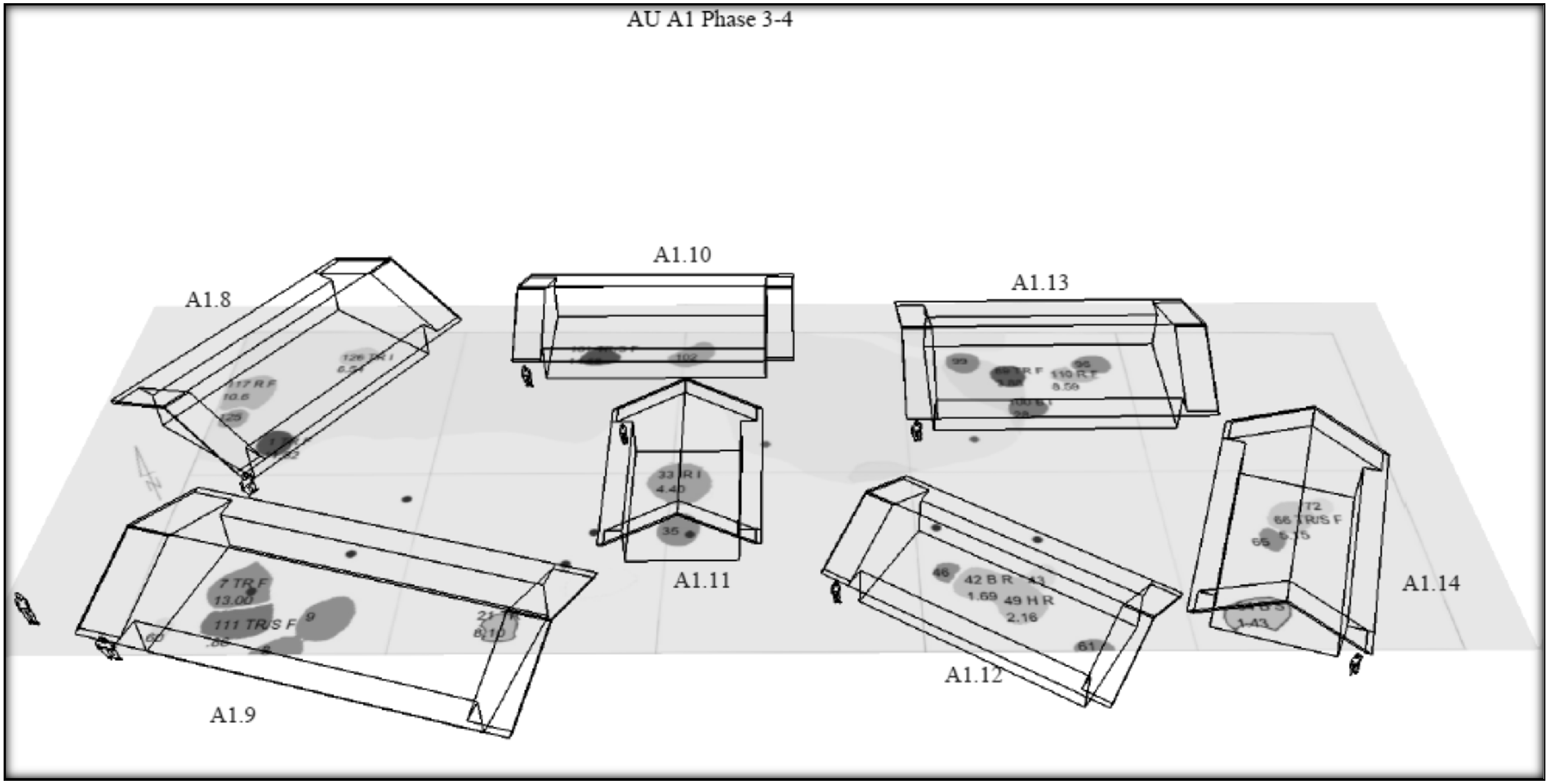

Figure F13. Unit A1 Phase 3/ Structures.

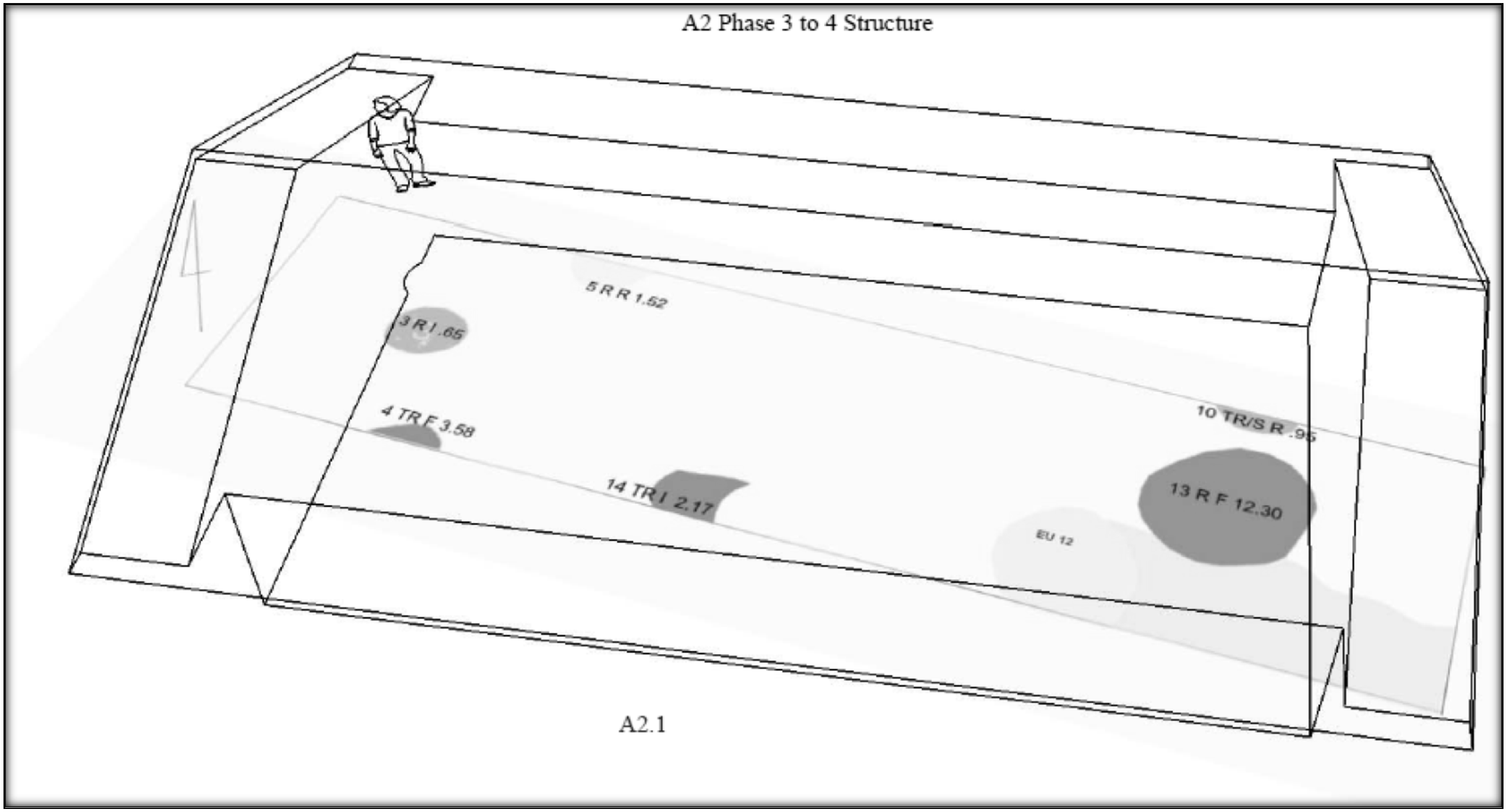

Figure F14. Unit A2 Phase 3/4 structure.

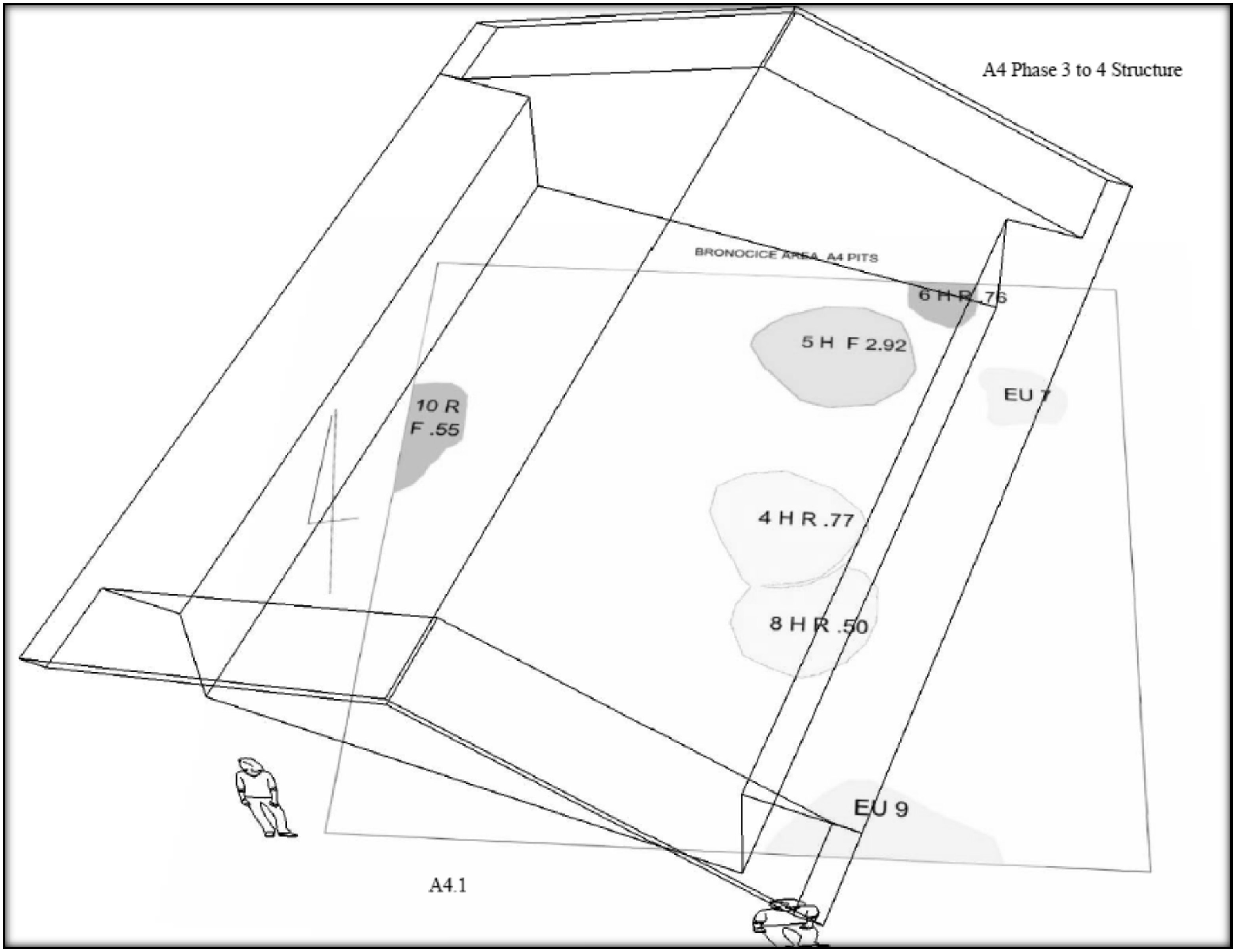

Figure F14. Unit A4 Phase 3/4 structure.

Table F5. Phase 4 structures and dimensions (M meters) and function, by excavation unit.

Area	Structure #	Structure Type	Associated Pit(s)	Shape (M)	Top Dia. (M)	Bottom Dia.(M)	Depth (M)	Cubic Vol.(M)	Pit Function	Comment
A1	A1.15	Medium House	119	TR	1.30	1.40	1.62	9.08	Cellar	These two pits may be separate units
			118	R	1.65	1.65	1.24	10.60	Cellar	PM in center of pit
	A1.16	Medium House	29	TR	1.00	1.20	.94	3.92	Storage pit	32 and 34 are related. They may be a separate unit.
			30,31,108	TR/S	1.80	1.20	2.70	8.70	Cellar with shelf	
	A1.17	Small Barn	32	TR	.58	1.17	1.00	3.22	Storage pit	
			34	TR	1.15	1.25	.56	2.53	Floor	
	A1.18	Large House	4	TR/S	1.75	1.50	1.90	10.85	Cellar with floor	Grinding stone (.50x.20). Burned clay above it.
			12	H	1.40	1.40	.96	3.12	Storage pit	
			16	H	2.40	?	1.22	9.31	Cellar	
			13	TR	.75	1.10	1.54	2.43	Storage pit	
			17	TR	1.05	1.70	1.80	10.88	Cellar with floor	
			18	H	1.40	1.40	.64	1.52	Postmold	
			123	TR	.75	?	1.48	2.61	Storage pit	
	A1.19	Large Barn	10	TR	?	?	?	?	?	
			20	TR	.75	.85	1.00	2.01	Postmold	
			27	B	.90	.90	1.10	.89	Steps	
			23,25	TR/St	2.00	2.00	1.40	2.99	Storage pit with steps	
			107	TR	.50	.75	1.00	1.24	Postmold	
	A1.20	Shed	59	B	.46	.46	1.66	.35	Storage pit	
	A1.21	Shed	39,40	H/B	2.10	.98	1.10	2.69	Storage pit with shelf	
			41	H	.54	.54	.38	.18	Postmold (Phase 0)	
	A1.22	Large Barn	50	B	1.20	?	1.14	1.64	Storage pit	
			53	H	1.00	1.00	.42	.47	Postmold	
			54	H	.85	.85	.88	.63	Postmold	
			55	H	1.54	1.54	.50	1.07	?	
			57	H	1.86	1.86	.64	1.47	?	
			109	H	.58	.58	.36	.18	Postmold	

Table F5 continued. Phase 4 structures and dimensions (M meters) and function, by excavation unit.

Area	Structure #	Structure Type	Associated Pit(s)	Shape (M)	Top Dia. (M)	Bottom Dia.(M)	Depth (M)	Cubic Vol.(M)	Pit Function	Comment
	A1.23	Large House	61	TR	1.20	1.25	.78	3.67	Storage pit	
			63	TR	1.10	1.70	1.32	8.24	Cellar	
			103	R	1.75	1.75	1.16	11.54	Cellar	
			104	B	.52	.52	.64	.39	Postmold	
			105,106	R	.90	.90	.64	1.67	Postmolds	
	A1.24	Medium House	68	TR	1..05	1.25	1.10	7.88	Cellar	
			74	H	1.50	1.50	.50	1.04	2 Postmolds	
			83,84	IR	1.42	.90	1.86	2.12	Storage pit with shelf	
	A1.25	Shed	82	R	1.12	1.12	.80	3.50	Weaver's hut, no pit	
	A1.26	Medium House	86	H	.46	.46	.46	.20	Postmold	
			90	B	.30	.30	.70	.06	Postmold	
			91	B/S	1.60	.64	1.06	.87	Storage pit with shelf	
			92-95	H	1.56	1.56	1.68	6.41	Cellar with 3 shelves/ledges	
	A1.27	Medium House?	85	B	.90	.90	1.86	.73	Postmold	
			113	H	1.10	1.10	.50	.18	Postmold	
			115	TR	.68	1.55	1.90	7.79	Cellar	
A3	A3.3	Small Barn?	16	TR	?	?	?	1.75	Storage pit	
	A3.4	Small Barn	9	TR	.85	1.15	.70	2.21	Storage Pit	Associated with 8 – daub pit?, 10/20 postmolds
B1	B1.1	Medium House	1	H	1.14	1.14	.57	.96	Unknown	
			2	TR	.75	.97	.76	1.77	Storage pit	
			3/4	TR/S	1.64	1.29	.80	2.14	Cellars and hearth	
			9	TR	.85	.95	.70	1.80	Storage pit	
			125	B	.136	1.36	1.14	6.62	Cellar	
	B1.2	Medium House	20	TR	.72	.78	.70	1.23	Storage pit	
			21	TR	.71	.77	.85	1.46	Storage [it	
			23	TR	.75	1.05	1.10	2.82	Storage pit	
			24/25	TR	.78	1.23	.72	5.08	Cellar and hearth	

Table F5 continued. Phase 4 structures and dimensions (M meters) and function, by excavation unit.

Area	Structure #	Structure Type	Associated Pit(s)	Shape (M)	Top Dia. (M)	Bottom Dia.(M)	Depth (M)	Cubic Vol.(M)	Pit Function	Comment
	B1.3	Medium House	31	TR	.65	.65	.70	.90	Storage pit	
			45/46	TR/S	.60	.94	1.44	3.20	Cellar and hearth	
	B1.4	Medium House	57/58	TR	1.00	1.15	.95	3.40	Storage pit	
			66	TR	.60	.80	.66	1.00	Storage pit	
	B1.5	Small Barn?	80	TR	.65	.77	1.20	1.90	Storage pit	
	B1.6	Medium House	98	TR/S	1.35	1.25	1.50	7.96	Cellar with shelf	
B2	B2.1	Small Barn?	9	TR	.98	1.06	.90	3.04	Storage pit	
B5/ B7	B**5**/7.1	Medium House	4	H	.41	.41	.56	.01	Postmold	May be associated with 3, 11 – postmolds
			5/6	TR	2.20	1.30	1.80	10.13	Cellar with shelf	
			7	H	.88	.88	.80	1.23	Postmold	
	B5/**7**.2	Medium House	2	TR	.98	1.10	1.38	4.43	Cellar	Associated with 1, 3 – postmolds
			5	TR	.88	.88	.75	.70	Storage pit	
B6	B6.2	Medium House	6	TR	1.65	1.68	1.00	4.07	Cellar	Associated with postmolds
	B6.3	Small Barn	8	H	.80	.80	.80	.49	Postmold	Possibly from B6.2

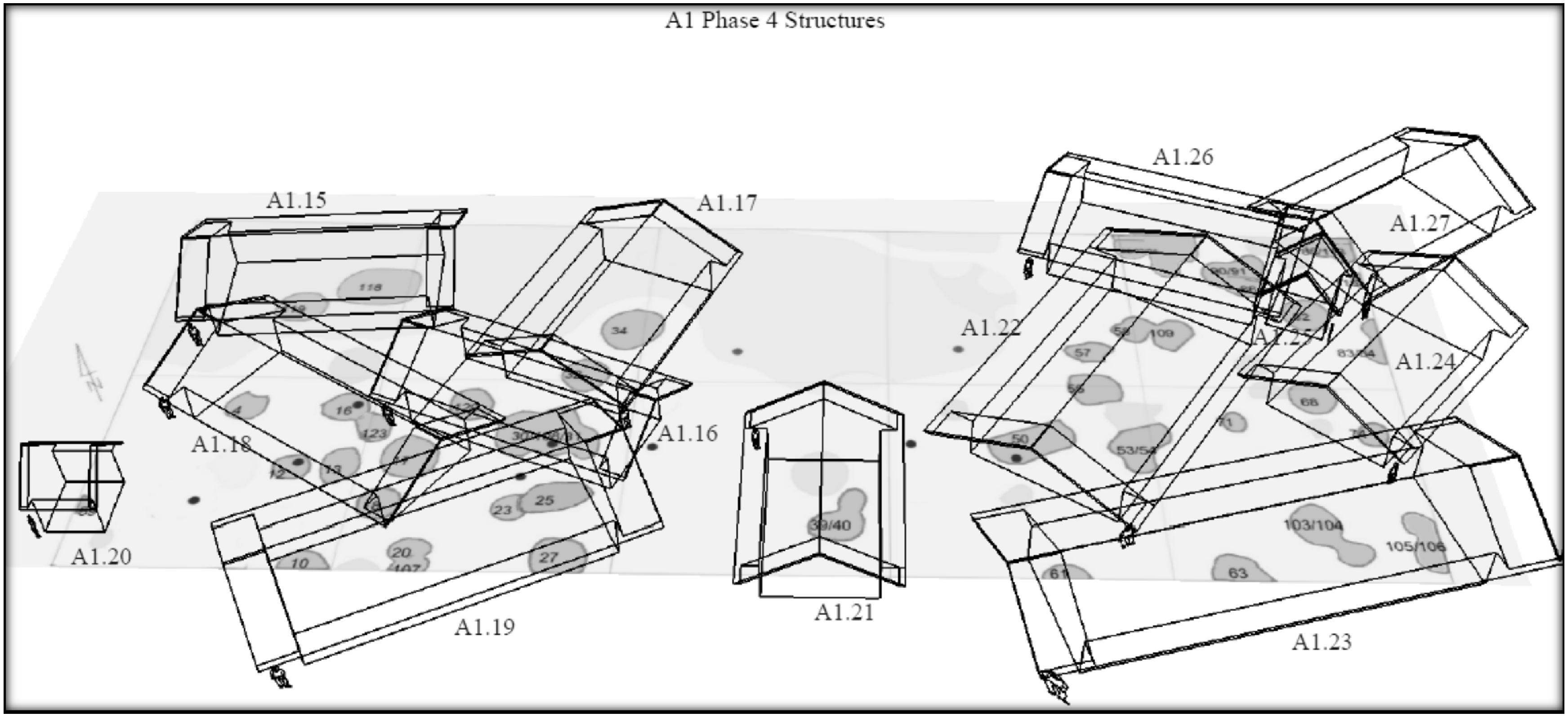

Figure F15. Unit A1 Phase 4 structures.

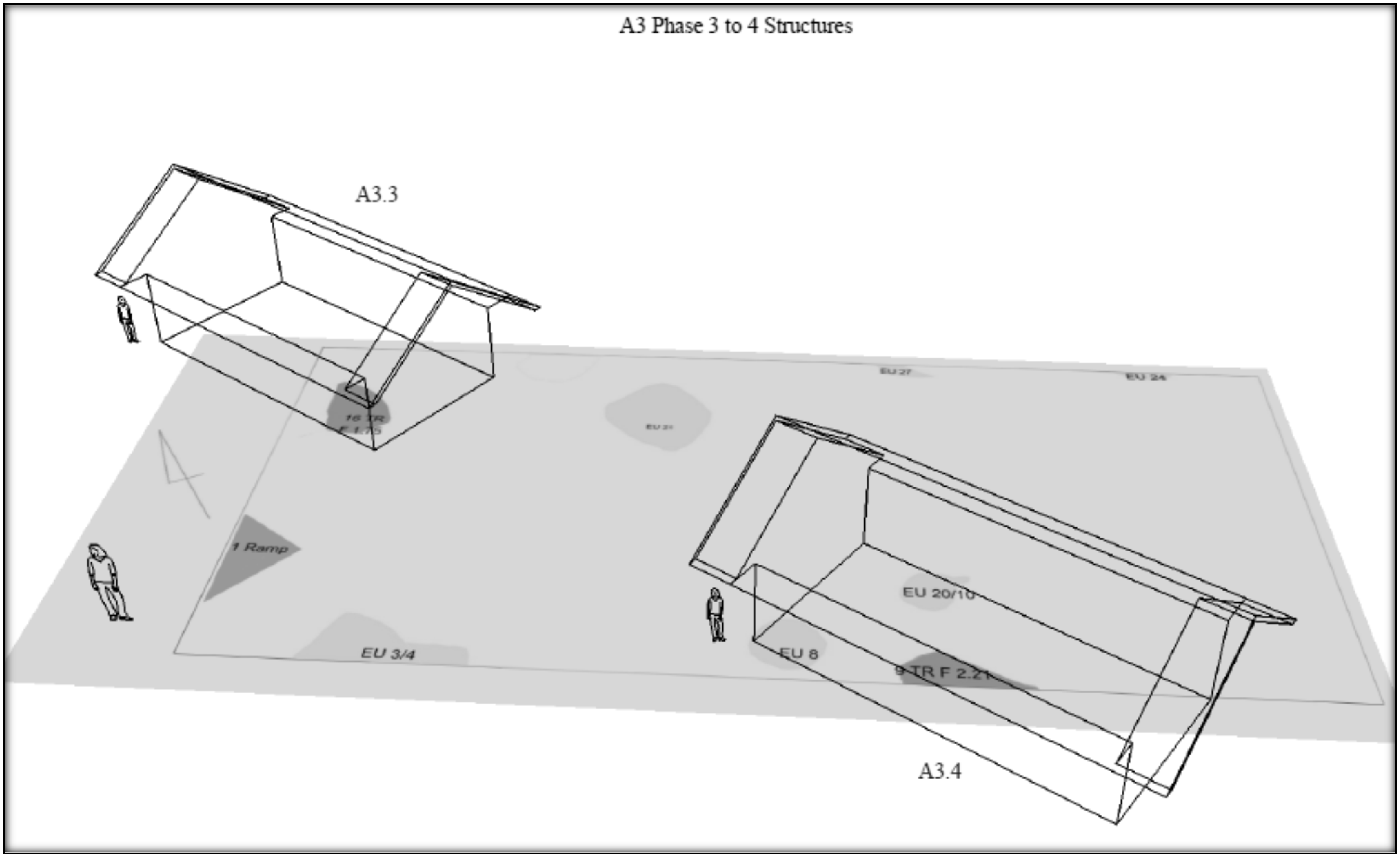

Figure F16. Unit A3 Phase 4 structures.

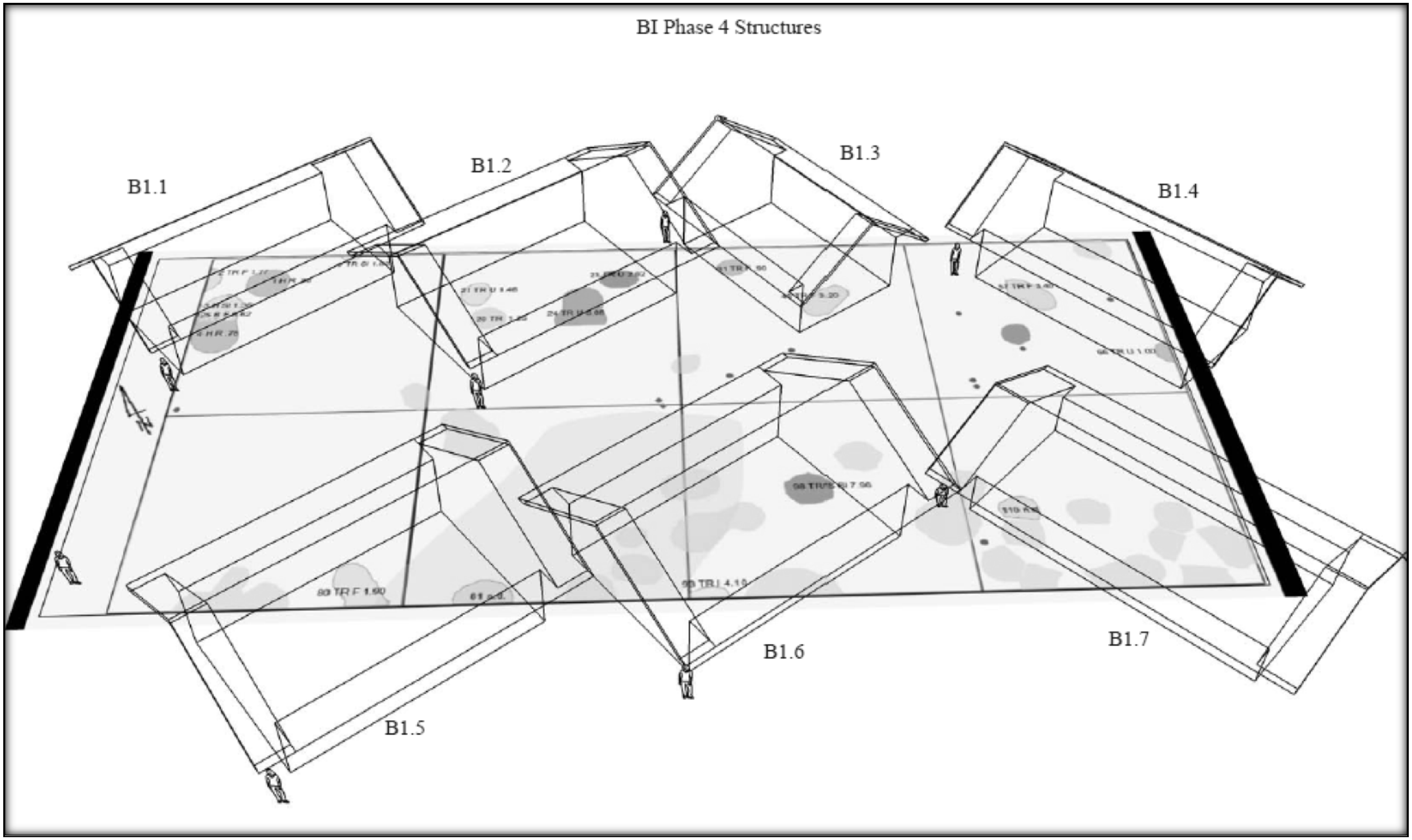

Figure F17. Unit B1 Phase 4 structures.

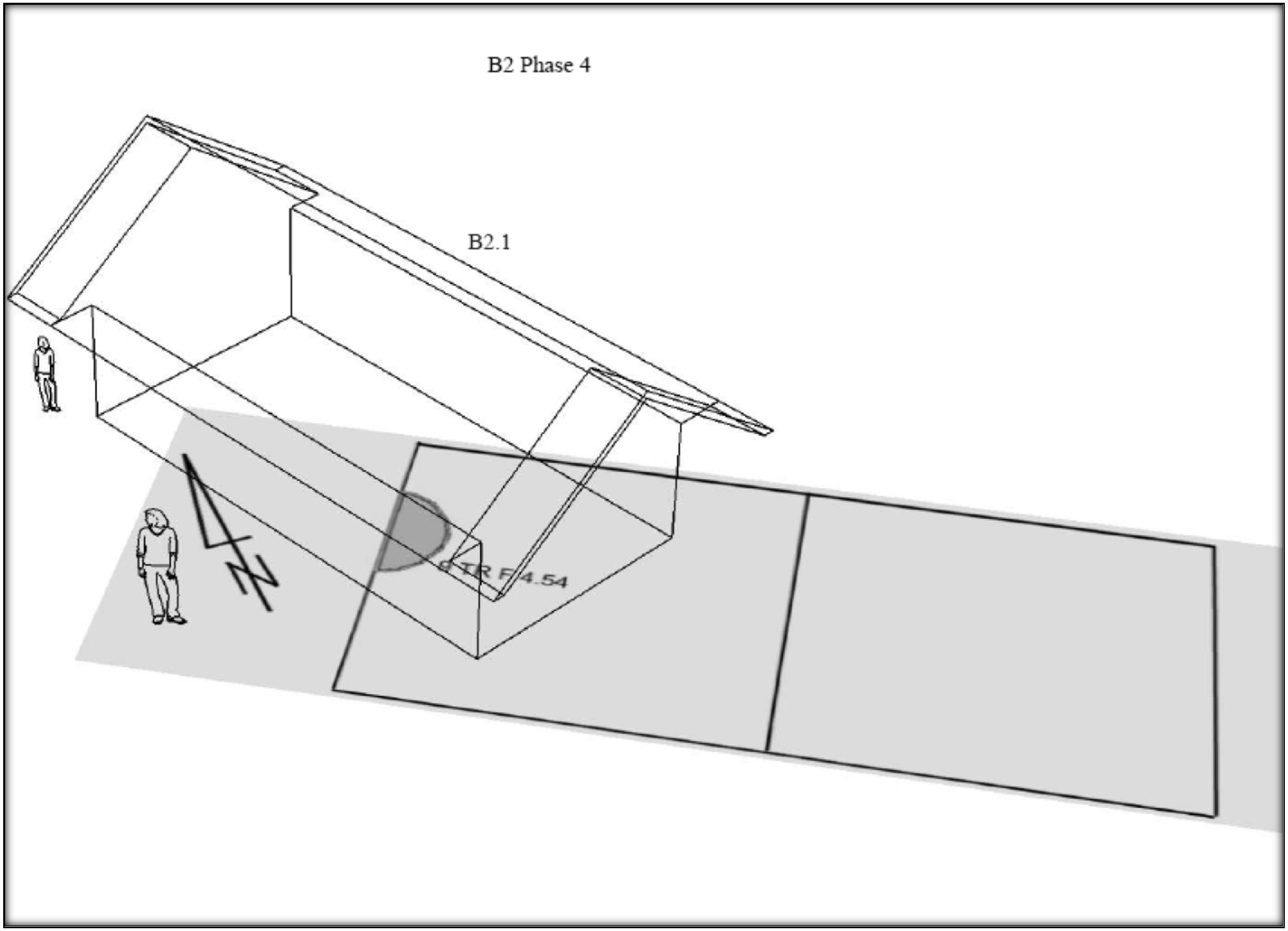

Figure F18. Unit B2 Phase 4 structure.

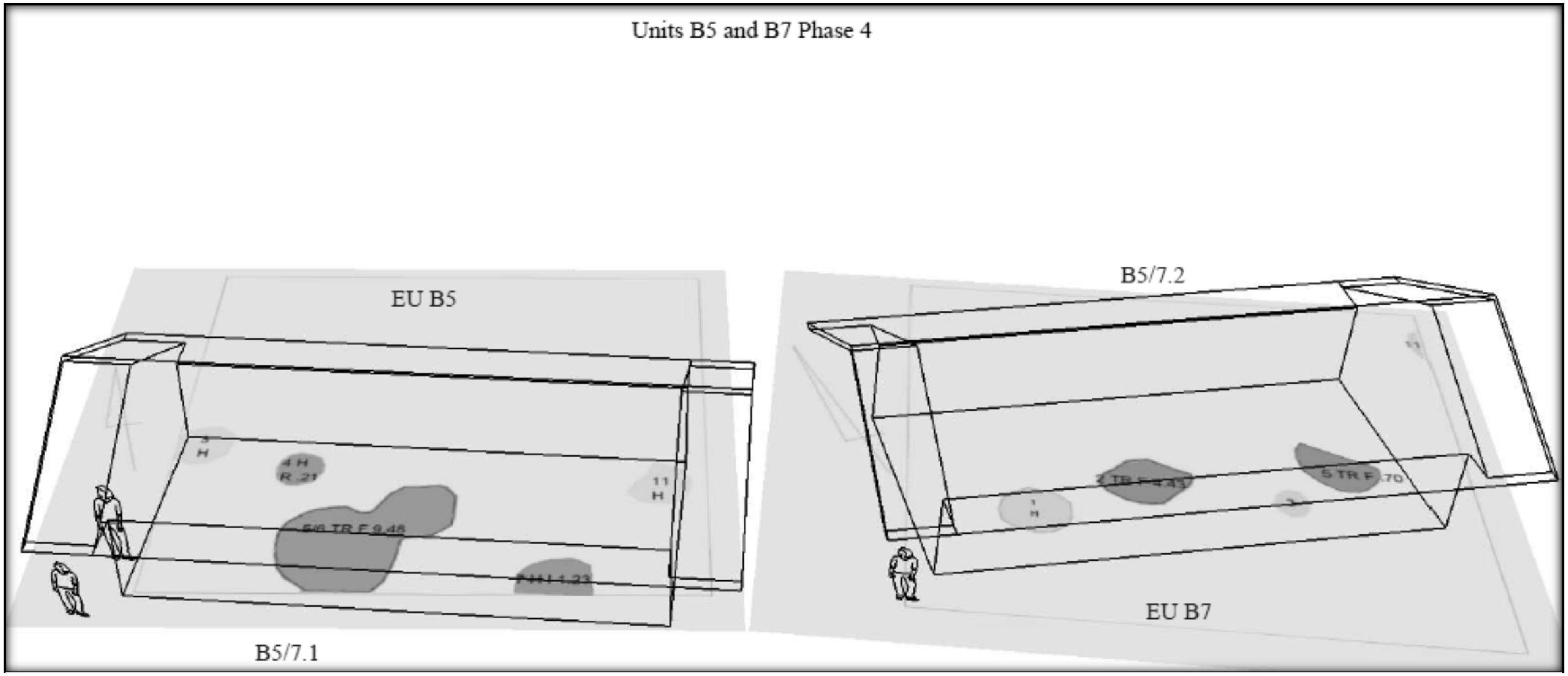

Figure F19. Unit B5/B7 Phase 4 structures.

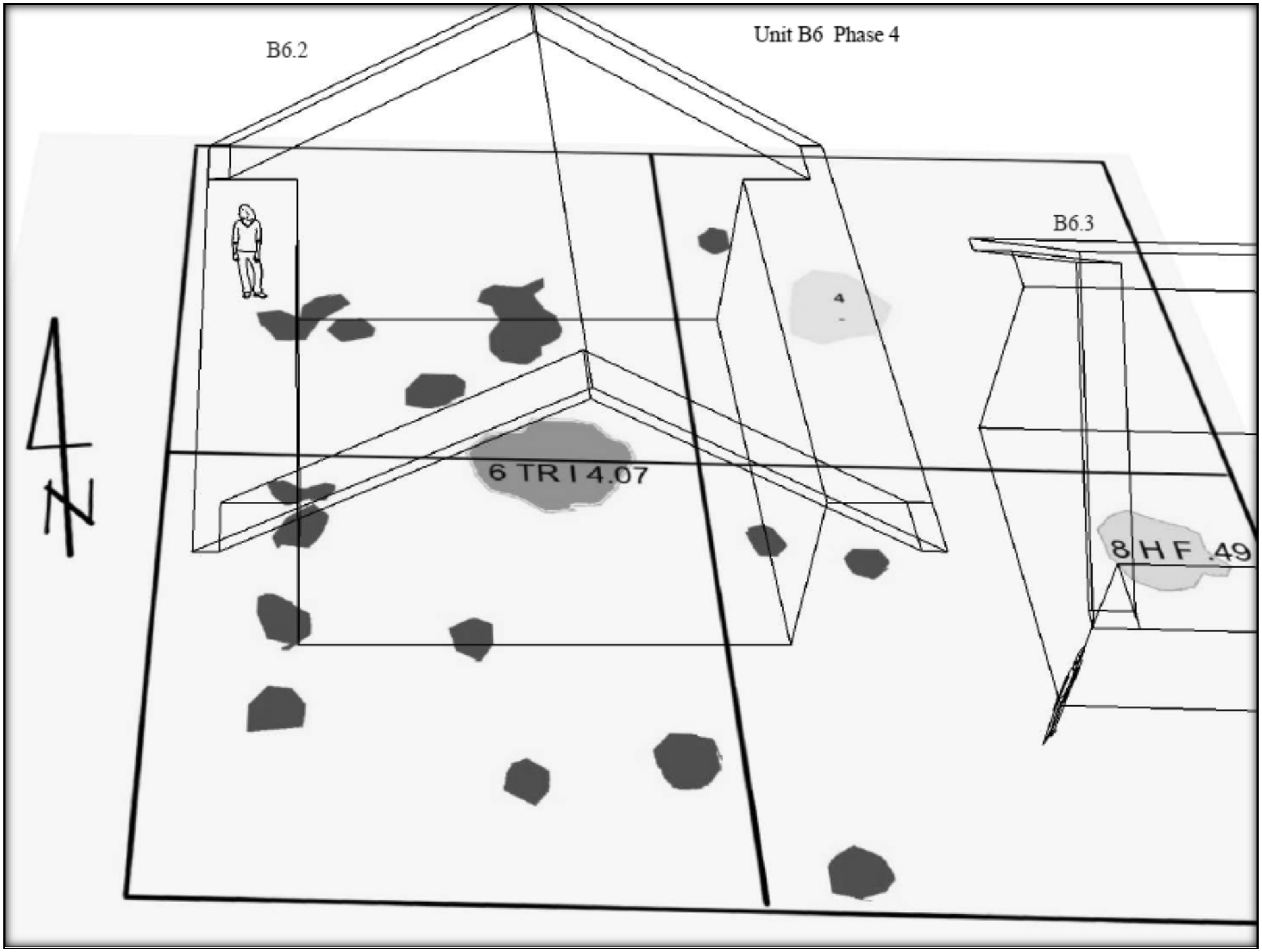

Figure F20. Unit B6 Phase 4 structures.

Table F6. Phase 5 structures and dimensions (M meters) and function, by excavation unit.

Area	House #	Type of Structure	Pit(s)	Shape	Top Dia.	Bottom Dia. (M)	Depth	Cubic Volume	Pit Function	Comment
A1	A1.28	Large Barn	2,122	TR	.83	.43	.50	1.64	Postmold?	
			5	R	1.65		1.24	10.60	Cellar with shelf	
			11	IR	1.80	1.80	.66	2.16	Storage pit	
			14	B	.40	.40	.90	.14	Postmold	
	A1.29	Small House	112	TR	1.14	1.0	2.40	12.19	Cellar	
	A1.30	Large Barn	22	B	.70	.70	1.10	.53	Postmold	
			24	H	1.56	1.56	.50	1.09	Storage pit	
			36	B	.65	.65	1.46	.61	Postmold	
	A1.31	Small House	48	?	?	?	??	?	?	
			56	TR	1.16	1.45	1.30	6.92	Cellar	
	A1.32	Shed	81	TR	1.20	1.25	.78	3.67	Storage pit	
			87	?	?	?	??	?	Postmold	
			88	H	?	?	.40	.93	Storage pit	
	A1.33	Small Ban	97	IR	1.70	1.70	1.20	3.46	Storage pit with steps	
			114 (PH 0)	IR	.45	.45	.82	.16	Postmold	
A2	A2.2	Large House	1	B	1.42	1.42	1.74	3.50	Storage pit	
			5	R	.90	.90	.60	1.52	Postmold	
			6	TR	1.70	1.75	1.58	14.76	Cellar	
			7	TR/S	1.40	1.00	1.20	3.47	Storage with shelf	
			8	TR	1.30	1.40	.80	4.58	Oven	
			9	TR	.79	1.10	.80	2.26	Storage pit with postmold, oven at the bottom?	
			12	TR	1.10	1.30	1.34	6.07	Cellar	
A3	A3.5	Medium House	15	TR	.70	.95	.84	1.80	Storage	
			18/29	TR/Pl	1.55	1.10	1.42	6.54	Cellar with platform	
			19	TR	.65	.90	.98	1.86	Storage	
	A3.6	Small House	25	TR	.60	1.20	1.30	3.42	Storage pit	
			26	TR	.80	1.10	1.64	4.68	Cellar	
	A3.7	Small House	22	TR	.68	1.05	1.74	4.15	Cellar	Human burial
			23	TR	.95	1.10	1.10	3.63	Storage pit	
	A3.8	Small Barn	8	H	1.34	1.34	.80	2.15	Daub pit?	This structure was rebuilt. A3.9 sits on top of it
			11	TR	.50	.95	.90	1.31	Postmold	
			13	R	1.00	1.00	.94	2.95	Storage pit	
			20	H	.60	.60	.54	.38	Postmold	

Table F6 continued. Phase 5 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Associated Pit(s)	Shape	Top Dia.	Bottom Dia. (M)	Depth (M)	Cubic Volume	Pit Function	Comment
	A3.9	Medium House	12	TR	.50	.75	1.10	1.36	Storage pit	
			14	TR/S	1.15	1.70	2.02	13.68	Cellar with shelf	
	A3.10	Medium House	2	TR	.90	1.00	1.50	11.03	Cellar	
			5	B	.80	.80	.90	.57	Postmold	
			17	R	1.50	1.50	1.90	13.84	Cellar	
A4	A4.2	Small Barn?	1	R	.70	.70	.50	.86	Postmold	
			2	R	.85	.85	1.00	2.26	Storage pit	Possibly associated with 7A4, shed?
			3	H	1.60	1.60	.60	1.68	Unclear	
B1	B1.7	Large House	7/8	TR/S	1.53	1.25	.82	4.10	Cellar with shelf	
			10	TR	.85	1.06	1.24	3.40	Storage pit	
			22	TR	.95	1.20	1.16	4.22	Storage cellar, animal burial	Roe deer
	B1.8	Small House	6	-	.70	.93	1.00	2.10	No cellar	Collapsed daub hut or oven
	B1.9/10	Medium House	11/12	TR/S	.87	1.15	.90	5.90	Cellar with floor	These three pits may be individual house units or different rooms in the house
			16	H						
			17	TR/S	.82	.85	.60	1.50	Floor and storage pit	
			19	TR/S	1.12	1.12	.47	3.85	Floor and storage pit	
			13/14/15	TR/S	1.42	1.65	1.04	11.20	Cellar with shelf	
			59	TR	.85	.97	1.10	2.87	Storage pit	
	B1.11	Medium House	52	TR	2.17	.70	1.46	?	Cellar with shelf	
			68	TR	.45	.53	1.10	.83	Postmold	
			69	TR	.98	.75	.90	2.12	Storage pit	
			71	TR	.90	.90	.60	1.22	Postmold	
	B1.12	Small House	26	TR	.85	.85	1.20	2.72	Storage pit	These may represent 2 household units
			27/28	TR	.90	1.00	1.06	6.10	Cellar with shelf	
			34/35	TR	1.23	1.26	1.06	5.10	Cellar with shelf	
	B1.13	Small House	29/30	TR	1.14	1.50	1.20	7.00	Cellar with shelf	
			33	TR	1.55	1.55	1.12	8.0	Cellar	
	B1.14	Small House	36/37/38	TR	.70	.75	1.00	11.50	Burial chamber	Likely attached to structure B1.13
	B1.15	Large House	95	TR	.90	1.45	1.25	7.76	Cellar with shelf	These may represent 2 household units
			96	TR	.67	1.03	1.82	4.19	Cellar	
			97	TR	.64	.80	1.10	1.79	Storage pit	
			103/104	TR	1.89	2.08	1.22	?	Cellar	
	B1.16	Small House	100	TR	?	?	?	?	Burial chamber	

Table F6 continued. Phase 5 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Associated Pit(s)	Shape	Top Dia.	Bottom Dia. (M)	Depth (M)	Cubic Volume	Pit Function	Comment
	B1.17	Large House	113/114	TR/S	1.76	1.90	1.35	6.43	Cellar with shelf	These may represent 2 household units
			119	TR	1.68	1.78	1.68	10.72	Cellar	
	B1.18	Small House	40/41/42	TR/S	2.75	-	1.70	9.60	Cellars with shelf	
			43	TR	1.115	1.10	.70	2.80	Burial	
			44	H	1.32	1.32	.46	.77	Postmold	
	B1.19	Medium House	47	TR	.70	.73	.76	2.80	Postmold	
			56	TR	1.27	1.37	1.25	6.80	Cellar with shelf	
	B1.20	Small House	54/55	TR/S	1.00	1.43	1.30	6.08	Cellar with shelf	These may represent 2 household units.63 is from Phase 4 but goes with pit 64
			63/64	TR/S	1.73	1.80	1.16	5.22	Cellar with shelf	
	B1.21	Medium House	61	TR/P	.25	.45	1.65	11.40	Cellar with shelf	
			62	TR	1.07	1.05	1.10	3.88	Storage pit	
			65	TR	.75	1.00	.90	2.10	Storage pit	
B2	B2.2	Medium House	4/5	TR/S	?	?	?	?	Cellar with shelf	These may represent 2 households
			6	TR/S	2.01	1.74	.74	6.92	Cellar	
B5/ B7	B5/7.3	Medium House	1/2	TR/S	?	?	?	?	Cellar with shelf	Pit 1 dates to Phase 6
			3	H	1.35	1.35	.90	2.92	Storage pit	No phases assignment
	B5/7.4	Large House	9A/11	TR/S	2.40	1.00	.70	9.63	Cellar with shelf (11B5)	11B5 was undated
			8	TR	.90	1.00	.90	2.27	Storage pit	
			18	TR/S	1.91	.85	1.10	2.81	Storage pit with shelf	These may represent 2 households
			19	TR	.74	.92	1.00	1.69	Storage pit	
	B5/7.5	Small House	6	TR/H	1.78	.98	1.00	5.66	Hearth	6 and 7 go together
			7	TR	.85	.98	1.50	12.46	Cellar	
			10	TR	.80	1.15	1.35	3.90	Storage pit	Associated with 11 B7
B6	B6.4	Large House	1	B	.91	.92	.65	1.95	Postmold	
			2	TR	1.00	1.06	1.00	2.05	Storage pit	
			3	H	.40	.40	.65	.15	Postmold	
			4/5	TR/S	1.98	1.40	.98	4.07	Cellar with shelf	
			7	TR/P	.85	.90	1.50	2.85	Storage pit	
			9	TR	.80	.91	.80	1.84	Storage pit	
			10	TR	.80	1.15	1.35	4.07	Cellar	
			11	TR	.52	1.13	1.80	4.02	Cellar	

Table F6 continued. Phase 5 structures and dimensions (M meters) and function, by excavation unit.

EU	Structure #	Structure Type	Associated Pit(s)	Shape	Top Dia.	Bottom Dia. (M)	Depth (M)	Cubic Volume	Pit Function	Comment
B8	B8.1	Large House	1	TR	.73	1.15	2.00	5.64	Cellar	Lithic workshop
			3	TR	1.35	1.45	1.65	5.79	Cellar	
			4	TR	.80	.80	1.30	2.61	Storage pit	
	B8.2	Large House	12,13,14	TR	2.27	1.58	1.90	4.62	Cellar with shelves	May represent 2 households
			8,9,11	TR	1.69	2.26	1.85	10.62	Cellar with shelves	
			10	TR	.55	1.02	1.40	2.79	Storage pit	
C1	C1.4	Small House	87	-				-	Burial chamber	Double burial
	C1.5	Medium House	84	H				1.31	Storage pit	
C4	C4.1	Large House	2	TR	.60	.90	1.48	2.64	Storage pit	Collapsed daub house
			3	B	.90	.90	.80	.64	Postmold	
			4	TR	.60	1.07	.60	3.25	Storage pit	
			5	B	.66	.66	1.04	.45	Postmold	
			6	B	.90	.90	1.18	.95	Postmold	
			7	TR	1.10	1.15	1.70	6.75	Cellar	
			8	TR/S	.47	.57	.42	6.16	Cellar with shelves	
			9	B	.80	.80	1.62	1.03	Postmold	
C5	C5.2	Shed	17	IR	.60	.60	1.74	.62	Postmold?	
			20	TR	.74	.95	1.50	3.38	Storage pit	
	C5.3	Shed	22	TR	.70	.85	1.40	2.64	Storage pit?	
			85	TR				6.40	Cellar	
	C5.4	Large Barn	7	TR	.75	1.12	.78	2.16	Storage pit	Phase 0
			8	B	1.00	1.00	.88	.88	?	Phase 0
			9b	B	.86	.86	.80	.59	Postmold	Phase 0
			10	TR	.82	.95	.82	2.02	Storage pit	
			11	H	1.08	1.08	1.36	3.63	?	Phase 0
			12	TR	.75	.90	1.30	2.78	Storage pit	Phase 0
			13	H	1.18	1.18	.70	1.45	?	Phase 0
			14	Burial	-	-	-	-	Burial	
			23	B	.55	.55	2.20	.60	Postmold	

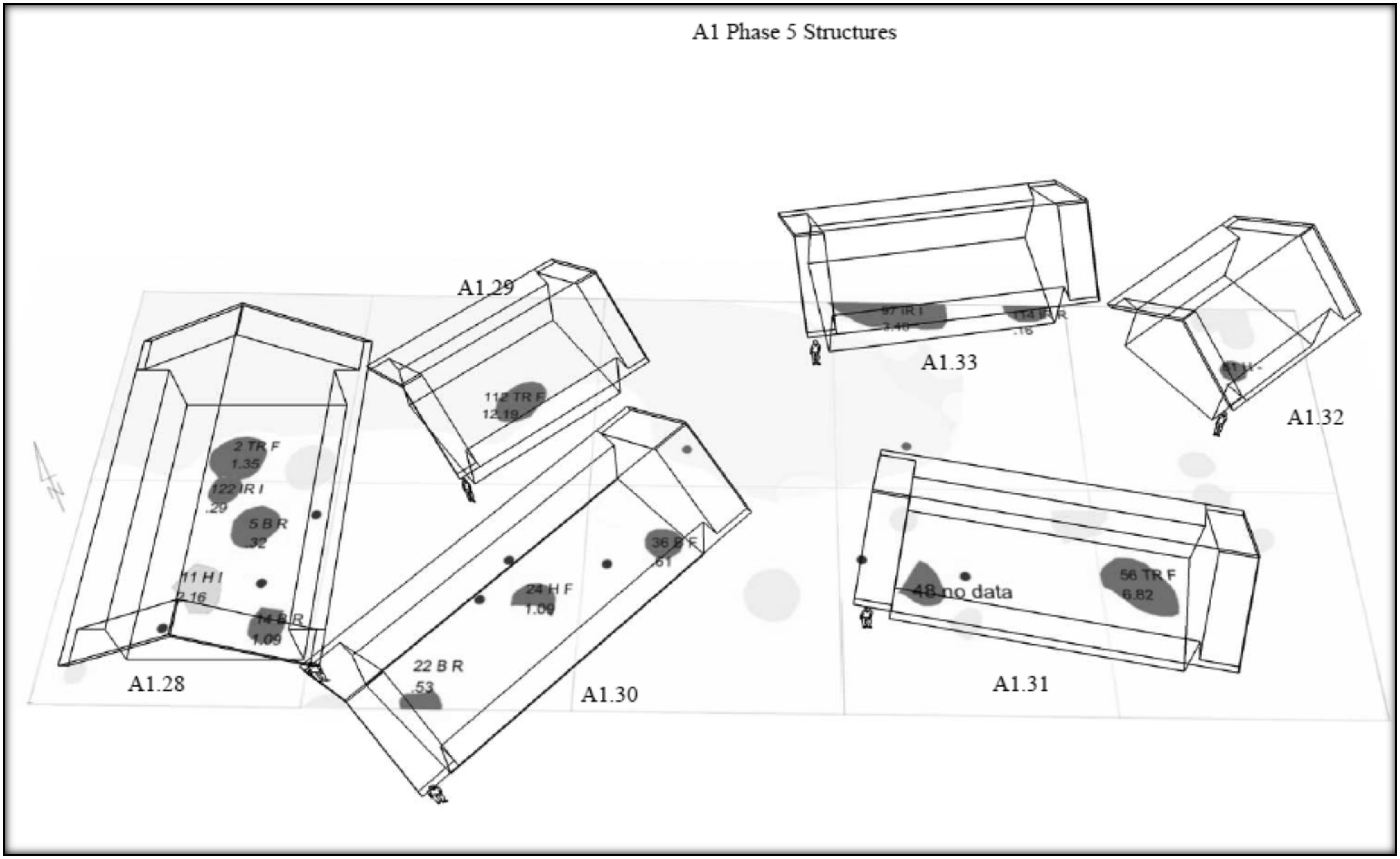

Figure F21. Unit A1 Phase 5 structures.

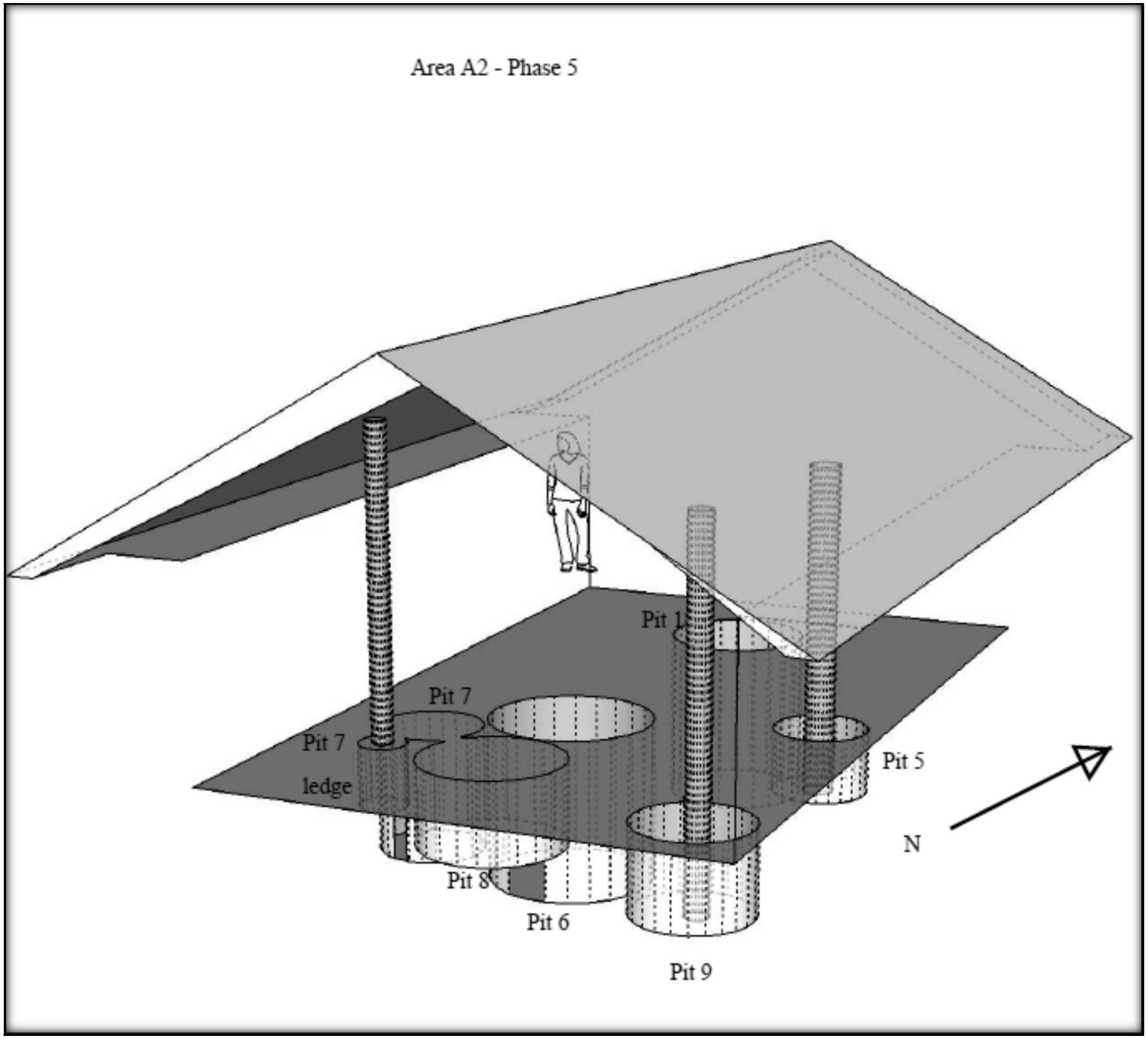

Figure F22. Unit A2 Phase 5 structures. Pit 9 is actually a former oven.

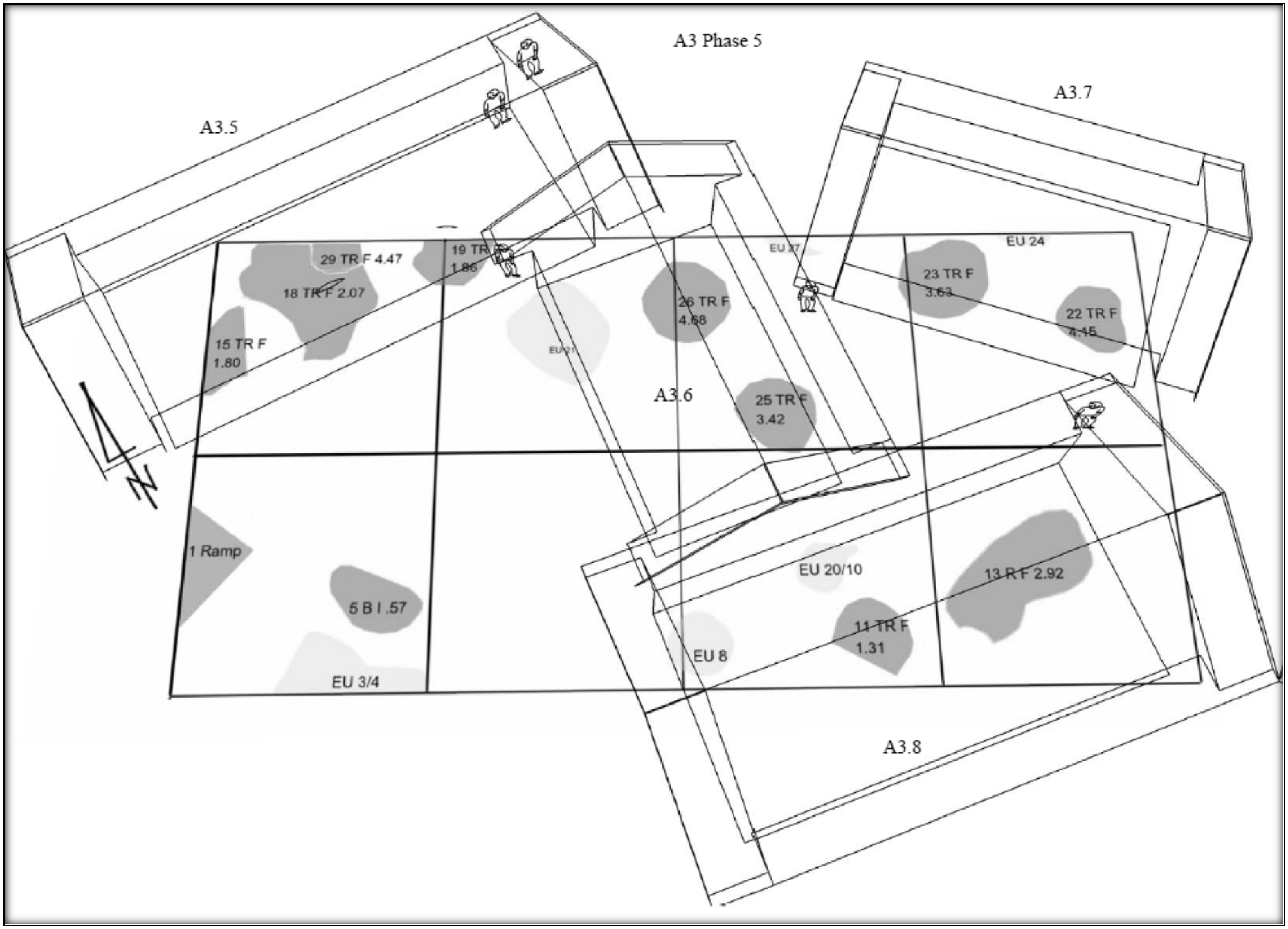

Figure F23. Unit A2 Phase 5 structures.

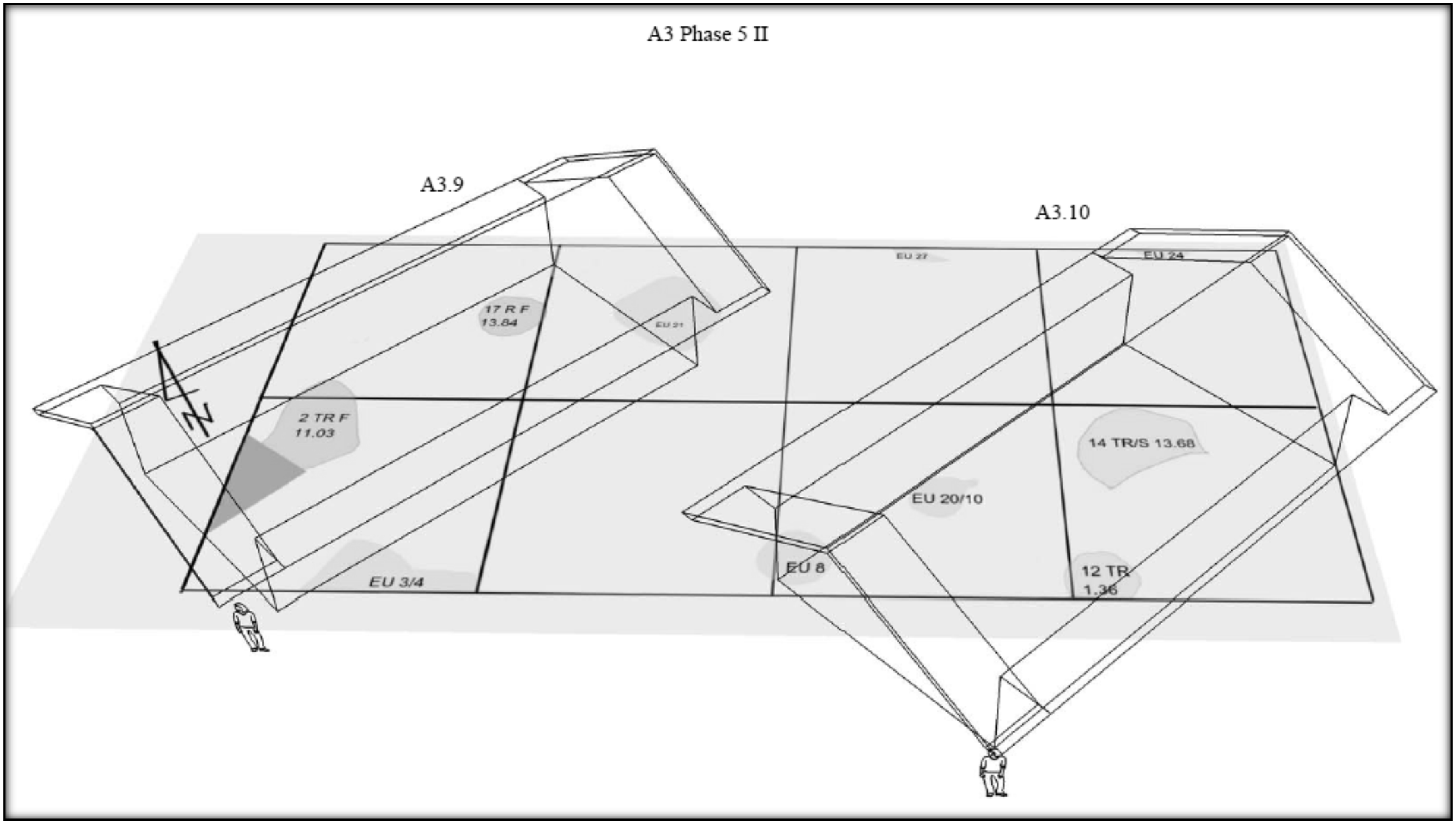

Figure F24. Unit A2 Phase 5 subphase II structures.

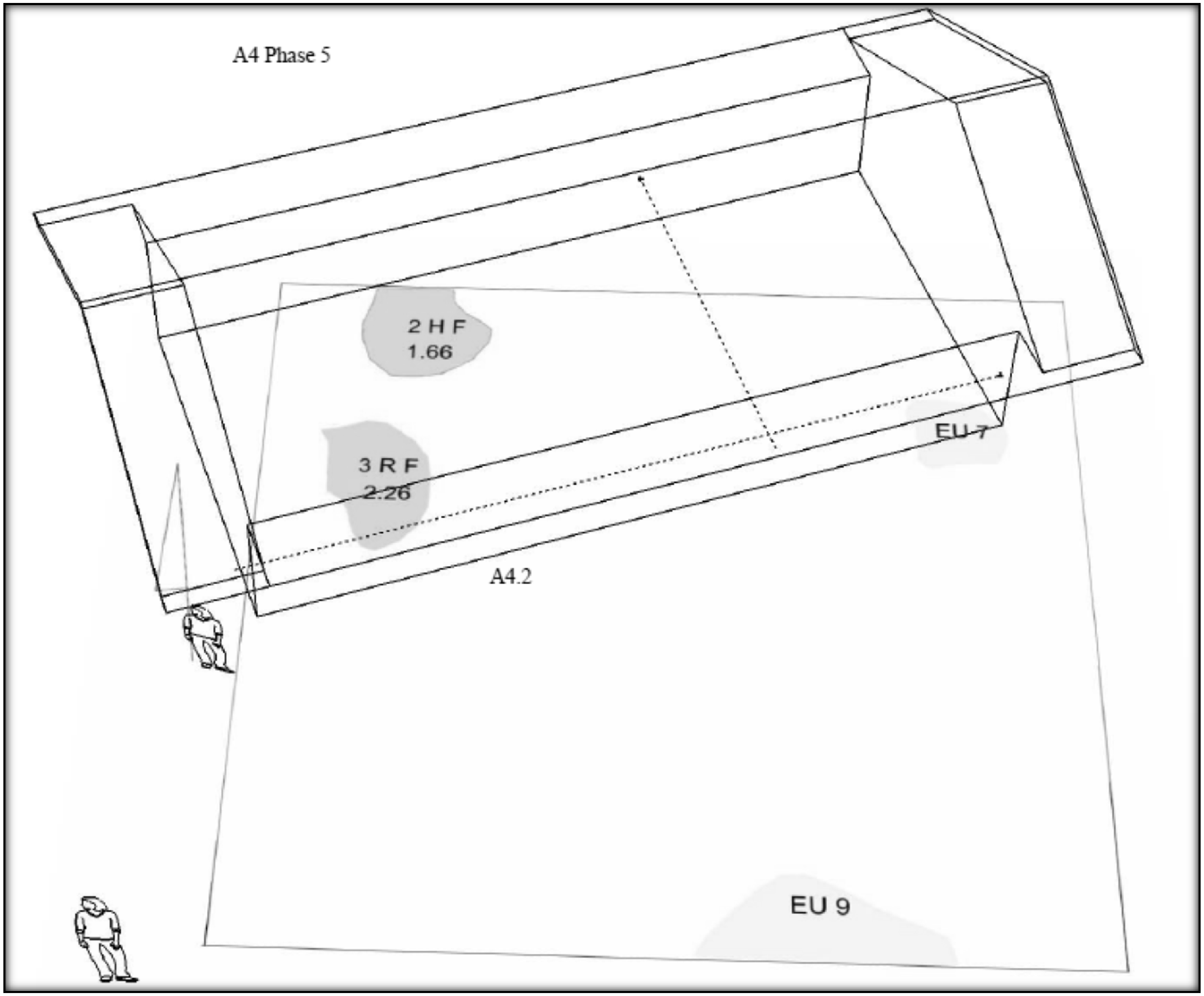

Figure F25. Unit A4 Phase 5 structure.

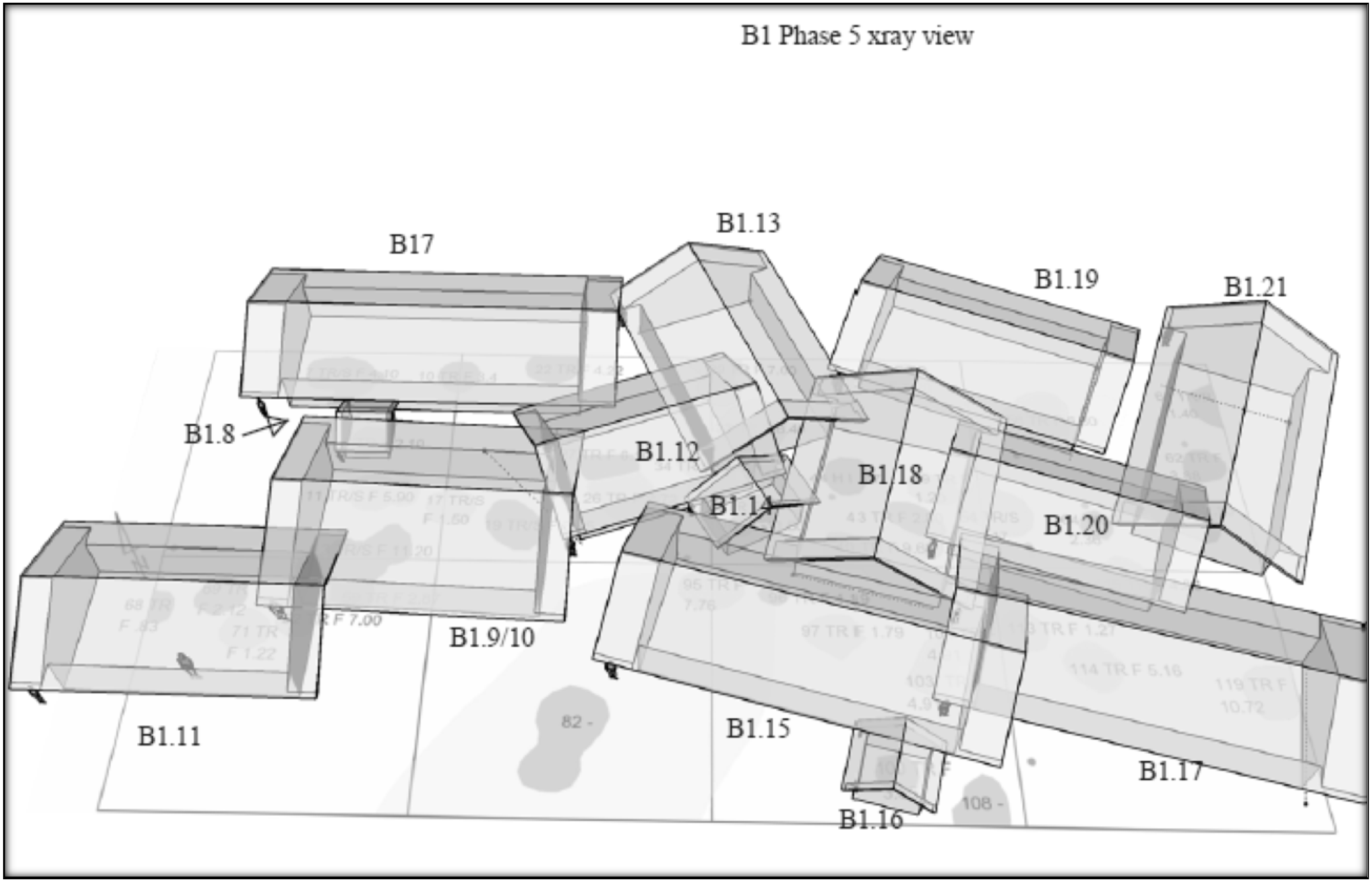

Figure F26. Unit B1 Phase 5 all subphases combined.

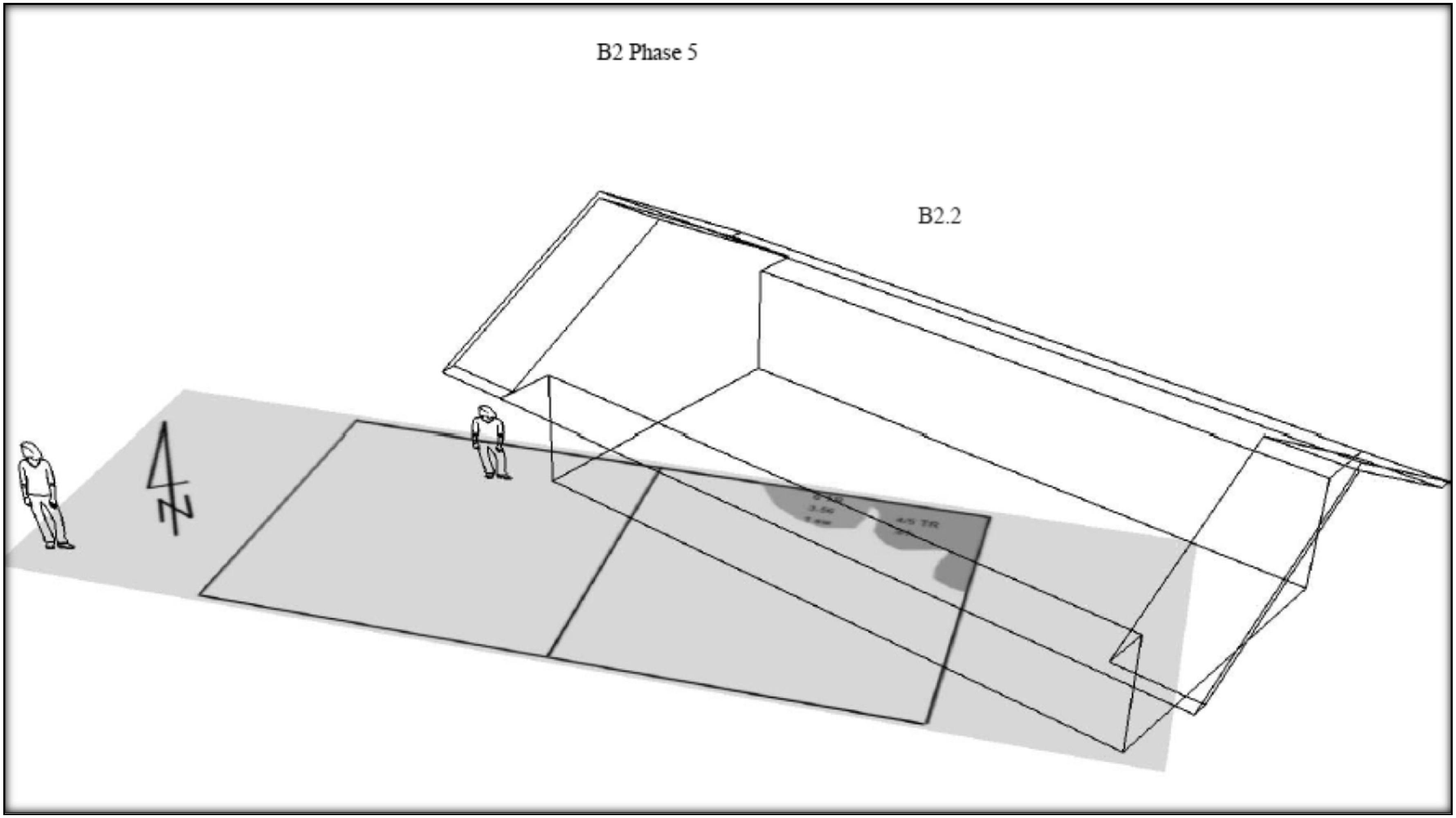

Figure F27. Unit B2 Phase 5

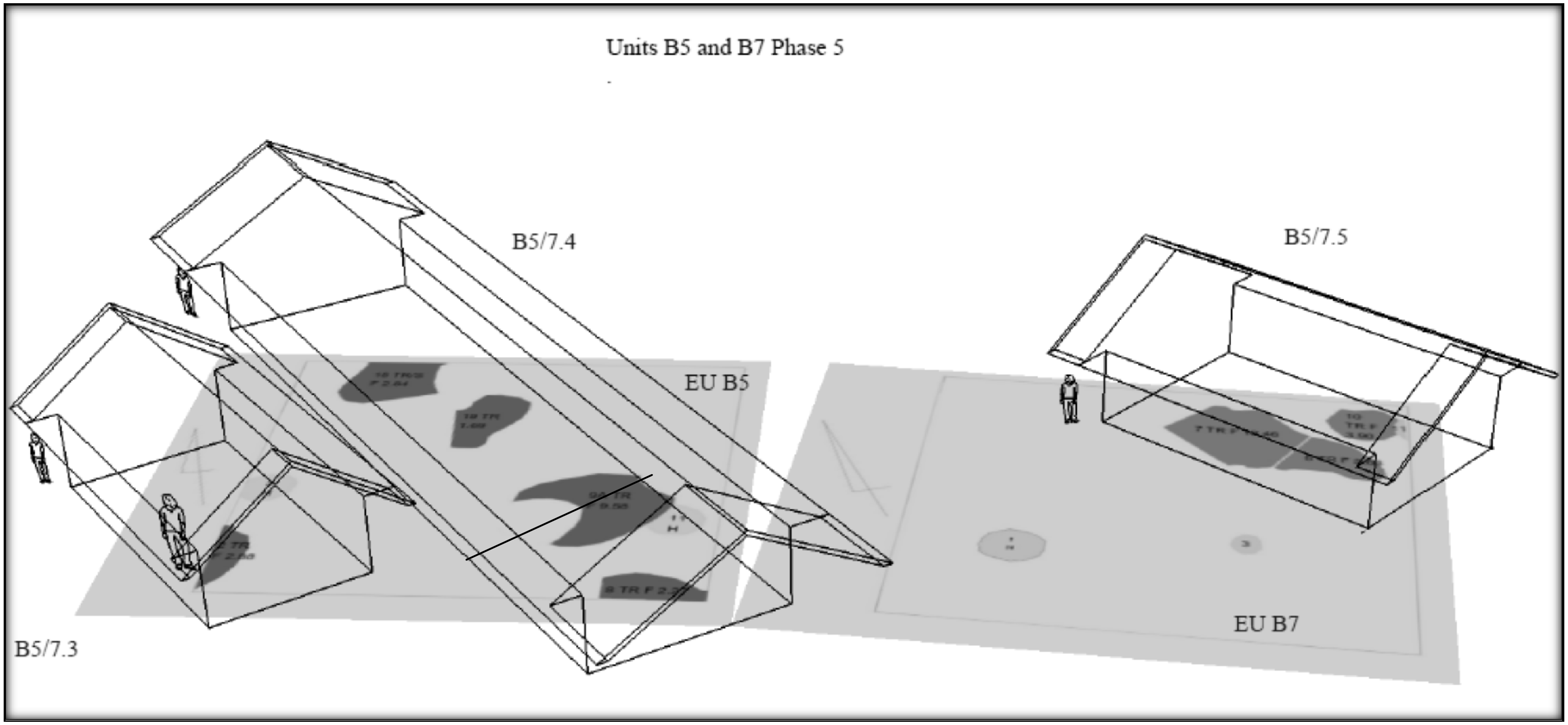

Figure F28. Unit B5/B7 Phase 5 Structures.

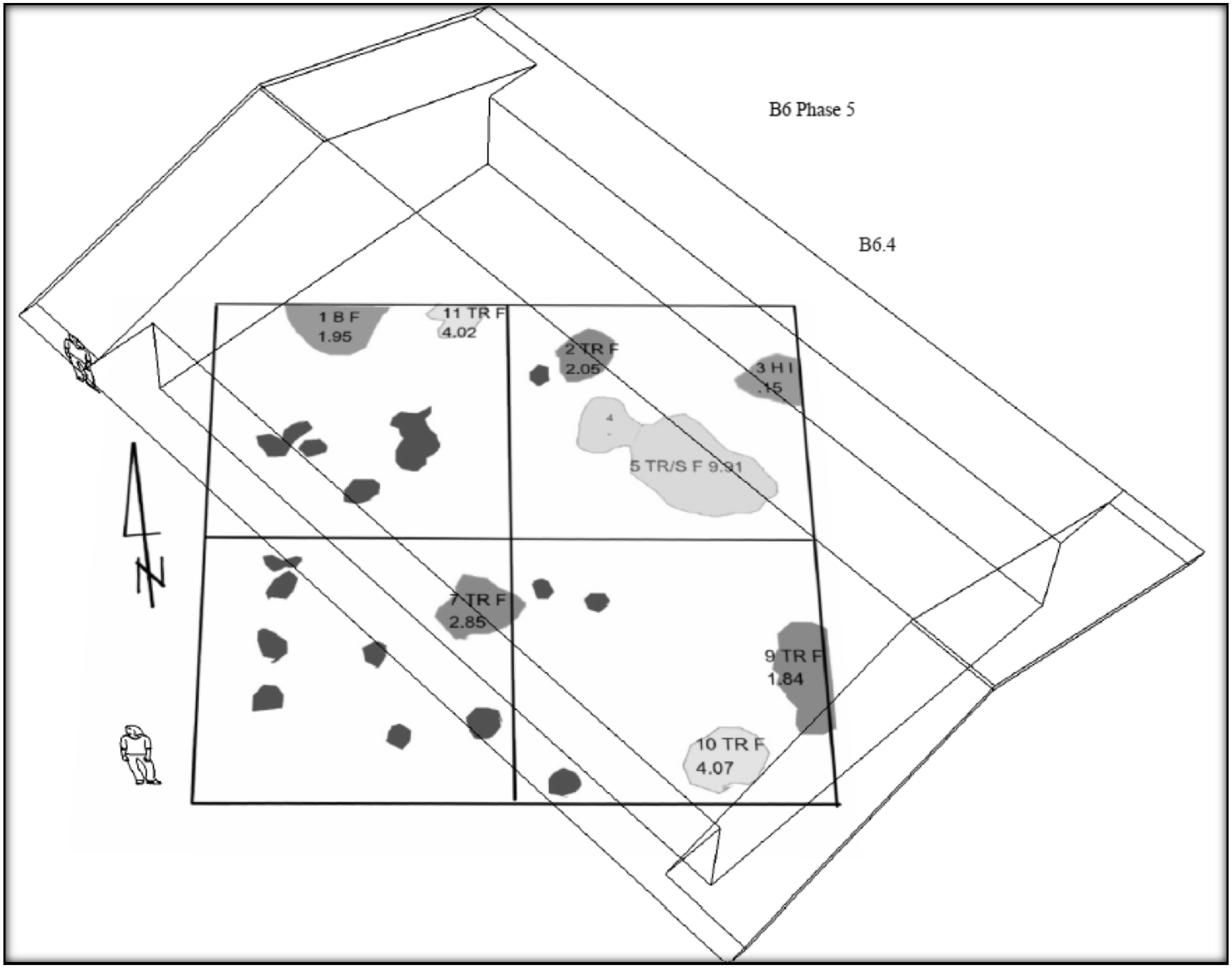

Figure F29. Unit B6 Phase 5 Structure.

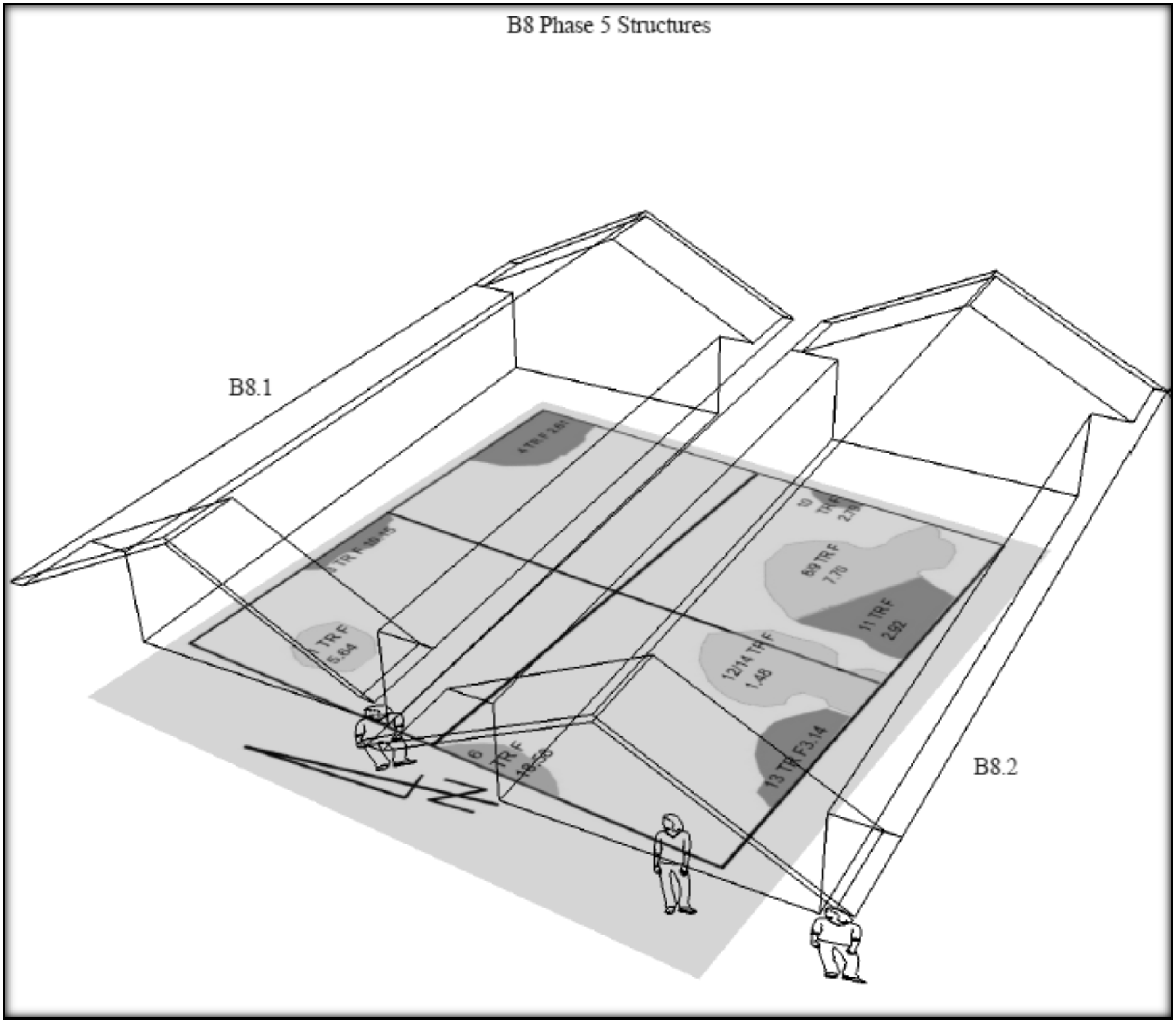

Figure F30. Unit B8 Phase 5 Structures.

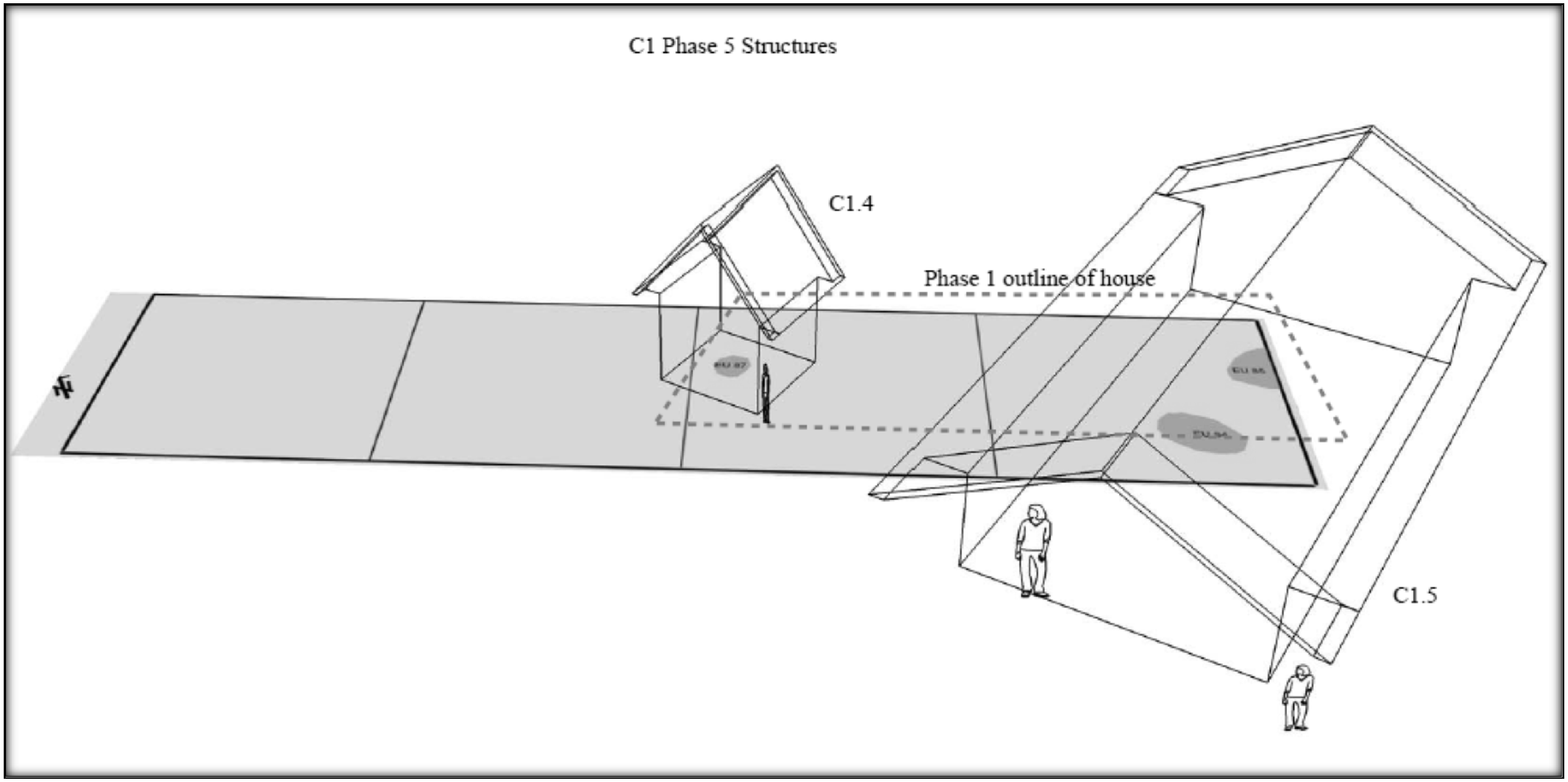

Figure 31. Unit C1 house and burial chamber.

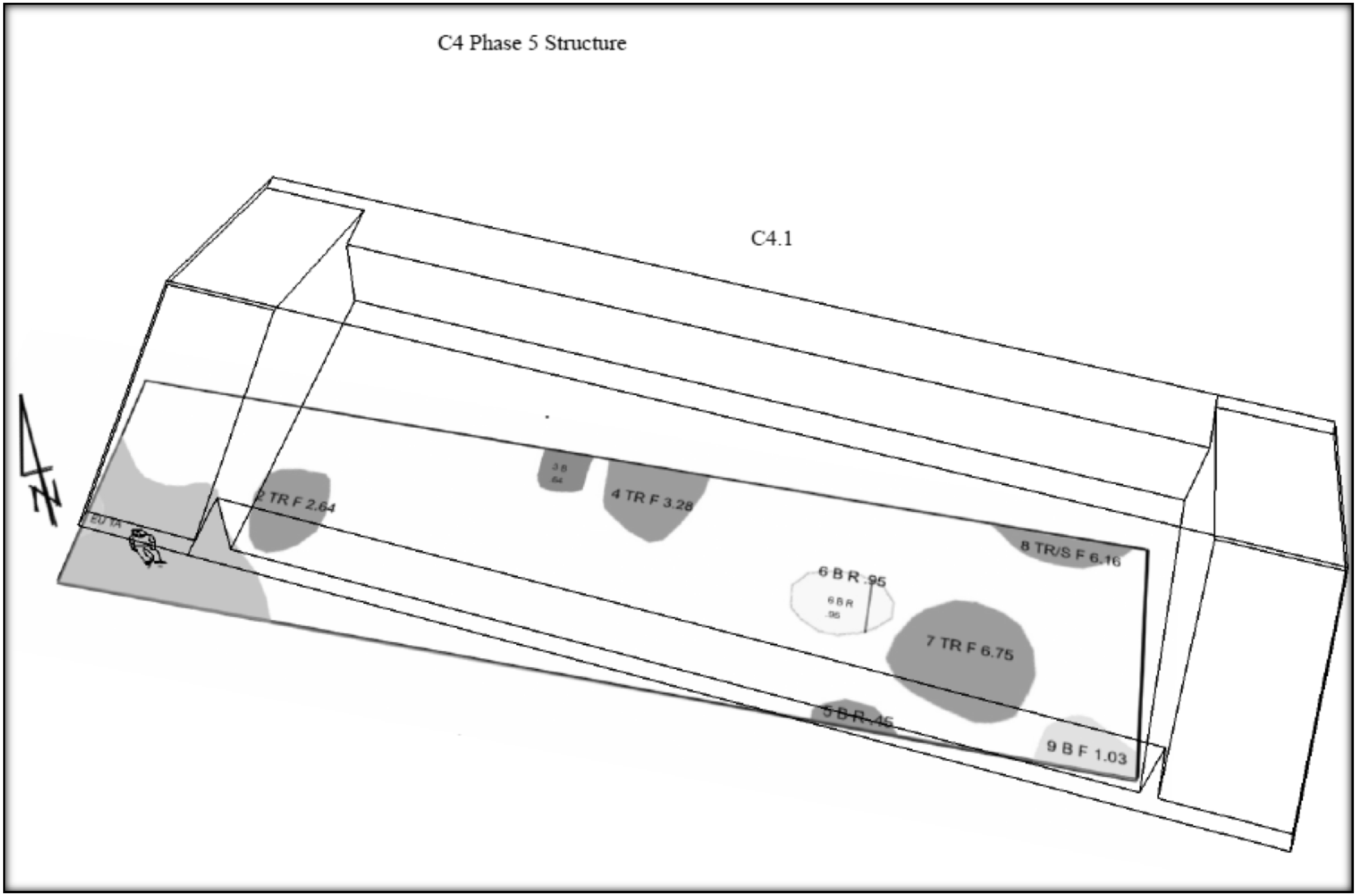

Figure F32. Unit C4 Phase 5 Structure.

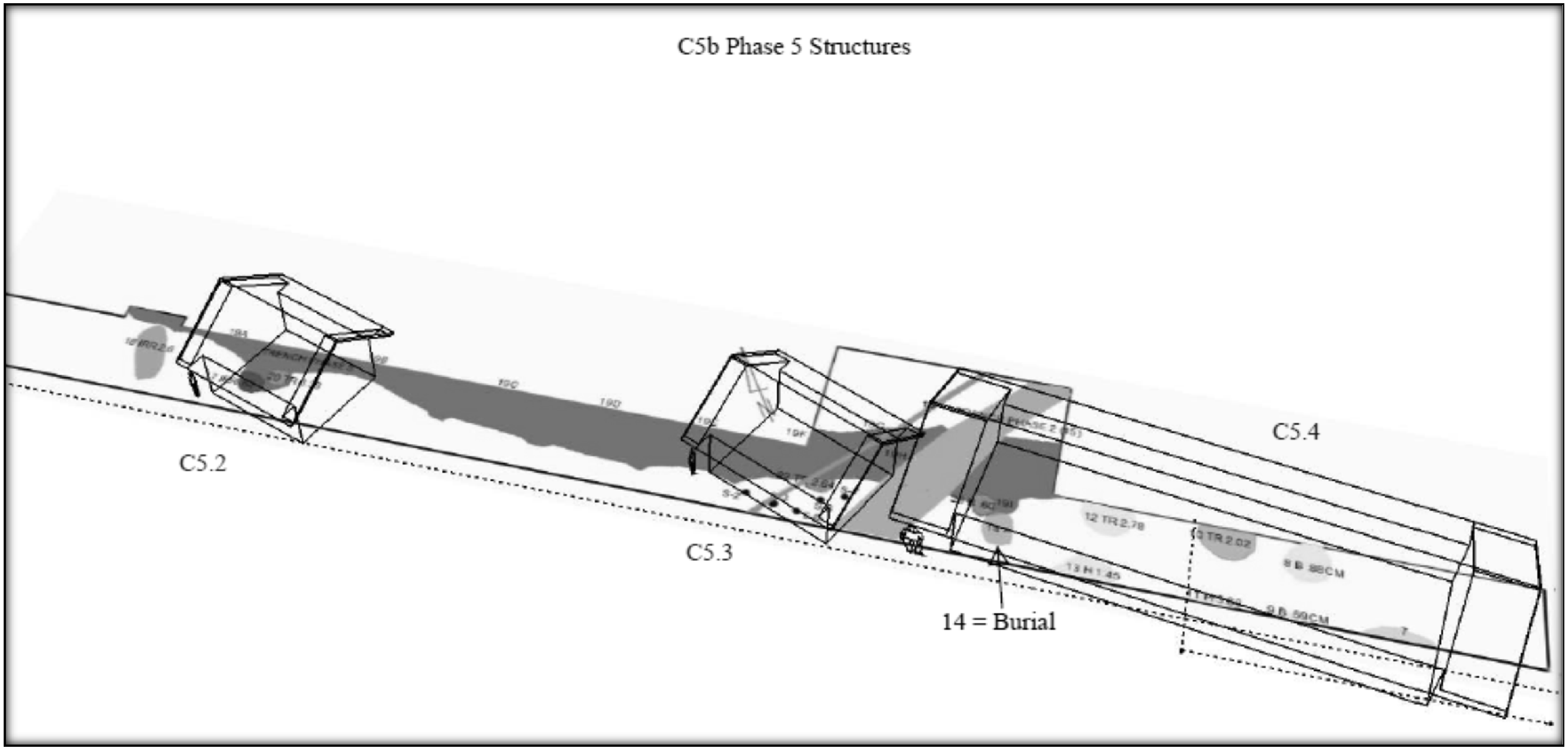

Figure F33. Unit C5 Phase 5 Structures.

Table F7. Phase 6 structures and dimensions (M meters) and function, by excavation unit.

Area	House #	Type of Structure	Associated Pit(s)	Shape	Top Dia.(M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
A2	A2.3	Small Barn?	2	TR	.85	.92	1.00	2.46	Storage pit	
	A2.4	Large House?	11	TR	2.05	2.60	1.50	25..57	Large Cellar	
B1	B1.22	Medium House	5	TR	1.02	1.10	.86	3.03	Storage pit	
			70	TR	1.21	1.40	1.18	6.32	Cellar	
	B1.23	Large House	73	TR	.95	1.10	1.00	3.03	Storage pit	These may represent multiple households
			76/77	TR/S	1.02	1.30	1.95	8.27	Cellar with shelf	
			78/79	TR/S	.75	1.35	1.70	6.92	Cellar with shelf	
	B1.24	Large House	39	TR	.58	1.12	1.66	3.89	Storage pit	
			86	TR/S	.82	1.40	2.14	8.80	Cellar with shelf	
			4849/50	TR/S	2.05	2.00	1.08	6.46	Cellar with shelf	
	B1.25	Shed	32	TR	.63	.76	.90	1.37	Postmold	These may represent multiple households
	B1.26	Large Barn?	51/53/101	TR/S	.80	.85	1.08	2.96	Storage pit with shelf	
	B1.27	Large Barn?	99/102	TR/S	1.05	1.10	.98	3.55	Storage pit with ledge	
	B1.28	Medium House	124	TR/S	.90	1.06	1.42	4.29	Shelf from a cellar outside unit	
B2	B2.3	Medium House	1	TR	.62	.77	.74	1.12	Hearth	These may represent multiple households or include a separate hut
			2/3	TR/S	1.08	1.20	.70	6.52	Cellar with ledge	
			8	TR/S	.98	1.06	.90	3.04	Storage pit with shelf	

Table F7 continued. Phase 6 structures and dimensions (M meters) and function, by excavation unit.

Area	House #	Type of Structure	Associated Pit(s)	Shape	Top Dia.(M)	Bottom Dia. (M)	Depth (M)	Cubic Vol. (M)	Pit Function	Comment
B3	B3.1	Large House	1	H	.62	.77	.74	1.12	Storage pit with pot indentations	
			3	TR	1.00	1.14	1.60	5.75	Cellar	
			4	TR	1.12	1.50	1.00	10.18	Cellar	
			6	TR	1.00	1.50	26.0	17.97	Hearth/Cellar with shelf	
			7	TR	.82	1.04	1.45	3.95	Storage pit	
B4	B4.1	Large House	1	TR	.55	1.00	1.30	2.52	Storage pit	These may represent multiple households
			2	TR	.55	1.00	1.30	1.65	Storage pit	
			3	TR	.90	1.88	1.20	4.29	Cellar with oven/hearth	
			4	TR	1.00	1.20	1.20	4.57	Cellar	
			6	TR/S	1.00	1.30	1.20	7.43	Cellar with shelf	
B5/7	B5/7.6	Medium House	13	TR	.93	.85	.80	2.24	Storage pit	
			14/17	TR/S	?	?	?	6.94	Cellar with shelf	
	B5/7.7	Large House	8	TR	.90	1.00	.80	2.27	Storage pit	
			9/20	TR/S	1.13	1.92	2.25	17.85	Large cellar with shelf	
	B5/7.8	Large House	10	TR/S	2.05	2.16	1.55	10.19	Cellar with shelf	
			12	R	.45	.45	.95	.60	Storage pit	
	B5/7.9	Small Barn	4	TR	.65	.80	1.00	1.65	Storage pit	
B8	B8.3	Large House	2	TR/S	.89	.92	.54	5.79	Cellar with shelf	
			5	TR/S	1.24	2.12	1.60	16.82	Large cellar	
	B8.4	Large House	6	TR	1.25	1.85	2.40	18.58	Large cellar	
			7	TR/P	.75	1.15	1.95	5.51	Cellar	

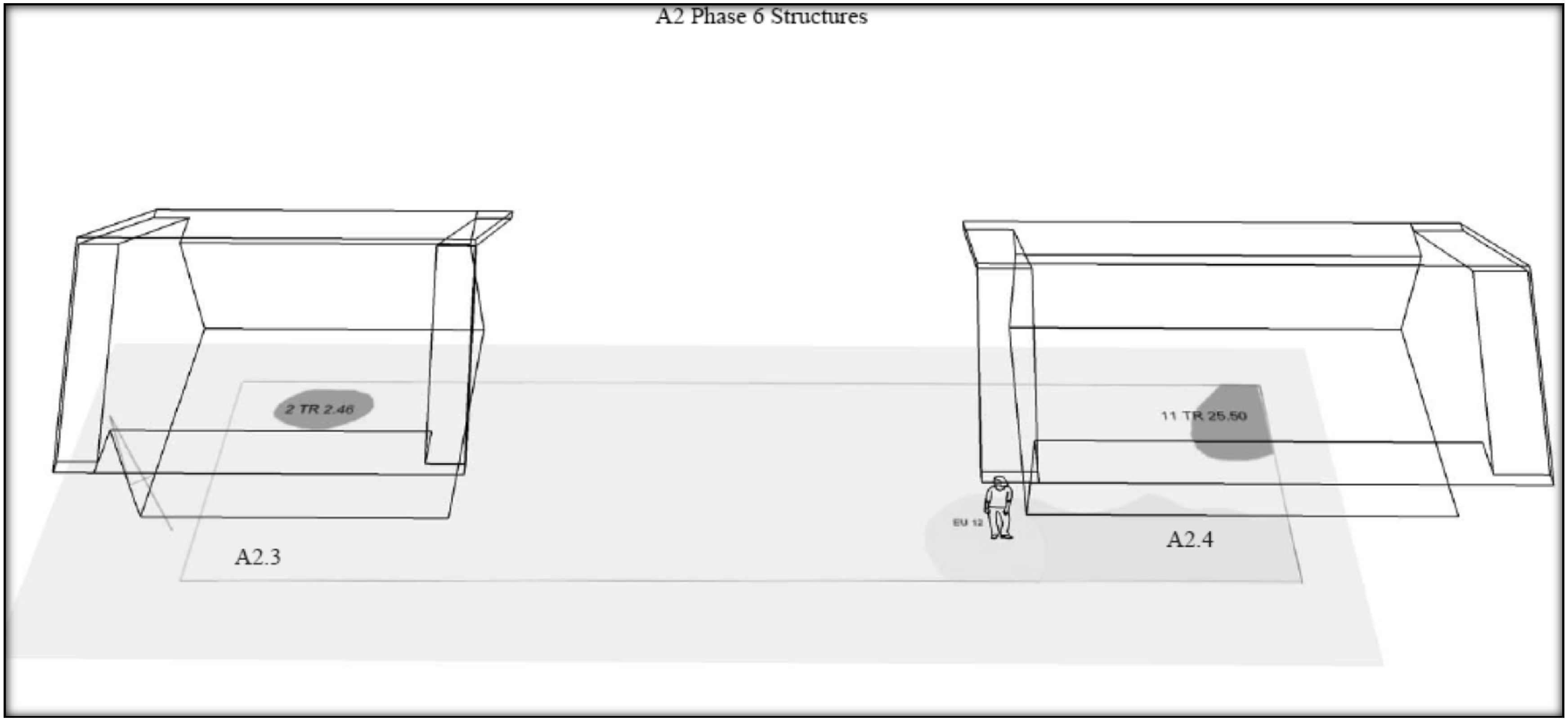

Figure F33. Unit A2 Phase 6 Structures.

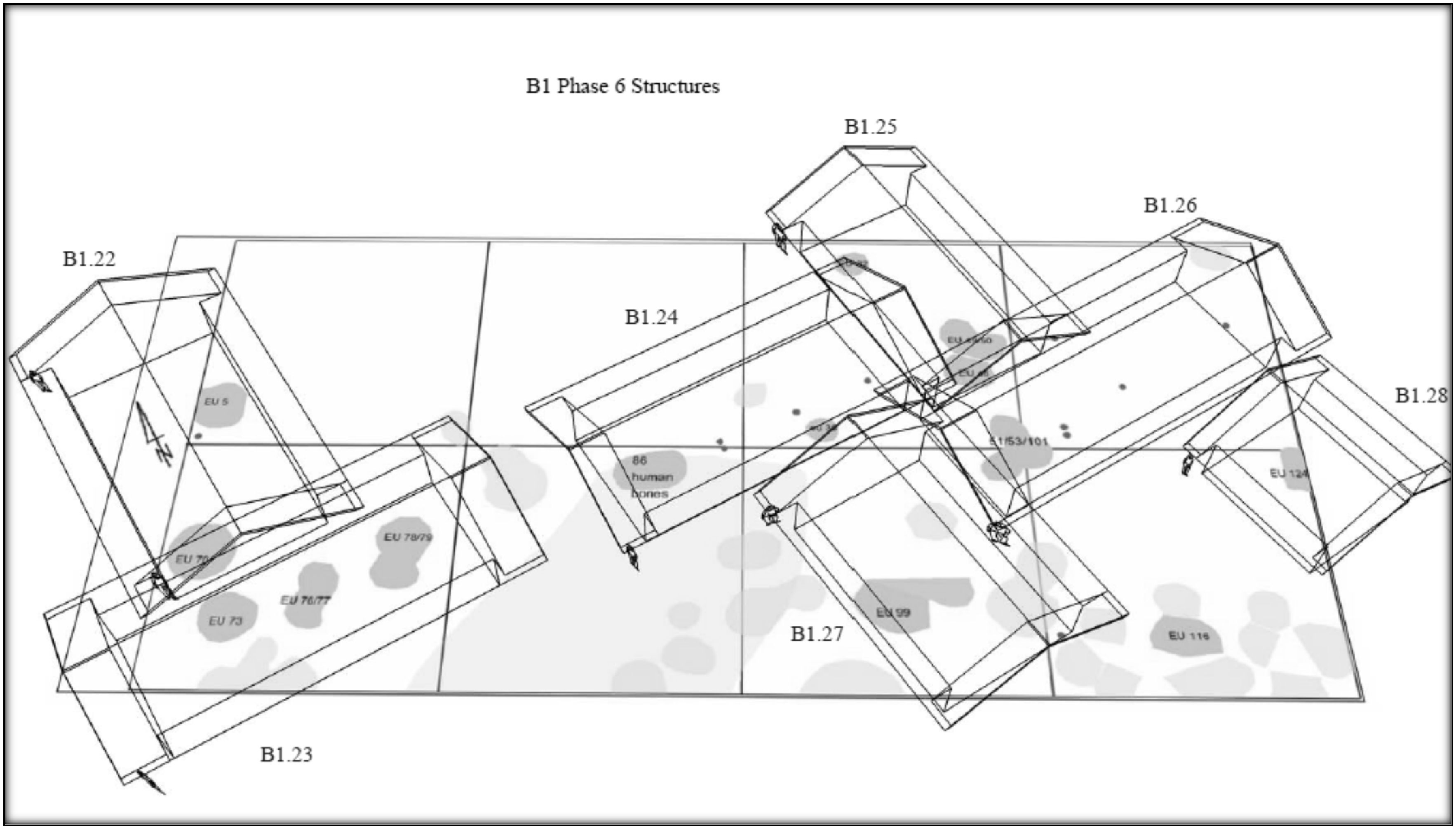

Figure F34. Unit B1 Phase 6 Structures.

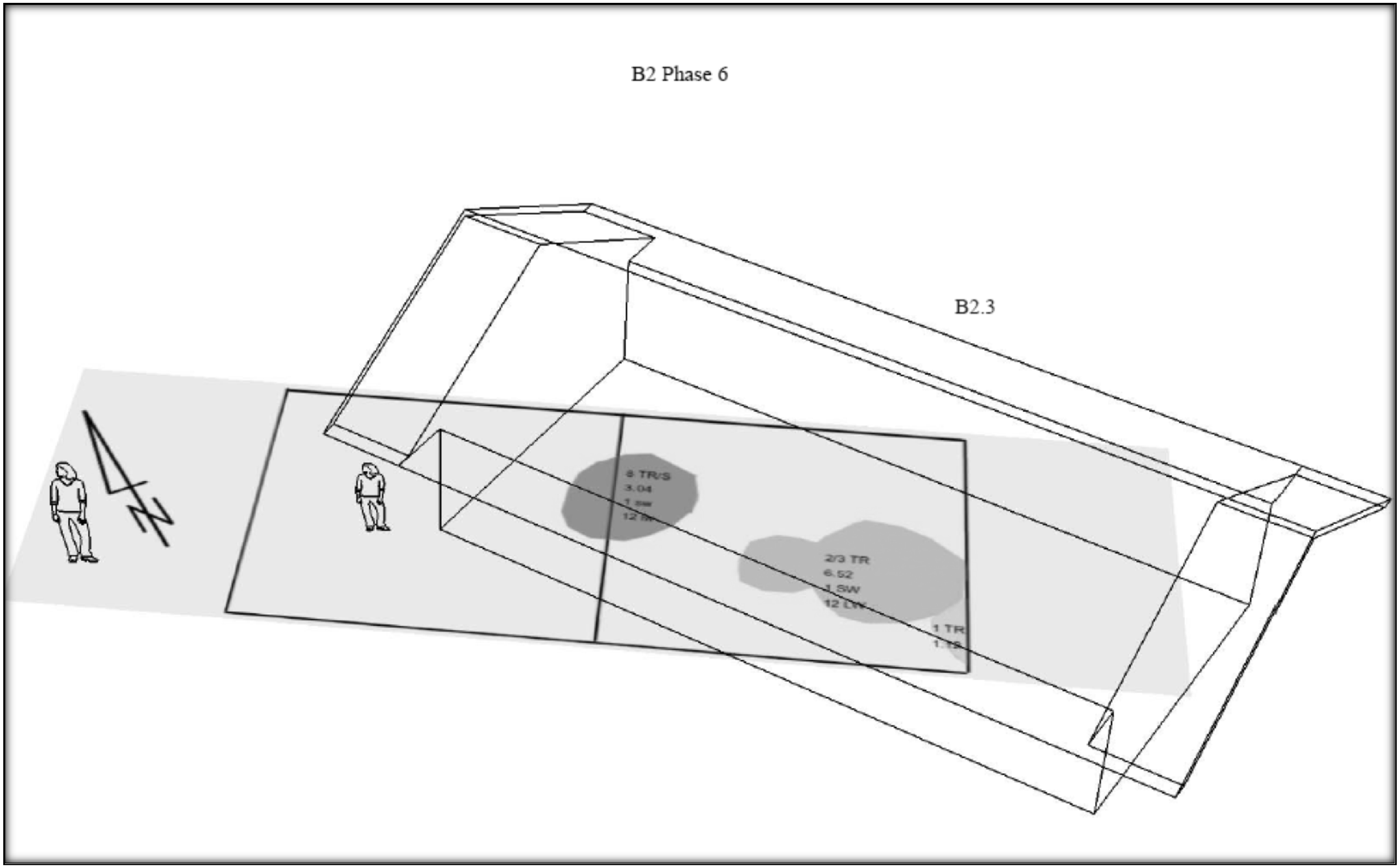

Figure F35. Unit B2 Phase 6 Structures.

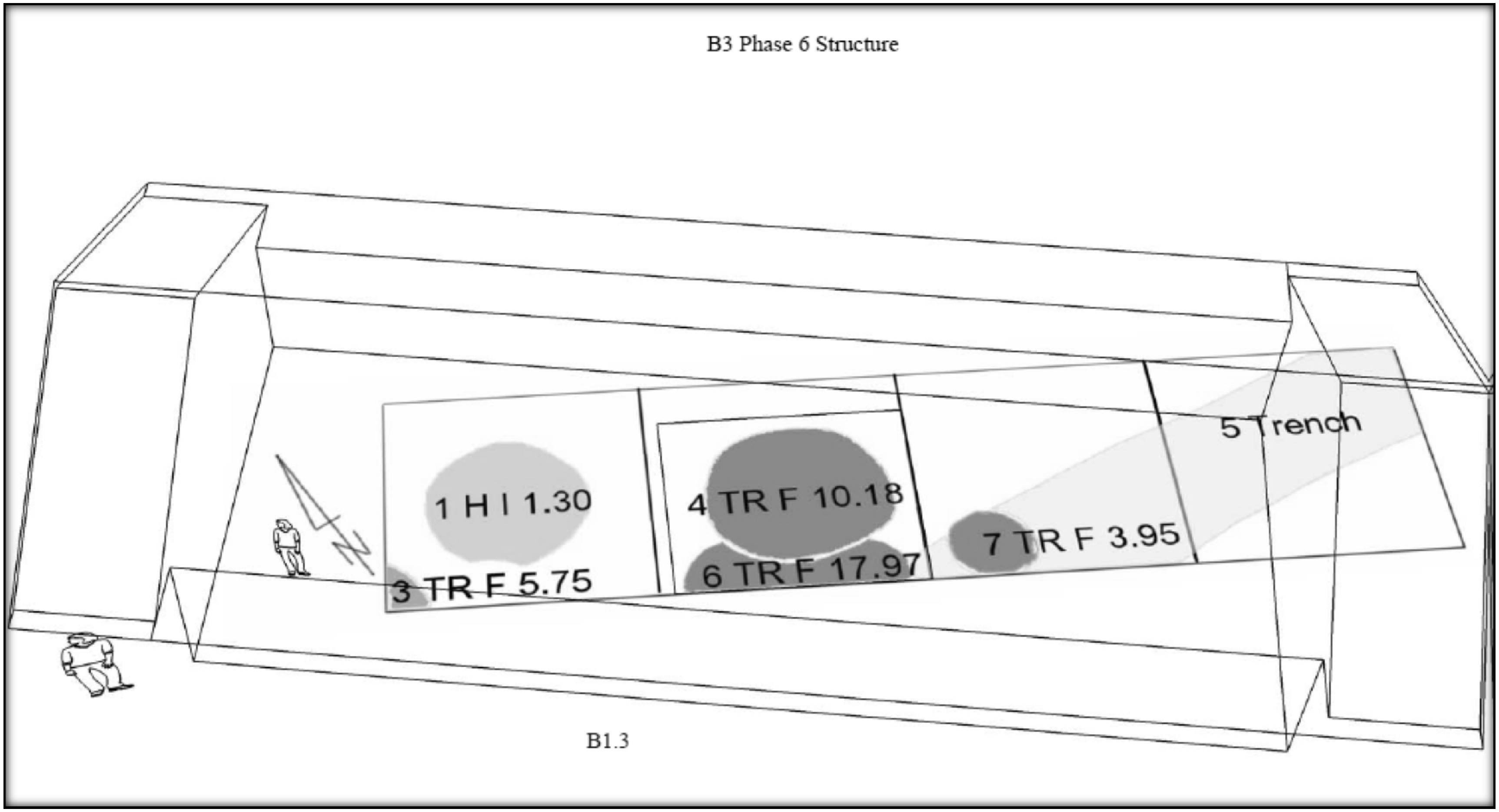

Figure F36. Unit B3 Phase 6 Structure.

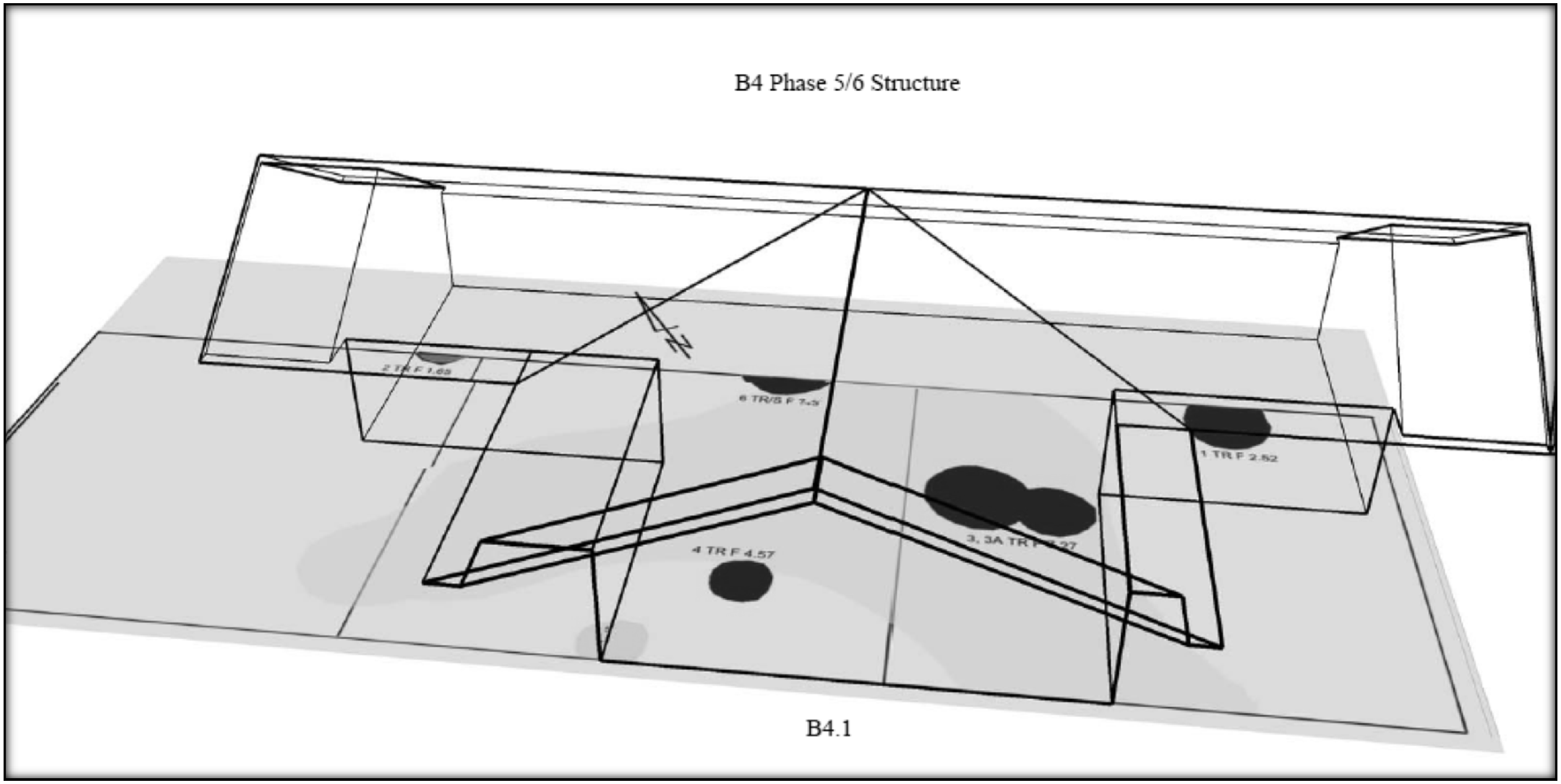

Figure F37. Unit B4 Phase 5/6 Structures

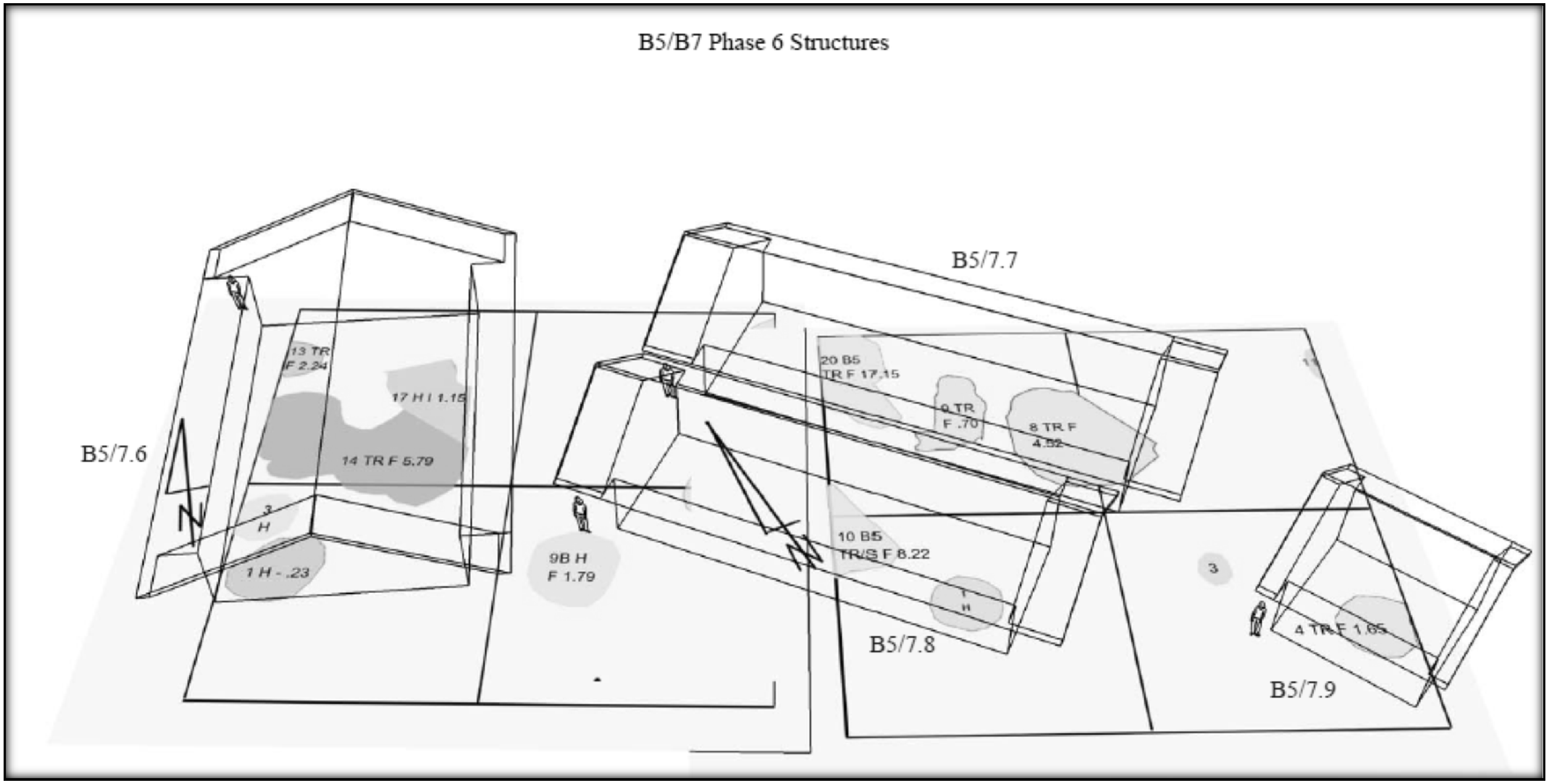

Figure F38. Unit B5/B7 Phase 6 Structures.

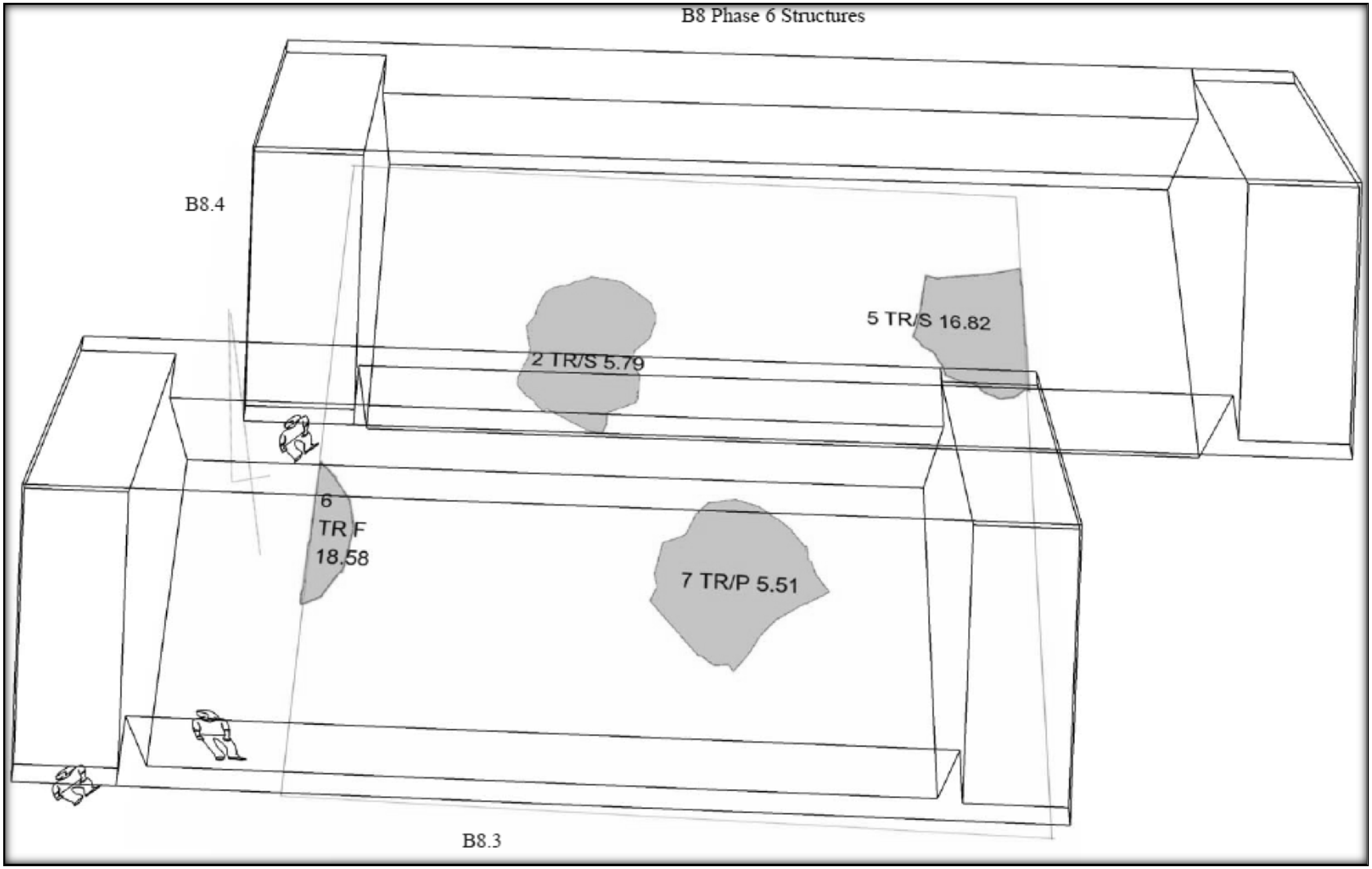

Figure F39. Unit B8 Phase 6 Structures.

Appendix G

Radiocarbon Dates

Table G.1. Bronocice first set of calibrated radiocarbon dates and assigned chronology (Milisauskas and Kruk 1990 and personal communication September 2014).

Area	Pit/Area	Bp	BC	Original Chronology	Revised Chronology
A1	21-A1	4700 ± 60	3370	Phase 3	Phase 3/4
	42-A1	4940 ± 125	3630	Phase 3	Phase 3
	54-A1	4590 ± 55	3210-3310	Phase 3/4	Phase 4
	56-A1	4330 ± 60	2920-2940	Phase 5	Phase 5
	68-A1	4520 ± 60	3160	Phase 4	Phase 4
	101-A1	4800 ± 70	3500-3470	Phase 3	Phase 3
A3	7- A3	4690 ± 75	3350-3370	Phase 3	Phase 3/4
	29-A3	4440 ± 80	3010-3110	Phase 5	Phase 5
A5	1-A5	4250 ± 115	2850-2870	Phase 6	Phase 6
B1	23-B1	4570 ± 70	3180-3200	Phase 4	Phase 4
	39-B1	4240 ± 115	2850	Phase 5/6	Phase 6
	45-B1	4440 ± 75	3010-3110	Phase 4	Phase 5
	54-B1	4440 ± 80	2970-2990	Phase 5	Phase 5
	95-B1	4340 ± 75	2930-2950	Phase 5	Phase 5
	98-B1	4500± 120	3210-3320	Phase 4	Phase 4
B2	2-B2	4320 ± 130	2920-2940	Phase 6	Phase 5
	6-B2	4340 ± 70	2930-2950	Phase 5	Phase 5
B3	4-B3	4090 ± 140	2580	Phase 6	Phase 7
B4	3-B4	4080 ± 110	2570	Phase 6	Phase 7
B5	5-B5	4610 ± 120	3240-3330	Phase 4	Phase 4
	10-B5	4080 ± 65	2570	Phase 6	Phase 7 (included in Ph6 XRF)
B6	5- B6	5060 ± 110	3720	Phase 1	Phase 4 (burial intrusive in Phase 1 pit)
	6-B6	4550 ± 70	3180	Phase 4	Phase 4
B7	8-B7	4200 ± 60	2700-2820	Phase 6	Phase 6
B8	1-B8	4320 ± 55	2920-2940	Phase 5	Phase 5
	6-B8	4260 ± 70	2860	Phase 6	Phase 6
C2	15-C2	4690 ± 240	3350-3370	Phase 2	Phase 3/4 (see below)

Table G.2 Niedźwiedż calibrated radiocarbon dates (Burchard 1977).

ID	House	Pit	uncalibrated	Calibrated
Bln-927			2765-100 bc	3380 BC
M-2323	2	62	2690-190 bc	3340 BC
M-2322			2650-190 bc	3320 BC
M-2321	2	72	2520-190 bc	3140 BC

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