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OF ROMUALD SCHILD

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Zofia Sulgostowska and Andrzej Jacek Tomaszewski

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T. DOUGLAS PRICE, KLAUS BOKELMANN AND ANNE PIKE-TAY

LATE PALEOLITHIC REINDEER ON THE NORTH EUROPEAN PLAIN

Dedication

This discussion of the movement of reindeer on the North European Plain is submitted in honor of Prof. Dr. Romuald Schild on the occasion of his seventieth birthday and in recognition of his abiding interest in the Paleolithic of Northern Europe (*e.g.*, 1976, 1984, 1996). The first two authors of this paper have known Roman for more than 30 years and have a deep respect for his intellect, his enthusiasm, his wide-ranging interests, and his people skills. This volume and the other activities accompanying Roman's milestone celebrate a remarkable career as field worker, author, scientist, and administrator. All the very best wishes to Roman.

INTRODUCTION

The present work is a very preliminary study involving a new method for the investigation of the movement of reindeer herds on the North European Plain during the late Pleistocene. This is an issue of substantial interest for those concerned with the nature of human adaptation in the late Upper Paleolithic period when plants, animals, and hunters first returned to this area following the retreat of glacial ice. Were the reindeer migratory or more sedentary? Did the reindeer move east to west, north to south? And how far did the herds migrate in the course of a year? Did the hunters continually pursue the herds of reindeer, their primary prey, or did they simply intercept the large migrating herds at certain times during the year? These questions are the focus of the present discussion, along with some suggestions on how to find answers.

A brief summary of the Late Paleolithic in northern Europe and current models of reindeer movement is followed by a description of isotopic studies of human and animal movement as a means for resolving questions about reindeer migration in the region. Preliminary results of the application of this method are presented and discussed in terms of future directions for such research. As such, this report is more about possibilities than conclusions.

LATE PALEOLITHIC REINDEER HUNTERS

Northern Europe is a laboratory for the study of the prehistoric human use of the landscape. The region changed from an ice sheet to dense Atlantic forest in less than 10,000 years between the end of the Pleistocene and the middle of the Holocene. In that same period, human groups changed from small bands of reindeer hunters to settled village farmers. It was a time of enormous transformation in both the environment and human behavior.

During much of the Pleistocene, the region was covered with continental ice, extending south into northern Germany and Poland. There is a distinctive absence of evidence for human occupation in northern Europe during the Lateglacial maximum between 21–13 K bp (Housley *et al.* 1997). From approximately 16 K bp a warming trend began that resulted in the retreat of the ice, a rise in sea level, and rapid changes in the environment. By 13 K bp the initial human resettlement of this area had begun. It was in this context of dramatically changing climate and a newly formed landscape that the early inhabitants of northern Europe began to enter the region.

Housley *et al.* (1997) have suggested that the first human occupants were seasonal visitors arriving several hundred years after the initial spread of vegetation and animals. These pioneer hunting groups were followed a few hundred years later by permanent residents. The almost simultaneous occupation of Britain and southern Scandinavia speaks to the regularity of this colonization process as human groups spread to the north and west from refugia in southern Europe (Housley *et al.* 1997). Bratlund (1996a) has argued that this two-stage colonization may relate to the fact that horse and several bovid species came slightly later than reindeer into this region.

The human occupation of northern Europe at the end of the Pleistocene is generally described as Late

Paleolithic and has four major cultural components (Fischer and Tauber 1986, Schild 1984, Terberger 2006). The area of interest for this discussion stretches from the Netherlands in the east to Poland in the west, and from northern Germany across Denmark and southern Sweden to the edge of the Scandinavian ice sheet, which at that time covered most of Norway and Sweden.

The earliest inhabitants of this region were Hamburgian reindeer hunters, followed by the Federmesser, Bromme, and Ahrensburgian phases of the Late Paleolithic. These groups are often termed shouldered or tanged point cultures because of their distinctive style of projectile point. The earliest dates for Hamburgian materials in northern Europe are around 12,500 bp (Fischer and Tauber 1986). The Federmesser is characterized by a distinctive artifact assemblage, often lacking tanged points, associated with somewhat warmer climatic conditions and a woodland fauna. Bromme materials are not well dated, but appear to be roughly contemporary with or slightly younger than the Federmesser. The sudden cold oscillation of the Younger Dryas resulted in the abandonment of newly occupied areas at the northern margins of southern Scandinavia (Berglund *et al*. 1994); there are very few dates from the earlier part of the Younger Dryas anywhere in this area (Fischer and Tauber 1986). By the end of the Pleistocene, however, Ahrensburgian groups re-occupied the region *ca.* 10,100–9900 bp. Ahrensburgian groups have a widespread presence across the North European Plain, Scandinavia, and Great Britain and are characterized by a distinctive tanged point. Because of the known emphasis on reindeer during the Hamburgian and Ahrensburgian, the remainder of this discussion will focus on these periods.

It is important to remember that the vast majority of Late Paleolithic sites in northern Europe lack any kind of organic material or charcoal and contain very little information on subsistence and seasonality. The few sites with good preservation (*e.g.*, Stellmoor and Meiendorf) contain large numbers of reindeer remains and the faunal evidence points to fall as the primary season of occupation. The faunal remains provide information about the herd and the time of year during which hunters occupied this settlement. Reindeer provided these hunting groups with most of the necessities of life. Other species were represented only by individual or a few animals; reindeer comprise more than 98% of the total number of animal bones. Over 1000 individual animals are represented in the upper, Ahrensburgian layer at Stellmoor (Weinstock 2001). Weinstock (2000, 2001) has convincingly shown through osteological analysis of the age and sex of these animals that males and females were hunted in the same frequency as they occur in a typical population and thus that the hunters were not selecting specific animals as their prey. Although the majority of the animals were killed in the fall, some reindeer and probably humans seem to have been present in northern Germany year round (Bratlund 1996b, Gronnøw 1987, Sturdy 1975). However, sites from seasons other than the autumn are virtually unknown.

The large numbers of animal bones convincingly indicate that these were mass-hunting sites (Bokelmann 1991) and this interpretation is followed by most authors (Clark 1975; Sturdy 1975; Tromnau 1920; Bokelmann 1979; Bratlund 1990, 1996b). Gronnøw (1987) has argued that hunting in the Hamburgian period involved only small drives or stalking. In the Ahrensburgian period, on the other hand, large herds of reindeer appear to have been ambushed and butchered on the spot (Bratlund 1991, Spiess 1979). Gronnøw (1987) has made a convincing argument that the reindeer were being butchered for marrow and meat for dry storage.

The spatial distribution of sites is also of interest and likely related to the seasonality of settlement and the behavior of reindeer. All of the known sites are inland, usually located along river banks or lake shores that may have intersected annual routes of animal migration (Vang Petersen and Johansen 1996). Site locations appear to have been chosen for strategic reasons, sometimes for view and sometimes at bottlenecks or places of forced passage. Settlements were located on higher spots on islands, promontories and coastal ridges that would have provided excellent viewpoints in the treeless tundra of the younger Dryas.

MOVEMENT OF REINDEER

Annual movement of the reindeer would have been of substantial importance for Late Paleolithic hunters who were dependent on this species for at least a part of the year. Little is known about the timing, geography, or distances traveled by these late Pleistocene herds. It is generally assumed that these herds were migratory like their descendents in northern Europe and Asia, moving between seasonal feeding and calving areas. In spite of the absence of evidence, a number of suggestions have been made regarding the movement of these animals.

Bokelmann (1979) has argued convincingly that it would be difficult for human hunters to follow the herd without some form of transportation. Proponents of the herd-following model point out that reindeer spread out widely in the summer and winter feeding areas. Presumably the large hunting groups gathered along the migration route split up into smaller units during periods of isolated stalking. If hunters followed the herds, the remains of small, scattered hunting groups during this period were likely quite limited and archaeologically obscure. It is likely easier to locate the

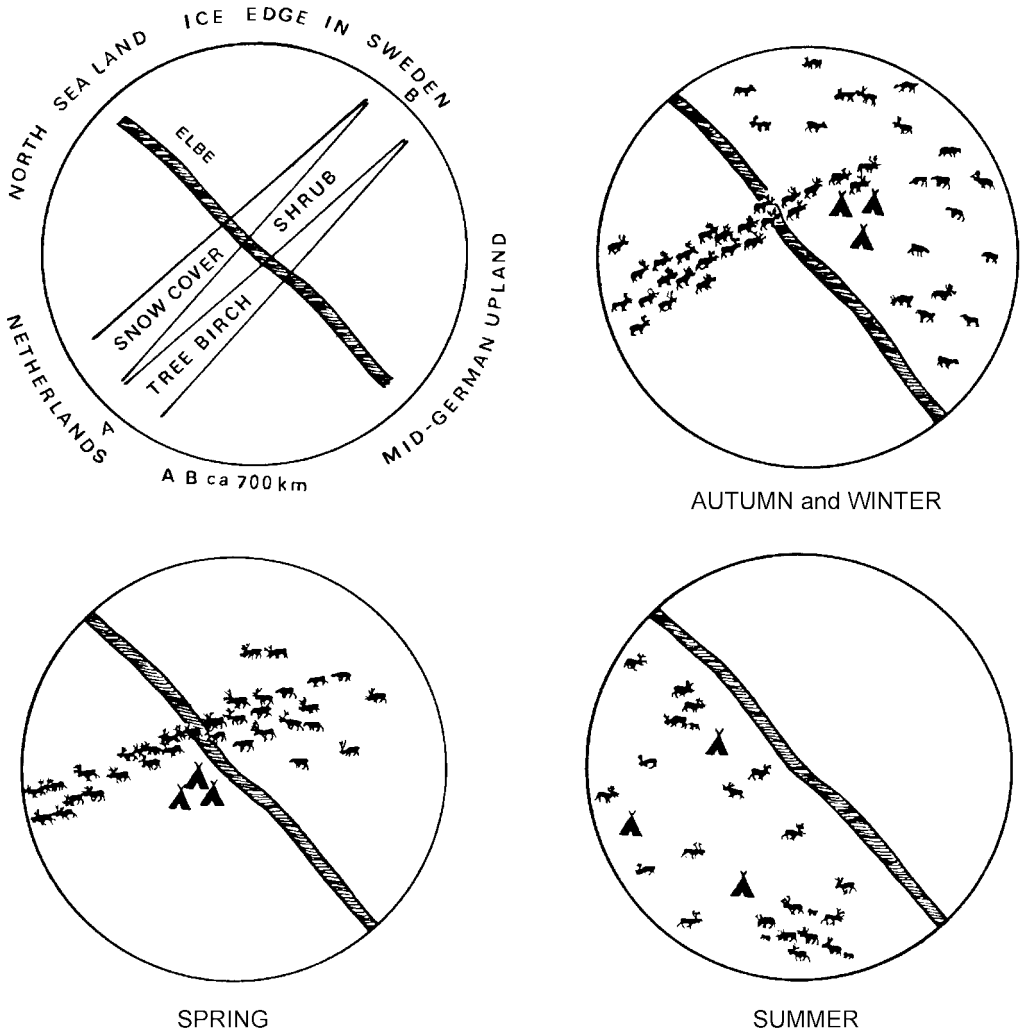

Fig. 1. Bokelmann's model of reindeer migrations across northwestern Europe (1979).

larger sites in the intercept areas where the migration must have been concentrated (southern Denmark and northern Germany) and where the greatest number of sites are known (Vang Petersen and Johansen 1996).

Bokelmann (1991) has suggested that the herds were north of the Elbe in the winter time and south of the river during the warmer months (Fig. 1). He envisions a migration from the region of the Netherlands at the end of summer to the ice edge in Sweden during the autumn and winter, returning in the spring. Following this model, the late spring calving period and the summer would have been spent in the western part of the North European Plain. The distance covered in this migration is estimated to be *ca.* 700 km. Bokelmann argues for winter calving near the ice front because of reduced snow cover and shrub vegetation.

Vang Petersen and Johansen (1996) argue that north European reindeer migrated between forested winter quarters to the south and summer calving areas in the northern part of Denmark and southern Sweden in the spring. Based on the distribution of sites in northern Germany and southern Scandinavia, they have identified several possible routes for reindeer migration, including the Elbe valley in Germany, the so-called ox route running north-south along the Jutland Ridge (the

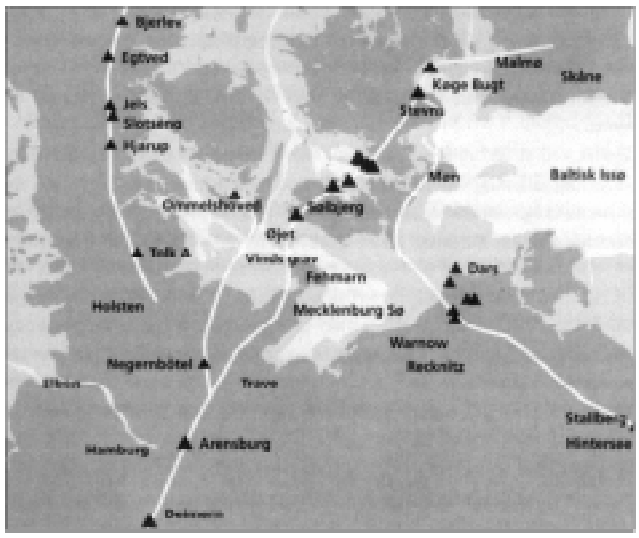

Fig. 2. Proposed routes of reindeer migration in northern Germany and southern Scandinavia (Vang Petersen and Johansen 1996).

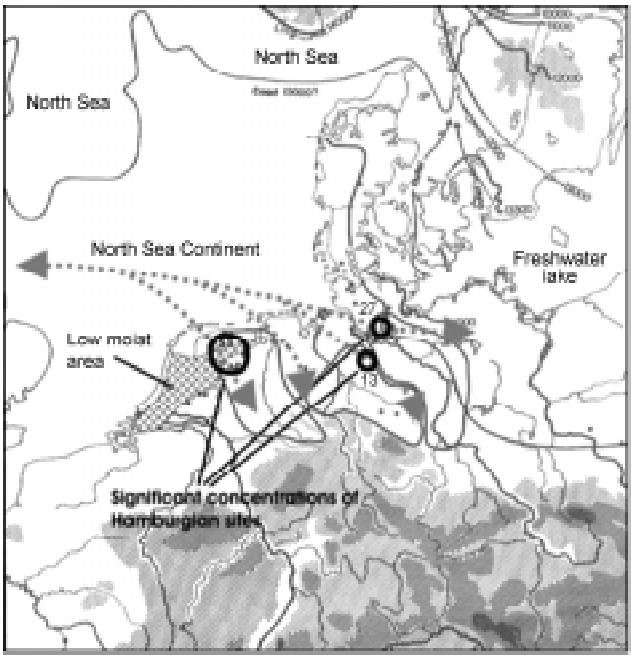

Fig. 3. Grøn's model of reindeer migration to the North Sea basin (2005).

continental divide in western Denmark), and a third to the east through Sølbjerg (Fig. 2).

Other routes are also possible. Hamburgian sites are found almost exclusively at intercept points along the probable paths of reindeer movement in the major river valleys of northern Germany and southern Scandinavia with direct access to the sea (Fischer 1991). It may be the case that the reindeer and the hunters may have moved seasonally to the now submerged coast of the North Sea (Fig. 3) for summer (or winter) pasture as suggested by Grøn (2005). The human utilization of this submerged region in the Late Paleolithic, in fact, is completely unknown.

ISOTOPIC SOURCING

It seems clear that the movement of both reindeer and humans in the Late Paleolithic of Northern Europe is not well understood. There is, however, a method in archaeology involving isotopic proveniencing that may provide a means to investigate this question in more detail. The technique of isotopic proveniencing of human and animal remains has been in use for approximately 15 years. Isotopes of strontium, oxygen, and lead have been employed in such investigations.

The isotopes of strontium and lead enter the body through the food chain and are deposited in skeletal tissue. Drinking water is the source of most oxygen in the body and most drinking water comes ultimately from rainfall. Oxygen isotopes are also deposited in skeletal tissue. The basic principle is essentially the same for the different isotopes and involves comparison of isotope ratios in tooth enamel with local levels. The enamel in teeth forms during the first years of life and undergoes little subsequent change (Boyde 1989, Dean 2000, Hillson 2005). Once fully mature, enamel is no longer in contact with cellular elements. However, it is not completely inert as ion exchange can take place from saliva into the surface layer of enamel (Carlson 1990:539). Post-mortem changes in enamel are minimal (Carlson 1990:537). Enamel has been shown to be generally resistant to contamination and a reliable indicator of biogenic levels of strontium isotopes (*e.g.*, Åberg *et al.* 1998, Budd *et al*. 2000, Kohn *et al*. 1999). Because isotopic ratios vary geographically, values in teeth (place of birth) that do not match the local ratio (place of death) indicate movement. In some cases distinctive places of origin can be identified.

Investigations of human migration and movement by prehistoric peoples using various isotopes have proven successful: oxygen (Stuart-Williams *et al*. 1995, White *et al*. 1998, 2000), lead (Carlson 1996, Gulson *et al*. 1997), strontium (*e.g.*, Knudson *et al*. 2004, Price *et al*. 1994a, 1994b, 2000, 2001, Sealy 1989, Sealy *et al*. 1991).

Focus in this discussion will be on the isotopes of strontium which have been used in the present study. Strontium is incorporated into bone as a substitute for calcium in the mineral hydroxyapatite (*e.g.*, Schroeder *et al*. 1972; Rosenthal 1981). The stable isotopes of strontium include ^{84}Sr (~0.56% in nature), ^{86}Sr (~9.87%), and ^{88}Sr (~82.53%). ^{87}Sr is formed over time by the radioactive decay of rubidium (^{87}Rb) and comprises approximately 7.04% of total strontium (Faure and Powell 1972). Variations in strontium isotope compositions in natural materials are conventionally expressed as $^{87}Sr/^{86}Sr$ ratios (the abundance of ^{86}Sr is similar to that of ^{87}Sr). Strontium isotope ratios vary with the age and type of rock as a function of the original $^{87}Rb/^{86}Sr$ ratio of a source and its age (Faure & Powell 1972). Geologic units that are very old (>100 m.y.) and had very high original Rb/Sr ratios will have very high $^{87}Sr/^{86}Sr$ ratios today as well as in the recent past (<1 m.y.). In contrast, rocks that are geologically young (<1– 10 m.y.) and that have low Rb/Sr ratios, such as late-Cenozoic volcanic areas, generally have $^{87}Sr/^{86}Sr$ ratios less than 0.706 (*e.g.*, Rogers and Hawkesworth 1989). These variations may seem small, but they are exceptionally large from a geological standpoint and far in excess of analytical error using TIMS, a Thermal Ionization Mass Spectrometer (±0.00001 for $^{87}Sr/^{86}Sr$). Differences in the third decimal place are usually significant in terms of movement.

There are two major geological provinces in the research area in Northern Europe which may have different isotopic baselines. The coversand deposits of the North German Plain run east-west from the Netherlands across northern Germany and into Poland. The

ground moraine and glacial deposits of the last glaciation cover the northernmost parts of Germany and almost all of southern Scandinavia. These two major landforms contain different kinds of sediments with distinctive sources and for this reason we can expect to see distinct isotopic variation from north to south across the region. The coversand region is dominated by aeolian sands consisting largely of reworked fluvial and glaciofluvial sediments, deposited largely between 17 K and 14 K bp years ago during the Late Glacial (Bateman and Van Huissteden 1999). The morainic landscape of southern Scandinavia is a mixture of rocks and sediments carried south by glacial advance and ground into the surface of the region.

SAMPLES AND RESULTS

Isotopic proveniencing of reindeer remains from archaeological sites in northern Europe offers an opportunity to learn about the movement of these animals during the late Pleistocene. There are several important variables to be considered: tissue formation, isotopic differences, and post-mortem contamination. These issues will be discussed in the context of ongoing research in this area, focusing on samples from the sites of Stellmoor and Meiendorf in northern Germany (Fig. 2), where the activities of reindeer hunters are documented in archaeological deposits of wood, bone, antler, tooth, and stone.

The two sites were excavated under the direction of Alfred Rust in the 1930s (Rust 1937, 1943). Two distinct horizons of archaeological remains were present at Stellmoor, with an earlier layer found at 6.5 m below the modern ground surface and a younger one at 3.5 m in depth. The older materials at Stellmoor belong to the Hamburgian culture (*c.* 10,500 bp) and the younger are Ahrensburgian (*c.* 9000 bp). Both layers contain numerous stone tools and hundreds of animal bones and other artifacts. The distinctive tanged points of the Late Paleolithic are common. Meiendorf contains a single horizon of bone, antler, and flint artifacts and is located less than 1 km southwest of Stellmoor. Meiendorf belongs to the Hamburgian period and is the oldest of the two sites dating to approximately 11,000 bp.

Our goal in this study is to analyze skeletal tissues of reindeer that formed during different seasons of the year when the animals were in different locations along the route of migration. If the isotope ratios vary among tissue types, then different areas along the migration route are signaled in the tissue.

There are three major types of skeletal tissue in reindeer: bone, tooth and antler. Bone undergoes continual replacement of its inorganic phase (Jowsey 1971), so that isotope ratios of bone strontium reflect the last years of the life of an individual. Chemical turnover in bone is estimated to be on the order of 2–20 years depending on the specific bone (Hill 1998, Jowsey 1961). Because reindeer in the wild have an average life expectancy of only 4.5 years and a life expectancy for males of less than 10 years, females less than 15 years, bone does not change substantially with age (Geist 1998, Kelsall 1968). Moreover, bone tissue will average the strontium isotope ratio of the annual diet so that values will likely be intermediate to the migratory range of the animals.

Because bone provides a summary measure of habitats, we initially chose to look at teeth, preferably the first molar, and antler. Antler forms quickly during the summer period in reindeer (Geist 1998); the strontium isotopes in antler should therefore reflect the geology of summer pasture. At the same time, antler is a rather spongy material and subject to diagenesis; care must be taken to ensure that biogenic isotopes are being measured (Price *et al*. 2002). Tooth enamel forms during gestation and shortly after birth (Miller 1974). Isotopically, the enamel of the deciduous incisors, premolars, and M1 should reflect the diet of the mother during the late winter and spring. As the M2 of *Rangifer* erupts at 10 to 13 months, and the permanent premolars and M3 erupt roughly one year after that (Miller 1974 : 14, Table 4), the enamel development (and isotopic signature) of all of these teeth should follow the same seasonal schedule as the deciduous teeth even though the animal has been weaned. Also, as noted above, tooth enamel is a denser, harder and more inert substance than bone and much less susceptible to diagenesis.

Thus we assume that antler will contain an isotopic signal from areas of summer pasture and that tooth enamel will hold the isotopic ratio of foods consumed during the late winter and spring, in places where the animals were wintering or along routes of movement during the spring migration. To begin our study we took samples of antler and tooth enamel from 12 animals, 11 from Stellmoor and 1 from Meiendorf. One of the specimens from Stellmoor comes from a red deer and is dated to 1220 bp (Benecke and Heinrich 2003). The strontium isotope ratio in this younger specimen is likely a reliable measure of the local value. The samples included enamel from five teeth and seven fragments of antler. The teeth were also identified and analyzed for skeletochronology by Pike-Tay, and the cementum annuli on the tooth root was used to estimate the age of the animal and the season of death (for details on modern *Rangifer* control sample, techniques, and protocol employed see Pike-Tay, 1995). This information appears in Table 1 along with the strontium isotope results given as $^{87}Sr/^{86}Sr$ with the standard deviation of the measurement. In addition, we have one measurement on a red deer from the

Table 1. Strontium isotope ratios on tooth enamel and antler from Stellmoor and Meiendorf reindeer and red deer.

Lab#	Site	Species	Material	Age	Season	87Sr/86Sr	s.d.
615	Stellmoor	Red Deer	Antler			0.710424	0.0008
616	Stellmoor	Reindeer	Antler			0.710244	0.0006
617	Meiendorf	Reindeer	Antler			0.709663	0.0012
618	Stellmoor	Reindeer	Premolar	8 or 9	unknown	0.709654	0.0008
1158	Stellmoor	Reindeer	Antler			0.710043	0.0009
1159	Stellmoor	Reindeer	Antler			0.710528	0.0012
1160	Stellmoor	Reindeer	Antler			0.710278	0.0007
1161	Stellmoor	Reindeer	Antler			0.710168	0.0008
1162	Stellmoor	Reindeer	M1 or M2	17 mos.–2.4	late fall	0.710391	0.0006
1163	Stellmoor	Reindeer	M1 or M2	17 mos.–2.4	fall	0.709224	0.0008
1164	Stellmoor	Reindeer	M1 or M2	2.4/3.4	fall/late fall	0.710275	0.0009
1165	Stellmoor	Reindeer	M1 or M2	17 mos.–2.4	late fall	0.709167	0.0008

archaeological site of Dragsholm in the northwest part of the Danish island of Zealand, dating to 5980 bp (Price *et al*. 2007). The tooth enamel of this red deer provided a $^{87}Sr/^{86}Sr$ value of 0.7105.

While only a few samples have been measured to date, there are some intriguing results seen in the graph of the data (Fig. 4). Samples are arranged by site, species, and tissue type in this graph. The four antler samples from Stellmoor have consistently high values, around 0.7100–0.71025. The antler from Meiendorf has a much lower value, around 0.7096. Because Meiendorf is in the same geological setting and very close to Stellmoor, it is possible that the difference in antler between the two sites suggests that migration patterns may have changed between the Hamburgian and Ahrensburgian periods. Clearly, however, more samples are needed to confirm this pattern.

Reindeer tooth enamel from Stellmoor shows a wide range of variation from 0.7092 to 0.7104. These are substantial differences in terms of strontium isotope ratios. Two of the values are slightly higher than the antler numbers while two of the value are the lowest in the series. This variation in tooth enamel very likely indicates that several seasons are contained in the enamel depending on where on the tooth samples are taken. Detailed studies of enamel formation in cervids and other species suggests that seasonal information is contained in intra-tooth enamel variation (Balasse 2002, Fricke *et al*. 1998, Passey and Cerling 2002, Pike-Tay *et al*. 2001, Zazzo *et al*. 2006). Our samples were taken at random locations on the teeth and likely vary significantly because of seasonal differences. On the one hand, it is unfortunate that sampling sites were not more uniform; on the other hand, these data from

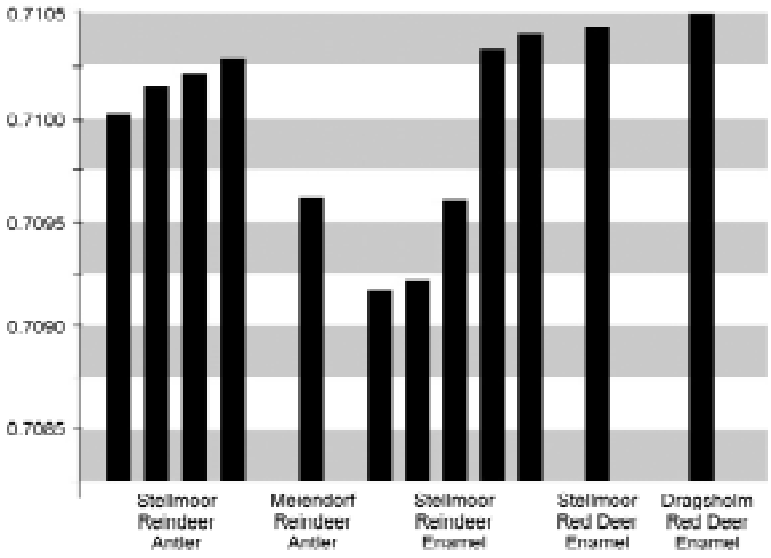

Fig. 4. Bar graph of the strontium isotope values from Late Paleolithic reindeer and red deer in northern Europe.

the Stellmoor enamel suggests that there is significant information on reindeer seasonality and movement in the tooth enamel alone.

The two red deer enamel samples from Stellmoor and Dragsholm are close in value and quite high. As red deer are largely non-migratory, these values may provide a measure of the local strontium isotope ratios in the area around the two sites. If these samples are representative – and it is very difficult to say based on one value – then there may not be substantial difference in the isotopic ratios for the two major regions of the study area. On the other hand, the fact that the values in reindeer enamel from Stellmoor exhibit significantly lower values than the red deer suggests strongly that there is an isotopically different area from which these animals are migrating. It is our hope that more detailed and continuing studies can reveal this information.

FUTURE DIRECTIONS

We would reiterate that this is a preliminary report on our ongoing study of reindeer movement at the end of the Pleistocene in northern Europe. We have measured only a few samples thus far and have very little information on variation in the natural environment. There are several directions that we hope this research will go in the coming years. In addition to strontium, we would like to measure oxygen isotopes in both teeth and antler. Studies of modern reindeer by Drucker *et al*. (2001) suggest that nitrogen and carbon isotope differences between winter and summer should show up in collagen samples of the tooth dentine taken from the root tips. Studies of modern cervids and bovids (Balasse 2002, Moss-Salentijn *et al*. 1997, Zasso *et al*. 2006) suggest that oxygen isotope differences between winter and summer should show up in longitudinal samples of the tooth enamel. If we can identify portions of the enamel from summer and winter pasture, we can then measure strontium isotopes in those portions to enhance our search for the source areas.

It is also essential that we obtain baseline information on the bioavailable strontium isotope ratios in the different geological provinces of northern Europe. We need more information on the coversand and moraine landscapes as well as adjacent regions. Although the North Sea basin is no longer part of the landscape of northern Europe, some proxy isotope information for this region should be obtained. Finally more samples need to be analyzed to be certain that the patterns that are found are repeated in other specimens. Hopefully, when this study is completed in a few years, we will have a clearer picture of the movement of reindeer in northern Europe and its significance for human adaptation.

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T. Douglas Price
Department of Anthropology
University of Wisconsin-Madison
1180 Observatory Drive
Madison WI 53706, USA
1-608-262-2575
tdprice@wisc.edu

Klaus Bokelmann
Haveholz 5
D-2440 Esgrus, GERMANY
affodil@aol.com

Anne Pike-Tay
Department of Anthropology
Vassar College
124 Raymond Ave
Poughkeepsie, NY 12604, USA
piketay@vassar.edu