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# Strontium isotope analysis and human mobility during the Neolithic and Copper Age: a case study from the Great Hungarian Plain

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ABSTRACT

From the Late Neolithic to the Early Copper Age on the Great Hungarian Plain (4500 BC, calibrated) a transformation in many aspects of life has been inferred from the archaeological record. This transition is characterized by changes in settlements, subsistence, cultural assemblages, mortuary customs, and trade networks. Some researchers suggest that changes in material culture, particularly the replacement of long-occupied tells with smaller, more dispersed hamlets, indicates a shift from sedentary farming villages to a more mobile, agropastoral society that emphasized animal husbandry and perhaps secondary products of domestication. In a previous study (Giblin, 2009), preliminary radiogenic strontium ($^{87}Sr/^{86}Sr$) isotope data from human dental enamel showed that Copper Age individuals expressed more variable isotope values than their Neolithic predecessors. These data provided support for the idea that Copper Age inhabitants of the Plain were acquiring resources from a greater geographic area, findings that seemed consistent with a more mobile lifestyle. In this article a larger sample from human and animal skeletal material is used to re-evaluate earlier work and shed new light on the transition from the Neolithic to the Copper Age in eastern Hungary. The expanded sample of strontium isotopes from human dental enamel shows that $^{87}Sr/^{86}Sr$ values are more variable during the Copper Age, but the change is more pronounced in the Middle Copper Age than in the Early Copper Age. These results, along with recently published complementary research, indicate that the transition from the Late Neolithic tell cultures of the Plain to the more dispersed Copper Age hamlets was more gradual than previously thought, and that the emergence of an agropastoral economy does not explain changes in settlement and material culture.



## 1. Introduction

On the Great Hungarian Plain, there is a change in settlement patterns from nucleated clusters of multi-generation tells and flat sites in the Late Neolithic (5000 BC, calibrated) to smaller, more dispersed hamlets in the Copper Age (4500 BC, calibrated) that were occupied for a few generations at most (Yerkes et al., 2009). This change was also associated with an increased focus on domesticated animals (versus wild species), the re-orientation of trade networks, homogenization of pottery styles across the Plain, and by the appearance of cemeteries located away from settlements (Bánffy, 1994; Bartosiewicz, 2005; Gyucha, 2009; Parkinson, 2006; Sherratt, 1997).

It is often assumed that a shift from more to less "permanence" in the archaeological record (smaller settlements, less cultural material) is an archaeological correlate of mobile societies. In the Near East and Europe, it has been proposed that mobile agropastoral or pastoral socioeconomic systems that extensively utilized secondary products of animal domestication (e.g., dairy, wool, labor) developed during the post-Neolithic (see Sherratt, 1981). It is thought that this economic shift led to significant changes in settlement, social organization, and population distribution that laid the foundation for the development of complex societies in the Old World. This idea is most often associated with Andrew Sherratt's "Secondary Products Revolution" model, which he proposed in the 1980s (Sherratt, 1981, 1983). Since then, much research in Europe and the Near East has focused on the identification of secondary product use and intensification in the archaeological record (for a recent review see Greenfield, 2010) and in eastern Hungary some have suggested that the transition from the Neolithic to the Copper Age marked a shift toward a more agropastoral economy based on cattle herding (e.g., Bánffy, 1994, 1995; Bökönyi, 1988; Molnár and Sümegi, 2007).

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According to Sherratt, the shift from using domesticated livestock primarily for their meat to their use for secondary products resulted in (1) increased domestic herd sizes to more effectively produce secondary products, and (2) the movement of herds to unoccupied upland pasture during the summer to avoid putting strain on local economies (Sherratt, 1981, 1983). Historically, eastern Hungary was used by transhumant herders who managed hundreds of thousands of sheep and goats between lowland winter pasture on the Plain and highland summer pasture in the southern and eastern Carpathians (see Bartosiewicz, 1999). This study addresses the question of whether humans were utilizing a greater geographic area of the Great Hungarian Plain and surrounding uplands during the Copper Age when archaeological correlates indicate that a more dispersed and short-term settlement practice was emerging.

In a previous study of Neolithic and Copper Age human dental enamel from the Great Hungarian Plain, it was found that the strontium isotope values from the Copper Age sample were more variable than the values in the Late Neolithic sample (Giblin, 2009). It was hypothesized that this increased variance was related to the consumption of food sources such as meat and dairy that were obtained from livestock that were grazed over larger areas. Variability in "background" $^{87}Sr/^{86}Sr$ isotope ratios exits throughout the Carpathians, particularly in the surrounding mountain ranges, due to differences in the age and mineral source material of the geological formations. If herders became more mobile in the Copper Age, and utilized greater areas, including the flanks of the Carpathian Mountains, this variability would be recorded in animal and human dental enamel because strontium is obtained from all dietary sources and is incorporated into the skeleton as these tissues are formed.

The aim of this study was to evaluate these previous assumptions and preliminary radiogenic strontium isotope results that suggested that a mobile agropastoral economy developed during the Hungarian Copper Age. To do this, small skeletal samples were taken from humans and animals from throughout the Great Hungarian Plain that span the Late Neolithic – Middle Copper Age time sequence. These samples were analyzed for their chemical composition to measure residence and dietary patterns over time, and the results are contextualized with several other lines of archaeological data.

## 2. Background

### 2.1. The radiogenic strontium isotope ratio and human mobility

The $^{87}Sr/^{86}Sr$ isotope ratio is useful in archaeological research because radiogenic strontium values vary in different geological contexts and these differences can be recorded in human and animal skeletal tissue via their dietary resources. There are four naturally occurring stable strontium (Sr) isotopes: $^{88}Sr$, $^{87}Sr$, $^{86}Sr$, and $^{84}Sr$. All of these isotopes are nonradiogenic except for $^{87}Sr$, which is produced by decay from the element rubidium ($^{87}Rb$, half-life 48.8 billion years). Because $^{87}Rb$ is decaying at a constant rate to $^{87}Sr$, $^{87}Sr$ can be used to measure the age and source of rock formations and these variations in the geological landscape have been characterized (Faure, 1986). However, strontium content varies in natural material. In order to normalize variations in strontium content so that the absolute $^{87}Sr$ abundance is measured, the isotope value is expressed in a ratio. $^{87}Sr$ and $^{86}Sr$ are the closest in approximate abundances (7.04% and 9.87%) therefore the ratio is expressed as $^{87}Sr/^{86}Sr$ (Price et al., 1994). In general, old geological units (greater than 100 million years) that have high original Rb/Sr content exhibit $^{87}Sr/^{86}Sr$ values of 0.710 or greater, while younger geological units (less than 1–10 million years) with lower Rb/Sr content have isotope ratios less than 0.704 (for an in-depth review of the methodology see Bentley, 2006).

Strontium from a region's flora, fauna, and water is incorporated into the skeletal tissues of humans during the formation of hydroxyapatite (Sr substitutes for calcium due to similarities in their chemical behavior and atomic radii) (Carr et al., 1962). Because of the geological information this isotope can record in ancient tissues, it has been used in archaeological applications to identify various scales of human and animal movement ranging from the presence of "non-locals" in a cemetery to shifts in subsistence strategy and livestock management (e.g., Balasse et al., 2002; Beard and Johnson, 2000; Bentley et al., 2002; Grupe et al., 1997; Haak et al., 2008; Haverkort et al., 2008; Knudson et al., 2004; Price et al., 2004; Tafuri et al., 2006).

The strontium isotope value recorded in human teeth reflects residence patterns in the early stages of life when these tissues are forming (compared to bone which remodels throughout life and therefore reflects adolescence and adult diet and residence patterns (Hedges et al., 2007)). Archaeological teeth are commonly used for isotopic sampling because their dense mineral structure reduces their susceptibility to contamination in the burial environment (Budd et al., 2000; Kohn et al., 1999). Molars were used in this study to evaluate patterns of human mobility over time. Most of the samples were taken from first molars which represents birth to three years of age. At one site, Tiszapolgár-Basatanya, second and third molars were also sampled which reflects the growth periods of two and a half-eight years, and seven-16 years, respectively (Hillson, 2005).

In regions where bone preservation is good, the strontium values in teeth can be compared to the values in bone from the same individual to evaluate whether the person changed residences within their lifetime (e.g., Price et al., 1994). Due to the porous nature of bone, strontium sources from the local soil and groundwater can replace *in vivo* isotopic signatures in archaeological samples (Bentley, 2006) (also see Section 4.1). If this is the case, then the signatures recorded in contaminated bone probably reflect strontium from local sources at the burial site but do not reflect values related to prehistoric residence or diet. These values still may be useful in determining the local signature of a region; however, it is also customary to analyze archaeological faunal teeth in order to get a more holistic characterization of the local biologically available isotope variability in a given region (Price et al., 2002).

### 2.2. Previous $^{87}Sr/^{86}Sr$ research on the Great Hungarian Plain

Prehistoric humans and animals living on the Great Hungarian Plain acquired the strontium retained in their skeletons from their food and water, which in turn reflects the strontium isotopic composition of the underlying bedrock in the catchment areas of the local rivers and streams. The Great Hungarian Plain itself has a relatively high strontium isotope composition because the silt, clay, and redeposited loess soils in this region are very old, which allowed for a longer period of radioactive decay from $^{87}Rb$. $^{87}Sr/^{86}Sr$ values from the dental enamel of several animal species from archaeological sites within the Great Hungarian Plain were used to evaluate the local biologically available strontium in this region (Giblin, 2004, 2007, 2009, 2011). Samples from cattle, pig, wild boar, sheep/goat, dog, clam and snail shell were collected from Polgár-Piócási-dűlő, Vésztő-Bikeri, Körösladány-Bikeri, Vésztő-Mágor, and Abony 36. Of the several species analyzed ($n = 60$), $^{87}Sr/^{86}Sr$ ratios ranged from 0.70909 (cattle) to 0.71026 (pig) with a mean value of 0.70967 (Table 1). Radiogenic strontium measurements taken from the Danube River and Tisza Rivers range from 0.7089 to 0.7096 (Palmer and Edmond, 1989; Price et al., 2004). In contrast, the surrounding Carpathians are composed of a series of parallel mountain ranges that formed at different geologic time periods (Salters et al., 1988;