Final report on scientific achievements related to the NSF Grant K109510 „Human landscape interactions in the Maros valley during the first half of the Avar period based on comparative interdisciplinary study of the archeology”

1. Introduction

The main goal of our research was to elucidate subsistence patterns, spatial-temporal relations of Early Avar Age communities inhabiting the Maros valley of SE Hungary during the 6-7th centuries A.D. via compilation and comparative analysis of a new database of the archeology complemented by results of new natural scientific investigations unprecedented for both the study area and the referred cultural group. Attempts were made to reconstruct the paleoenvironmental conditions, anthropological characteristics of the inhabitants, regional and distant relations with other cultural groups inhabiting the Carpathian Basin.

Special attention was paid to the systematic analysis of Meroving, Byzantine relations as well as those with Transylvania and the Eastern European steppes. In addition, the complex analysis of funerary practices read from the archeology complemented by natural scientific investigations have promoted the assessment of similarities and differences between the individual sites and reveal underlying causes. Provenience of raw materials produced metal artefacts, jewelry have also carried information on cultural, craftsmanship and trade relations as well as the distribution of exploited resources. By reviewing the archeology and setting up a new archeostratigraphy complemented by absolute dating techniques, chronologies of the period have been better confined enabling more reliable temporal correlations between sites and regions as well as paleoenvironmental proxies. This latter is especially important in understanding the cultural, climatic and paleoenvironmental causes that may have triggered and/or contributed to the abandonment of the cemeteries from the mid-7th century and a shift in subsistence from nomadic to a settled lifeway.

The foundation of our work was based on 557 graves from 22 Early Avar Age sites located along the Hungarian reach of the Maros River. In addition, other sites with data published during the project interval (Kövegy M43-49; Maroslele M43-43) has been included along with sites across the border (Nagylak, Pécska 15). The majority of the sites are cemetery fragments. However, the newly excavated largest cemetery (251 graves) of Makó-Mikócsa Hill as well as Kiszombor E and Kiszombor Tanyahalom dűlő were expected to yield reliable new results. As the location of these cemeteries are known, field surveys, cemetery maps as well as both the archeological, anthropological as well as the archeozoological material was readily available for interdisciplinary studies. Due to this duality of the artefact types and the availability of samples collected adequately for natural scientific studies during the excavation enabled us to call in interdisciplinary methods and tools to complement information read from the archeology.

2. Chronology

The most important aspect giving one of the cornerstones of our comparative study was the establishment of a reliable chronology for the studied period of 6-7th centuries in the Maros valley (Gulyás et al. 2015 b, 2018 a, b). For the Avar Age in the Carpathian Basin covering a time-scale from 568 till the opening of the 9th century AD, reliable ages based on archeo-typostratigraphy and coins are available from the 7-9th centuries A.D. alone (Garam 1992; Martin 2008; Somogyi 2011; Zábojník

2008). The exact age of the Avar invasion at 568 A.D. is known from Byzantine historical records (Szádeczky-Kardoss 1992). In addition, entry of Byzantine coins to the Avar Khaganate is recorded for this date alone (Somogyi 1997, 2005, 2014). Developing a reliable archeo-typochronology for the period of the first two generations (568-600 A.D.) and the 9th century is thus still a major challenge in Migration Age archeology in Hungary. This is due on one hand to the general lack of dateable coins. Lack of clearly dateable typically Avar type artefact assemblages poses further hardships. Assemblages with pressed buckles are good examples. These are generally dated after 600 A.D, as press stones used for producing them have been recovered from graves of that age so far (Rácz 2014). For the 9th century assemblages, only some buckle types with a use extending into the century give some information on the age (Szalontai 1991, 1996).

Archeo-typochronology estimates the interval when certain goods, objects, tools etc. were manufactured and uses this information to estimate the time (also in interval) when these were placed into the grave (Balogh 2015, 2017; Garam 1992; Martin 2008; Somogyi 2005, 2011, 2014; Zábojník 2008). Thus, the time of death is indirectly estimated using this type of approach. The use of coins and dateable artefact assemblages is the primarily applied tool for establishing a chronology of Avar Age cemeteries in general (Balogh 2015, 2017; Garam 1992; Martin 2008; Somogyi 2005, 2011, 2014; Zábojník 2008). Adoption of this method for the Avar Age is highly restricted, as these artefacts are rather rare in graves of the referred archeological period. Furthermore, graves dating to the last third of the 7th century AD, are completely lacking coins suitable for absolute dating. In addition, the derived chronologies must be confirmed by detailed numismatic examinations to be accepted. Due to these constraints, the most widely used methods in archeochronology focuses on the presence of horizons, which are characterized by similar artefacts to coin-dated artefact assemblages. This method was adopted for developing a typochronology-based absolute chronology for the period of the 6-7th centuries A.D. (Avar Conquest) in Hungary too (Balogh 2015, 2017; Garam 1992; Martin 2008; Somogyi 2011; Zábojník 2008). In this chronology, the highest attainable resolution is between 25-30 years. Nevertheless, it must be emphasized that as many artefacts are used for a longer time, they can be assigned to multiple periods. This uncertainty related to the overlap of artefact use between different cultures or settlement horizons reduces the fidelity of the created typochronology. Thus, in practice dating of complete artefact assemblages (grave goods, graves) rather than individual artefacts is adopted.

Radiocarbon dating of bones on the other hand can help us assess the date of death of the deceased directly (Gillespie et al. 1984; Long et al. 1989; Taylor 1992; Tuniz et al. 2004). This date is however not a single calendar date, but rather a certain time interval with a certain probability expressing the error of the actual measurement (Libby 1965; Suess 1970; Aitken 1990, 2003; Bowman 1995). This measurement error is only a couple ten years presently for Holocene samples (Taylor and Bar-Yosef 2014). However, the diet of the deceased, attributable to freshwater and marine resource intakes, can further bias the measured dates themselves (Cook et al. 2001; Taylor and Bar-Yosef 2014; Meadows et al. 2016; Schoeninger 2010). Additional uncertainty from calibration of raw dates to calendar dates can further widen the age span due to the presence of numerous wiggles and plateaus in the calibration curve leading often to uncertainties at the multidecadal scale (40-60 or even 80-100 years). This is a serious problem in cross-validation of archeo-typochronologies with an available resolution of 20-40 years. There is an opportunity for fine tuning a series of radiocarbon dates with known stratigraphy using the method of Bayesian analysis (Bayliss 2007, 2009; Bayliss & Bronk Ramsey 2004; Bayliss et al. 2007). Application of this method clearly supersedes simple calibration. Simple calibration generally yields time-intervals, which are often broader than the original uncalibrated measurements themselves due to the previously mentioned reasons. However, if we have a-priori information on the stratigraphic position of the samples and their association, this knowledge can help us to adjust uncertainties of the calibration curve using Bayesian statistics relying on the so-called Bayesian theorem. According to this theorem, the probability of the outcome is highly influenced and constantly modified by previously available and newly added knowledge on the input (Gulyás et al. 2018 a, b,c). The resulting outcome is more precise, reduced time intervals which may be more in line with archeostratigraphic dates (Bayliss & Bronk Ramsey 2004; Bayliss et al. 2007; Bayliss 2007, 2009). Combination of the results of both methods can help us filter out outliers and establish an internally more consistent chronology than any method would yield on its own (Gulyás et al. 2018 a, b,c). First application of this kind of approach to the Avar Period is known for the Late Avar cemetery of Szegvár-Oromdűlő (Siklóssy & Lőrinczy 2015). Conditions for application however were better in our Early Avar Age cemetery of Makó enabling us to assess pitfalls and advantages of the method (Gulyás et al. 2018 a,b,c).

13 samples with known archeo-typochronology were used in our work. In our study, information on the dietary habits of the community are readily available from analyses of marker trace elements and C and N isotope variations of human bones, including those selected for ^{14}C dating as well (Gulyás et al., 2015 a,b, 2018 a,b,c,d). According to these results, exploitation of freshwater resources is negligible in the community and completely missing in the individuals selected for our study (Gulyás et al., 2015 a,b, 2018 a,b,c,d). So, the received conventional ^{14}C dates are not biased by freshwater reservoir effect.

Out of the 13 samples selected for ^{14}C dating, two graves had coins issued under the reign of Emperor Maurice (583/584-602 AD) from the Rome and Constantinople mints (Gulyás et al., 2018 a, b,c). These coins are older than the point in time when the studied individual died. Other clearly dateable artefacts were missing apart from an early example of a Millefiorian-type pearl. However, the pearl-based chronology has not yet been fully established. So, its age can be put after 584-602 A.D. The remaining graves contained highly similar artefact assemblages enabling better dating. The presence of pressed buckles with masks, pressed boot mounting, Martynovka type pressed buckles (Balogh 2015, 2017) puts most of the samples to the end of the 6th and first third of the 7th centuries A.D (Gulyás et al. 2018 a,b,c). The youngest artefacts appearing in some graves are pseudo-buckle mountings with a frame of ball series assigning them to the middle of the 7th century A.D (Balogh 2015, 2017; Gulyás et al. 2018 a,b,c).

Based on the archeochronology most of the samples can be dated to the end of the 6th and first third of the 7th century A.D. The last two samples are dated to the turn of the two centuries (Gulyás et al. 2018 a,b,c). Based on the archeochronology, the cemetery must have been opened during the late 6th century A.D. (after 568 A.D.). It must have been in use until the mid-7th century A.D. (630-650 A.D.). Burials thus span the interval of roughly three generations (80-90 years).

Based on simple calibrated 14 C dates the use of the cemetery must have started between 427-580 A.D (95.4%) and ended between 622 and 685 A.D. The proposed ending is only 20 years younger than the one established by archeo-typochronology However, the opening of the cemetery is chronologically impossible as the first date of Avar invasion is clearly put to 568 A.D (Gulyás et al. 2018 a,b,c). Older dates and the twofold increase in uncertainty might be attributed to various factors like contamination by organic matter or the diet of the individual (reservoir effect). However, both can be excluded because of findings of trace element and isotope analyses of bone samples (Gulyás et al. 2015 a,b; 2018 d). A clearly apparent plateau can be noted between 420 and 520 cal. AD, which results in an unreal widening of the age span of the first 4 samples by ca. 100 years; i.e. our seen uncertainty after calibration.

To eliminate uncertainty due to the mentioned plateau, conventional ages were recalibrated using Bayesian modeling (Model 1) (Fig.1). In addition, another model has also been constructed where control by relative chronology of the samples derived from archeostratigraphy was also applied (Model 2). The dates produced by Model 1 show that burial at this site must have begun after 525-560 AD

(68.2%) or 494-581 AD (95.4%) with a median of 538 AD +- 22 years (68.2%) or 538+/-44 (95.4%) years, respectively. Knowing the exact time of Avar invasion from historical records, the starting boundary's upper limit is in the range acceptable for the first generation (570 A.D.). The lower limit at both confidence levels is significantly different from the expected boundary of 568 though. According to the modelled dates use of the cemetery as a burial site must have come to an end before 647-675 AD (68.2%) or 626-697 AD (95.4%) with a median of 662 AD+-16 years (68.2%) or 662 AD+/- 35 years (95.4%), respectively. The total estimated span of the cemetery was put between 88 and 123 years (68.2%) and 55-145 years (95.4%) with a median of 104+-22 years (68.2%) or 100+/-45 years (95.4%). This roughly represents 3 generations of use as estimated by archeo-typochronological investigations.

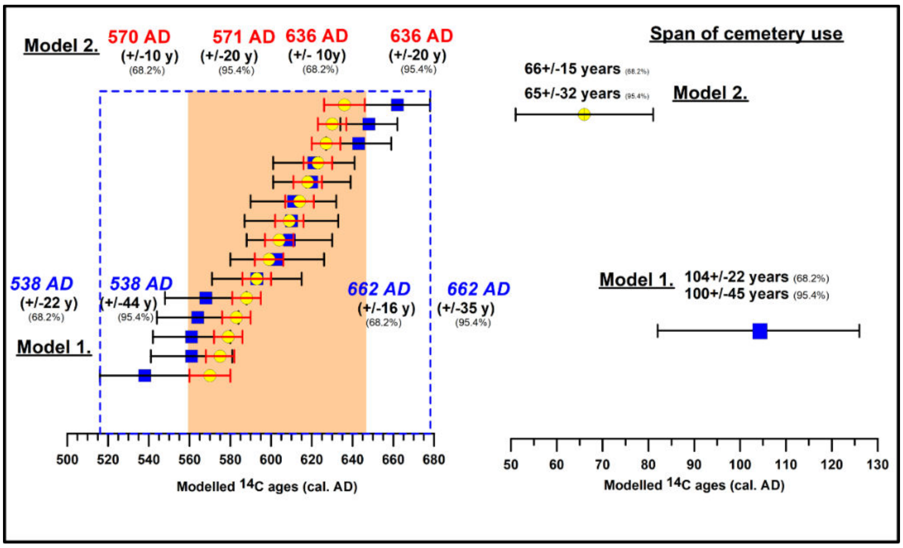

Fig.1 Chronological models built for the Makó-Mikócsa hill cemetery (Gulyás et al., 2018 a,b,c)

In Model 2, the likelihood of absolute age ranges estimated by archeo-typochronology and the recorded radiocarbon dates were combined to better constrain 14C ages to the expected age interval of the cemetery. As a result, uncertainties for dates was reduced by half compared to the previous model (7-10 years (68.2%), 15-20 years (95.4%). The opening of the cemetery must have started between 560-580 AD (68.2%) or 551-591 AD (95.4%). The cemetery was abandoned between 626-646 AD (68.2%) or 616-656 AD (95.4%). The estimated span of cemetery use by Model 2 (66+-15 years (68.2%), 65+-32 years (95.4%), respectively was half of that of Model 1. This data is more congruent with that proposed based on archeo-typochronology (80-90 years) (Gulyás et al. 2018 a,b,c).

Looking at the spatial distribution of absolute ages, at this stage we may presume a site use starting from the SW towards the E-NE. Calibrated ages obtained for Kiszombor-O, Deszk-Ördöghalom and Kiszombor-Tanyahalomdűlő (628, 633 and 637+/- 10 y AD) seem to overlap with the youngest periods of Makó-Mikócsa site (turn and first half of the 7th century AD) (Gulyás et al. 2018 a,b,c).

3. Anthropological characteristics, similarities, differences

Although numerous Early Avar age burials (557) are recorded in the Maros valley (Balogh 2013, 2015a,b, 2017a,b, 2018), the number of preserved human skeletons is much less (375 individuals from 7 sites). Systematic anthropological analysis of human skeletal remains from the largest site of Mikócsa and adjacent sites have revealed important information on the anthropological characteristics of the Maros valley Avar populations. After the establishment of a demographic profile, metric and taxonomic analysis of the cranium and post-cranial bones was done. Major nosological units have also been established following a thorough pathological investigation (Marcsik 2010, 2015, 2018 a,b).

Fig.2. Male and female Mongolic (Sinid-X, Saian-X) skulls from Makó-Mikócsa Hill and a photo of mandibular tori observed (Marcsik 2015, 2018a,b)

Studies of age and sex distribution of the skeletons in the largest cemetery of the Maros valley Makó-Mikócsa Hill revealed a relatively balanced demography in terms of adult/children and male/female ratios with the complete lack of newborns. Children seemed to pass away during their early childhood, while most females deceased during their young adulthood. Males passed away during their senior years. The general height of the individuals was medium and moderately high. The neurocranium was mostly narrow (brachycranic type) and high (hypsicranic type). The viscerocranium was long or moderately long. Based on cranial metrics no significant difference could have been observed between sexes (Fig.2). Among the anatomic variances mandibular tori, a heritable character (Johnson et al. 1965; Mayhall et al. 1970) and spatula-like upper incisors are dominant (Fig.2). Mandibular tori are a bony growth in the mandible along the surface nearest to the tongue. This latter dental feature is a hallmark character of Asian and Inuit populations (Mayhall 1979). Among the adults 58% of the skeletons suitable for typological analysis proved to be Mongolian/East Asian type. 42% had European features. Among the Europeans, however 50% seemed to display mixed features of Asian/European origin. Humans of Makó are narrow and high headed, mostly Mongolic Sinid-X and Saian-X subtypes (Marcsik 2018 a,b; Benedek & Marcsik 2017; Marcsik & Varga 2017; Marcsik et al. 2017).

Among the various pathological features signs of arthritis, spondylitis, metabolic-hematogenic disorders and in case of two individuals' backbone tuberculosis could have been observed. In addition, based on endocranial features this infection could have affected 3 adults and 9 children as well (Marcsik 2018 a,b; Marcsik et al. 2016,2017).

Signs of artificial cranial deformation (ACD) could have been observed as well mainly restricted to female Mongolic types. These are only slight deformations observed in the flattening of the forehead, a depression of the skull top and a steep flat occipital region. Most ACD types were achieved using simple bandaging techniques.

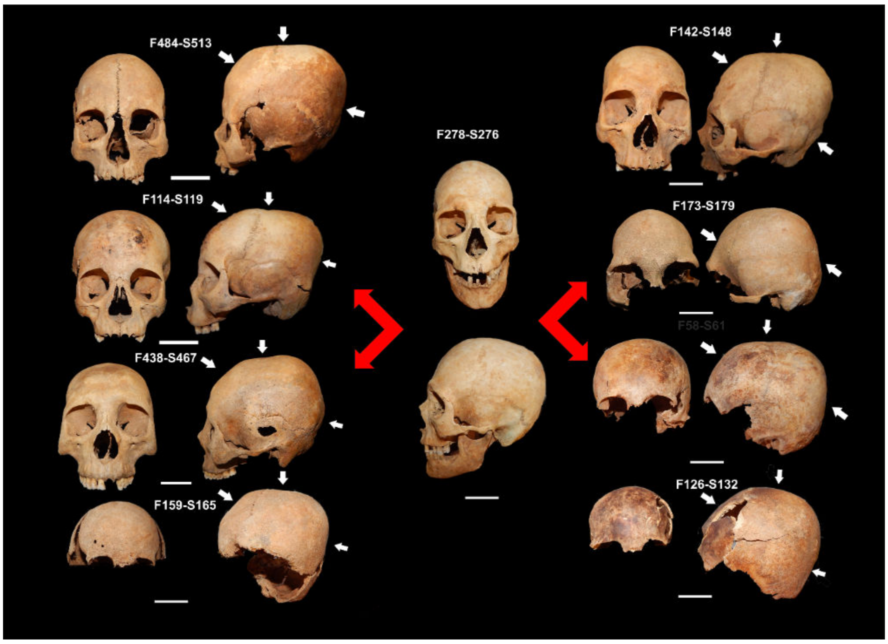

Fig.3. Artificially distorted skulls from Makó-Mikócsa compared to a reference sample in the center (white arrows mark affected anatomical areas) (Gulyás et al. 2016)

ACD is characteristic of other Maros valley cemeteries too. To assess similarities in ACD along the Maros valley Avars and other coeval groups samples have been subjected to cranial morphometric investigations (Marcsik 2015; Marcsik 2018 a,b; Gulyás et al., 2016, Marcsik & Gulyás 2018).

To assess the degree of ACD, the OGẐ index is generally used in anthropology. It's a ratio of linear distance measurements between given anatomical landmark points on the side of the skull capturing the degree of flatness. Application of this index however is flawed in several aspects. Shape is not independent of size. Thus, equal values may represent highly different shapes. Furthermore, shape changes can't be visualized after parametrization. To handle these flaws, in our work landmark-based geometric morphometrics was adopted for Avar and Gepid female vaults in lateral, frontal and top views. To filter out unnecessary geometric information like size, location and orientation GPA has been used via general least squares fit. GPA coordinates were subjected to further multivariate statistical analyses to determine the most important components of shape variation (PCA). The first 4 PCs captured 90% of total shape variation. PC1 and PC2 was interpreted to represent a widening of the skull base and a flattening of the crown. In addition, the outward arching of the forehead. PC 3 and PC 4 describe more localized transformations. Gained shape variables have been subjected to cluster analysis (UPGMA, cosine similarity) to identify subgroups. Covariation of shape variables with size age, group affiliation was assessed using regression analysis (Gulyás et al. 2015c, 2016, 2017 a, b; Gulyás & Marcsik 2015; Marcsik & Gulyás 2018).

Morphometric studies on the practice of artificial cranial deformation in Early Avar and Gepid groups in the Maros valley have initiated and continued in 3D. 20 skulls from Makó-Mikócsa, Kövegy and Kiszombor E have been cat scanned. Methods were developed for digitization, segmentation and fit of skull parts and fragments in surface laser scans and CTs and presented on international geomathematical conferences (Gulyás et al., 2017a, b). Initial surficial differences in areas affected by ACD have been quantified and data compared (Fig.5).

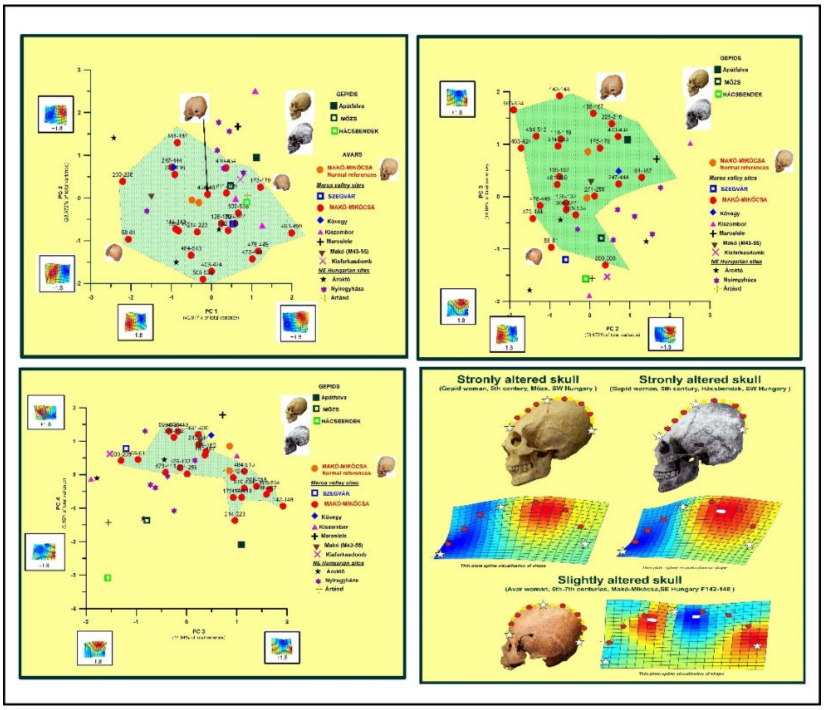

Fig.4. Anatomical variations connected to ACD by age and site and visualized changes in shapes (hot colors represent expansion, cold colors retraction of anatomical points compared to the reference shape) (Gulyás et al., 2017b, Marcsik & Gulyás 2018)

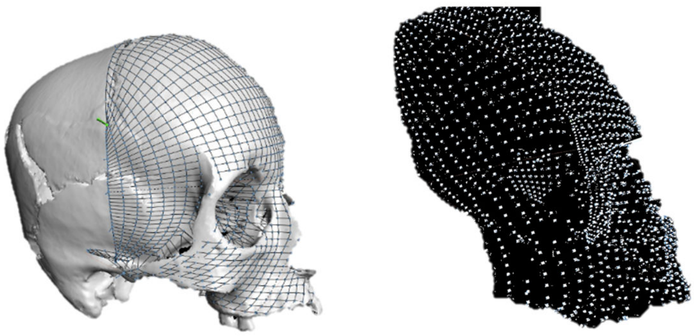

Fig.5. Method of surficial landmark-based 3D geometric morphometrics on frontal and temporal regions of a female skull from Makó subjected to ACD

For the first time in such studies potential anatomical and structural changes have been quantified and evaluated using CT scans and medical software packages of Amira and Amide to tackle any neurological or anatomical effects of ACD to populations (Gulyás et al. 2017a,b). Signs of bone density loss could have been observed and quantified in areas affected during ACD (Fig.6). Further anatomical variations and potential alterations as the side effect of ACD have also been evaluated: e.g. shape volume of sella turcica hosting the pituitary gland, angle of the clivus (Gulyás et al. 2017 a,b; Marcsik & Gulyás 2018). Extreme ACD may have effect on not only the optical nerves but the clival angle and the shape, volume of the sella turcica and sphenoid sinus (Fig.6). A deformation of sella turcica may either lead to the compression of the pituitary gland or the enlargement causing significant alterations in important body functions. Pituitary gland controls the production of hormones regulating growth, blood pressure, certain aspects of pregnancy and childbirth, brest milk production, sex organ functions, thyroid gland functions, body temperature, metabolism, osmoregulation and pain relief. So, any major changes to these areas could have altered body functions. Recent studies have revealed that a larger pituitary volume is associated with higher social anxiety in children (Murray et al. 2016). Introduction of these novel measurements into Avar anthropological studies in our work could reveal such behavioral, social aspects of studied individuals which have remained hidden from environmental archeological studies so far (Gulyás et al., 2017 a,b; Marcsik & Gulyás 2018).

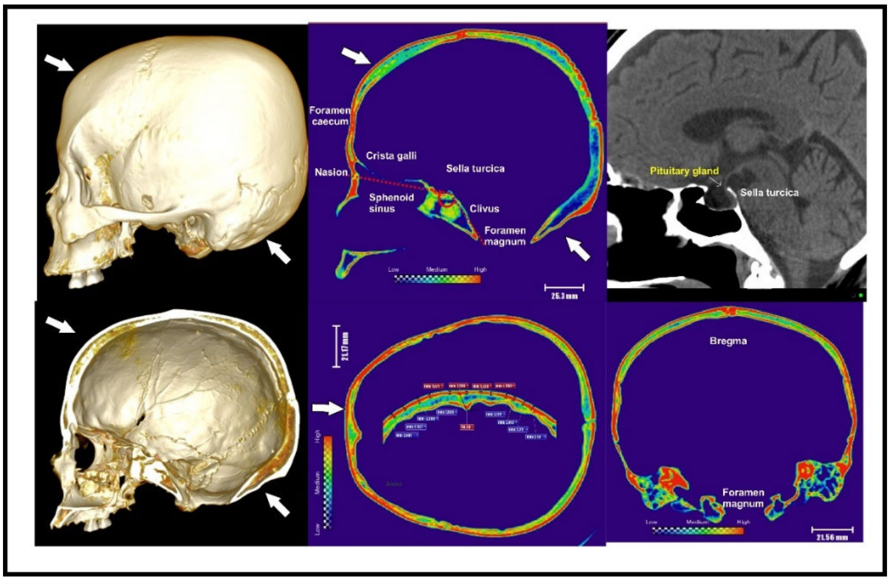

Fig.6. Medical anatomical analysis of a female skull from Makó subjected to ACD (arrows point to areas subjected to ACD)(Gulyás et al. 2017 a,b, Marcsik & Gulyás 2018)

Our findings on ACD characteristics have revealed the close-knit relationship of Maros valley Avar groups in terms of ACD practice hinting to the uniformity of the population. This was further corroborated by a dominance of certain Mongolian haplotypes, which is completely different from the Avar Age populations of the Danube-Tisza Interfluve (Marcsik & Molnár 2017, 2018).

In case of 77 people (32 male and 45 female) osteological alterations attributable to extended use of given muscles in general were observed in areas near the hip-, thigh and shin bones. Three groups have been created characterizing weak, moderate and pronounced alterations. From the males 19 had moderate and 2 pronounced osteological alterations in the mentioned anatomical areas. Only 5 moderate and 2 pronounced cases were observed for females. Evaluation of the results is highly subjective as various types of activities can result in similar osteological changes (Marcsik 2018a,b).

4. Early Avar economies in the Maros valley

4.1 Subsistence

A comparative study of animal remains, tools and artefacts used to include the sourcing and function of bone tools, food remains, sacrificial animals aided subsistence reconstructions (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017). Animal remains appear in two forms in the studied graves: as food or sacrifice (Fig.7). The sheer number of animal bones retrieved from the graves is a clear indication of a dominantly nomadic agropastoral economic system in which these communities were engaged. 37% of the graves had animal bones representing food remains. These are generally restricted to sheep sacral bones, plus shoulder blades but metacarpals also turn up. Pig and poultry remains appear in less 1% of the graves. Leg bone of a red deer was recorded from a single grave alone (Kiszombor-Tanyahalom dűlő Grave 11). All this information indicates the prevalence of lamb in the diet of these Avar communities (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017) .

Fig.7 Animal food remains recovered from the largest cemetery Makó-Mikócsa Hill (Balogh 2016b,2017a,2018b)

A stunning feature of the Early Avar Age cemeteries located along the Maros River is the exceptionally high number of animal burials (Fig.8). Out of the 557 graves 928 animal burials have been recorded. The taxonomic composition of these is rather surprising with a clear dominance of cattle/calf (45%), a similar proportion of sheep/lamb (40%) and a highly subordinate ratio of horse (14.4%). Records of 6 dog burials are also known. The spatial distribution of animal burials is by no means uniform. Some of the studied cemeteries are characterized by an outstanding number of such features and animal remains (Deszk G, Deszk H, Deszk Sz, Makó-Mikócsa Hill), while in others these are present in lower numbers or completely missing (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017) .

The site of Makó yielded 698 of sacrificial animal remains. Calf/cattle (280) prevail in addition to sheep (270). Most are dismembered, with a single complete sheep skeleton. Partial horse remains in 142 graves with a mere 20 complete skeletons were also recorded. Some unique features so far unprecedented in the literature have been recorded from two cemetery sites: the burial of horse and cattle embryos together with the deceased at Makó-Mikócsa. Three solitary horse graves so far unknown for the Trans-Tisza area have been noted in the cemetery of Kiszombor-Tanyahalomdűlő (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017) .

Zooarcheological analysis revealed information on the anatomical characteristics of herded animals. Horses of Makó were stout, small and medium sized with 2 different head and 3 different leg and hoof types. Sheep were mid-size, hornless and pariah types. Mid-size cattle were prevalent (Kőrösi 2015 a,b, 2018a,b).

Certain artefacts and artefact assemblages also carry information on the importance of free range animal husbandry (iron bell, flint stones or tinder). Examples of the former two have been recorded. In the cemetery of Makó presence of a bifurcating iron tool with downward folding spikes and a wooden handle was noted in several graves most likely representing hoof scraper. Carved wooden, bone and horn objects preparation of which requires less raw material or practical knowledge like needle cases made of sheep shinbone, disentangles, bits, tool handles made of antler are also clear records of a pastoral lifestyle (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017) .

Fig. 8 Sacrificial animal burials from Makó-Mikócsa and Kiszombor F

Hunting was an important activity of the studied communities as most of horn and bone tools and objects are made of red deer ribs and antlers (65% in Makó-Mikócsa). Iron lances recorded in the graves must have been used for hunting big game too, while arrows and arches could have been used for small game and wild fowl. Arrowhead and arch plate remains recorded in 5 children graves at Makó may correspond to weapons used for hunting rather than simple target practice.

Gathering of wild berries, mushrooms, herbs, seeds, grains must have been part of everyday activities too. Wooden bowls and jars placed into the graves might have been useful for the storage of such food complements and medical resources. Signs of reed and bulrush use are clearly recorded in daub fragments retrieved during the wet sieving of ca. 16 tons of soil removed from the site. These might have been used for preparation of weaved baskets, bowls etc (Balogh 2014a, 2015a, 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017) .

No tools indicating plant cultivation are known in the records. Yet detailed analysis of textile remains attached to some iron tools attest the use and cultivation of flax and hemp. In addition, as a part of the pottery emplaced into the graves must have had food remains cultivation of cereals (millet, barley) can also be presumed (Gulyás et al. 2018d). Use of these types of plants in the diet have been independently attested via biogeochemical analysis of human bone remains to be detailed in the next subchapter. Geochemical, sedimentological analysis of soil (Corg, inorg, pH, EC, MS, grain-size, color, 8 elements) retrieved from jars of the Makó cemetery also aided elucidation of the nature of organic matter emplaced into them (Fig.9). Anomalies were assessed via statistical methods plus parameter maps. Elevated values of K, Mg helped identification of wood ash and burnt flesh, bone remains. Others (Ca, Mg) may indicate the burial of water bank plants (reed, bulrush) (Gulyás et al. 2015a, 2018e).

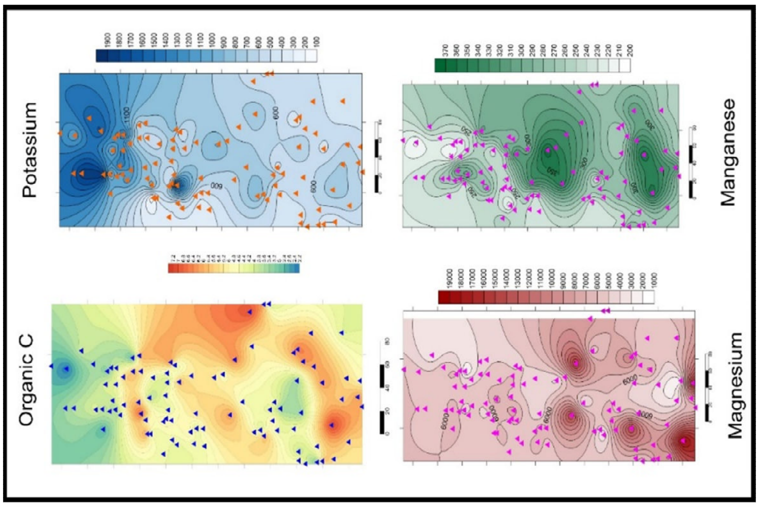

Fig.9. Concentration of selected trace elements in soils from jars

Most analyzed graves had high concentration of Corg indicating the placement of organic matter (food, flesh) into the pots. Spatial distribution of marker elements connected to the presence of flesh and cereal meals (Mn, Cu, Zn) in the pots were highly correlated with the amount of Corg. However, burials on the northern and northeastern margin of the cemetery had anomalously low values implying a different perhaps plant origin of the organic matter. K also had a moderate spatial correlation with the mentioned marker elements indicating the presence of burnt flesh and bone remains. Highest K values are found in the areas characterized by the lowest organic matter, which clearly indicate that these anomalies must represent burnt inorganic matter (bones) rather than organics (wood ash, burnt flesh) placed into the jars. High Mg was observed for only a few graves hinting to a subordinate use of water bank plants in grave goods (Gulyás et al. 2015a, 2018e).

4.2 Dietary reconstructions

To confirm and widen knowledge gained regarding subsistence of the Early Avar communities of the Maros valley archeological data was complemented with information on bone geochemistry (trace elements of Mn, Zn, Cu; C, N, O isotopes) containing records of the diet.

Marker trace elements carrying information on wheat, meat, dairy consumption have been analyzed from the largest cemetery of Makó-Mikócsa Hill (Fig.10). Wheat and other cereal produce have high manganese content resulting high concentrations of this element stored in the body and the bones. Values below 500 pp generally indicate a meat & dairy based diet (Watts 1990; Subira and Malgosa 1992). In Makó the average Mn concentrations in studied bones of 96 individuals ranged between 160-400 ppm. Zn is above 200 ppm, again indicating meat consumption. Cu ranged between 20-40 ppm. Values above 20 generally mark meat consumption. Elevated level of metals in goldsmith and blacksmith burials was attested (Gulyás et al. 2015a, 2018d).

Stable isotopic analysis of carbon and nitrogen from bone collagen can assist in distinguishing patterns of subsistence. Nitrogen is found at its highest concentration in amino acids. These amino acids are linked together to form proteins, which serve both metabolic and structural functions in tissues. By examining different nitrogen isotopes in a protein, it is possible to differentiate between animal protein sources and plant carbohydrates (Ambrose 1993; Larsen 2002). The $\delta^{13}C$ values of enamel, bone apatite and collagen can be used to distinguish if the individual had a primarily C3, C4, or intermediate plant diet. Additionally, it can be determined if the individual consumes primarily a marine or terrestrial animal protein diet. Plants follow different metabolic pathways in CO_2 fixation which leads to different number of carbon atom bonding during photosynthesis (C3, C4). Both pathways are represented by clear

$\delta^{13}C$ values. C3 plants generally have lower, while C4 plants have higher $\delta^{13}C$ values (van der Merwe 1982; Ambrose 1993).

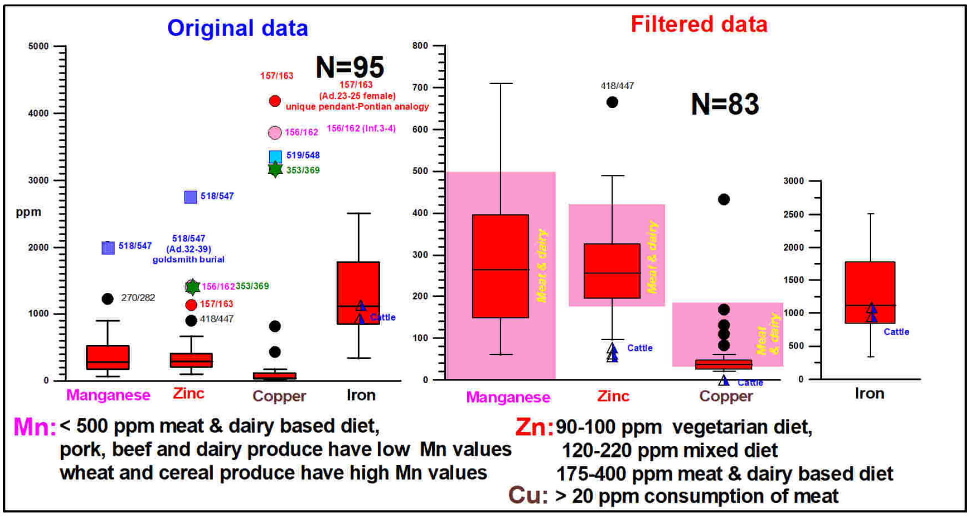

Fig.10. Concentration of marker elements of Mn, Zn, Cu, Fe in bones from Makó-Mikócsa Hill (Gulyás et al. 2015a, 2018d)

Most plant life and plant products of nutritional value fall into the C3 group. These include wheat, barley, rice, wetland grasses, legumes, vegetables, all root crops, nuts, most fruits, and honey. The C4 groups of nutritional value include millets (e.g. setaria millet, broomcorn millet), maize, sorghum, sugar cane, some amaranths, chenopods, and tropical grasses (Ambrose 1993; Tykot 2004; Le Huray & Schutkowski 2005). To assess the taphonomic reliability of the data the C/N ratio and the collagen content is checked primarily (Ambrose 1993). In our samples the C/N ratios ranged between 2.9-3.2 (mean 3.04) indicating ideal preservation of bone collagen (Ambrose 1993). Collagen content of bones were also high enough to yield reliable data (5-25%).

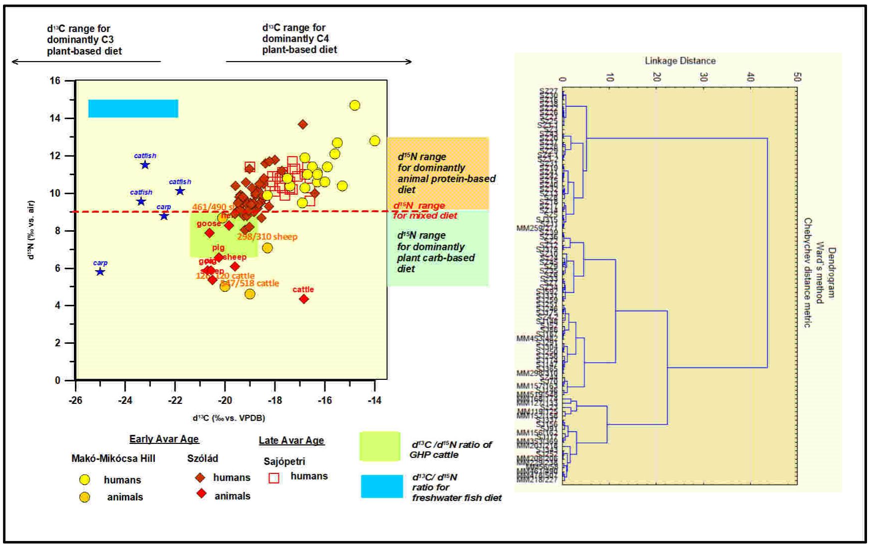

Fig.11. Ratio of $\delta^{15}N$ and $\delta^{13}C$ values for the study sites of Early Avar Age Makó-Mikócsa SE Hungary and Szólád W Hungary, and the Late Avar Age site of Sajópetri, NE Hungary reflecting diet (Gulyás et al. 2018d)

The $\delta^{15}N$ stable isotope values for the Avars at Makó ranged from 9.2-14.6 ‰ with values above 12 ‰ being outliers (Fig. 11). The general range for most samples is not a high enough value to indicate freshwater fish was a staple food item within their diet. This is congruent with the lack of fishbones from the graves at all Maros valley sites. However, the $\delta^{15}N$ values do fall within the ranges that indicate the use of secondary products of domesticated livestock for the entire analyzed population. Individuals characterized by $\delta^{15}N$ values of a mixed diet or dominantly plant carb diet were missing from the analyzed sample population of Makó(Gulyás et al. 2018d). A similar trend is observed for the Late Avar Age population of Sajópetri (9.6-11.4‰ with a mean of 10.7‰ ± .5) indicating no major difference from Makó in consumption of animal proteins (Noche-Dowdy 2015). Most individuals from the 6th century Lombard cemetery at Szólád in Transdanubia, W Hungary also had similar δ 15N values to the coeval site of Makó and the younger site of Sajópetri (Alt et al. 2014). Conversely, individuals at the baseline of a mixed diet and a dominantly plant carb diet are also present in large numbers. The picture is even more interesting when we examine $\delta^{13}C$ values. Apart from one or two outliers the mainline individuals from the Lombard cemetery at Szólád have strictly lower values and well separated from the individuals of coeval Makó Mikócsa site (Gulyás et al. 2018d). This implies that the diet of the Lombard was dominantly C3 type plant (barley, wheat etc.) based. Conversely, the Early Avar Makó group had dominantly C4 plants in their diet (millet). This clearly corroborates the archeological assumption of millet production by the Makó group and the emplacement of millet porridge into the burial jars (Gulyás et al. 2018d). As other Central European populations occupying the region utilized wheat and barley, both C3 plants, as staple crops (Hoekman-Sites & Giblin 2012; Motuzaite-Matuzeiciute et al. 2013; Papathanasiou et al. 2013) the Avars of Makó were non-locals to the area. The Late Avar Sajópetri population occupies a mid-position between the two extremes indicating a somewhat similar, yet different plant-based diet from the Early Avar Makó group. Their diet is still C4 plant based but composition must have been different from the Early Avar Makó group. Individuals with outlying $\delta^{15}N$ and $\delta^{13}C$ values at Makó indicate breastfeeding infants (Gulyás et al. 2018d).

4.3 Utilization of local natural resources in subsistence

The investigation of plant remains yielded useful information on the composition of the wood and plant matter used as well as that of the nearby available resources. Most of them had poor preservation rendering them unsuitable for analysis. The presence of oak, maple, lime, elm, poplar, hornbeam, willow wood and charcoal remain talks about the existence of a mixed temperate deciduous gallery forest in the surrounding areas (Gulyás et al. 2015a,b, 2018e). In some objects including daub remains reed could also have been identified harvested from the banks of the adjacent creeks like the Száraz brook. It also refers to the use of reed in wattle and daub. In addition, grass and cereal chaff were also observed in pottery remains indicating the use of these in daub preparation. Visual as well as chemical analysis of certain hair and leather remains revealed the use of squirrel hair, fox hair in make-up brushes, these animals were constant inhabitants of the nearby gallery forests. Plant remains from pottery grave goods were dominantly goosefoot and grass remains readily available in dry grasslands (Gulyás et al. 2015a,b, 2018e).

4.4 Craftsmanship and workshops in the Maros valley

Archeotypological overview of artefacts carrying information on various types of crafts (woodworks, metalworks: blacksmith-goldsmith, pottery, wool & textile weaving, fur & skin making, bone, stone tool & pearl making) complemented by archeometric analysis (chemical composition of dyes, gold plates, jewels, metal artefacts, pearls, excipients of jewelry) was another way to explore questions of subsistence in our work (Balogh 2015a,b 2016b,2017a 2018b; Balogh & Lőrinczy 2016, 2017). Geometric morphometrics have been introduced to shape analysis of artefacts as a novel approach.

4.4.1 Woodworks

Remnants of wooden artefacts placed into the graves but only partially preserved talk about the wide array of wood crafting activities of the community. These artifacts range from handles attached to rusted iron tools, saddles, wood fragments on sword handles and sheaths. Tools used have also been recovered from the area like the handsaw, planes, metal files from Makó. In addition, part of the iron knives might have been suitable for wood carving. Planes must have been used for thinning and smoothing the surface of wooden buckets, bowls, coffins, furniture (Balogh 2016a,c). Anthracological analysis of wood remains revealed a wide array of wood types used sourced from the local gallery forests (oak, maple, lime, elm, poplar, hornbeam, willow).

4.4.2. Pottery

Production of clay jars, granaries was known to Avar communities. Jars containing meat and/or porridge were placed into the graves. Certain pottery shapes and more sophisticated decoration types (dripped dyed jars, nosed bottles) attest the presence of potters using basic techniques. Nosed bottles and wheeled pottery from Szőreg A also speak about the presence of skilled potters.

4.4.3 Fur and animal skin making

Fur and skin production is an embedded part of a pastoral lifestyle. The presence of red deer bones may refer to the use of deer skin as well besides those of herded animals. Belts, small belt cases, saddlery, sandals and laces as well as certain clothes were made of leather. Although the majority of these are not preserved decorations, pins, pegs used are clear signs of their production. Punchers and prickers recovered from female graves also belong here. Punchers have so far been recovered from Makó- Mikócsa alone. Accordingly fur and skin making was a task of women. Two furrier knives with blades perpendicular to the handle recovered from certain cemeteries of Transdanubia also from female graves corroborates our assumption.

4.4.4 Wool and textile weaving

Sheep bones clearly speak of sheep herding. There is every reason to believe that both sheepskin and wool has been used. There are several spinning rings and buttons used for wool spinning. Flax and hemp must have been grown and used for weaving clothes. Textile fragments attached to rusty iron surfaces, needle holders made of animal bone also signal this kind of crafting activity. Bulrush, sedge growing along the riverbanks and shores of oxbow lakes must have been used for basket, hive weaving.

4.4.5, Bone tool industry

Bone and horn tools (197) are mostly bow plate fragments, but tiny hangers, clutches, buckets of the horse harness or antler bits, bone combs, sabretache sealers, awls, hole-punches, needle cases also turn up in various forms. The majority is made of red deer antler or rib bone, followed by cattle, sheep, and goat and horse bone in much smaller quantities. Grave 61 of Makó holds remains of a former bone and horn craftsmen. A small casting mold holding unfinished bow plate fragments complemented by several various tools of saws, drill bits, scrapers, and files was recorded. Two similar type of graves are known from the wider surroundings of the area (Mokrin 30 and Hódmezővásárhely-Szárazérdűlő) (Balogh 2015b,c). According to our analyses hematite was used as a dye for painting carved motifs of bow plates, bone latches (Fintor et al. 2018) (Fig.12).

Fig.12 Bone comb, carved and painted bow plate fragment and leather belt case latch

4.4.6. Stone tool industry

Numerous different types of flint stones, polishing stones, grinding stones, grinding handles have been recovered some of them bearing marks of knife and sword sharpening. Most of flint was hydro quartzite and radiolarite which are readily available from the Southern Carpathians and the Northern Mid-Mountains. In addition, various shale types, limestones, sand stones, gneisses, schists have been recovered all pointing to the area of the Southern Carpathians located south of the Maros valley in

Transylvania as source areas. Miocene sandstones found among the stone tools must have been sourced from the marginal areas of the Transylvanian Basin. Some grindstones are made of dark brown coarse-grained sandstone, which is a characteristic Cretaceous rock found and mined along the southern margin of the Apuseni Mts from Alba Iulia to Berzova. The general composition of stones with the majority having a provenience in Transylvania indicates a strong trade link along the Maros river (Gulyás & Szónoky 2015; Gulyás et al. 2018j; Szónoky et al. 2017).

4.4.7 Metal works: blacksmith, goldsmith

Artefacts recovered speak about the wide array of skills blacksmith and goldsmith had among Avars populating the Maros valley. These include various types of buckles, decorations, saddlery, iron tools, weapons and of course jewelry. The number of goldsmith graves recovered in the study area clearly attest that a part of these products must have been produced locally (Klárafalva B 60, Fönlak, Deszk T, Makó-Mikócsa). Some of them had partially ready bronze rivets, blow pipes, bronze plates used as raw material, metal files, hammers, measuring cups, melting pots, scissors, pliers attesting the wide array of metalworks. While the formerly recovered blacksmith and goldsmith graves were solitary, the new ones nicely fit into the well-documented line of cemeteries from SE Hungary offering possibilities for further comparative studies.

A comprehensive analysis of Maros valley graves containing artisan tools was also done and prepared for publication (Balogh 2017a,b, 2018). Archeometric analyses of Avar gold artefacts have been completed. According to our results, quality of gold jewelry was outstanding (24 K) with ca 98% of gold content and 1.5-1.7% of silver as alloy in general. Byzantine gold coins have the same composition. This may indicate the direct use of coins in jewel making. A somewhat higher (ca.3-4%) of silver alloy was noted in case of gold threads, plates used for decorative purposes alone where a more flexible matter was needed. A Byzantine type of cross pendant have also been evaluated (Balogh 2018a, Balogh & Pásztor 2016; Gulyás et al., 2018f,g).
Archeometric analyses also focused on the types of auxiliary materials used by goldsmith as well. Infilling and glue material used for gemstone and glass encrusting as well as gluing metal sheets have been in use since the 5th century A.D. in the Carpathian Basin (Borbíró, 1996; Horváth 2008). Studies analyzing such material dated between the 5-8th centuries revealed a complex of organic and inorganic matter, where the former was interpreted as some type of wax, the latter embedded a large variety of components ranging from carbonates to silicates. In some cases, the presence of beeswax has been assumed (Arrhenius 1985; Daim 2002; Heinrich-Tamáska 2006). A disk fibula described from Keszthely-Dobogókő also contained traces of beeswax (Daim 2002). In addition, plate knives described from the Balkans and Southern Italy, taken as secondary archeological records also contained traces of this organic matter. (Daim, 2002; Vida 2002). Arrhenius also recorded traces of wax in artefacts dated between the 5-6th centuries A.D. assuming links with Eastern Gothic traditions (Arrhenius 1985). Nevertheless, the use of wax in fills and glues has been present in the Carpathian Basin since the 5th century A.D. Analysis of such fills and glues from Early Avar cemeteries along the Maros using FT-Raman spectra revealed peaks strictly known for beeswax from the literature in addition to calcite, silicate and inorganic carbon (flue ash) (Conti et al. 2016; Edwards et al. 2016; Fintor et al. 2018).

4.4.8. Pearl and bead production and trade

Pearls of Gepid burials found in our study area (Szőreg A, Magyarcsanád-Bökény, Kiszombor B) as well as those of Avar age (Makó, Kiszombor, Deszk) have been reviewed, photographed and assembled into a database enabling further typological evaluations (Balogh 2014b,c, 2015b, 2017a; Pásztor 2018). Out of the 251 graves of the largest Early Avar Age cemetery of Makó-Mikócsa 104 had pearl grave goods of various composition and decoration types. (867 analyzed in total) classified into 10 different groups. The raw material used was glass, silver, gemstones, organic gemstones and stone. 61% of the pearls are monochrome translucent glass beads. The next largest group had different type of raw materials and decorations (31%). Group 3 contained 17 glass beads of Millefiorian type (Pásztor 2018). The remaining group contained gold plated glass beads, polished gemstones (calcedony, carneol, coral, amber). The Antique and Avar type beads were classified into two major groups. Both groups of necklaces contained all the major bead types characteristic of Late Roman, Late Antique, Early Byzantine fashion. Add on of a smaller number of monochrome beads as accessories to necklaces was also present in West German Meroving Age cultures. A pronounced preference for monochrome beads was present among the Gepids and Langobard too. The sheer number of such monochrome beads at Makó compared to other Early Avar sites is a unique feature. Necklaces containing merely monochrome beads or antique mixed beads are less frequent during the Early Avar Age in the Carpathian Basin though (Keszthely-Déli erődfal, Keszthely, Pusztaszentegyházi-dűlő, Szekszárd Bogyiszlói út, Szegvár-Oromdűlő, Tiszavasvári, Kashalom-dűlő, Deszk) (Pásztor 1996, 1997, 2008, 2010, 2014a, 2014b, 2014c; Lőrinczy, 1996; Csallány, 1939, 1943).

To tackle similarities and differences between bead production industries of previous (Sarmatian, Gepid) and coeval groups in the Maros valley a selected sample of colored beads were subjected to chemical analysis using microprobe and the same methodology as presented in Fórizs et al. (2001, 2006). Data is still under evaluation using a previously assembled database of bead chemistries for the mentioned period on beads measured by the same instrument and methodology enabling reliable comparison. In addition, XRF measurements of Millefiorian and traditional stone beads have also been implemented. Evaluation of results is in progress (Gulyás et al., 2018h)

Finally, amber beads from the largest cemetery of Makó-Mikócsa, coeval Early Avar sites from the Maros valley (Szőreg, Kiszombor) as well as a Maros valley Gepid site (Kiszombor B) (ca. 60 pc in total) have also been analyzed for chemical composition using Raman spectroscopy. Published spectral data on Baltic and Romanian amber types, own measurements of contemporary Baltic amber, as well as list of amber localities enabled us to make initial presumptions regarding the provenance of amber beads. Multivariate analysis of spectral data pointed to a clear overlap of Early Avar amber beads of coeval Maros valley sites. Some beads from the Gepid cemetery cluster together with the Avar ones implying partial relations (Gulyás et al., 2018h) (Fig.13).

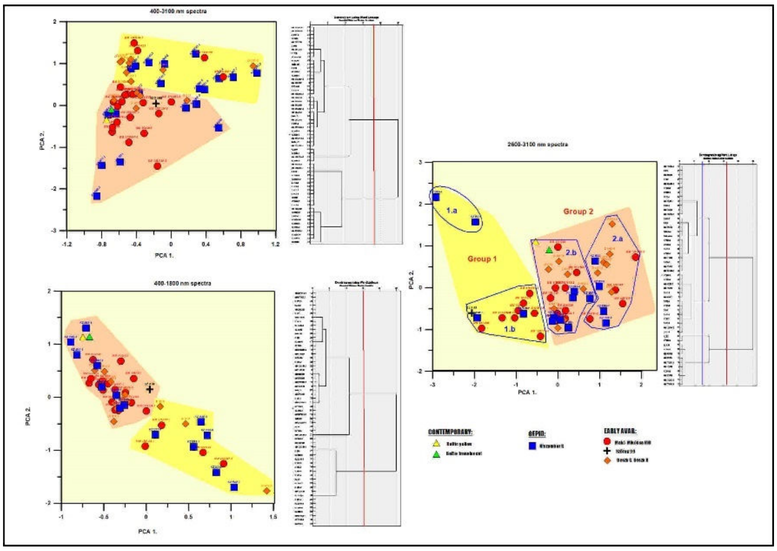

Fig.13. PCA and cluster analysis results of FT-Raman spectra of amber beads (Gulyás et al. 2018h)

According to initial evaluations, Romanian amber types seem to be the dominant ones. Localities with amber are clearly confined to the valley of the Olt and the Maros River in addition to the SE corner of the Carpathians. This information seems to corroborate the assumptions on a strong Transylvanian link of the first generation of Avar communities seen in the tooth Pb isotopes and petrological composition of stone tools and artefacts of Makó-Mikócsa as well. This may hint to the use of a route along the Olt valley to Transylvania by the first group of Avar communities on their way to the Carpathian Basin from Bulgaria. Comparison of amber bead industries between the individual sites is in progress as well as the direct evaluation of finer fingerprint spectral peaks (Gulyás et al., 2018h).

5. Funerary practices, regional similarities, differences

A complex study of funerary practices has been carried out. One major achievement was the assembly of an archeological database of 558 features dated to the Early Avar period. The distribution of studied features by sites is the following: Deszk G: 58 graves, Deszk H: 18 graves, Deszk L: 13 graves, Deszk M: 4 graves, Deszk N: 9 graves, Deszk O: 5 graves, Deszk P: 6 graves, Deszk Sz 31 graves, Deszk T: 70 graves, Ferencszállás 8 graves, Kiszombor B 6 graves, Kiszombor E: 61 graves, Kiszombor G: 3 graves, Kiszombor O: 6 graves, Kiszombor-Tanyahalom dűlő: 26 graves, Klárafalva B: 1 grave, Klárafalva-Barna: 6 graves, Kövegy: 12 graves, Magyarcsanád-Bökény: 4 graves, Makó-Mikócsa Hill: 251 graves, Szőreg A 15 graves (Balogh 2015a, 2017a,b, 2018b).

Spatially and chronologically two groups were identified, where both type, orientation and shape of the graves were different and animal burials were either frequent or completely missing. Out of 557 graves 98 (17.5%) were pit graves, far below the 30% ratio observed in Szegvár-Oromdűlő. In Makó only 10% of the graves were pit graves. In contrast graves with a sidewall chamber were present in larger numbers (58%, 323 graves) compared to the lower ratio of 30% for Szegvár (Balogh 2015a, 2017a,b, 2018b). When individual sites are taken, dominance of this latter type is even more remarkable giving 80% of all burials in Makó. Based on these observations we may conclude that the latter sidewall chambered graves were the prevailing type in the Maros valley. Pit graves of Makó are also markedly different from the others of the Maros valley and Szegvár-Oromdűlő as well. They seem to show a closer affinity to the catacombs of the Eastern European Plains (Balogh 2015a, 2017a,b, 2018b). Some graves, or cluster of graves with a N to S or NW to SE orientation seem to be different from the mainstream of burial types. Sacrificial animal remains are rare, but solitary horse burials turn up (Kiszombor, Klárafalva, Ferencszállás). They are exclusively pit graves, chambered pit graves with a complete lack of sidewall chamber graves. Chambered graves have steeper walls compared to the traditionally observed NNE to SSE oriented ones. An age younger than the mid-7th century can be inferred. Based on archeotypology, the first group (Deszk, Makó¬Mikócsa Hill, Szőreg A) existed until the first third of the 7th century. The second group lasting until the second third of the 7th century was completely lacking animal burials (Balogh 2015a, 2017a,b, 2018b).

6. Migration, cultural, trade relations

6.1. Migration, geographical area of inhabitation

Heavy isotopes have also been used for evaluation of human skeletal remains. The analysis of strontium isotope ratios ($^{87}Sr/^{86}Sr$) and lead ($^{206,207,208}Pb/^{204}Pb$) in human skeletal material reveals information about migration throughout an individual's life (Turner et al. 2012; Kamenov and Gulson, 2014). Strontium and lead isotopes vary among different types of geological bedrock, and this variation can be used to identify different geographic areas. These isotopes are transferred from the local soil by food, water, and soil and/or dust ingestion and become incorporated into an individual's biochemical profile (Beard and Johnson, 2000; Price et al. 2004; Bentley 2006; Bentley et al., 2004; Kamenov, 2008; Voerkelius et al., 2010; Kamenov and Gulson, 2014). ^{87}Sr is the daughter product of the ^{87}Rb isotope decay. Therefore, depending on the age and initial Rb/Sr ratios different rocks will have different $^{87}Sr/^{86}Sr$ isotopic ratios at present. The highest Rb/Sr ratios are found in clay minerals and oldest igneous, metamorphic rocks or soils developed on them. Younger rocks and soils on them have lower values. Voerkelius et al. (2010) suggest that Hungary's $^{87}Sr/^{86}Sr$ has a range of 0.70901–0.71100 based on its natural mineral waters. Several works are known, which has baseline natural Sr values from the Carpathian Basin and adjacent areas (Seghedi et al. 2004; Harangi et al. 2007; Harangi & Lenkei 2007) in addition to archeological material (Giblin 2009; Gehrling et al. 2012; Giblin et al. 2013; Alt et al. 2014; Noche-Dowdy 2015; Bickle & Whittle 2016). These can also be used for comparison. However, it must be noted that spatially extensive bedrock such as the loess belt stretching from W Germany to the East European Lowlands, are characterized by similar range of Sr values posing hardships in evaluation. In addition, long-distance importation of food and water may affect the individual's strontium isotope ratios and may not be entirely controlled by the local environment.

Lead is more directly absorbed through soil and/or dust ingestion or inhalation including those of anthropogenic origin as a side-product of domestic good production (Kamenov and Gulson, 2014). Due to this primary mechanism of absorption, its isotopes are not likely to be affected by importation of foods from other regions. Therefore, the combination of ($^{87}Sr/^{86}Sr$) and ($^{206, 207, 208}Pb/^{204}Pb$) isotope compositions of skeletal remains allows for a tighter constraint to estimate the origin and geographic mobility of individuals (Turner et al., 2012; Gulson and Gillings 1997). Lead is an element that has also historically been used for anthropogenic purposes. Lead isotopic values for source rocks, ores of nearby volcanic mountains are readily available for comparison (Damian 2003; Marcou et al. 2002; Baron et al. 2011; Harangi et al. 2007; Harangi & Lenkei 2007). Unfortunately, there is only a single study from the Late Avar Age site of Sajópetri, which could have been used for regional comparison for the period of the 6-8th centuries (Noche-Dowdy, 2015).

Accordingly, enamel of PM, M1 of different human age groups capturing the first 5-6 years of environmental history of an individual, plus soil, cattle bone samples have been analyzed for Sr, Pb isotopes from the largest cemetery Makó-Mikócsa to assess potential differences regarding the geographic origin of the population. In addition, concentration of 67 trace elements in enamel has also been included. Based on Sr for cattle bone & soil a narrow local range of 0.7089-0.7096 was established (Fig.14) overlapping with published ranges for this part of the GHP (Giblin 2009; Giblin et al. 2012). Most samples are more radiogenic than those of similar age from Transdanubia (Heinrich-Tamáska & Schweissig 2011; Alt et al. 2014), but less radiogenic (Gulyás et al. 2015, a, b; Gulyás & Marcsik 2018) than published dates from the NE GHP (Giblin 2009; Giblin et al. 2012), including recent Late Avar age study of Sajópetri (Noche-Dowdy 2015). The majority fall into the local range implying consumption of local resources during early childhood. Samples of similar ^{14}C age have similar Sr values in general with 5 less radiogenic outliers. Values around 0.7083 (2 samples) are partly overlapping with that of natural ranges for mineral waters for Transdanubia and the Avar site of Kölked-Feketekapu(Vorkelius 2010; Heinrich-Tamáska & Schweissig 2011; Gulyás et al. 2015,a,b; Gulyás & Marcsik 2018).

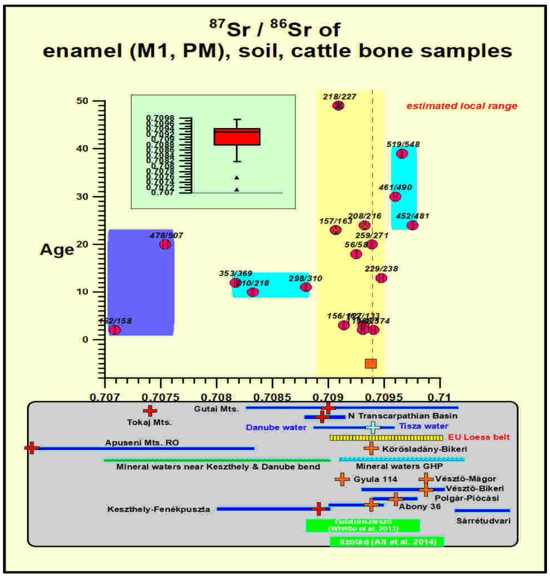

Fig.14. Comparison of $^{87}Sr/^{86}Sr$ values for Makó-Mikócsa with other data (Gulyás et al. 2015 a,b; Gulyás & Marcsik 2018)

Also fall into the lower end for Gutai Mts, higher end for Apuseni Mts (Seghedi et al. 2004; Giblin 2009). Other samples are least radiogenic (bw 0.7070 and 0.7075) covering the low end of mineral waters for Transdanubia, and close to that for young volcanic rocks of Tokaj. These outliers have also some metals (Ag, Au, Cu) lacking in the others implying an out of site origin or food consumption during early childhood. Several grave goods (bronze brush holder, dripped dyed jar, metal plate pendant, filter spoon) may hint to relations different from the mainstream group and most likely integrated or travelled with the Early Avars (Gulyás et al. 2015, a, b; Gulyás & Marcsik 2018).

For Pb isotopes our samples are more radiogenic than those of modern Romanians, Bulgarians (Kamenov 2008; Kamenov & Gulson 2014), or historical Romano-early Medieval populations (Noche-Dowdy 2015; Montgomery et al. 2004) (Fig.14). They show a good overlap with Late Avar age Sajópetri population (Gulyás et al. 2015,a,b; Gulyás & Marcsik 2018; Noche-Dowdy 2015). Unfortunately, Pb isotope analysis was not included in the coeval cemetery of Szólád (Alt et al. 2014) enabling comparison with Langobard groups.

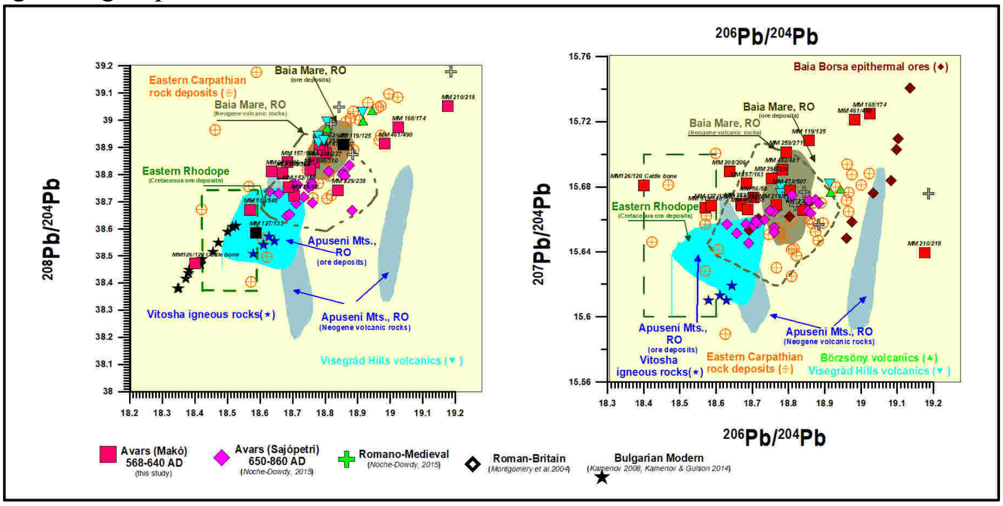

Fig.14. Lead isotope ratios of the Early Avar site Makó, the Late Avar site Sajópetri and nearby potential source rocks, ores as well coeval and contemporary European population (Gulyás et al., 2015a, b, 2018).

The Avars show distinct Pb isotopic compositions when compared to coeval European individuals. This provides direct evidence that the individuals buried at the cemetery were not exposed to Roman Pb during their childhood years. This indicates that the buried Avar were not born and raised in the Carpathian Basin. Therefore, the Pb isotope data further support the earlier conclusion based on $\delta^{13}C$ isotopes, and to some extent Sr isotopes, that the Avar individuals were foreigners to the region (Gulyás et al. 2015,a,b; Gulyás & Marcsik 2018).

Most of our samples fall into the area of Neogene volcanic rocks and ores from NW Transylvania. Comparative multivariate statistical analysis of Pb isotope data from the two referred Avar Age sites and natural rock and ore sources have clustered the Late Avar Age site of Sajópetri, the Early Avar Age site of Makó-Mikócsa into one group with the Neogene volcanics of the eastern, southeastern Apuseni Mts and the Inner Carpathian volcanic belt of NE Romania. This group was clearly separated from the second one embedding the Neogene volcanics of the Eastern Carpathians, metal ores of the Apuseni Mts. in Transylvania and those of the Eastern Rhodope Mts in Bulgaria. These observations point to a strong relationship with Transylvania especially NE Romania and the eastern southeastern side of the Apuseni Mts. fringing the Transylvanian Basin from the west. Several Early Avar Age sites are documented in this area as well (Gulyás et al. 2015, a, b; Gulyás & Marcsik 2018).

Values for two cattle remains are much less radiogenic than those for humans and fall close to the values characteristic of the modern Bulgarian population (ratio of $^{208}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$). Regarding the ratio of $^{206}Pb/^{204}Pb$ the Avar populations of Sajópetri and Makó clearly overlap. Conversely, the individuals from Makó seem to be more radiogenic for $^{208}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ than those of Sajópetri and the Romano-Medieval populations of Central Europe, modern Bulgaria (Gulyás et al., 2015 a, b, 2018; Montgomery et al. 2010; Kamenov 2008; Kamenov & Gulson 2014). So, although both populations were alien to the Carpathian Basin, including the area of Makó (at least during their early childhood), their differences in the latter two isotope ratios indicate different areas of origin in the same wider region. There are three outliers in the Makó populations, whose Pb isotope values are higher than the rest. Two of these have outlying $^{87}Sr/^{86}Sr$ values too and high concentrations of lead, gold and silver in their premolars corroborating the differing origin from the rest of the Avars (Gulyás et al. 2015, a, b; Gulyás & Marcsik 2018).

6.2.Meroving, Byzantine, Mediterranean, Eastern European relations

Archeological studies focused on the investigation of these distant relations cultural, trade connections within the Maros valley (Gepids) as well as other regions: e.g. study of Byzantine artefacts (secondary use of coins in gold jewelry), Meroving and Mediterranean links (buckles), Transylvanian links (stone tools, amber and colored beads). A comprehensive evaluation of Gepid and Early Avar archeology enabled us to tackle Gepid Avar relations in the light of cultural aspects, acculturation and assimilation as well as trade. The investigation of Byzantine and Meroving relations was implemented via the comparison of the uppermost horizons of serial Gepid cemeteries, and review of Avar graves in serial Gepid burials. Within the Gepid period presence of a secondary temporal horizon could have been attested dated to the second half of the 6th century A.D. The presence of two Germanic origin artefact types was also noted in the Early Avar period of the Maros valley implying the strong relations between Gepids and Avars (Kiss P. 2014, 2015a-e)

The most complex and prominent relationships could have been tackled with artefacts of the Eastern European steppe regions (Martynovka type buckles, Deszk and Hajdúszoboszló type pendants, cone shaped earrings with granulations, collared metal plate globes, veil decorations). Some fragmental sites from the Maros valley (Nagylak, Pécska) has also been studied for comparison. The composition of beads from Makó hint to a wide array of trade relations with the Late Antique workshops found along the northern shoreline of the Black Sea, in the Northern Caucasus, Southern Russia or Western Europe (Maastricht) (Pásztor 2011a,b, 2018). A close-knit relationship is also present with the workshops of the Banat (Mokrin, Viminacium) (Ranisavljev, 2007; Ivanišević et al. 2006), Slovenia (Stare 1980; Bolta, 1981) and several sites along the Maros (Deszk, Kiszombor) (Csallány 1939, 1943; Török 1936). Distant relations with Northern Italy and Constantinople could have been proved as well (Pásztor 2011a,b, 2018).

7. Paleoenvironmental causes contributing to abandonment of the cemeteries and subsistence changes during the mid-7th century

All cemeteries were abandoned in the Maros valley during the middle part of the 7th century. At the same time, new cemeteries were opened in the inner areas of the Körös-Tisza-Maros triangle far away from the rivers. Based on the documented burial practices these cemeteries are in close relationship with the early cemeteries of the Maros valley (Szarvas, Orosháza, Székkutas). This has been noted by Bende, however no archeotypological analysis has been made to refine the age of the opening of these cemeteries. In our work an attempt was made via revising the earliest artefact horizons of these sites to elucidate potential causes of cemetery abandonment during the middle part of the 7th centuries.

According to our newly constructed climatic proxy data for the period between 400 and 800 A.D. (Gulyás et al 2018k,), the period preceding the Avar Conquest (450-568) was generally characterized by cold and wetter summers in much of Western Europe known as the Late Antique Little Ice Age (Büntgen et al. 2016). This was triggered by three major volcanic eruptions in 536, 540 and 547 A.D, whose climatic impact was prolonged further by the retardant effect of the oceans and a minimum in solar activity. This period bore witness to a whole series of social upheavals from a famine to the Justinian plague (541-543 A.D) possibly contributing to the decline of the Eastern Roman Empire (Büntgen et al. 2016). Proto-Slavic-speaking people migrated, supposedly from the Carpathian region, into the eastern areas of modern-day Europe that had been abandoned by the Romans, thereby forming the Slavic language area. In cooler areas, various peoples also migrated east towards China, maybe driven away by a lack of pastureland in central Asia. As a result, hostilities broke out in the steppe regions of northern China between nomadic groups and the local ruling powers. Subsequently, an alliance between these steppe populations and the Eastern Romans conquered the Sasanian Empire in Persia, leading to its collapse (Büntgen et al. 2016).

Yet mollusk composition and proxies indicating solar radiation strength talks about the presence of a mild climate with strong continental influences marked by a strong Siberian High during most of the site use (Gulyás et al 2018k; Gulyás et al. in prep). There is a shift from a negative Arctic Oscillation phase towards a positive by 600 A.D. (Gulyás et al 2018k; Gulyás et al. in prep). The degree to which Arctic air penetrates middle latitudes is related to the AO index, which is defined by surface atmospheric pressure patterns. When the AO index is positive, surface pressure is low in the polar region. This helps the middle latitude jet stream to blow strongly and consistently from west to east, thus keeping cold Arctic air locked in the polar region. When the AO index is negative, there tends to be high pressure in the polar region, weaker zonal winds, and greater movement of frigid polar air into middle latitudes.

There is a major climatic change from ca. 650 lasting until 720 A.D. (Gulyás et al 2018k; Gulyás et al. in prep). We must stress, however, that potential links between this and socio-political changes always need to be treated with great caution whether it fits in well with the main transformative events that occurred in Eurasia during that time. The referred climate transformation is seen in the weakening of the Siberian High and a positive phase of Artic Oscillation yielding stronger westerlies and Jetstream bringing more cyclones from the Atlantic to Western Europe on a more southward storm track (Gulyás et al 2018k; Gulyás et al. in prep). Solar activity has also decreased marking the weakening of sub-Mediterranean influences. As the watershed area of the Maros is lacking sub-Mediterranean influences in general precipitation increases might have caused higher floods during the spring and the early summer. Isotopic and trace element analysis of freshwater mussel shells from Makó also indicate fluctuations of periods of still and moving water conditions (Gulyás et al 2018; Gulyás et al. in prep). Similar changes documenting signs of the Late Antique Little Ice Age have been noted from the Migration Age for the Transdanubia site Szólád (Gulyás et al. 2018i,k; Gulyás et al. in prep) and the western margin of the Danube Tisza Interfluve (Gulyás et al. 2018i,k; Gulyás et al. in prep; Törőcsik et al. 2018).

So according to our data, there is every reason to believe that this pronounced climatic change must have had significant impact on the groundwater table of the GHP and the extension of inundated areas reducing the spatial extent of available pasturelands. This particularly must have affected sheep, which was a dominant element of the herds (40%) besides cattle (45%). Similar subsistence crisis has been documented for the Early Neolithic and Late Neolithic of the Middle and Lower Tisza valleys even at sites near Makó (Gulyás et al., 2011a,b, Gulyás & Sümegi 2012). Numerous new cemeteries were opened mid-late 7th century in the Maros valley. Artefacts and funerary practices as well as the reduced number of animal burials indicate the immigration of a group different from the early groups of the Maros valley. The composition of herded animals has also changed with a clear dominance of cattle, negligible amounts of sheep and goat. The former is better suited to wet meadows than sheep (Gulyás et al 2018; Gulyás et al. in prep).

8. Future outlook

In light of the newly gained results and interpretations of this interdisciplinary project, a decision was made for spatial expansion of the study area to the entire Trans-Tisza region as part of a new proposal handed in for evaluation this year (NKFIH). The manuscript for the monographic work on the Early Avar cemetery of Makó-Mikócsa Hill has been assembled along with the corporal volume of the 6-7th century Avar history of the Maros valley both embedding numerous natural scientific results. Publishing requires funding by a separate grant.

9. Achievements in numbers

- 30 plates displaying artefacts of the cemeteries of Kiszombor-tanyahalomdűlő and Kiszombor E in a graphical form
- 140 plates depicting artefacts of the largest site Makó-Mikócsa-halom.
- 65 plates display finds of 216 Early Avar age graves from older excavations by F.Móra and D. Csallány in the Maros valley.
- old maps and figures related to the studied cemeteries have been digitized (Deszk L-Sz-T, Deszk P, Kiszombor E, Kiszombor G, Kiszombor O, Klárafalva-Barna.).
- 295 total artefact drawings has been assembled into a pre-publish format from Maros valley sites.
- High quality photos have been taken on grave goods from 558 Early Avar age graves.
- Archeological database of studied graves (558 in total)
- 15 ^{14}C dates, 200 human samples for trace element analysis, 20 samples of human teeth, cattle bone and soi for Sr, Pb, C, N, O isotope analysis and 67 trace element analysis of tooth samples
- 16 tons of wet sieved material selected, material identified
- 20 ACD skulls CT scanned and analyzed for morphometry and anatomical changes
- 50 ACD skulls analyzed using 2D geometric morphometrics
- 70 amber beads analyzed for chemical composition using Raman Spectra
- 20 gold artefacts analyzed for chemical composition using XRF
- 88 conference proceedings, edited manuscripts, book and book chapters, scientific papers have been published or under publication as part of the project. Additional publications in SCI papers are to come.

10. References

Aitken, M.J. 1990. Science-based Dating in Archaeology. London: Longman

Aitken, M. J. 2003. Radiocarbon Dating. In: Ellis, L (ed). Archaeological Method and Theory. New York: Garland Publishing. 505–508.

Alt KW, Knipper C, Peters D, Mu¨ ller W, Maurer A-F, et al. 2014. Lombards on the Move – An Integrative Study of the Migration Period Cemetery at Szo´ la´d, Hungary. PLoS ONE 9(11): e110793. doi:10.1371/journal.pone.0110793

Ambrose SH. 1993. Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations. In Sandford MK, editor. Investigations of Ancient Human Tissue: Chemical Analyses in Anthropology. Langhorne, PA: Gordon and Breach. p 59-130.

Arrhenius, B. 1985. Merovingian Garnet Jewellery. Emergence and Social implications.Stockholm.

Balogh Cs.2013. Az avar–bizánci kapcsolatok újabb kutatási lehetőségei egy új Maros-menti kora avar kori temető leletanyaga kapcsán (Makó, Mikócsa-halom), Avar kori régészeti kutatások (Helyzetkép), 06/12/2013 Budapest

Balogh Cs. 2014a. A Maros-menti kora avar kori temetők ló-, lovas és lószerszámos temetkezései (Horse burials from the Early Avar age in the Maros valley), manuscript

Balogh Cs. 2014b Az avar kori gúlacsüngős fülbevalók — Die awarenzeitliche Ohrgehänge mit Pyramidenanhänger. (On the Avar age pyramid hanging earrings), Komárom Megyei Múzeumok Közleményei

Balogh Cs. 2014c Az avar kori gúlacsüngős fülbevalók. — Die awarenzeitlichen Pyramidenförmigen Ohrgehänge — Avar dönemindeki piramit biçimli küpeler., Kuny Domokos Múzeum Közleményei 20 (2014) 91–144.

Balogh Cs. 2015a. A Maros völgyében élő kora avar kori közösségek életmódjának rekonstruktiós lehetőségei a régészeti adatok alapján. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alaján workshop, Szeged

Balogh Cs. 2015b Mesterek dícsérete — A Dél-Alföld 6–7. századi kézművesei, monography, manuscript

Balogh Cs. 2015c A homokrévi 8. sír faragott csontlemezei. Adatok az avar kori tegezek típusaihoz. — The carved bone plates of grave 8 from Mokrin (Srb). New data to the types of the Avar, In: „…in nostra lingua Hringe nominant" – Tanulmányok Szentpéteri József 60. születésnapjára. Szerk.: Balogh Cs. – Petkes Zs. – Sudár B. – Zsidai Zs. Budapest 2015, 39–70.

Balogh Cs. 2016a Aranypillangók" — Adatok az avar kori halotti szemfedők és koporsók díszítéséhez — „Golden Blutterflies" — Contributions to the Ornaments of the Avar-Age Shrouds and Coff, Beatus homo qui invenit sapientiam. Ünnepi kötet Tomka Péter 75. születésnapjára. Szerk.: Csécs T. – Takács M. Győr 2016, 45–70.

Balogh Cs. 2016b. Early Avar-age cemetery from Makó-Mikócsa halom, monography, manuscript

Balogh Cs. 2016c. Szaluk avar kori sírokban, manuscript

Balogh, Cs. 2017a. Orta Tisa Bölgesi'nde Doğu Avrupa Bozkır Kökenli Göçebe Bir Topluluğa Ait Mezarlık (Makó, Mikócsa-halom, Macaristan) – A Cemetery Belonging to an Nomad Community of Eastern Europe Steppe Origin in the Middle Tisza Region (Makó, Mikócsa-halom, Hungary). Art Sanat 7, 53–70.

Balogh Cs.2017b. A Maros völgyében élő kora avar kori közösségek életmódjának rekonstrukciós lehetőségei a régészeti adatok alapján, manuscript

Balogh Cs. 2018a A Byzantine Gold Cross in an Avar Period Grave from Southeastern Hungary., Lebenswelten zwischen Archäologie und Geschichte. Festschrift für Falko Daim zu Seinem 65. Geburtstag. Monographien des Römisch-Germanischen Zentr

Balogh Cs. 2018b. A Maros völgyében élő kora avar kori közösségek életmódjának rekonstruktiós lehetőségei a régészeti adatok alapján. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Balogh Cs, Lőrinczy G. 2016. A Kiszombor-Tanyahalom dűlői kora avar temető és a Kiszombor E avar temető, monography manuscript

Balogh Cs, Lőrinczy G. 2017. Két avar temető Kiszombor határából: Kiszombor-Tanyagahalom dűlő és Kiszombor E, cemetery monography

Balogh Cs, Pásztor A. 2016. Az avar kori nagy gyöngycsüngős fülbevalók — Large bead-pendant earrings from the Avar period, Studia ad Archaeologiam Pazmaniensia. Archaeological Studies of PPCU Department of Archaeology – A PPKE BTK Régészeti Tanszékének kiadványai 4. — Magyar Tudományos Akadémia

Baron S., Tamas C.G, Cauuet B., Munoz M. 2011. Lead isotope analyses of gold-silver ores from Rosia Montana (Romania): a first step of metal provenance study of Roman mining activity in Alburnus Maior (Roman Dacia). Journal of Archeological Science 38/5, 1090-1100

Bayliss, A., 2007. Bayesian buildings: an introduction for the numerically challenged, Vernacular Architecture 38: 75–86.

Bayliss, A., 2009. Rolling out revolution: using radiocarbon dating in archaeology, Radiocarbon 51: 123–147.

Bayliss, A., Bronk Ramsey, C., 2004. Pragmatic Bayesians: a decade of integrating radiocarbon dates into chronological models, in: Buck, C.E., Millard, A. (Eds.), Tools for constructing chronologies: tools for crossing interdisciplinary boundaries, Springer-Verlag, London, pp. 25–41.

Bayliss, A., Bronk Ramsey, C., van der Plicht, J., Whittle, A., 2007. Bradshaw and Bayes: towards a timetable for the Neolithic, Cambridge Archaeological Journal 17: 1–28.

Beard, B.L., Johnson, C.M., 2000. Strontium isotope composition of skeletal material can determine the birth place and geographic mobility of humans and animals. Journal of Forensic Sciences 45, 1049-1061

Benedek A., Marcsik A. 2017. Kora avar kori temetőrészlet Kövegyről. Új temetkezési szokások a Tisza–Körös–Maros mentén a kora avar korból. In: T.Gábor Sz., Czukor P. (eds). Út(on) a kultúrák földjén. Az M43-as autópálya Szeged-országhatár közötti szakasz régészeti feltárásai és a hozzá kapcsolódó vizsgálatok, MFM, Szeged, 369-442.

Bentley A.R. 2006. Strontium isotopes from the Earth to the archaeological skeleton: A review. Journal of Archaeological Method and Theory, 13/3 DOI: 10.1007/s10816-006-9009-x

Bentley RA, Price TD. Stephan E. 2004. Determining the 'local' 87Sr/86Sr range for archaeological skeletons: a case study from Neolithic Europe. J Archaeol Sci 31:365-375

Bickle P., Whittle A.(eds) 2016. The first farmers of central Europe. Diversity in LBK lifeways. Oxbow Books.

Bolta, A. 1981. Rifnik pri Šentjurju. Poznoantična naselbina in grobišče / Rifnik – spätantike Siedlung und Gräberfeld («Katalogi in monografije» 19), Ljubljana.

Borbíró M. 1996.Újabb adatok az avar kori ötvösművességhez. MFMÉ 79-84.

Bowman, S. 1995. Radiocarbon Dating. London: British Museum Press.

Cook, G.T., Bonsall, C., Hedges, R.E.M., McSweeney, K., Boroneanţ, V. Pettitt, P.B. 2001. A freshwater diet-derived 14C reservoir effect at the Stone Age sites in the Iron Gates gorge. Radiocarbon 43: 453–460.

Conti C., Botteon A, Bertasa M, Colombo C. Realini M, Sali D. 2016. Portable sequentially shifted excitation Raman spectroscopy as an innovative tool for in situ chemical interrogation of painted surfaces. Analyst 141, 4599-4607.

Csallány, D. 1939. Kora-avarkori sírleletek. Grabfunde der Frühawarenzeit. FolArch 1–2. 1939, 121–155.

Csallány, D. 1943. A Deszk D. számú temető avar sírjai. Les tombes avares du cimetière de "Deszk D". Arch. Ért. III. 4., 160-170,170-173.

Daim F. 2002. Pilgeramulette und Frauenschmuck? Zu den Scheibenfibeln der frühen Keszthely-Kultur. Közlemények a Zala-megyei Múzeumokból 11, 113-124.

Damian G. 2003. The genesis of the base metal ore deposit from Herja. Stud.Univ. Babes/Bolyai Geol XLVII, 85-100.

Edwards H.G.M., Farwel D.W., Daffner L. 1996. Fourier transform Raman spectroscopic study of natural waxes and resins. Spectrochim. Acta A 52 1639–1648.

Fintor K., Gulyás S., Balogh Cs., Németh G.2018. Ötvöstechnikai segédanyagok valamint íjfestékek kémiai és ásványtani összetétel vizsgálata a Makó-Mikócsa halom kora avar kori temetőből, In: Gulyás S.-Balogh Cs.(eds). EMBER ÉS KÖRNYEZET A KORA AVAR KORBAN" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera, Szeged, in press

Fórizs, I., Pásztor, A., Nagy G., Tóth, M.2001. Avar és szarmata gyöngyök Csongrád megyéből Az anyaguk is különbözik vagy csak a típusuk? A Wosinsky Mór Múzeum Évkönyve XXIII. "Hadak útján" Konferencia kötet. Szekszárd 2001. 69-89.

Fórizs, I., Pásztor, A., Nagy G., Tóth, M.2006. Üveganyag újrafelhasználása az avar és szarmata kori üveggyöngyök mikroszöveti és (geo)kémiai vizsgálata tükrében. Arrabona Múzeumi közlemények 2006. 44/1. 141-150.

Garam, É. 1992. Die münzdatierten Gräber der Awarenzeit. Awarenforschungen I. Archaeologia Austriaca Monographien: 135–250.

Gehrling C., Bánffy E, Dani J, Köhler K, Kulcsár G, Pike A.W.G, Szeverényi V. Heyd V. 2012. Immigration and transhumance in the Early Bronze Age Carpathian Basin: the occupants of a kurgan. Antiquity 86, 1097-1111.

Giblin, J.I. 2009. Strontium isotope analysis of Neolithic and Copper Age populations on the Great Hungarian Plain. Journal of Archaeological Science 36: 491–97.

Giblin J.I., Knudson K.J., Bereczky Zs., Pálfi Gy., Pap I. 2013. Strontium isotope analysis and human mobility during the Neolithic and Copper Age: a case study from the Great Hungarian Plain. Journal of Archaeological Science 40, 227-239.

Gillespie, R., Hedges, R.E.M, Wand, J.0. 1984. Radiocarbon dating of bone by accelerator mass spectrometry. Journal of Archeological Science 11: 165-170.

Gulson B.L., Gillings B.R. 1997. Lead exchange in teeth and bone-a pilot study using stable lead isotopes. Environmental Health Perspectives 105/8, 820-824.

Gulyás, S, Sümegi, P 2012. Édesvízi puhatestűek a környezetrégészetben. Geolitera Kiadó, Szeged, 165 p. ISBN 978-963-306-191-6

Gulyás S, Balogh Cs (eds) 2018. Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Gulyás S., Marcsik A. 2015. Torzított koponyák geometriai morfometriai vizsgálatának előzetes eredményei a kora avar korból a Maros mentéről. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján workshop, Szeged

Gulyás S, Szónoky M 2015. Adatok a Makó-Mikócsa halomi temetőből származó kőeszközök geológiájához, „MARVAR" — Ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján. A K-109510 OTKA workshop

Gulyás, S, Sümegi, P. 2011a. Farming or foraging? New environmental data to the life and economic transformation of Late Neolithic tell communities (Tisza Culture) in SE Hungary. Journal of Archaeological Science 38: 3323-3339.

Gulyás, S, Sümegi, P. 2011b. Riparian environment in shaping social and economic behavior during the first phase of the evolution of Late Neolithic tell complexes in SE Hungary. Journal of Archaeological Science 38: 2683-2695

Gulyás, S., Balogh, Cs., Sümegi, P., Marcsik, A., Körössi, A., Rodushkin, I., Kelemen, H. 2015 a. Preliminary results of anthropological, zooarcheological and geochemical (isotope and trace element) analyses of human, animal and soil remains from and Early Avar Age (6-7th century AD) cemetery of SE Hungary. XIX. INQUA Congress, Nagoya, Book of Abstracts T02927

Gulyás, S., Kelemen H., Balogh Cs. 2015 b. Előzetes eredmények a Makó Ipari Park 4. számú lelőhely abszolút kronológiájához, archeomágneses, geológiai, geokémiai és geomorfológiai jellemzéséhez. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján workshop, Szeged

Gulyás S., Balogh Cs., Marcsik A., Sümegi P. Kókai D. 2015c. Geometric morphometric analysis of artificially distorted skulls from an Early Avar Age site near Makó, SE Hungary. In Horváth J. et al. (eds). Geomathematical models: the mirrors of geological reality or science fictions? Proceedings of 7th HR-HU and 18th HU Geomathematical Congress, Mórahalom-Szeged.

Gulyás, S., Marcsik, A., Balogh, Cs. 2016. Koponyatorzítás a kora avar kori népesség körében a Makó környéki lelőhelyek tükrében. Természet Világa 147. évf./1916, 63-67.

Gulyás S., Nyúl L., Németh G., Balogh Cs., Kardos L., Sümegi P. 2017a. Data acquisition, pre-processing of 3D image data of artificially distorted skulls, archeological artefacts, fossils for 3D geometric morphometric analysis using CT and laser scanning: a comparison. Fedor F, Hatvani I.(eds). Geomathematics-Proceedings of the 20th HU and 9th HU-HR Geomathematical Congress, Pécs

Gulyás S., Marcsik A., Balogh Cs., Sümegi P. 2017b. Landmark-based geometric morphometrics of Early Medieval artificially distorted skulls from Hungary. Proceedings of the IAMG 2018 Congress, Perth

Gulyás S, Balogh Cs, Marcsik A, Sümegi P. 2018 a. Simple calibration vs. Bayesian modeling of archeostratigraphically controlled ^{14}C ages in an Early Avar Age cemetery from SE Hungary: results, advantages and pitfalls. 12th Radiocarbon in the Environment Conference, Debrecen, Proceedings.

Gulyás S, Balogh Cs, Marcsik A, Sümegi P. 2018 b. Simple calibration vs. Bayesian modeling of archeostratigraphically controlled ^{14}C ages in an Early Avar Age cemetery from SE Hungary: results, advantages and pitfalls. Radiocarbon (in press).

Gulyás S, Balogh Cs, Marcsik A, Sümegi P. 2018 c. Archeotiposztratigráfiai és 14C korok Bayes-féle feltételes valószínűségen alapuló kormodelljei a Makó-Mikócsa halmi kora avar kori temetőből. In:

Gulyás S, Marcsik A., Balogh Cs. Palcsu L., Rodushkin I. 2018 d. Komplex biogeokémiai (csont nyomelem, izotóp) viszgálatok alkalmazási lehetőségei az életmód, származás és vándorlás kapcsolatainak feltárásához a kora avar korban. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Gulyás S, Balogh Cs., Kelemen H., Sümegi P. 2018 e. Archeomágneses, régészeti geológiai, geokémiai, geomorfológiai vizsgálatok a Makó-Mikócsa halom kora avar kori temetőből. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Gulyás S, Balogh Cs, Bozsó G.2018f. Metallurgical Characteristics of a Gold Byzantine Cross from the Early Avar Period Cemetery Makó, Mikócsa-halom, Lebenswelten zwischen Archäologie und

Geschichte. Festschrift für Falko Daim zu Seinem 65. Geburtstag. Monographien des Römisch-Germanischen Zentralmuseums 150. Hrsg.: Dr.

Gulyás S., Bencsik A., Bozsó G., Balogh Cs.2018g Aranytárgyak archeometriai vizsgálata a Makó-Mikócsa halom kora avar kori temetőből, In: Gulyás S.-Balogh Cs.(eds). Ember és környezet a kora avar korban" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera (in press)

Gulyás S., Fintor K., Balogh Cs., Kiss P. A. 2018h Maros-völgyi kora avar és gepida kapcsolatok a borostyángyöngyök kémiai összetétel vizsgálatai alapján, In: Gulyás S.-Balogh Cs.(eds). Ember és környezet a kora avar korban" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera, Szeged, (in press)

Gulyás S., Sümegi P., Balogh Cs., Kiss P. A.2018i Éghajlati, környezeti változások és hatásaik a Maros-völgy gepida és kora avar népességére a kr.u. VI-VII.században, In: Gulyás S.-Balogh Cs.(eds). Ember és környezet a kora avar korban" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera, Szeged, (in press)

Gulyás S., Szónoky M., Balogh Cs.2018j Kőeszközök archeometriai vizsgálatának alkalmazási lehetőségei az erdélyi és magyarországi nyersanyagforrások és kereskedelmi kapcsolatok feltárásához a kora avar korban, Ember és környezet a kora avar korban" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera, Szeged, (in press)

Gulyás S., Törőcsik T., Sümegi B.P., Sümegi P. 2018k. Environmental history of an embayment of Lake Balaton near Szólád from the Late Glacial to the Migration Age. In: Vida T. (eds). RGZM studie Ferschrift für Monographien des Römisch-Germanischen Zentralmuseum (in press)

Gulyás S., Sümegi P., Balogh Cs., Kiss P. A., Nagy B., Gál V. (submitted). Climatic changes connected to the Late Antique Little Ice Age during the 6-8th centuries and their potential impacts on Avar and Gepid communities occupying the Maros River valley in SE Hungary. Journal of Archeological Science

Harangi, S., Lenkey, L., 2007. Genesis of the Neogene to Quaternary volcanism in the Carpathian-Pannonian region: role of subduction, extension, and mantle plume. In: BeccaIuva, L., Bianchini, G., Wilson, M. (Eds.), Cenozoic Volcanism in the Mediterranean Area. Geological Society of America, Special Paper 418, pp. 67-92.

Harangi Sz. Downes H, Thirlwall M., Gméling K. 2007. Geochemistry, petrogenesis and geodynamic relationships of Miocene calc-alkalnie volcanic rocks in the Western Carpathian Arc, Eastern Central Europe, Journal of Petrology 48, 2261-2287.

Heinrich-Tamáska O. 2006. Az avar kori kő- és üvegberakásos technikák. Hadak útján-Népességek és iparok a népvándorláskorban. 137-151.

Heinrich-Tamáska O., Schweissig M. 2011. Strintiumisotopen und radiokarbonuntersuchungen am anthropologischen Fundmaterial von Keszthely-Fenékpuszta: Ihr aussagepotenzial zur Fragen der Migration und Chronologie. In: Heinrich-Tamáska O.(ed). Keszthely-Fenékpuszta im Kontext Spatantiker kontinuitatsforschung zwischen Noricum und Moesia: Castellum Pannonicum Pelsoense, Budapest-Leipzig,Keszhely, 457-474.

Hoekman-Sites HA, Giblin, JI. 2012. Prehistoric animal use on the Great Hungarian Plain: A synthesis of isotope and residue analyses from the Neolithic and Copper Age. J Anthropological Archaeol 31:515-527.

Ivanišević, V. Kazanski, M. Mastykova, A. (2006): Les nécropoles de Viminacium à l'époque des Grandes Migration. Collège de France – CNRS, Monographies 22, Paris 2006.

Johnson, C.C., Gorlin, R. J., Anderson, V.E. 1965. Torus mandibularis: A Genetic Study. American Journal of Human Genetics, 17 /5, 133–438.

Kamenov GD. 2008. High-precision Pb isotopic measurements of teeth and environmental samples from Sofia (Bulgaria): insights for regional lead sources and possible pathways to the human body. Environ Geology 55:669-680.

Kamenov GD., Gulson BL. 2014. The Pb isotopic record of historical to modern human lead exposure. Sci Total Environ 490:861-870.

Kiss P. A. 2014.Huns, Germans, Byzantines? The origins of the narrow bladed long seaxes. Acta Archaeologica Carpathica 49 111–144.

Kiss P. A. 2015a. Bizánc és a hunok vonzásában? Keskeny pengéjű langsaxok a Kárpát-medencei gepida anyagban. In: Székely M., Horti G (ed) Res Militares Antiquae II. A II. ókori hadtörténeti és fegyvertörténeti konferencia tanulmányai. Szeged, 101–169.

Kiss P. A. 2015b. „ut strenui viri" A gepidák kárpát-medencei története. Szegedi Középkorász Műhely, Szeged, 289pp

Kiss P. A. 2015c. Germán pajzsok és nomád íjak. Egy szokatlan kora avar kori fegyverkombináció értelmezési lehetőségei. III. Ókori és kora középkori had-és fegyvertörténeti konferencia. 2015. május 14–15. Debrecen.

Kiss P. A. 2015d. Mert a germán lóra termett? Megjegyzések a Tisza-vidék 6. századi germán lovas és lószerszámos temetkezéseinek időrendjéhez. IX. Szegedi Medievisztikai Konferencia. 2015. június 17–19. Szeged. (http://www.medievkonf.hu/)

Kiss P. A. 2015e. Fokéles egyélű vágófegyver a gepidáknál? A szentes-nagyhegyi 7. sír és a Tisza-vidéki gepida temetők késői fázisa. Hadak útján. A Népvándorlás Kor Fiatal Kutatóinak XXV. konferenciája. 2015. október 19–22. Komárnó (Révkomárom).

Kőrösi A. 2015a. Makó-Ipari Park 4.sz. lelőhely temetőjének archeozoológiai elemzése. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján workshop, Szeged

Kőrösi A. 2015b. Magzati és újszülött állatok a Makó Ipari Park 4.sz lelőhely sírjaiban. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján workshop, Szeged

Kőrösi A.2018a. Archeozoológiai adatok a Makó-Mikócsa halmi kora avar kori temetőhöz. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Kőrösi A. 2018b.Magzati és újszülött állatok a Makó-Mikócsa halom kora avar kori temetőjében. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Larsen CS. 2002. Bioarchaeology: The Lives and Lifestyles of Past People. J Archaeol Res 10(2):119-146.

Le Huray JD. Schutkowski H. 2005. Diet and social status during the La Tene period in Bohemia: Carbon and nitrogen stable isotope analysis of bone collagen from Kutna Hora-Karlov and Radovesice. J Anthropol Archaeol 24:135-147.

Libby, W. F. 1965. Radiocarbon Dating. Chicago, Phoenix

Long, A., Wilson, A., Ernst, R., Gore, B., & Hare, P. 1989. AMS Radiocarbon Dating of Bones at Arizona. Radiocarbon, 31(3): 231-238. doi:10.1017/S0033822200011735

Lőrinczy, G. 1996. Kora avar kori sír Szentes-Borbásföldről. [Ein frühawarenzeitliches Grab in Szentes-Borbásföld.] MFMÉ – StudArch 2. 1996. 177–190.

Marcsik, A. 2010. Felgyő, Ürmös-tanya avar kori temető humán csontvázmaradványai. In: Balogh, Cs., P.Fischl, K.: Felgyő-Ürmös tanya. Bronzkori és avar kori leletek László Gyula felgyői ásatásának anyagából. Móra Ferenc Múzeum Évkönyve – Monumenta Archaeologica 1., 383–391.

Marcsik A. 2015. Kora avarok a Maros mentén antropológus szemmel. „MARVAR" — ember és környezet kapcsolata a Maros mentén az avar kor első felében a régészeti leletanyag és interdiszciplináris vizsgálatok alapján workshop, Szeged

Marcsik, A. 2018a Szegvár-Oromdűlő avar kori lelőhely humán csontanyaga. Újabb adatok az Alföld avar kori népességéhez. Kézirat.

Marcsik, A. 2018b.Embertani adatok a Makó-Mikócsa halom kora avar kori temetőhöz. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Marcsik A., Gulyás S. 2018. A kora avar kori koponyatorzítás szokásának elemzése hagyományos antropológiai és 2-3D geometriai morfometriai és csontszerkezeti vizsgálatokkal a Maros völgyből. In: Gulyás S, Balogh Cs (eds). Ember és környezet kapcsolata a kora avar korban-Régészeti geológiai tanulmányok a Maros mentén, Geolitera, Szeged (in press).

Marcsik A., Molnár E. 2017. A Duna-Tisza köze avar korának biológiai rekonstrukciójáról (Rövid ismertetés). Avarkor legújabb kutatásának eredményei konferencia, Kecskemét 2017. május

Marcsik A., Molnár E. 2018. A Duna-Tisza köze avar korának biológiai rekonstrukciójáról (Rövid ismertetés). Cumania

Marcsik A., Varga S. 2017. Az Apátfalva-Nagyút dűlőn feltárt avar kori temetkezések. In: T.Gábor Sz., Czukor P. (eds). Út(on) a kultúrák földjén. Az M43-as autópálya Szeged-országhatár közötti szakasz régészeti feltárásai és a hozzá kapcsolódó vizsgálatok, MFM, Szeged, 479-488.

Marcsik A, Molnár E, Pálfy Gy, Balogh Cs, Gulyás S, Kujáni Y, Benedek A, Hajdú T. 2016. New data of bone tuberculosis from ancient human populations in Hungary, IUAES Inter Congress. World anthropologies and privatization of knowledge: engaging anthropology in public. Abstract book.

Marcsik A, Gulyás S, Balogh Cs, Kujáni Y, Hajdú T. 2017. Physical anthropological analyses on human remains from the Migration Period in Maros Valley, SE Hungary, In: Mihai Gligor, Raluca Kogalniceanu, Andrei Soficaru (szerk.) "Homines, Funera, Astra": Death and Children from Prehistory to the Middle Ages.

Marcou E., Grancea L., Lupulescu M., Mileasi J.P. 2002. Lead isotope signatures of epithermal and porphyry-type ore deposits from the Romanian Carpathian Mountains. Mineralum Deposita 37, 173-184.

Martin, M. 2008 Die absolute Datierung der Männergürtel im merowingischen Westen und im Awarnreich. Antaeus 29–30: 143–173.

Mayhall, J.T., Dahlberg, A.A., Owen, D.G. 1970. Torus mandibularis in an Alaskan Eskimo population. American Journal of Physical Anthropology, 33, 57–60.

Mayhall, J.T. 1979. The dental morphology of the Inuit of the Canadian Central Artic. Ossa, 6, 199–219.

Meadows, J, Meadows, B, Ute, V., Ute, B., Harald, L., Schmölcke, U., Staude, A., Zagorska, I., Zarina, G. 2016. Dietary freshwater reservoir effects and the radiocarbon ages of prehistoric human bones from Zvejnieki, Latvia. Journal of Archaeological Science: Reports. 6: 678–689.

Montgomery J, Evans J, Chenery S, Pashley V, Killgrove K. 2010. Gleaming, white and deadly":using lead to track human exposure and geographic origins in the Roman period in Britain. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire, Suppl. 78, 11. Journal of Roman Archaeology p 199-226.

Motuzaite-Matuzeiciute G, Staff, R, Hunt HV, Xinyi L, Jones MK. 2013. The early chronology of broomcorn millet (Panicum miliaceum) in Europe. Antiquity, 87, (338):1073-1085.

Murray, CR; Simmons, JG; Allen, NB; Byrne, ML; Mundy, LK; Seal, ML; Patton, GC; Olsson, CA; Whittle, S 2016. "Associations between dehydroepiandrosterone (DHEA) levels, pituitary volume, and social anxiety in children". Psychoneuroendocrinology. 64: 31–9.

Noche-Dowdy L.D. 2015. Multi-Isotope Analysis to Reconstruct Dietary and Migration Patterns of an Avar Population from Sajópetri, Hungary, AD 568-895" (2015). Graduate Theses and Dissertations. http://scholarcommons.usf.edu/etd/5547

Pásztor A. 1996. A magyarországi kora és közép avar kori gyöngyök tipológiai vizsgálata – Typologische Untersuchung der früh- und mittelawarischen Perlen aus Ungarn. *MFMÉ – StudArch* 2 195–220.

Pásztor, A 1997.:Typologische Untersuchung der früh- und mittel-awarenzeitlichen Perlen aus Ungarn. Perlen. Arcäologie, Techniken, Analysen. Akten des Internationalen Perlensymposiums in Mannheim vom 11. bis 14. November. 1994. Bonn 1997.

Pásztor, A 2008. Ergebnisse der typochronologischen Untersuchung awarenzeitlicher Perlenfunde in Ungarn – Perlentracht in der Früh- und Mittelawarenzeit. Antaeus 29-30, 307-324.

Pásztor, A. 2010. Die Perlenfunde aus den Gräbern der Keszthely-Kultur in der Nekropole vor der Südmauer der Befestigung von Keszthely-Fenékpuszta. In: Müller, R., Die Gräberfelder vor der Südmauer der Befestigung von Keszthely-Fenékpuszta.. Castellum Pannonicum Pelson, Keszthely-Fenékpuszta déli erődfal, 2010.

Pásztor, A. 2011a. A Keszthely-Fenékpuszta, Horreum melletti temető gyöngyleleteiről. — Perlenfunde aus dem Horreum-Gräberfeld Keszthely-Fenékpuszta. Móra Ferenc Múzeum Évkönyve – Studia Archaeologica 12. (2011), 235–244.

Pásztor, A. 2011b. Die Perlenfunde aus dem Gräbefeld Keszthely-Fenékpuszta, Horreum. In: Tivadar Vida: Das Gräberfeld neben dem Horreum in der Innerfestigung von Keszthely-Fenékpuszta. KeszthelyFenékpuszta im Kontext spätantiker Kontinuitätsforschung zwischen Noricum und Moesia. Hrsg. Orsolya Heinrich-Tamáska. Castellum Pannonicum Pelsonense Vol. 2. Budapest – Leipzig – Keszthely – Rahden 2011, 438–442.

Pásztor, A. 2014a. Perlenfunde aus dem frühawarenzeitlichen Gräberfeld von Keszthely-Fenékpuszta, ÖdenkircheFlur. In: Müller, R.: Die Gräberfelder von Keszthely-Fenékpuszta, Ödenkirche-Flur. Keszthely-Fenékpuszta im Kontext spätantiker Kontinuitätsforschung zwischen Noricum und Moesia. Hrsg. Orsolya Heinrich-Tamáska. Castellum Pannonicum Pelsonense Vol. 5. Budapest–Leipzig–Keszthely–Rahden 2014, 257–373.

Pásztor, A. 2014b: Gyöngyleletek a szegvár-oromdűli avar kori temet szűrkanalas sírjaiban. Beads from the burials with strainer-spoons of the Avar period cemetery at Szegvár-Oromdűlő. In: AVAROK PUSZTÁI Régészeti tanulmányok Lőrinczy Gábor 60. születésnapjára.AVARUM

SOLITUDINES Archaeological studies presented to Gábor Lőrinczy on his sixtieth birthday.Szerkesztette / Edited by Anders. A., Balogh, Cs., Türk A. Budapest, 2014, 291–312.

Pásztor, A. 2014c.Tiszavasvári– Kashalom-dűlő avar kori sírjainak gyöngyleleteiről. Bead finds of Avarian graves from Tiszavasvári–Kashalom-dűlő. NyJAMÉ LVI. 2014, 219–228.

Pásztor A.2018. A Makó-Mikócsa halom kora avar kori temető gyöngyleletei, In: Gulyás S.-Balogh Cs.(eds). Ember és környezet a kora avar korban" „Régészeti geológiai tanulmányok a Maros mentén" Geolitera, Szeged, (in press)

Papathanasiou A, Panagiotopoulou E, Beltsios K, Papakonstantinou MF, Sipsi M. 2013. Inferences from the human skeletal material of the Early Iron Age cemetery at Agios Dimitrios, Fthiotis, Central Greece. J Archaeol Sci 40(7):2924-2933.

Price, T.D., Knipper, C., Grupe, G., Smrcka, V., 2004. Strontium isotopes and prehistoric human migration: the bell beaker period in central Europe. European Journal of Archaeology 7, 940.

Rácz, Zs 2014. Die Goldschmiedergräber der Awarenzeit. Monographien des Römisch-Germanisches Zentralmuseums 116. Mainz

Ranisavljev, A. 2007. Ranosrednjovekovna nekropola kod Mokrina. Early Medieval necropolis near Mokrin. Glasnik Srpskog arheološkog društva 23. Srpsko Arheološko Društvo, Beograd 2007.

Stare, V. 1980. Kranj. Nekropola iz časa preseljevanja ljudstev (Katalogi in monografije 18), Ljubljana 1980.

Schoeninger, M. J. 2010. Diet reconstruction and ecology using stable isotope ratios. In Larsen, Clark Spencer. A Companion to Biological Anthropology. Oxford: Blackwell, 445–464.

Seghedi, I., Downes H., Szakacs A., Mason P., Thirlwall M., Rosu E., Zoltan P., Marton E., Panaiotu C. 2004. Neogene–quaternary magmatism and geodynamics in the Carpathian-Pannonian region: a synthesis. Lithos 72: 117–46.

Siklóssy, Zs, Lőriczy, G. 2015. Radiocarbon dating, Bayesian analysis and archaeological evaluation of the Late Avar cemetery at Pitvaros-Víztározó. In: Balogh, Cs, Major B. (eds). Hadak útján XXIV. Archeolingua, Budapest, 707-718.

Somogyi P. 1997. Byzantinische Fundmünzen der Awarenzeit. In: Daim, F. (ed). Monographien zur Frühgeschichte und Mittelalterarcheologie 5. Innsbruck

Somogyi P. 2005. Újabb gondolatok a bizánci érmék avarföldi elterjedéséről. Numizmatikai megjegyzések Bálint Csanád közép avar kor kezdetére vonatkozó vizsgálataihoz. — Neue Überlegungen über den Zustrom byzantinischer Münzen ins Awarenland. Numismatischer Kommentar zu Csanád Bálints Betrachtungen zum Beginn der Mittelawarenzeit. A Móra Ferenc Múzeum Évkönyve – Studia Archaeologica 11: 189–228.

Somogyi, P. 2011. Byzantinische Fundmünzen in der Awarenforschung — eine Forschungsgeschichte von den Anfängen bis zum Jahre 2010. A Móra Ferenc Múzeum Évkönyve – Studia Archaeologica 12: 171–224.

Somogyi, P. 2014. Byzantinische Fundmünzen der Awarenzeit in ihrem europäischen Umfeld. Dissertationes Pannonicae Ser. 2. No. 4. Budapest

Subirà, M. E. and Malgosa, A. 1992. Multi-element analysis for dietary reconstruction at a balearic Iron Age site. Int. J. Osteoarchaeol., 2: 199–204. doi: 10.1002/oa.1390020303

Suess, H.E. 1970. Bristlecone-pine calibration of the radiocarbon time-scale 5200 B.C. to the present". In Olsson, Ingrid U. (eds) Radiocarbon Variations and Absolute Chronology. New York: John Wiley & Sons., 303–311.

Szádeczky-Kardoss S. 1992. Az avar történelem forrásai I. Szeged.

Szalontai Cs. 1991.Megjegyzések az Alföld IX. századi történetéhez. A késő avar karéjos övveretek (Bemerkungen zur Geschichte des Alföld im 9. Jahrhundert. Spätawarenzeitliche schuppenförmige Gürtelbeschläge). A Móra Ferenc Múzeum Évkönyve 1984–1985:2: 463–482.

Szalontai Cs. 1996.„Hohenbergtől Záhonyig”. Egy késő avar kori övverettípus vizsgálata („Von Hohenberg bis Záhony”. Untersuchung eines spätawarenzeitlichen Gürtelbeschlagtyps). Savaria Pars Archaeologica 22: 145–162.

Szónoky M, Gulyás S, Balogh Cs. 2017. A Délkelet-Alföld és Szeged építő-, díszítő-, használati köveinek erdélyi vonatkozásai a kora népvándorlás kortól a török korig, Szónokyné Ancsin G (szerk.) Magyarok a Kárpát-medencében 2.: Tudományos Nemzetközi Konferencia. 532 p.

Taylor R.E. 1992. Radiocarbon Dating of Bone: To Collagen and Beyond. In: Taylor R.E., Long A., Kra R.S. (eds) Radiocarbon After Four Decades. Springer, New York, NY

Taylor, R.E.; Bar-Yosef, O. 2014. Radiocarbon Dating (2nd ed.). Walnut Creek, California: Left Coast Press.

Törőcsik T., Gulyás S., Molnár D., Tapody R., Sümegi B.P., Szilágyi G., Molnár M., Jakab G., Sümegi P., Novák Zs. 2018. Probabilistic 14C age-depth models aiding the reconstruction of Holocene paleoenvironmental evolution of a marshland from southern Hungary, Radiocarbon (in press)

Török, Gy. (1936): A kiszombori germán temető helye népvándorláskori emlékeink között. – Das germanische Gräberfeld von Kiszombor u. unsere Denkmäler der Völkerwanderungszeit. Dolg 12 (1936) 102–154.

Tuniz, C., Zoppi, U., Barbetti, M. 2004. Radionuclide dating in archaeology by accelerator mass spectrometry. In Martini, M.; Milazzo, M.; Piacentini, M. (eds) Physics Methods in Archaeometry. Amsterdam: IOS Press, 385–405.

Turner BL, Zuckerman MK, Garofalo EV, Wilson A, Kamenov GD, Hunt DR, Amgalantus T, Frohlich B. 2012. Diet and death in times of war: isotopic and osteological analysis of mummified human remains from southern Mongolia. J Archaeol Sci 39:3125-3140.

Tykot RH. 2004. Stable isotopes and diet: You are what you eat. In Martini M, Milazzo M, Piacentini M. editors. Proceedings of the International School of Physics "Enrico Fermi" Course CLIV, 433-444.

van der Merwe NJ. 1982. Carbon Isotopes, Photosynthesis, and Archaeology: Different pathways of photosynthesis cause characteristic changes in carbon isotope rations that make possible the study of prehistoric human diets. American Scientist 70(6):596-606.

Vida T. 2002. Heidnische und christlische elemente der awarenzeitlichen Glaubenswelt, Amulette in der Awarenzeit. Közlemények a Zala-megyei Múzeumokból 11, 179-210.

Voerkelius S, Lorenz GD, Rummel S, Quétel CR, Heiss G, Baxter M, Brach-Papa C, Deters-Itzelsberger P, Hoelzl S, Hoogeweff J, Ponzevera E, Van Bocxstaele M, & Ueckermann H. 2010. Strontium isotopic signatures of natural mineral waters, the reference to a simple geological map and its potential for authentication of food. Food Chemistry 118:933-940.

Watts, D.L. 1990. The nutritional relationships of manganese. Journal of Orthomolecular Medicine 5, 219-222.

Zábojník, J. 2008. Die Rolle der Münzdatierung in der Mittelawarenzeit. Antaeus 29–30: 301–306.