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The history of sheep husbandry in Austria from the Neolithic to the Roman Period

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(with 4 figures)

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Abstract

After cattle, sheep were in Austrians prehistory the most relevant domesticated animals, but their relevance shifted between periods in which the human subsistence based on sheep and periods with minor importance. Possible reasons for these dynamics from the Neolithic to the Roman period are investigated. Another focus of the study is directed to the different products of sheep and in particular the emergence of woolly sheep. Using the Logarithmic Size Index (LSI) technique on previously published morphometrical data we found no indication of an introduction of a larger, foreign kind of woolly sheep as assumed hitherto. From Middle Neolithic to Germanic settlements of the Roman period hardly any differences in size of sheep can be determined. Only in Roman period a statistically highly significant larger sheep breed occurred. At least in Austria but presumably in most European regions the development of sheep with woolly fleece seems to have been a multiple and independent event produced by human selection. The larger sheep recorded in Roman periods were very probably introduced from Roman stocks.

Keywords: sheep husbandry, livestock development, wool sheep, introduction of wool, Neolithic, Bronze Age, Iron Age, Alpine region.

Zusammenfassung

Nach den Rindern waren Schafe in Österreichs Vorgeschichte meist die wirtschaftlich zweitwichtigsten Haustiere. Ihre Bedeutung schwankte allerdings im Laufe der Zeit von Perioden, in denen die menschliche Nahrungsökonomie ganz wesentlich auf der Schafhaltung beruhte, bis zu Zeiten von untergeordneterer Relevanz. Ausgehend von morphometrischen Untersuchungen bereits publizierter Knochenmaße mittels Logarithmic Size Index (LSI) werden mögliche Gründe für diese Unterschiede und Veränderungen vom Neolithikum bis zur Römischen Kaiserzeit diskutiert. Ein weiterer Schwerpunkt des Beitrags liegt auf den unterschiedlichen

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und wechselnden Nutzungsschwerpunkten, insbesondere auf der Entstehung und Entwicklung der Wollnutzung. In Österreich entstanden wolligere und später wollige Schafe offenbar aus autochthonen Beständen der ursprünglichen Haarschafe heraus, und die Bildung wolliger Vliese ist somit auf unabhängige menschliche Selektionen in verschiedenen lokalen Schafbeständen zurückzuführen. Indizien für das Erscheinen eines neuen, importierten Wollschafs im Laufe der Vorgeschichte finden sich nicht. Vielmehr lassen sich aufgrund morphologischer Kriterien und – abgesehen vom Verlust der Hornzapfen beim Weibchen – über Jahrtausende hinweg keine wesentlichen Veränderungen im Phänotyp von Schafen feststellen. Erst in der Römischen Kaiserzeit tritt ein neuer, wesentlich größerer Schlag auf, der höchstwahrscheinlich aus Italien stammt. Er erreichte in Österreich eine weite Verbreitung, verdrängte aber den kleinwüchsigeren bodenständigen Bestand nicht.

Schlüsselworte: Schafhaltung, Viehbestand, Wollschaf, Entwicklung der Wolle, Neolithikum, Bronzezeit, Eisenzeit, Alpenraum.

Introduction

The Neolithic lifestyle with its cultivation of plants and animal husbandry started out at the upper sections of Euphrates and Tigris between 8200 and 7500 BC (calibrated radiocarbon dates are used throughout this paper; Uerpmann 1979; Peters *et al.* 2005) and spread in stages across Europe in the following millennia (Dolukhanov *et al.* 2005; Lemmen *et al.* 2011). One of two main routes ran alongside the coastal lines of the Mediterranean Sea and reached the Provence and Liguria about 6000 BC (Rowley-Conwy *et al.* 2013), the other route led over the Balkans into the Carpathian Basin. In the Carpathian Basin the expansion of agriculture came for some centuries to a halt, before about 5600 BC a rapid new expansion began, which first reached present Austria and later more northern parts of Central Europe. The latter spread is archaeologically visible as the expansion of the characteristical LBK culture (LBK: *Linearbandkeramik*, linear pottery culture).

The early Neolithic husbandry of the Balkans focused in many regions on keeping sheep and goat (Bökönyi 1974, 1984a; Bartosiewicz 2005; Greenfield 2008), thus continuing older Near Eastern and Greek traditions (Bökönyi 1984a; Halstead 1996; Gehlen & Schön 2003; Schmitzberger 2010). As Erich Pucher pointed out in 2004, even if regressive human selection (in favour of smaller specimen) had already caused a diminution in body size and changes of behaviour (confidingness and stress tolerance) in comparison to wild sheep, the general ecological requirements of the first Austrian sheep were similar to their wild ancestors: as long as sheep were kept in ecosystems relatively similar to their natural habitat, *i. e.*, concerning temperature, humidity, and vegetation, they were easily manageable (Pucher 2004a). Because the early Neolithic temperature optimum with its warm, rather dry climate and long vegetation period (Grabundžija & Russo 2016) favoured this domestic species in Europe, at archaeological sites in the Carpathian Basin sheep reach quite frequently portions of 70 or even 80 percent amongst the livestock remains (Benecke 1994; Schmitzberger 2010; Orton 2012).

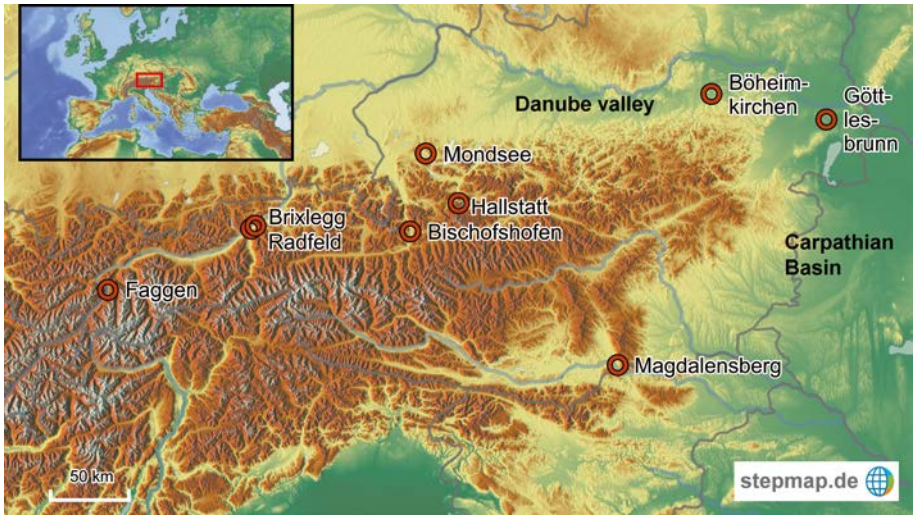

Fig. 1. Map of Austria, showing the most relevant archaeological sites mentioned in the text.

The first Austrian sheep: stock farming during the LBK

The first farmers who migrated from the Carpathian Basin with its special climate and steppe-like environment to the forested Danube valley in the north were confronted with different vegetation and cooler and moister conditions than they and their animals were used to (Fig. 1; STADLER & KOTOVA 2010). Nevertheless, during the earliest stage of the LBK sheep keeping was still the dominating aspect of animal husbandry (SCHMITZBERGER 2010). Already in 1987 Erich PUCHER argued that the earliest Austrian farmers still used similar practices in animal keeping than their Hungarian ancestors (PUCHER 1987), and in the meantime analyses of bones and teeth for age-at-death profile showed that the early Neolithic sheep were bred for their meat, coat, and horn, potentially also for their milk (CRAIG *et al.* 2005).

Little is known about the habitus of the earliest Austrian sheep. This is caused by the very limited number of sheep bones coupled with a high degree of bone fragmentation. Thus only a few bones are measurable, often with a limited number of osteometrics, which restricts considerable conventional calculations of the body size. Under such circumstances the use of the Logarithmic Size Index (LSI) is an appropriate method (MEADOW 1999). It overcomes the problem by the aggregation of measurements of different sites and bones into a single figure. For our study, breadth measurements of humerus, radius, metacarpus, femur, tibia, talus, calcaneus, and metatarsus remains identified to species level by the original author were collected and converted into LSI-values. Our LSI values refer a reference skeleton from a modern adult female wild sheep from western Iran, stored in the Field Museum of Natural History in Chicago (registration number 57951; UERPMANN 1979). The shoulder height of this reference sheep is unknow, but

female wild sheep in Iran have a body size of about 80 cm (Valdez *et al.* 1977). This same standard individual is also used for instance in a study about the early spread of domesticated animals across Neolithic Anatolia, so that comparative data are available (Arbuckle *et al.* 2014).

Our data show that the early Neolithic LBK Austrian sheep have been considerably smaller than female wild sheep. With a median LSI value of −0.075 they were even smaller than their ancestors in the Neolithic cultures in Anatolia, and only the largest early Neolithic Austrian sheep reached withers heights of 60 cm. In Anatolia, subsequent to the ending of the phase of domestication, Stone Age domestic sheep show stable LSI values of median −0.05 (Arbuckle *et al.* 2014). The size difference between the Anatolian and the earliest Austrian sheep are surely caused by environmental factors. Thus it seems possible that the first Austrian farmers tried to continue their traditional sheep-based husbandry regardless the different ecological conditions in their new environment, and if so they still acted as parts of the south-eastern European culture group they originated from (Schmitzberger 2010). But since only small grasslands were available in the new region – contrary to the areas occupied in Hungary – an adaptation was necessary to built up a durable existence. The general observation of the now starting, strongly decreasing economic importance of sheep husbandry during the successive Neolithisation of Europe is already known since the 1980s at the latest (Bökönyi 1984a). The adaptation process to the new unfamiliar ecological conditions took some centuries and affected in particular sheep farming (Fig. 2; Pucher 2004a; Schmitzberger 2010).

Within about 200 years the relative number of sheep remains in archaeological assemblages decreased strongly, and at 5300 BC a change towards a cattle-based subsistence has taken place in Austria (Pucher 2001a). With the end of the LBK, around 4800 BC, sheep remains are rare in archaeozoological assemblages and at some sites there are no records of sheep any more (Schmitzberger 2001; 2010; Pucher 2004a). Sheep lost their position as species of highest economic relevance and became nearly negligible.

The data shows clearly that the continuation of the traditional mode of subsistence economy failed at the border to the temperate climate of western Central Europe, especially since an improvement of the sheep gene pool by local domestication was impossible far away from the range of the wild form. It is known that under Stone Age conditions, sheep fared much better in their native regions than in Europe and that their morbidity increased prone to illnesses with environmental differences in comparison to the natural habitat (Bartosiewicz 2008).

Sheep husbandry during the Middle and Late Neolithic

At the beginning of the Middle Neolithic (Lengyel Culture, 5000–3400 BC) the sheep stocks more or less collapsed (Pucher 2004a). During the following centuries, however, the relative number of sheep remains at Austrian sites partly recovered and reached quite stable portions of around 17 percent of livestock remains (Fig. 2). Details of the

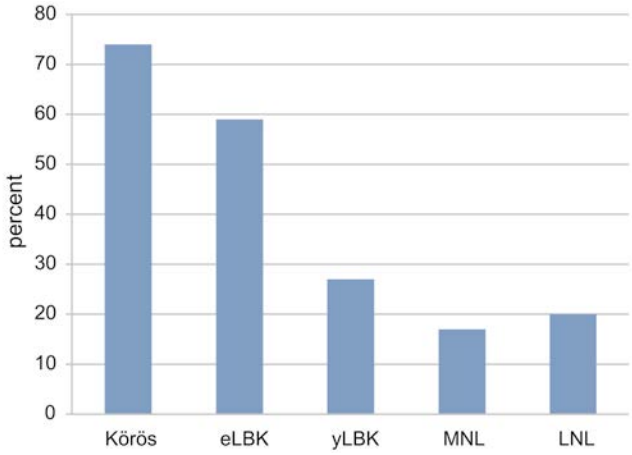

Fig. 2. Portion of sheep remains within the number of identified specimens during the Körös culture, early and late Linear Pottery culture (eLBK, yLBK), Middle Neolithic (MNL), and Late Neolithic (LNL). Data compiled after SCHMITZBERGER (2010).

regeneration process of the sheep stocks are still unclear, and during the Late Neolithic there are still sites with a very low portion of sheep remains (KUNST 2006).

In this context, the development of their size from the Early Neolithic to the Middle/Late Neolithic and thus during the population crash and the transition towards a new subsistence economy was analysed by the LSI method. The result of our analyses show a statistically significant increase of size of Austrian sheep from the Early to the Middle/Late Neolithic (Fig. 3; Kruskal-Wallis-test: $p=0.032$), *i.e.*, during the crisis of sheep husbandry. In the course of the crisis of Austrian sheep husbandry at the end of the Neolithic the size of the animals reached values similar to those of Bronze Age and Iron Age sheep. A summarising calculation of the body size by the multiplication factors of TEICHERT (1975) has shown that their withers height spread now from about 59 to about 66 cm (SCHMITZBERGER 2010).

Three explanations for this size development are possible: first, during the early LBK new sheep stock reached the region from the direction of the Balkans and these new sheep were larger. Second, after the strong decrease of sheep stock, the remaining animals had more adequate resources to survive in the semi-optimal Austrian conditions and therefore a better supply. Finally, the structure of the population has changed after the bottleneck, because the crash affected primarily sensitive individuals, whereas robust sheep survived. It remains yet unsolved which of the three proposed explanations are the most likely ones, and it cannot be excluded that it was an interplay of all of them.

It is a common result that the size distribution of adult sheep show no normal (Gaussian) distribution during the Austrian Neolithic, but positive skewness. Such kind of

distribution, where the majority of finds is concentrated on the left of the figure mirrors the sexual dimorphism in size typical for sheep, and it demonstrates a predominance of females in the Neolithic herds (Schmitzberger 2010). Such management of the sheep stocks seems to be a heritage of older traditions from the Balkans basin and was also clearly visible in Early Neolithic sheep in Hungary (Bartosiewicz 1997). Also investigations of horn cores have locally proven a predominance of females of 85 percent (Bökönyi 1992). Whereas hornless female sheep were not only known but usual and frequent in Hungary (Bökönyi 1992), they are unknown in Austria's LBK and later in the Central European Neolithic (Benecke 1994; Pucher 1986). Very probably this striking difference is result of a bottleneck effect during the migration of the LBK founder groups to the north, which had taken only a limited numbers of livestock with them. Typical Austrian Neolithic male and female sheep had strong horns or short, goat-like ones, respectively (Schmitzberger 2010).

During the Late Neolithic the very first settlements in the inner Alps are traceable, initially with lake dwellings such as Mondsee and also very first mining sites. Probably because sheep were the most robust livestock species in the local topographic conditions, they by far dominated some inner Alpine bone assemblages during the Late Neolithic (Deschler-Erb 2010). However, a sufficiently large number of sites is yet to be found with reliable numbers of animal bones to evaluate if this phenomenon can be generalised.

At Mondsee (3800–3200 BC; Pucher & Engl 1997) the simultaneous strong dominance of older adults and the preponderance of remains of females could point to a considerable role of milk and dairy products. Size and proportions of bones demonstrate that the livestock kept at Mondsee was without exception smaller and more gracile than their contemporaneous conspecifics in the Austrian lowlands. At Mondsee, the size of the sheep varied between 57 and 69 cm (62 cm on average) and these values show more similarities to size calculations from lake dwellings located in the Swiss western Alpine area than to coeval Austrian lowland sites (see following paragraph). Kurt Engl and Erich Pucher supposed in 1997 that during the Neolithic two different, permanently isolated populations of livestock existed in the Alps, each with a completely different history and origin (Pucher & Engl 1997; Pucher 2014). Today it is verified by comprehensive supra-regional comparisons that the Neolithisation of Switzerland did in contrast to Austria not occur from the Balkans but from the alternative way mentioned above, along the Mediterranean coastal lines and the valley of the Rhône; this is also manifest in the ancient DNA of sheep remains (Nikulina & Schmölcke in press). Consequently, unlike Austria, the whole of Switzerland, including the Rhône Valley, was continuously influenced by Mediterranean husbandry traditions during the Neolithic (Schibler 2013). These developments are particularly manifest in the following example: at the same time when Austria's sheep populations were collapsed pastoral people with a strongly sheep-based economy lived in the western parts of the Alps (Hafner & Schwörer 2017).

A new kind of sheep?

Since mid of the 4th millennium BC first in southeast Europe but later also in several Central European regions, a striking increase in the medium size of sheep (bones) is observed (Benecke 1994; Döhle 1994). In the Carpathian Basin, for instance, the withers height of the animals increased about 10 cm on average (Bökönyi 1974). Can this development be observed in Austria, too, and does it reflect an improvement of the methods of sheep keeping or the appearance of a new, larger kind of sheep, perhaps again as an import from the southeast? Is there any connection between the larger sheep and the first use of wool (Ryder 1991; Benecke 1994; Chessa *et al.* 2009)?

Generally speaking, a better indirect evidence of the use of wool is an increasing average age at the time of death than the size; since it suggests that the meat was not the prior reason or motivation of sheep keeping. To exploit secondary sheep products such as milk or wool as often as possible during an animal's life particularly females were kept longer. An increasing medium age of death within a population of domesticated sheep can be seen for the first time between 6500 and 6000 BC in northern Mesopotamia (Helmer *et al.* 2007; Vila & Helmer 2014). However, it took as long as to the mid of the 4th millennium BC that the change of sheep husbandry towards wool production in Mesopotamia and Palestine is clearly visible in depictions of woolly sheep and trough textile remains (Bender Jørgensen 1992; Greenfield 2010). In the 3rd millennium BC numerous cuneiform inscription prove a highly developed and established wool economy in that region (Charvat 2011), and particularly Anatolian sheep husbandry focused between 2000 and 1800 BC on an intensive exploitation of wool (Arbuckle *et al.* 2009). Subsequent, the "wool revolution" and its impact on societies can be studied in detail in the early states from Mesopotamia to Greece (Breniquet & Michel 2014)

As mentioned above, morphological changes within populations of domestic sheep can successively be observed from Greece to the Balkans and finally Central Europe since the mid of the 4th millennium BC: the median body size of the animals increased, the structure of the populations changed, and the age of sculling significantly shifted towards older animals (von den Driesch 1987; Greenfield 1988; Benecke 1994). It is at the same time that in very different parts of Europe the first archaeological remains of woollen textiles appear, but they are exceptionally rare (Shishlina *et al.* 2003; Rast-Eicher 2014). The Ice Man (~3200 BC), for example, wore several pieces of sheep skin but no woollen clothes (O'Sullivan *et al.* 2016). Around 2900/2700 BC the above mentioned archaeozoological phenomena also occur at some sites in the western Alps, and the contemporaneity of the oldest records of woollen textiles suggests that these centuries show the onset of the use of wool for producing textiles in the Alpine area (Hüster-Plogmann & Schibler 1997; Schibler 2004). In contrast to that, in Austria there is no indication of an increasing size of sheep (Fig. 3), and the oldest remains of woolly textiles from Austria are also much younger and date to the middle Bronze Age (~1600 BC; site Mühlbach/Hochkönig-Mitterberg, Hallstatt site Christian-von-Tuschwerk; Grömer 2012).

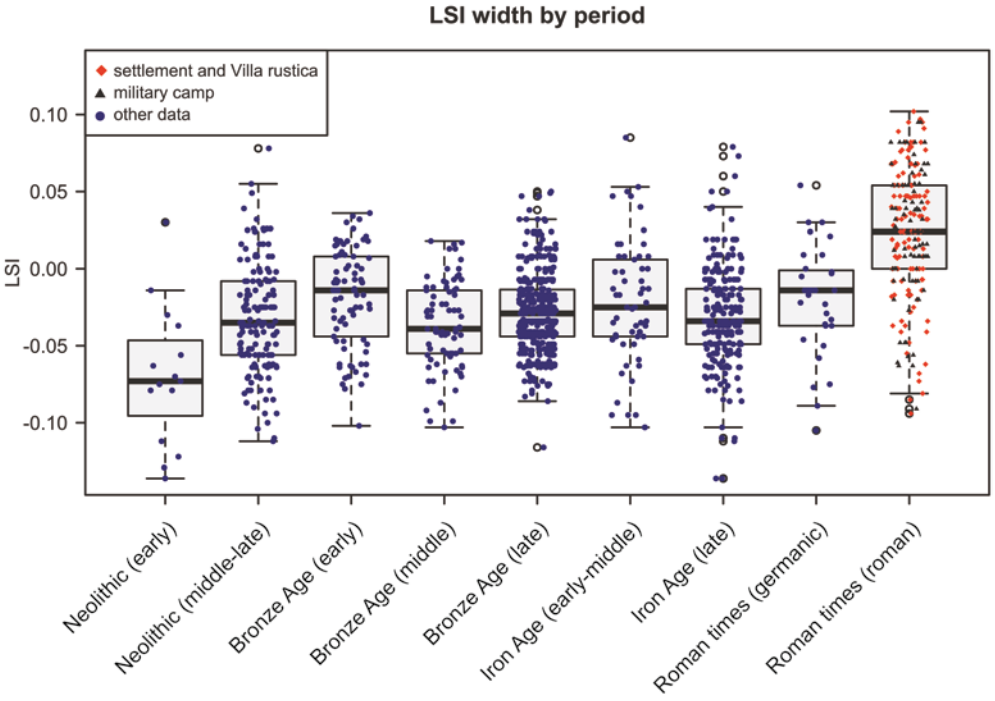

Fig. 3. Distribution and box-plot overlay of LSI transformed measurements (n = 1237) for sheep bones (humerus, radius, metacarpus, femur, tibia, talus, calcaneus, and metatarsus) categorized by chronological periods and, in the case of Roman times, people and site function. The measurements were obtained from the following 33 archaeological sites in Austria:

Early Neolithic: Brunn am Gebirge (Pucher 1998a), Gnadendorf (Boschin 2009), Mold bei Horn (Schmitzberger 2010), Strögen (Pucher 1987a). Middle and Late Neolithic: Ergolding/Fischergasse (Neumann 1990), Gnadendorf (Boschin 2009), Götschenberg (Peters 1992), Künzing-Unternberg (Ott-Luy 1988), Michelstetten (Schmitzberger 2009b), Mondsee (Wolff 1975; Pucher & Engl 1997), Potzneusiedl (Schmitzberger 2009a), Schanzboden bei Falkenstein (Pucher 1986). Early Bronze Age: Brixlegg (Riedel 2003), Michelberg (Schmitzberger 2001), Schleinbach (Pucher 1996; Boschin & Riedel 2009). Middle Bronze Age: Böheimkirchen (Riedel 1998), Buhuberg (Pucher 1987b), Kiabichl (Tecchiati 2012). Late Bronze Age: Brixlegg (Boschin & Riedel 2011), Hallstatt (Pucher 2013b), Michelstetten (Schmitzberger 2009b). Early and Middle Iron Age: Göttlesbrunn (Pucher 2004b), Hallstatt (Pucher 2009). Inzersdorf ob der Traisen (Pucher 1998b). Late Iron Age: Dürrnberg (Abd El Karem 2009; Saliari *et al.* 2016), Göttlesbrunn (Pucher 2006), Kiabichl (Tecchiati 2012), Rosendorf-Sandberg (Abd El Karem 2011). Roman times (germanic): Bernhardsthal (Riedel 1996). Roman times (roman): Brunn am Gebirge (Pucher 1998a), Lauriacum (Müller 1967), Michelstetten (Schmitzberger 2009b), Traismauer/Augustiana (Riedel 1993).

Already between 1460 and 1245 BC textiles of the miners in Hallstatt were nearly all made of wool (Grömer 2012; Bender Jørgensen & Rast-Eicher 2016). Obviously, the use of wool started in Austria with the beginning of the middle Bronze Age, but was the

final introduction of wool in the textile production really and necessarily induced by the appearance of a new kind of woolly sheep?

We do not think so. Even unspecialised herding without human selection towards a special kind of fleece will always include single sheep individuals within the flock with more woolly fleeces. It is very probable that the wool of such woolly hair-sheep was preferentially used by the humans and it is plausible that such sheep were supported in the way that they were killed later than sheep with not such interesting fleece. By such unintentional human selection the genes responsible for the development of wool (ADELSON *et al.* 2004) gradually accumulated at least in some local populations, up to the point at which a stable portion of first woolly hair-sheep and later woolly sheep was established. Such a selection could have easily been promoted or triggered by climate cooling or by migrations into regions with harsher weather – and thus the demand for warm textiles. In the Carpathian Basin, for instance, analyses of spindle-whorls have shown that here the first exploitation of sheep fibres might have begun between 4000 and 3700 BC, as a consequence of deteriorating climate conditions (GRABUNDŽIJA & RUSSO 2016). In Austria, the human selection towards a slow improvement of sheep fleece must have produced first successes during the first half of the 2nd millennium, *i. e.*, during the early Bronze Age. By archaeozoological methods, however, these successes and developments are not detectable yet, but first results of this process can be observed in the textile remains from Bronze Age Hallstatt, where wool was a common material around 1400 BC. In consequence, it can be assumed that in Austria there was probably no particular time for the introduction of a new kind of woolly sheep, and that the development of woolly sheep was generally a multiple and independent event (*cf.* for other regions HALSTEAD & ISAAKIDOU 2011 and GRABUNDŽIJA & RUSSO 2016). This conclusion is also supported by recent ancient DNA analyses (NIKULINA & SCHMÖLCKE in press).

The beginning of mining: Copper and Bronze Age sheep husbandry

Between 3500 and 2200 BC the people living in the eastern pre-Alps region started to use copper in addition to stone, wood, and bone. In that period active copper mining started, too. In Austria the sheep were still kept for meat production only, and many of them were slaughtered before they became sexually mature (SCHMITZBERGER 2010). It can be assumed, based on the portion of sheep remains in archaeozoological assemblages from the Hungarian and Slovakian area, that sheep husbandry was intensified again (BENECKE 1994), but similar developments are so far not detectable in Austria (SCHMITZBERGER 2010). At an inner Alpine site with separated find layers from Late Neolithic, Copper Age and early Bronze Age, the portion of sheep remains decreased gradually, and sheep lost its position as the most frequent animal to cattle (DESCHLER-ERB 2010).

Furthermore, another phenomenon is not visible in Austrian bone assemblages: the increasing size of sheep mentioned above and reported for Central Europe firstly from the Copper Age of the Carpathian Basin (BÖKONYI 1984a). In Austria there are no statistically significant changes between the size of sheep remains from Late Neolithic and

from early Bronze Age, in contrast, both the average body size as well as the variability in size of these animals was significantly reduced in that time frame (Kruskal-Wallis-test: $p = 0.021$; Fig. 3). More than this, also the culling age of sheep neither from the Baden Culture nor from the early Bronze Age cultures of Aunjetitz and Věteřov shows any indication of the use of secondary products such as milk and wool (Riedel 1998; Pucher 2001b; Schmitzberger 2009a).

At 2200/2000 BC, at the beginning of the Bronze Age, human settlements were erected along the inner Alpine river valleys for the first time. A special category of settlements were the Central Alpine mining sites. They show differences in several important archaeozoological features in comparison to "normal" rural sites. While the latter indicate aspects like animal keeping, especially in the eastern pre-Alpine region, it is obvious that the mining sites were (mainly) sites of consumption. Vice versa, the inner Alpine rural sites became now centres of a purposeful overproduction of food, and it was only this overproduction which made the establishment of special mining sites possible. Archaeozoological analyses of the mining sites Blixlegg (Riedel 2003; Boschin & Riedel 2011), Bischofshofen (Pucher 2014), Radfeld-Mauken (Hüster-Plogmann *et al.* 2011), and Hallstatt in particular (Pucher 2009, 2013a) demonstrate that the supply of the pitmen was not based on local husbandry but on delivered meat from livestock (Pucher 2014). Hallstatt with its extraordinary good preservation of organic finds provides generally detailed insights into provisioning structures of a mine and its connections to the surrounding landscape (Kowarik *et al.* 2015).

An indication for such a supply are the kill-off patterns, with young adults or even subadults being the majority of recorded sheep. As the distribution of skeletal elements demonstrate, some animals were brought alive from the rural settlements near to the mines for slaughter, or kept there for short periods, but also a supply of meat-rich parts of the sheep body took place, probably added by milk and dairy products such as cheese (Schibler *et al.* 2011). At some Late Bronze Age sites sheep were the preferred supply of the miners and reach portions of 40 to 50 percent of the animal bone assemblage (Hüster-Plogmann *et al.* 2011). Another most remarkable feature of the mining sites is the high portion of pig bones, showing that that the miners were particularly fed with pork as well. This development is not only recorded in the eastern Alps but also in Switzerland (Schibler *et al.* 2009).

Conclusive assemblages of animal remains from the rural sites of meat production are not numerous, but examples such as Early Bronze Age Böheimkirchen (Lower Austria; Riedel 1998) and Middle Bronze Age Faggen (Tyrol, occupied around 1500/1400 BC; Tecchiati 2012), provide at least some information about local sheep husbandry. At both sites the portions of sheep/goat remains are quite high and vary between 27 percent in Böheimkirchen and 34 percent in Faggen (based on the number of identified specimen). This result demonstrates a significant role of sheep husbandry, but since the number of bones from larger cattle is always much higher it is also clear that they had no essential importance in the food economy in Austria – in contrast to the neighbouring regions Southern Tyrol and Trentino (Riedel 2003).

Even if the Alps and the pre-Alps areas are highly diverse concerning their ecosystems, during Bronze Age the portions of domestic animals were quite similar in archaeozoological assemblages of the whole region. Cattle became the economically most important animal nearly everywhere and always. An exception was the Swiss Valais where sheep and goat are dominant not only in Bronze Age bone assemblages but without interruption since the time of Neolithisation. This result is very probably due to the special ecological conditions in a quite dry mountain valley (Curdy & Chaix 2009; Stopp 2015). Although the strategies of animal husbandry show regional specialisation more as result of ecological adaptation than of cultural differences, Alpine sites of western Austria yield a quite uniform pattern in comparison to other Alpine regions, documenting a local focus on secondary products in general (Stopp 2015). A comparison of the size of sheep bones from Alpine and pre-Alpine Austrian sites, however, shows statistically significant differences in the size distribution with smaller sheep dominating in the lowlands and larger ones in the mountains. This points to differences in the main focus of sheep utilisation (see following paragraph).

Phenotype of Austrian Bronze Age sheep

On the basis of complete long bones a mean body size of Austrian Bronze Age sheep of 60 to 63 cm has been reconstructed, showing that they were significantly larger than contemporaneous sheep in north Italy, Switzerland, and southwestern Germany (Riedel 2003). Further constant differences are related to the horn cores of the female sheep, whereas in Bronze Age northern Italy hornless are widespread and frequent, contrary to this, Austrian females have almost always well-developed horn cores (Riedel 2003). Since the comparable climatic and environmental conditions give no explanation for these very stable discrepancies, it is likely that they were caused at least by a lack of genetical mixture (Riedel 2003), probably even by a different genetical origin of the sheep populations (Pucher 2014; Stopp 2015). Within Austria, however, comprehensive analyses of measurements from sheep bones over the course of the Bronze Age demonstrate no statistically significant changes or developments of the size, neither generally, nor between Early and Middle Bronze Age nor between Middle and Late Bronze Age (Fig. 3). More than this, it is remarkable that the size remained very stable in medium size and size distribution over 5000 years from the Middle Neolithic up to the Roman period. A separate analysis of sheep remains from the pre-Alpine area versus the inner Alps shows no distinctions over time either (Fig. 4). Therefore, this allows comparing measurements from the Neolithic to the Roman times. This combination analysis highlights statistically significant differences in size distribution between sheep bones of these two main geographical regions (Fig. 4, Wilcoxon-test including the Roman samples: $p<0.001$. Without bones from Roman sites: $p=0.057$; i.e not statistically significant, but visually suggesting a tendency): a comparison of the particular size distributions show for the lowlands of Austria a predominance of smaller individuals (LSI median: −0.034; LSI mean: −0.031), whereas in the mountains the distribution is shifted

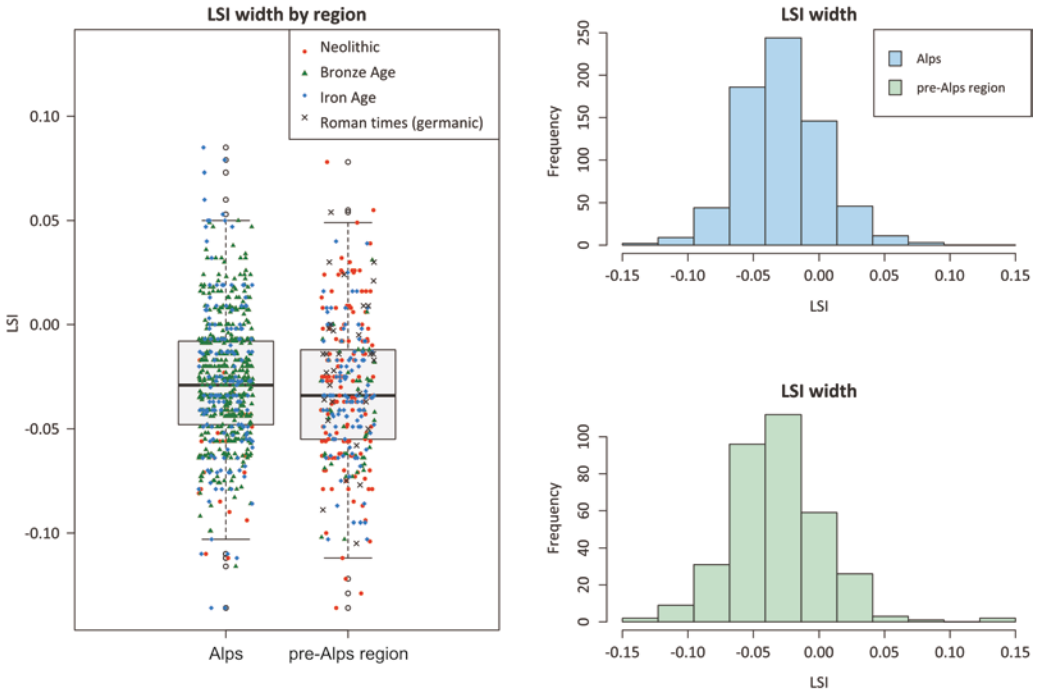

Fig. 4. Left: Distribution and box-plot overlay of the same LSI transformed measurements for sheep bones as in figure 3 categorized by the main topographic Austrian regions Alps (n = 691) and pre-Alps (n = 546) and by chronological periods. Right: Spread of the LSI values from sheep bones from the Alps and the pre-Alps, based on the same data set.

towards larger individuals (LSI median: −0.023; LSI mean: −0.025). These small but statistically significant differences were probably not caused by different sheep breeds, but reflect the sexual dimorphism in size and therefore differences in the main focus of sheep utilisation: in the lowlands the sample is stronger dominated by remains of the smaller females and consequently wool and milk production was the centre of the farmers' interest, whereas in the Alps the portion of males in the sample is higher and thus meat production was in the same way relevant as secondary products. Interestingly, for Switzerland a study of culling ages from Bronze Age lowland and mountain sites came to very similar conclusions (Stopp 2015).

Again, the Hallstatt salt mines and their surroundings provide further detailed information about Bronze Age sheep since the region offers an ideal preservation environment for animal skins (Ryder 1990, 1992, 1993; Grömer 2005, 2012; Harris 2006; Rast-Eicher & Bender Jørgensen 2013; Bender Jørgensen & Rast-Eicher 2016). The Bronze Age textiles made from sheep wool are quite coarse, but some finer types are also known (Grömer 2005), generally it can be stated that typical Bronze Age Hallstatt sheep fleece was uniform, short (less than 5 cm) and consisted of coarse fibres with fine underwool (Rast-Eicher & Bender Jørgensen 2013). The dominant colour of the animals

must have been grey (Ryder 1990), since the coarser fibres were dark and the underwool had only a low degree of pigmentation (Rast-Eicher & Bender Jørgensen 2013).

Remarkably, these special fleeces from Bronze Age Hallstatt with nearly white wool do not correspond with the typical fleeces found in the salt mines and white wool is also rare among the local textiles. Therefore it has been suggested that either some very few whitish sheep lived in Hallstatt, or that such wool was an import and given evidence for wool trade in Bronze Age Europe (Rast-Eicher & Bender Jørgensen 2013).

Iron Age sheep husbandry

During the early Iron Age (= Hallstatt culture; 800 to 450 BC) the economic relevance of sheep husbandry was closely related to the environmental conditions in the broader Alpine area, which were in those days already influenced by thousands of years of human exploitation and cultivation. Generally, an opening of the landscape should have advanced sheep husbandry, especially if continuous grazing caused a development towards dry grasslands. However, because there is still a lack of large animal bone assemblages from Austria's early and middle Iron Age, it cannot be answered yet if a growing importance of sheep husbandry was really the case supra-regionally. Only some baselines seem to be clear: in the Hallstatt culture sheep were of special importance in regions less suitable for pig husbandry, and thus centres of sheep husbandry were besides the Swiss Alps, Southern Tyrol, and north-western Slovenia such as the deforested lowlands of eastern Austria (Müller-Scheessel & Trebsche 2007). However, nearly all early Iron Age assemblages show a strong dominance of cattle remains – which is characteristic for whole Central Europe during the Iron Age – and there is no doubt that cattle was not only highly important as a draught animal and for its milk, but also provided the basis of human meat supply (Benecke 1994).

In the Hallstatt culture sheep were assigned a common role in spiritual contexts. At the graveyard of Statzendorf in the Austrian lowlands sheep/goat are the most frequently recorded species as food gifts (Rebay 2006). Since their remains were more often found in female burials a closer symbolic connection between women and sheep can be assumed even though this remains speculative (Pucher 2004b; Müller-Scheessel & Trebsche 2007).

The animal husbandry of the subsequent La Tène period (450 to Roman occupation) is known for Austria in much more detail, particularly in the lowlands. This is due to the fact that large assemblages of animal remains are known from archaeological sites such as Dürrnberg, an ancient salt-mining complex used for 250 years with excellent preservation conditions for bones (Pucher 1999, 2002, 2010; Abd El Karem 2009; Saliari *et al.* 2016) or Roseldorf (Bruckner-Höbling 2009). During the La Tène period, the climate was colder and this is probably the reason why the foci of the animal husbandry changed: cattle was as always the by far most important species but instead of keeping pigs to a large extent, the farmers became very interested in sheep husbandry. Even if

their importance was reduced sometimes (this applies for Dürrnberg und Göttlesbrunn; Pucher 2004b), in many Early La Tène lowland assemblages the portion of sheep within remains of domestic animals is high and comprises in mean 26 percent and this value rises during Middle and Late La Tène up to 33 percent (Trebsche 2014). These are the highest portions since the very first Neolithic farmers migrated into Austria, and after cattle sheep had become the most important domestic species in the Austrian pre-Alps. 5000 years of deforestation, agriculture and livestock- keeping has changed the landscape of the Austrian lowlands completely towards an absolutely favourable habitat for sheep. Mining sites such as Dürrnberg, in contrast, show different species compositions with clear dominance of cattle and minor relevance of sheep, which were not only delivered but also kept locally (Pucher 2002). However, in the nearby settlements the farmers first exploited the secondary products of sheep intensively before the animals were sent to the miners – this again underlines the importance of wool and dairy products during the La Tène period (Pucher 1999). The relevance of wool production was promoted by the introduction of shears during La Tène B around 350 BC; prior to this invention the wool was harvested by plucking it (Rast-Eicher & Bender Jørgensen 2013). At the same time, the majority of sheep had developed continuously growing fleeces that must be shorn (Rast-Eicher 2008).

As during the Hallstatt culture, sheep and in particular rams were also part of the spiritual life of La Tène people. Heads of male sheep were a common iconographic motif and dedicated to the god Teutates (Hatt 1980). Besides other animals also sheep were offered at special sacred sites, and there is some evidence that mainly lower jaws were used for that, probably as *pars pro toto* (Grill 2009). Accurately sawed and worked bucrania were obviously elements of priestly rituals (Grill 2009).

The phenotype of Iron Age sheep

The sheep remains found in Iron Age layers at the Hallstatt site derive from relatively large animals (withers height 63 cm on average), and their contemporary conspecifics from the lower Austrian farm at Göttlesbrunn were even larger (height 69 cm on average; Pucher 2004b, 2006). The Dürrnberg sheep are with withers height of 66 cm on average intermediate and show the common size of Iron Age sheep in Austria, even if single remains of exceptionally large individuals of sheep have been recorded, too (Fig. 3; Pucher 1999).

Male sheep from Hallstatt had big horns, while the females had small ones or none (Pucher 2004). In contrast to earlier times, the La Tène period shows most female sheep hornless or with rudiments of horns. The male sheep had often slightly curved horns (Pucher 2002).

In Austrian Iron Age the remains of sheep skins show a much broader variety than during the Bronze Age: some still have the old coarse type, but others are brown and with longer hairs (7–8 cm), and the highest type developed is long, quite white and quite regular

in diameter (Rast-Eicher & Bender Jørgensen 2013). This evolution in fleece types towards a wider rage and a general improvement of wool from Bronze Age to Iron Age is surely a result of human selection. Several kinds of sources, *e.g.*, remains of woollen textiles, depictions, or special tools for spinning and weaving even as gifts in graves, show that during pre-roman Iron Age wool processing was common in Austria. From the Hallstatt period onwards there was not only a well-organised textile manufacturing in Austria, partly with mass-production, but also textile art arose and was continously improved up to the Roman period (Grömer 2010, 2013).

Sheep husbandry during Roman Period

It has been frequently discussed that indigenous and Roman livestock can be separated during the existence of the Roman Danube provinces, since the quality of Roman agriculture and a purposeful breeding of special kinds of animals has created large size breeds. In detail this phenomenon is analysed in cattle (Boessneck 1958; Benecke 1994; Peters 1998; Pucher 2013a; Trixl *et al.* 2013), and it has been worked out that there was an extraordinary range of variation in size and stature within Austrian cattle during Roman time (Pucher & Schmitzberger 2003). Remains from small individuals can be considered to be of autochthonous origin, *i. e.*, from local populations and descendants of La Tène stocks, whereas much larger bones point to imports of the bigger Roman cattle from Italy.

For sheep similar developments are known. Here, the presence of animals much larger than during Pre-Roman Iron Age is recorded regularly in the Roman provinces at Danube and Rhine (Benecke 1994; Peters 1998). Analyses of widths from 236 bones verify statistically high significant differences in size between finds from contemporaneous Germanic and Roman sites (Fig. 3; Kruskal-Wallis-test: $p<0.001$). The sheep remains from purely Germanic sites (following the local archaeological features and finds) of the Roman period show on average exactly the same size distribution like bones from Pre-Roman Iron Age. In contrast to that, the average size of sheep remains from Roman settlements reaches the values of the largest bones found at Germanic sites. This applies although smaller bones similar to typical "Germanic sheep" are common in Roman contexts. Consequently, sheep remains from Roman sites show an extraordinary variability in size from very small up to very large individuals. Estimations of their withers height based on completely preserved metacarpals show for the Roman province Noricum – which included most of modern Austria – a range from 55 to 74 cm (mean 64 cm; Peters 1998), demonstrating both the variability of sheep during the first centuries AD and the coexistence of the traditional sheep stocks and new ones. Roman sheep reach potentially a withers height of 70 cm on average (61 to 77 cm; Riedel cit. in Peters 1998), since this value is estimated from sheep remains found in the neighboured *Gallia cisalpina* in northern Italy as well as from bones from the province Pannonia in today's Hungary. In Pannonia even some extraordinary large individuals with withers heights of 85 cm are recorded (Bökönyi 1984b) and it can be safely assumed that such animals were also kept in Austria.

In the centuries when Austria was part of the Roman Empire statistically significant changes in the mean size of Austrian sheep occur for the first time since the successful establishment of sheep husbandry during the Middle/Late Neolithic 5000 years ago. With the larger size of northern Italian sheep in mind, it is very probably that the large sheep appearing now in Austria were imports in the course of the Roman colonisation. Single remains of uncommon large animals in the bone assemblages from the La Tène site at Dürrnberg mentioned above may indicate single imports from Italy to Austria even earlier (Pucher & Schmitzberger 2001). However, until now there are no aDNA results supporting the interpretation of imported vs autochthonous breeds. In any case, long-distance contacts including the appearance of large domestic animals from Italy were possible during La Tène period (Abd El Karem 2011).

It is remarkable that the new breed did not replace the autochthonous sheep. Instead it came to a coexistence and at some sites to a mixture of both breeds. Distinct foci, however, are obvious: in Germanic settlements the traditional type dominated by far and only single remains of larger animals point to Roman influence; in Roman settlements sheep of the "Italian type" prevailed, but animals alike the local breeds are also common. In this respect, however, there are further differences between Roman sites. In Michlhallberg and Traismauer, for instance, nearly exclusively sheep of the "Italian type" were kept (Riedel 1993; Pucher & Schmitzberger 2001), in Lauriacum and Magdalensberg sheep of the "Germanic type" were also relatively common (Müller 1967; Hornberger 1970). Differences between civil locations such as towns, villages or Villae rusticate on the one hand side and military camps on the other are not showing any significant differences. It is remarkable that Roman sheep were rare in Germanic sites, since thanks to many archaeological excavations it is well known that the local elite in Austria adopted Roman customs rapidly during the 1st century AD and turned their houses into Roman villae with many Mediterranean elements (Wagner 2000).

Analogue to cattle, after thousands of years of human selection and ecological adaptation the autochthonous Austrian sheep were perfectly adapted to the very special local environmental conditions (*cf.* Nikulina & Schmölcke in press), and probably both kinds of sheep complemented each other concerning supply of meat and secondary products as well as robustness. Similar developments are known also for the Roman Rhine provinces, where local breeds still persisted (Peters 1998).

A supra-regional phenomenon also to observed in Austria is the increase of the mean size of sheep bones in the northern Roman provinces during the imperial period. Possibly, these changes did not result from improved breeding technologies or better husbandry conditions, but were the consequence of a climate warming, which enhanced the living conditions for sheep (Peters 1998; Büntgen *et al.* 2011; McCormick *et al.* 2012).

In Roman times wool manufacture played an important economic role in Noricum. This can be seen in the number of respective tools excavated in particular at Magdalensberg, which was obviously a centre of textile production. But nearly at every investigated

site, if rural or urban, the number of such tools increase (Gostenčnik 2010). Based on a variety of different archaeological finds and written sources the organisation of wool production and trade during the Roman period can be reconstructed in many details (Gostenčnik 2013; Grömer 2013).

Conclusion

The very first farmers who migrated from the Hungarian plain into Austria were shepherds, and their food economy was mainly based on sheep's meat. The moist and cool forests in the country they arrived, however, turned out to be unfavourable for the animals so that their mortality was probably high and it was difficult to supply the animals which are adapted to open grasslands. The sheep stocks collapsed, and the humans had to change their food economy and their husbandry completely. In Late Neolithic times, however, the population regenerated and reached a stable level. Sheep became the second or even third important livestock for a long time, far behind the importance of cattle, but often more frequent than pig. At the end of the Stone Age when the humans started to explore the Alps, the small and frugal sheep were again essential, and their meat was an important part of the provision of the miners during the Copper and later the Bronze Age. The cold temperatures in the Central Alps increased the demand for warm textiles, and this requirement probably changed the human selection strategy within their sheep populations. Animals with woollier fleece were kept longer than just hairy sheep so that their wool could be used several times. Due to this selection in the course of numerous generations, the sheep became woollier and finally woolly animals became the dominant breed and woolly textiles became common. At the latest during Iron Age, the use of wool and milk was the dominant motivation of farmers to keep sheep. After becoming part of the Roman Empire the autochthonous sheep were mixed with animals from Italy, easy to discriminate by their larger size. The new Roman sheep gave more meat and probably also wool of better quality, the traditional sheep breeds, however, persisted in all parts of Austria, probably, because they were best adapted to the local environmental conditions and therefore robust and less susceptible to risk.

With exception of the important, but successive development of woolly sheep, no further fundamental diachronous changes of Austrian sheep husbandry are to be identified from the Middle/Late Neolithic until the late pre-Roman Iron Age. Notably, this applies only for the size of the sheep. After a local type has been developed in the lowlands and the inner Alps, respectively, the particular stock remained on a constant level of withers height. Remarkably, the differences between the lowland and Alpine stocks were not statistically significant, but at the same time the differences to populations in the western or Southern Alps and the neighbouring regions were also stable throughout the millennia. A regular exchange or even trade with animals did not exist, obviously. The very limited contact between neighbouring people is also mirrored by the fact that the regular use of sheep wool started in the western Alpine area about a thousand years earlier than in Austria.

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