

Continuities and changes of animal exploitation across the Bronze Age – Iron Age boundary at mining sites in the Eastern Alps

KONSTANTINA SALIARI¹, ERICH PUCHER¹, MARKUS STAUDT² & GERT GOLDENBERG²

¹Naturhistorisches Museum, 1. Zoologische Abteilung, Archäozoologie.
Burgring 7, 1010 Wien, Österreich.
konstantina.saliari@nhm-wien.ac.at

²Universität Innsbruck, Institut für Archäologien, Fachbereich Ur- und Frühgeschichte.
Langer Weg 11, 6020 Innsbruck, Österreich.

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ABSTRACT: Since the 1990s, the Schwaz-Brixlegg mining district in the Lower Inn Valley, North Tyrol, Austria, features excavations on mostly Late Bronze (LBA) to Early Iron (EIA) Age sites, focusing on the reconstruction of metallurgic activities and of all aspects related to it. This paper reviews the Schwaz-Brixlegg archaeozoological materials and compares them with those from contemporaneous mining (copper and salt) sites on the Eastern Alps, to assess diet and subsistence strategies of the early alpine, geo-resource-centered, communities.

The faunal remains from Schwaz-Brixlegg document a change in diet for the Lower Inn Valley area from the LBA to the EIA exemplified by a shift from a pig-based economy to another one based on cattle and occasionally small ruminants. These species were most often brought whole to the sites and only occasionally as meat cuts (in particular, ribs). Age and sex profiles indicate that miners consumed high-quality meat. As is also documented on prehistoric mining sites from the Eastern Alps, butchery marks evidence a standardized slaughtering process carried out by professional butchers. At Weißer Schrofen, pig was the main meat provider during the LBA, whereas cattle and sheep/goat were more important as dairy products and wool/skin providers. This pattern changed in the EIA, when sheep became the dominating meat supplier at the site of Bauernzeche.

This shift may reflect an adaptation to climate changes, which determined the amount of fodder available for stocks, and/or to the impact of cultural and economic developments taking place during the Final Bronze Age. Variations on the faunal assemblages might also reflect agents such as topography and altitude. All in all, a logistic balance between miners (consumers) and peasants (producers) is revealed although more information is required (e.g. archaeobotany), to shed more light on the major changes recorded in the EIA.

Based on gnawing marks from Weißer Schrofen, some of the dogs there must have been large-sized. Although this may constitute an exceptional case for the Bronze Age, similar results were reported from the EBA Brixlegg settlement at Mariahilfberg1. Future research is needed to elucidate the possible functional role of dogs in the context of early mining activities.

KEYWORDS: SCHWAZ-BRIXLEGG, EASTERN ALPS, MINING SITES, BRONZE AGE, IRON AGE, ANIMAL EXPLOITATION, SUBSISTENCE STRATEGIES, CLIMATE CHANGE

RESUMEN: Desde los años 1990 se realizan excavaciones arqueológicas en el distrito minero de Schwaz-Brixlegg, en el valle bajo del Inn, Tirol septentrional, Austria, principalmente sobre yacimientos que discurren entre la edad del Bronce tardío (LBA) y la del Hierro inicial (EIA) al objeto de inferir los detalles de la actividad extractiva metalúrgica y aspectos asociados con la misma. Este trabajo revisa los materiales arqueozoológicos de Schwaz-Brixlegg y los compara

con los de otros yacimientos mineros (cobre y sal) de los Alpes orientales a fin de valorar la dieta y estrategias de subsistencia de las tempranas comunidades alpinas explotadoras de geo-recursos.

Los vestigios faunísticos de Schwaz-Brixlegg documentan un cambio en la dieta en el valle bajo del Inn entre LBA-EIA, ejemplificado por la substitución de una economía porcina por otra basada en el vacuno y ocasionalmente los pequeños rumiantes. Estas especies alcanzaron los yacimientos como animales completos y sólo ocasionalmente como porciones cárnicas (especialmente costillares). Los perfiles de edad y sexo indican que los mineros consumieron carne de alta calidad. Asimismo, como documentan los yacimientos mineros prehistóricos de los Alpes orientales, las marcas de despiece apuntan a un descuartizamiento de carcasas estandarizado, realizado por carniceros profesionales. En Weißer Schrofén, durante la LBA el porcino fue el principal proveedor de carne en tanto que el vacuno y los caprinos lo fueron de productos lácteos y lana/piel. Este patrón cambió en la EIA, cuando la oveja se convirtió en el primer proveedor de carne en Bauernzeche.

Este cambio podría reflejar tanto adaptación a cambios climáticos que habrían dictado la disponibilidad de pasto y forraje, como cambios culturales y económicos que se produjeron al concluir la edad del Bronce. Las variaciones en las asociaciones de fauna podrían también responder a diferencias en la topografía o la altitud. Globalmente, parece emerger una suerte de equilibrio logístico entre mineros (consumidores) y paisanos (productores) que sería bueno analizar con registros alternativos (p.ej. arqueobotánica) a fin de arrojar luz sobre los grandes cambios operados en la EIA.

Basados en marcas de mordidos del yacimiento de Weißer Schrofén, parece que algunos de los perros fueron de gran tamaño. Aunque esto puede ser un caso excepcional para la edad del Bronce, datos similares se documentan durante la EBA en el yacimiento de Mariahilfbergl. (distrito de Brixlegg). Futuras investigaciones aclararán el papel funcional del perro en el contexto de las tempranas actividades mineras.

PALABRAS CLAVE: SCHWAZ-BRIXLEGG, ALPES ORIENTALES, YACIMIENTOS MINEROS, EDAD DEL BRONCE, EDAD DEL HIERRO, EXPLOTACIÓN ANIMAL, ESTRATEGIAS DE SUBSISTENCIA, CAMBIO CLIMÁTICO

INTRODUCTION

PREHISTORIC COPPER MINING IN THE FAHLORE DISTRICT OF SCHWAZ-BRIXLEGG, NORTH-TYROL, AUSTRIA

Location and environmental setting

The fahlore mining district of Schwaz-Brixlegg extends along the southern side of the central Lower Inn Valley between Schwaz and Radfeld over a distance of more than 20 kilometres and is divided by the Ziller Valley into an eastern and western part (Figure 1). Fahlore is a complex sulfidic copper ore mineral with high antimony and arsenic components. The ore commonly occurs in the so called “Schwazer Dolomit”, a hard and compact sedimentary rock of Devonian age (Pirkl, 1961; Gstrein, 1978). Due to their copper and silver content the fahlore deposits were extracted on a large scale during the fifteenth and sixteenth centuries AD. In this period the region became one of Europe’s leading mining centres, as pictured in the

“Schwazer Bergbuch” of the years 1554/56 (Bartels *et al.*, 2006). However, this deposit was already exploited since the Early Bronze Age, as it is proved by archaeological investigations on hilltop settlements along the Lower Inn Valley, furnishing remains of primary copper metallurgy (smelting of local copper ores). Such sites are the Kiechlberg (Thaur; Töchterle, 2015a), the Buchberg (Wiesing; Martinek & Sydow, 2004) and the Mariahilfbergl (Brixlegg; Bartelheim *et al.*, 2002; Huijsmans & Krauß, 2015) as well as the cave site Tischofer Höhle (Kufstein; Neuninger *et al.*, 1970). A second period of prosperity of copper production from the local fahlores started during the 12th century BC and continued till the Early Iron Age. From this period (1200 – 700 BC) a remarkable number of prehistoric mines and connected sites (beneficiation and smelting sites) are still preserved today, even though there is a strong overprinting of the ancient structures by the more recent activities (15th/16th century AD). The remains of the prehistoric mines can be found from the valley bottom near the Inn River at 520 m a.s.l. (Kropfsberg, Reith im Alpbachtal) up to 1,890 m a.s.l. (Gratlspeitz, Reith im Alpbachtal). First discoveries and investigations of

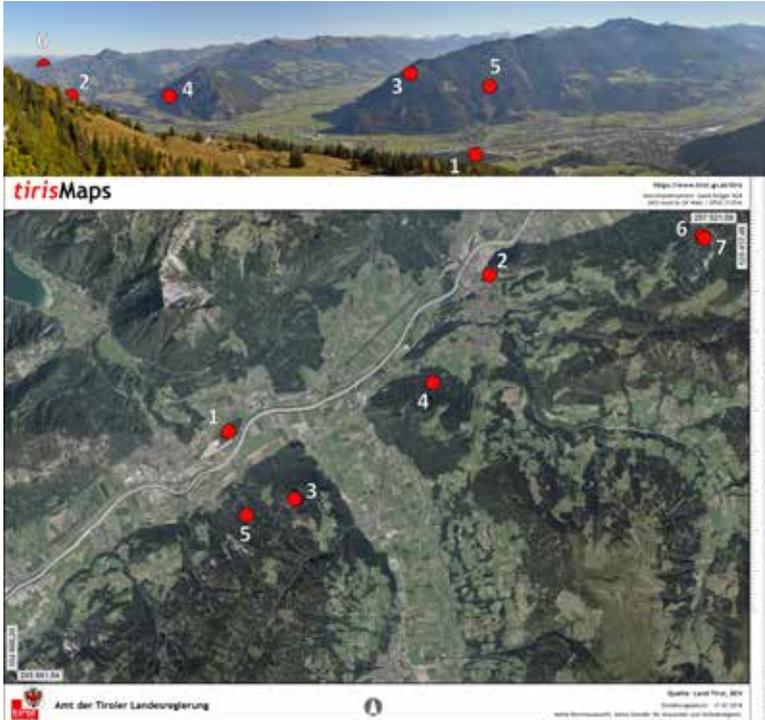


FIGURE 1

Investigated sites with animal bones from the mining area Schwaz-Brixlegg. 1: Buchberg (EBA, settlement), 2: Mariahilfbergl (EBA & LBA, settlement), 3: Weißer Schrofen (LBA, pit field), 4: Bauernzeche (EIA, mine), 5: Rotholz (LBA, smelting site), 6: Mauk A (LBA, smelting site), 7: Mauk D (LBA, pit field) – Graphic: M. Staudt.

prehistoric mines only started in the 1980s (Gstrein, 1981), quite late if compared with the research activities in the neighbouring province of Salzburg, where prehistoric copper and salt mining was already recognised and documented in the 19th century AD (Mitterberg, Hallstatt).

Archaeological investigations

Since 1994, archaeological investigations have brought to light large scale prehistoric mining activities from the Late Bronze Age to the Early Iron Age in the fahlore mining district of Schwaz-Brixlegg (Goldenberg, 1998; Rieser & Schräntenthaler, 1998/99, 2004; Goldenberg & Rieser, 2004; Tomedi *et al.*, 2013; Staudt & Tomedi, 2015). For this period a complete operational sequence related to the copper production (ore mining, beneficiation and smelting) could be documented at Brixlegg-Zimmermoos and Radfeld-Mauken within the interdisciplinary special research program Hi-Archaeofauna 29 (2020): 77-106

MAT (Austrian Science Fund FWF, F-3106-G02, Goldenberg *et al.*, 2012; Goldenberg, 2013, 2015). These studies were continued and extended by the RC HiMAT team (Research Centre: History of Mining Activities in the Tyrol and adjacent areas – impact on environment and human societies) within the framework of the DACH (D: Germany, A: Austria, CH: Switzerland) project “Prehistoric copper production in the eastern and central Alps – technical, social and economic dynamics in space and time” (Austrian Science Fund FWF, I-1670-G19, the DFG and the SNF, 2015 - 2018).

The main goals of the mentioned project (Innsbruck part) were to investigate and to demonstrate the spatial and chronological development of the prehistoric mining landscape in the Lower Inn Valley and to reconstruct the production chain for copper from fahlore. In 2015-2018 archaeological excavations were carried out at different places below and above ground comprising a series of fire-set mines (Figure 2), areas with surface depressions (pit fields, German: “Pingenfelder”) and one smelting site (Staudt *et al.*, 2017a, b, 2018a, b, c).

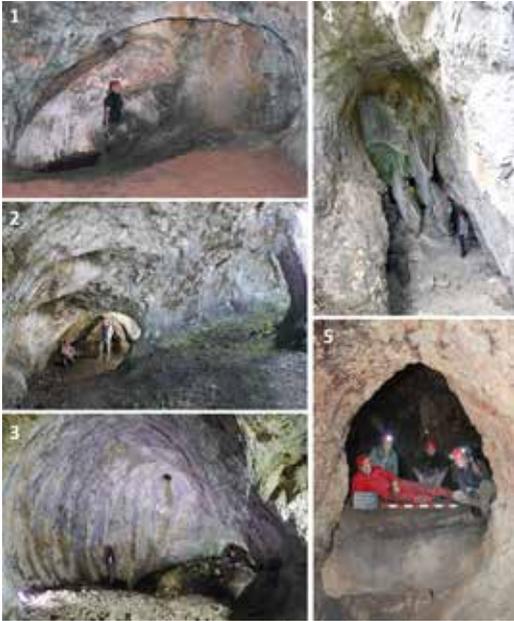


FIGURE 2

Dendrochronologically dated mines from the Early Iron Age (EIA, 8th century BC). 1: Mauk E (Sommerau/Maukenözt); 2: Gratspitz 1 (Thierberg); 3: Schönbieglerbau Süd (Burgstall); 4: Mooschrofen; 5: Mauk E (Sommerau).

Besides the uncovering, documentation and interpretation of the prehistoric structures it was essential to obtain organic materials like wood, charcoal and bones for radiocarbon dating and – in the ideal case – timber and/or charcoal for high resolution dating by dendrochronological analyses (Figure 3).

The radiocarbon analyses performed on animal bones and charcoal fragments from underground mining date from the 9th/8th century BC up to the 7th - 5th century BC. Often the radiocarbon ages are not very precise due to the unfavourable course of the ¹⁴C-calibration curve corresponding to the first half of the Iron Age (“Hallstatt plateau”). Only the analysed samples from the mine Knappenkuchl prove underground mining activities already in the 12th/11th century BC. Dendrochronological analysis provide more precise results. So far, all dendrochronological dated mines in the area of Schwaz-Brixlegg date into the second half of the 8th century BC, which represents the final stage of the fahlöre mining activities in general. From the pit fields on the surface only ¹⁴C-dates are available for the moment, which are older than the ages derived from underground mines. For example, the radiocarbon dates from the pit field Weißer Schro-

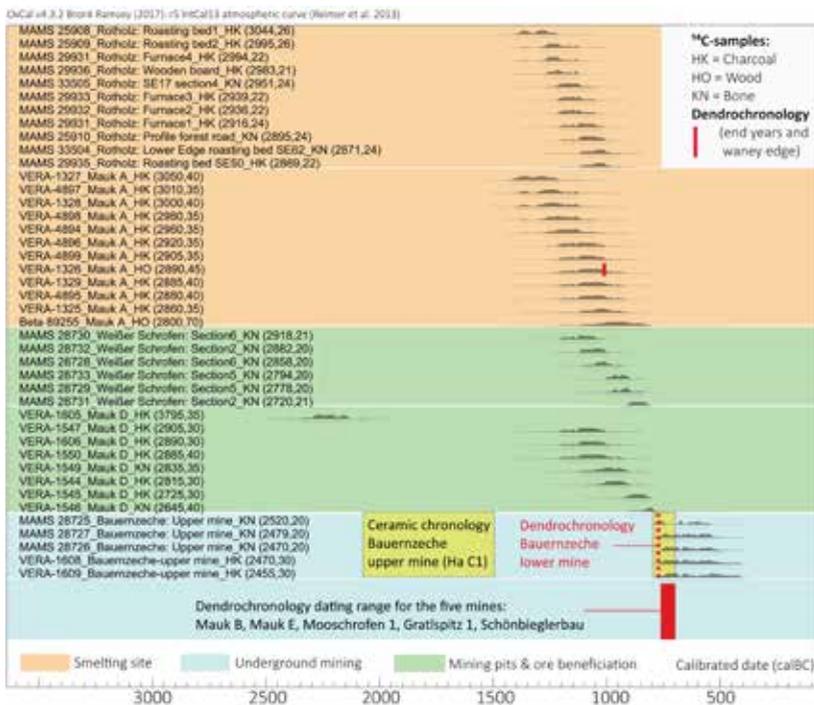


FIGURE 3

Radiocarbon and dendrochronological data from different mining and smelting sites with archaeozoological investigations in the Schwaz-Brixlegg mining district – Graphic: M. Staudt.

fen prove activities from the 12th to the 9th century BC. The dating results are overlapping with those from the nearby smelting site Rotholz (12th to 10th century BC). It can be assumed that both sites were active at the same time and that the ore from the Weißer Schrofen was smelted at the Rotholz smelting site. Thus, present age determinations suggest, that the second prehistoric fahlore mining boom in the Lower Inn Valley at Schwaz-Brixlegg lasted for about 500 years and ended in the Early Iron Age around 700 BC.

Parallel to the excavations relevant sectors of the mines were mapped, mine plans were drawn and 3D-models of some underground mines were generated by photogrammetric methods (Structure from Motion, SfM). Due to environmental conditions the conservation of animal bones connected to the prehistoric features is often very good. This is the case where the geological environment consists of carbonate rocks (dolomitic limestone) and where copper salts are abundant in the waste heaps of mining, beneficiation and smelting sites (weathering products). Especially the deposits of crushed slag (“slag sand”) of the smelting sites Rotholz and Mauken (Mauk A) provide ideal conservation

conditions for organic materials. Here the animal bones are intensively green coloured by impregnation with copper salts (Figure 4), exceptionally well preserved and thus furnishing an excellent material for archaeozoological investigations (Schibler *et al.*, 2011).

ENVIRONMENTAL SETTING AND CONNECTIONS BETWEEN COPPER AND SALT MINING SITES

In North Tyrol the Neolithic and Early Bronze Age people settled along established traffic routes on places with a certain strategic importance (Tomedi & Töchterle, 2012). Such locations were *inselbergs* (hilltop settlements), mid-range mountain terraces and alluvial fans (Töchterle, 2015b). The colonization is based on subsistence economy and can be demonstrated by the anthropogenic influences observed in pollen profiles (Oeggel & Nicolussi, 2009). First cereal cultivation in Tyrol is proved already around 3,600 BC (Oeggel & Walde, 2015). An intensification of the subsis-



FIGURE 4

Animal bones green stained by copper salts – Photo: M. Staudt.

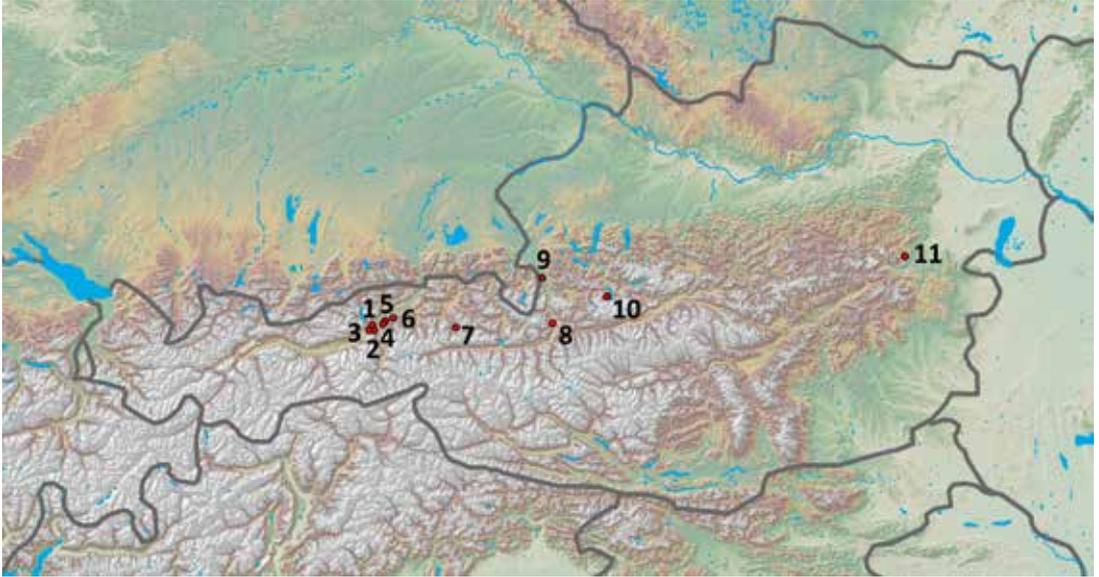


FIGURE 5

Investigated animal bones from different copper and salt mining sites and their corresponding settlements. Copper mining: 1: settlement Buchberg (EBA), 2: pit field Weißer Schrofen (LBA), 3: smelting site Rotholz (LBA), 4: mine Bauernzeche (EIA), 5: settlement Mariahilfbergl (EBA, LBA), 6: smelting site Mauk A and pit field Mauk D (LBA), 7: mining site Kelchalm (MBA/LBA), 8: settlement Bachsfall (EBA), 11: settlement Priggglitz (LBA); Salt mining: 9: Dürrnberg (IA), 10: Hallstatt (LBA) – Graphic: M. Staudt.

tence system of the alpine valleys is significant for the Bronze Age (Meyer, 2003; Oeggel, 2015). It seems that the specific needs of communities connected to mineral exploitation respectively copper production influenced the supply structure of settlements with comparable topography like Wiesing-Buchberg, Mariahilfbergl-Brixlegg and Bachsfall-Bischofshofen (Figure 5). The food supply concentrated on animal husbandry and was provided by the farmers of the surrounding area (Riedel & Pucher, 2015). The upswing of metal production during the Bronze Age required already existing permanent settlements and the availability of agricultural resources (Kienlin & Stöllner, 2009).

From the Middle and Late Bronze Age periods only a few settlements are known and investigated so far (Sperber, 1992, 2004). This is in contrast to the numerous cemeteries of the Urnfield culture (LBA) along the Lower Inn Valley, which are mostly related to the Late Bronze Age copper mining activities. Some pollen-analytical studies (Oeggel, 2015) even suggest that there was a decrease of Late Bronze Age settlement activities in the central alpine region, which is in contrast to the evidence of the usage of higher altitudes (alpine farming). Oeggel considers that settlements probably relocat-

ed from mid-altitude terraces to the valley bottoms, where archaeological evidence is impeded due to erosion and/or sedimentation in the alluvial zones.

The Bronze Age mining landscape in the Eastern Alps has been intensively investigated since the first half of the 19th century. Famous sites such as the copper mining districts Mitterberg-Bischofshofen, Kelchalm-Kitzbühel and Schwaz-Brixlegg in the Lower Inn Valley or the salt mining centres at Hallstatt and Dürrnberg give deep insights into the inner alpine economic and social prehistory. Widely-used specific practices regarding technological and/or economical aspects of the Bronze Age society point to the fact that there was an ongoing and long-lasting contact between the different alpine regions. Therefore it can be assumed that these communities were closely cross-linked and influenced each other in various ways (Stöllner *et al.*, 2016). This is the case for instance for the livestock farming and meat supply when comparing the archaeozoological results from Bronze Age and Iron Age mining sites. Similarities within the different investigated mining districts (Figure 5) as well as changes in time are clearly visible.

PREVIOUS RESEARCH ON FAUNAL ASSEMBLAGES FROM METAL AND SALT MINING SITES AND THEIR CORRESPONDING SETTLEMENTS

Species representation

An important characteristic of bone assemblages of the Bronze Age mining sites is the high number and sometimes even prevalence of pigs (Figure 6, Table 1). One of the earliest studies on mining sites was conducted by Amschler (1939), who investigated the Late Bronze Age (LBA, Urnfield culture) faunal assemblages from the Kelchalpe at Aurach-Kitzbühel (North Tyrol), where he could attribute almost 60% of the bone remains to pigs. The investigation of further faunal remains in the following years yielded similar results (e.g. Pucher, 1986). At the settlement Mariahilfbergl-Brixlegg (Tyrol) animal bones were found from the Early Bronze Age (Plateau C) to the Late Bronze Age (Plateau E) (Riedel, 2003; Boschin & Riedel, 2011). According to the Number of Identified Specimens (NISP) in animal remains from the EBA and LBA assemblages, pigs dominated with 44% and 50% respectively (Riedel, 2003; Boschin & Riedel, 2011). The prevalence of pigs was also documented at the EBA/MBA settlement at Bachsfall-Bischofshofen (Salzburg) with 39% (NISP) (Pucher, unpublished results). In Hallstatt (Upper Austria), one of the most famous LBA salt mines of

Central Europe, pigs were the major meat supplier, reaching a percentage of more than 60% (Pucher *et al.*, 2013), similar to the Kelchalpe. A high percentage of pigs (34%) has also been documented at the EBA assemblages from the settlement Buchberg-Wiesing (Tyrol) (Pucher, 1986). New research on material from the LBA copper mining settlement Priggwitz-Gasteil (Lower Austria) illustrates the significance of pigs in the diet of the miners, reaching 56% (Pucher, unpublished results).

Another observation concerning the faunal composition of the Bronze Age mining sites and related settlement sites is that bones of small ruminants that could be identified at species level indicate that sheep usually prevail over goat; in some assemblages, goats are completely absent (Trebsche & Pucher, 2013).

Little information is available concerning animal remains from Iron Age mines (IA). The salt mine of Bad Dürrenberg is one of the best-known examples of this period, especially due to the excellent preservation of archaeological and biological finds (Stöllner, 2003). The site probably replaced the Bronze Age salt mine of Hallstatt and was in use during a large part of the La Tène culture (A-C). The composition of the faunal remains shows a very significant change in the economic organisation of the miners from the Bronze Age to the Iron Age, most notable the prevalence of cattle instead of pig (Pucher, 1999a; Abd el Karem, 2009; Schmitzberger, 2012; Saliari *et al.*, 2016). At Dürrenberg, cattle prevail with 78.4% (Figure 6, Table 1).

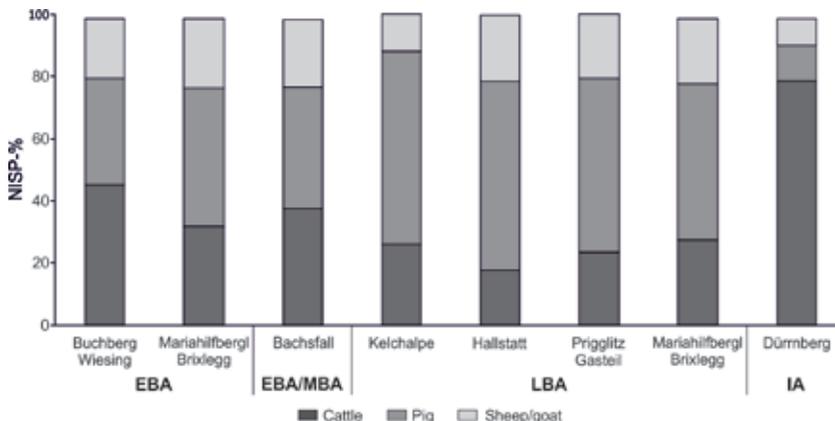


FIGURE 6

Distribution of domesticated species from mining sites and settlements related to mining districts dating from the Early Bronze Age (EBA) to the Iron Age (IA) (NISP-%). During the Bronze Age, pig is in most sites by far the prevalent species. During the Iron Age, the example of Dürrenberg shows the different economic organisation, when cattle became economically the most important domesticated species concerning meat supply and secondary exploitation.

Site	NISP		
	Cattle	Pig	Sheep/goat
Buchberg Wiesing (EBA)	839	637	358
Mariahilfbergl Brixlegg (EBA)	1381	1926	982
Bachsfall (EBA/MBA)	1256	1301	729
Kelchalpe (LBA)	961	2444	592
Hallstatt (LBA)	1869	6438	2285
Priggilitz Gasteil (LBA)	3786	9126	3338
Mariahilfbergl Brixlegg (LBA)	398	733	305
Dürrenberg (IA)	12223	1798	1318

TABLE 1

NISP data on the distribution of cattle, pig and sheep/goat from the Early Bronze Age (EBA) to the Iron Age (IA) mining sites and settlements related to mining districts (supplementary to figure 6).

Age and sex distribution

The age and sex distribution of the faunal assemblages from the various sites indicates notable variations. At the EBA site of Mariahilfbergl-Brixlegg (Plateau C) the vast majority of the recorded cattle, sheep/goats and pigs derives from young adults (M_3^{0-+} , 3-7 years for ruminants and 1.5 to 2.5 for pigs)¹. Cattle and pigs are mainly represented by male and castrated individuals, whereas sheep/goats by both males and females (Riedel, 2003). Contrasting age and sex profiles were noted from Buchberg at Wiesing (Pucher, 1986). There, cattle and sheep were predominantly represented by older female individuals (> 7 years), whereas pigs were mostly dominated by males (and possibly castrated?) slaughtered at an earlier age stage (2 years). In the LBA mining site of Hallstatt male and castrated pigs were chiefly slaughtered at an age between 1.5 and 2.5 years. In Hallstatt, cattle and sheep also exhibited a high number of male and castrated individuals, slaughtered at young age mainly between 3 and 4 years (Pucher *et al.*, 2013). Different biological profiles have been noted from the LBA phase of Mariahilfbergl at Brixlegg (Plateau E). Cattle were largely dominated by castrated individuals, whereas pigs by females. The age distribution for cattle could not be estimated due to the low number of finds, but pigs were slaughtered as young adults. Concerning sheep/goat the limited number of bones and teeth did not allow the reconstruction of the profiles (Riedel, 2003; Boschin &

Riedel, 2011). At the Iron Age site of Dürrenberg, the vast majority of cows (which dominate with 77.9% based on pelvis) derived from older individuals (M_3^{++} , > 7 years) (Pucher, 1999a).

The dominance of males and castrated animals of various species, the young slaughtering age and in some cases the absence of specific age stages convincingly indicates supply from outside. Still this general pattern does not exclude that in some cases animals might have been kept at the site at small scale, as it has been proposed for Mariahilfbergl in Brixlegg (Plateau C) (Riedel, 2003).

Skeletal element distribution

Another important aspect of the faunal assemblages concerns the skeletal element distribution. According to the available data, the body part representation shows significant variations (Figure 7). In particular, different sites can show (i) a normal distribution of body parts (e.g. Amschler, 1939; Riedel, 2003), or (ii) an overrepresentation of regions rich in meat (fore- and hind limbs) (e.g. Pucher, 1999a; Boschin & Riedel, 2011; Pucher *et al.*, 2013), or (iii) an overrepresentation of regions with less meat (e.g. head and extremities) (e.g. Trebsche & Pucher, 2013). These variations can be explained as the result of different factors, including economic organisation, topography and accessibility.

In cases of the presence of all body parts, it is usually argued that whole (living) individuals have been delivered, encouraging the hypothesis that at some sites limited breeding activities might have taken place (Riedel, 2003; Pucher, unpublished results). The overrepresentation of body parts rich in meat might be related to delivery of meat pieces, whereas the significant underrepresentation of these regions and in the same time the high number of elements with much less meat might be connected to butcher waste (Trebsche & Pucher, 2013; Pucher, 2014). The case of LBA Hallstatt is a text book example of delivery of very specific body parts rich in meat (Pucher *et al.*, 2013; Pucher, 2015a). There, a high number of fore- and hind limbs from pigs suggest the delivery of meaty packages, which were preserved in salt, interpreted as large-scale LBA ham production. In contrast, the contemporaneous LBA copper mining settlement Priggilitz-Gasteil offered evidence for the

¹ Mandibular molar 3 (M_3).

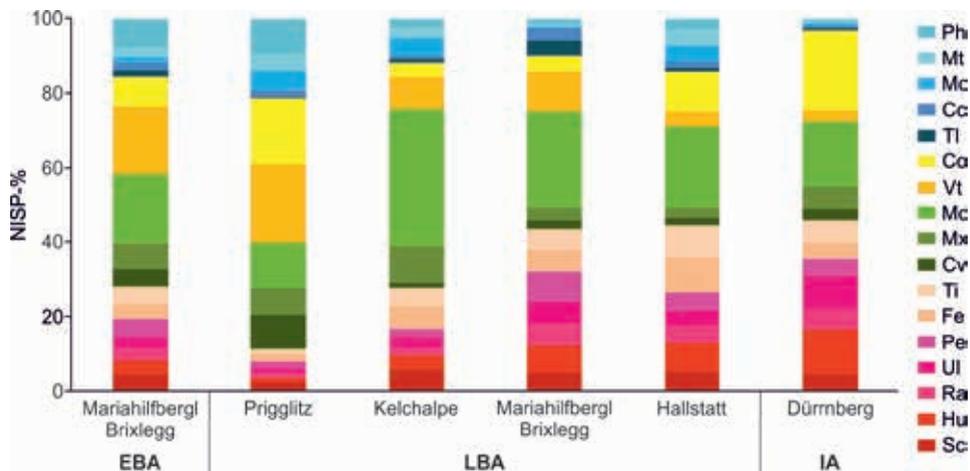


FIGURE 7

Examples of differences in skeletal element distribution of pig (NISP-%). EBA Brixlegg and LBA Kelchalpe show normal distribution; LBA Prigglitz is characterized by slaughter waste with an overrepresentation of regions with less meat; LBA Brixlegg, LBA Hallstatt, and Iron Age (IA) Dürrenberg indicate delivery of regions rich in meat.

Abbreviations: Cv: calvaria, Mx: maxilla, Md: mandibula, Vt: vertebrae, Co: costae, Sc: scapula, Hu: humerus, Ra: radius, Ul: ulna, Mc: metacarpus, Pe: pelvis, Fe: femur, Ti: tibia, Tl: talus, Cc: calcaneus, Mt: metatarsus, Ph: phalanges.

existence of a slaughter site (Trebsche & Pucher, 2013, Pucher unpublished results). Although pigs similarly to Hallstatt prevailed, skeletal regions rich in meat were significantly underrepresented (11%).

Overview of archaeozoological observations

The presented case studies offer important insights into the economic organisation of Alpine mining sites. Firstly, the high variation of age/sex distributions and body part representation suggests a relatively flexible animal economy. Variations could result from differences in geographic location, altitude, topography, ecology, availability and accessibility, but also cultural background. For instance, the transport of meaty body parts of pigs to Hallstatt could be viewed in relation with steep terrains and presence of only little agricultural areas as well as salt availability, which probably supported the extensive ham production.

Despite some differences, the mining sites and related settlements share several similarities. One of the most important common characteristics is the relationship between providers/suppliers (peasants) and consumers (miners). It seems that the animals delivered to the mining settlements did

not cause difficulties for the economy of the animal husbandry, suggesting a sustainable relationship between both sides. Animals with economic importance, such as cattle and sheep/goat, usually were slaughtered after their secondary exploitation. For example, at Buchberg Wiesing cows dominate, but they derive from an older age stage, suggesting prior exploitation and subsequent slaughtering (Pucher, 1986). Similarly, in Dürrenberg cows were slaughtered at a later stage, after delivery of offspring and milk exploitation (Pucher, 1999a). There male and castrated individuals were important meat suppliers too. Usually immature males and castrated animals were slaughtered as young adults or older individuals, depending on the exploitation. Slaughtering oxen at a young age stage – as is the case in many examples (Mariahilfberg Brixlegg Plateau C and E, Bachsfall, Hallstatt) – indicates the economic possibility to produce very good meat quality. Concerning sheep/goat the economic situation was similar. Pigs were usually slaughtered at an optimal age for meat consumption, between 1 and 2.5 years. Slaughtering piglets and young adult pigs was a common phenomenon. Pigs are ideal meat suppliers since they reproduce very early and they deliver many offsprings (Pucher, 1986, 1999b).

One of the questions that remain challenging is the location of the producers/suppliers, who delivered the animals to the miners. Morphometric investiga-

tion of pig bones from Hallstatt exhibits a mixed pig population, suggesting that pigs were imported from various areas of the broader region (Pucher *et al.*, 2013). Currently, DNA analysis is also in progress.

The MBA settlement of Saalfelden-Katzentauern has been suggested as a potential rural site of producers (Pucher, 2019). The analysis of cattle and sheep/goat bones indicates a normal peasant economy; older cows and ewes dominate, suggesting that secondary exploitation played a significant role. The pig bones on the other hand exhibit the absence of piglets and of male/castrated individuals (Pucher, 2019). Taking into consideration that at many Bronze Age mining settlements young male (and probably castrated) pigs are common, the biological profiles from Saalfelden-Katzentauern would fit to a complementary producers' site.

Besides clearly identifiable mining settlements, there are also sites which function and/or relation to mining sites are difficult to understand. This is the case of the EBA/MBA site of Bachsfall at Bischofschöfen (Pucher, unpublished results). The fact that this site is located very close to the copper mines of Mitterberg has encouraged the connection between the two sites (Pucher, unpublished results). The archaeozoological analysis offered evidence for a rural economy; for example, the age and sex profiles of cattle remains are typical for a peasant economy (Pucher, unpublished results). More particularly, older cows (M_{3++} , >7 years) prevail and the relation between males and females is 1:4. The probably uncastrated male calves were slaughtered for meat consumption. Nevertheless, sheep and pigs provided evidence for supply from outside (Pucher, unpublished results). Sheep and pigs were mostly represented by immature male animals, indicating that even if they might have been slaughtered at the site, they have been imported. For this reason, it has been suggested that the Bachsfall site represents an intermediate site between miners and peasants (Pucher, unpublished results).

ARCHAEOZOOLOGICAL RESEARCH IN THE SCHWAZ-BRIXLEGG COPPER MINING DISTRICT

Previous archaeozoological studies in the region of Schwaz-Brixlegg have been conducted in the framework of the SFB HiMAT (The History of

Mining Activities in the Tyrol and Adjacent Areas – Impact on Environment and Human Societies), established at the University of Innsbruck and supported by the Austrian Science Fund (FWF, from 2007 to 2012). Faunal remains have been investigated from sites in the Mauken Valley (Schibler *et al.*, 2011; Goldenberg *et al.*, 2012). The material derived from the LBA (12th/11th century BC) smelting site Mauk A and the pit field Mauk D and comprises 4005 fragments weighing about 20 kg. The composition of the bones showed that pigs prevail with almost 44%, whereas cattle were significantly underrepresented with barely 19%. Although dog bones were not recovered, their presence is indirectly revealed by gnawing marks. Similarly, to other sites (e.g. Hallstatt) an overrepresentation of body parts rich in meat was documented, showing that the Mauken miners and smelters were largely dependent on imported meat.

MATERIAL AND METHODS

The animal bones used for the present study were retrieved from the Late Bronze Age mining pits and ore beneficiation site Weißer Schrofen, the Late Bronze Age smelting site Rotholz as well as the Early Iron Age underground mine Bauernzeche, weighing in total almost 29 kg (Table 2).

The animal bones from the (upper) mine Bauernzeche come out of a cultural layer which was excavated inside the mine (Figure 8). After the prehistoric extraction activities, this place was used as a miner's shelter for a while in the Early Iron Age. During the excavation, a fireplace, a huge amount of pottery fragments as well as some stone tools and a few antler tools came to light. So far the radiocarbon analyses date this layer into the Early Iron Age, showing inaccurate dating due to the "Hallstatt-plateau" problematic. The pottery gives a clear hint that the shelter was used mainly in the Early Hallstatt period Ha C1 (Staudt *et al.*, 2018c).

The main part of bones from the pit field Weißer Schrofen comes from an excavated LBA waste dump. This up to 1 m thick layer represents a mixture of rock debris from mining and ore beneficiation processes (mainly fine picked dolomite) and classic "settlement" waste, including stone tools and a relatively big amount of ceramic fragments. The material and layers from the excavation Weißer Schrofen dates between the 12th and 9th cen-

Element	Weißer Schrofen			Bauernzeche			Rotholz		
	Cattle	Sheep	Pig	Cattle	Sheep	Pig	Cattle	Sheep	Pig
Processus frontalia	1	9	-	-	-	-	-	-	-
Calva	12	18	102	5	14	2	1	-	21
Maxilla	19	24	63	5	8	2	5	10	18
Mandibula	19	41	117	3	32	4	6	17	43
Hyoid	-	-	-	-	-	-	2	-	-
Vertebrae	39	31	186	6	34	6	9	8	17
Costae	48	137	180	12	109	72	2	11	23
Scapula	7	16	30	4	3	2	2	7	5
Humerus	7	24	73	2	12	2	-	3	-
Radius	11	28	42	1	6	3	-	1	5
Ulna	2	17	39	-	13	3	1	1	4
Carpalia	2	-	7	-	5	-	1	-	1
Metacarpalia	4	10	44	2	4	3	2	5	-
Pelvis	9	33	45	1	14	1	-	3	6
Femur	15	21	74	-	16	4	-	5	2
Patella	3	-	-	-	2	-	-	-	-
Tibia	12	26	59	-	13	2	1	2	6
Fibula/Os malleolare	-	-	14	-	-	2	-	-	4
Talus	-	-	15	-	3	-	-	4	1
Calcaneus	2	16	22	-	11	-	-	1	2
Tarsalia	-	-	-	-	5	-	-	-	2
Metatarsalia	3	11	28	1	8	5	-	5	-
Metapodien	4	-	12	4	3	-	-	2	8
Phalanx 1	5	16	20	2	21	-	1	3	3
Phalanx 2	8	-	6	1	5	-	-	-	4
Phalanx 3	4	-	5	-	3	-	-	1	1
NISP	236	478	1183	49	344	113	33	89	176
NISP-%	12.4	25.2	62.4	9.7	68.0	22.3	11.0	30.0	59.0
Weight	5320	3640	13542	1087	2639	884	460	402	852,4
Weight-%	23.6	16.2	60.2	23.6	57.2	19.2	26.8	23.4	49.7
Total NISP	1897			506			298		
Total weight	22502 g			4610 g			1714 g		

TABLE 2

Faunal composition from Weißer Schrofen, Bauernzeche and Rotholz.

turies BC, based on six ^{14}C analysed animal bones (Staudt *et al.*, 2018a).

Nearly all of the bones from the smelting site Rotholz originate from a dump of slag sand (Figure 9). The “slag sand” is a left over from a wet mechanical beneficiation process similar to gold washing. Primary slags from the ore smelting process were systematically crushed and grinded with

stone tools into the grain size of sand. Copper rich inclusions (copper and matte droplets) could then be enriched in washing basins/sluices by gravity separation. Because of the cuprous salts included in the slag sediments and having antibacterial properties, bones and other organic materials are very well preserved. The period of activity of this smelting site seems to be parallel with the one from the



FIGURE 8

Bauernzeche: The location of the upper mine Bauernzeche with ① the excavated prehistoric cultural layer, ② the belonging fire place and ③ the overlapping backfill from later mining activities. Pictures: M. Staudt.



FIGURE 9

Rotholz: The well preserved remains of two smelting furnaces (above) and the southern profile through the dump of slag sand (below) at the Late Bronze Age smelting site Rotholz. Pictures: M. Staudt.

Mauken Valley (Mauk A) and dates on the basis of eleven radiocarbon analyses (bones and charcoal) into the 12th and 11th century BC (Staudt *et al.*, 2017b, 2018b).

The preservation of the faunal material provided for the archaeozoological investigation is very good and thus a high number of the excavated bones and bone fragments could be successfully analysed. The vast majority of identified bones derives from the site Weißer Schrofen with 1897 bones, followed by the Bauernzeche with 506 bones and the smelting site Rotholz with 298 bones. The identification was carried out at the Natural History Museum Vienna (1. Zoological Department, Archaeological Zoological Collection) using the osteological collection and the Adametz collection.

The age estimation was based on the epiphyseal fusion of the bones and on the eruption and wear stages of the maxillary and mandibular deciduous premolar Pd4 and permanent molar M3. These teeth were chosen because their identification is relatively easy and they share only a small period of coexistence. The system followed for noting the wear stage was based on four different stages (Schmitzberger, 2009: figure 2): 0 (no wear), + (slightly), ++ (medium) and +++ (significantly).

Sex estimation for cattle was addressed on cranial elements (horn cores), pelvis and metapodials. Horn cores were used for sheep, canini teeth and tooth sockets (alveoli) for pigs. The skeletal element representation was based on the number of identified fragments (NISP) for better compatibility with other sites. The animal bones were morphologically studied and compared with other faunal assemblages. Whenever it was possible, the measurements that were taken according to the

standard of von den Driesch (1976) were statistically processed. Finally, modifications including butchery marks and gnawing marks were recorded. Concerning butchery marks their type, orientation and location were documented.

RESULTS

Species representation

The archaeozoological analysis shows that only domesticated species have been retrieved (Table 2). Cattle, sheep and pig prevail at all the three sites, whereas horse and dog were not found. Wild fauna was also absent. The application of the criteria for the separation between sheep and goat (Boessneck *et al.*, 1964; Schramm, 1967; Kratochvíl, 1969; Payne, 1969; Prummel & Frisch, 1986; Helmer, 2000; Halstead & Isaakidou, 2002; Zeder & Lapham, 2010; Zeder & Pilaar, 2010; Salvagno & Albarella, 2017) shows the absence of goat bones.

Based on NISP the pig prevail at the LBA faunal assemblages of Weißer Schrofen and Rotholz with 63% and 59%, respectively (Figure 10a). Sheep follow with 25% and 30%, whereas cattle are found with just 12.4% and 11%. The weight analysis also shows the prevalence of pig at Weißer Schrofen with 60.2% and at Rotholz with 49.7% (Figure 10b).

In contrast, a notable difference has been recorded concerning the Iron Age faunal assemblages of the Bauernzeche, with 68% sheep (NISP-%),

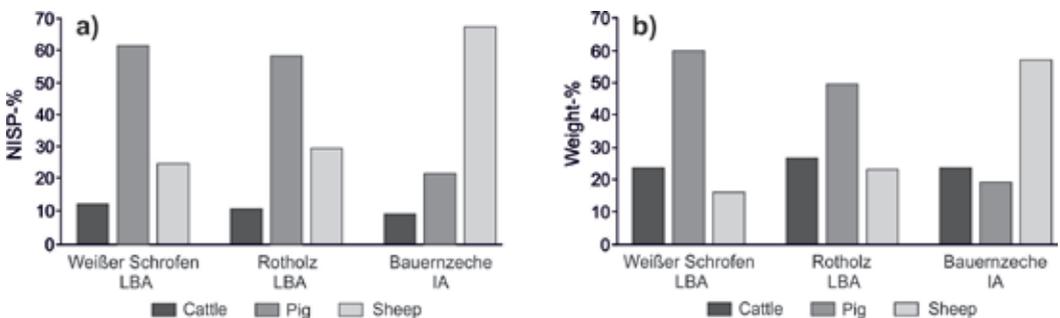


FIGURE 10 a-b.

Abundance (NISP-% and weight-%) of domesticated species from Weißer Schrofen (LBA), Rotholz (LBA) and Bauernzeche (IA). The diagrams show the remarkable change that took place in the transition period from LBA to EIA (Bauernzeche). In this case, sheep become the dominant species and pigs, which prevailed during the Bronze Age, are found at a significantly lower percentage.

followed by 22.3% pig and 9.7% cattle (Figure 10a). There, the weight analysis also confirms the dominance of sheep with 57.2% (Figure 10b). This marked change of the faunal composition from Late Bronze Age to Early Iron Age is very distinctive and has been observed already at the Iron Age faunal material from Dürrenberg (Figure 6, Table 1). Pigs lose their Bronze Age dominance in mining complexes and are substituted by cattle and in some cases small ruminants (especially sheep).

Age and sex structure

The material from Weißer Schrofen shows in general a very low number of immature individuals (Pd_4) (Figure 11). The vast majority of pigs was slaughtered at the best age for meat consumption between 1 and 2.5 years ($M^3/3_0$). Sheep are mainly represented by young adults (M^3_0+) and slightly older individuals (M^3_{++}). Animals older than 10 years ($M^3/3_{+++}$) were not recorded at all. Cattle teeth were rarely found, but the study of the epiphyses ($n=60$) indicates that most cattle bones derive from adult individuals older than 3.5–4 years. The age structure of sheep shows similar results ($n=192$). In both cases, more than 80% of the bones exhibited fused epiphyses. Pigs demonstrated a higher number of young individuals (Table 3); almost 37% of pig bones exhibited unfused epiphyses ($n=408$).

The analysis of cattle ($n=11$) and sheep ($n=101$) epiphyses from Bauernzeche showed very similar

results compared with Weißer Schrofen. Pig epiphyses ($n=20$) indicate a higher number of adult individuals; only 20% of the remains exhibited unfused epiphyses. The very low number of material from the Rotholz smelting site did not allow further conclusions in this respect.

The sex distribution for cattle at Weißer Schrofen indicates the prevalence of female individuals ($n=7$). Castrated animals were found at a lower number ($n=2$) and male cattle were not recorded. Sheep were equally represented by both sexes ($n=4$), whereas pigs exhibited a higher frequency of males ($n=22$) that is almost 69%. The number of pig bones from Rotholz and Bauernzeche is very low, but the few pig remains point towards a higher number of males at both sites (Rotholz $n=3$, Bauernzeche $n=3$). Only one cattle metacarpus from Bauernzeche could be identified as a castrated individual.

Skeletal element representation

The skeletal element representation from Weißer Schrofen and Bauernzeche will be presented in comparison to other well-studied sites. The LBA pig material from Weißer Schrofen displays several differences compared with sites of similar age and/or function (Figure 12). It does not show the overrepresentation of fore- and hind limbs so characteristic in Hallstatt and Dürrenberg. Additionally, in Hallstatt, the region of head, with the exception of the mandibles, was significantly underrepresent-

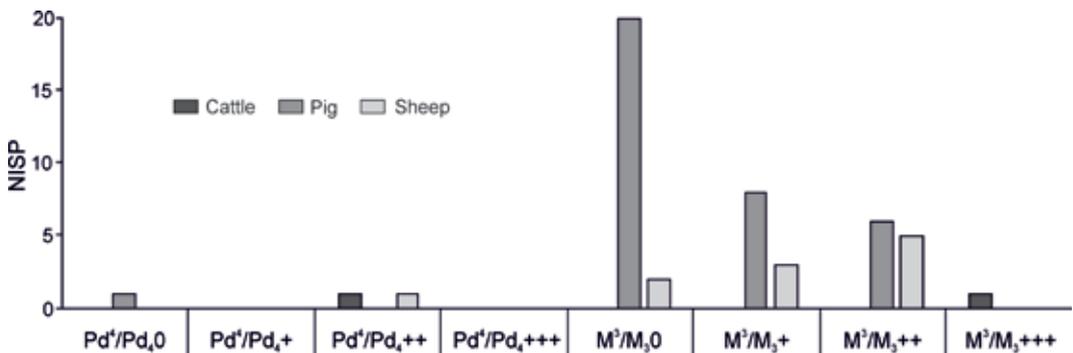


FIGURE 11

Age reconstruction at Weißer Schrofen for the domesticated animals based on maxillary and mandibular teeth (NISP). The different age spectrum between sheep and pigs indicate the different function and economic exploitation of the animals. Sheep were slaughtered at a later age stage than pigs, which were important mainly as meat suppliers. The low number of cattle teeth did not allow the reconstruction of the age distribution.

Pig					
Element	Epiphyseal plate	Unfused	Fused	Total	Unfused in %
Scapula	tuber	1	15	16	6.3
Humerus	proximal	14	5	19	73.7
	distal	-	28	28	0
Radius	proximal	-	33	33	0
	distal	-	4	4	0
Ulna	proximal	19	2	21	90.5
	distal	10	-	10	100
Pelvis	acetabulum	-	18	18	0
Femur	proximal	17	5	22	77.3
	distal	17	5	22	77.3
Tibia	proximal	16	1	17	94.1
	distal	5	13	18	27.8
Calcaneus	tuber	17	5	22	77.3
Metacarpus	proximal	-	44	44	0
	distal	23	18	41	56.1
Metatarsus	proximal	-	24	24	0
	distal	10	13	23	43.5
Phalanx 1	proximal	1	19	20	5
Phalanx 2	proximal	-	6	6	0

TABLE 3

Age estimation for pig individuals from Weißer Schrofen based on the epiphyseal fusion (NISP).

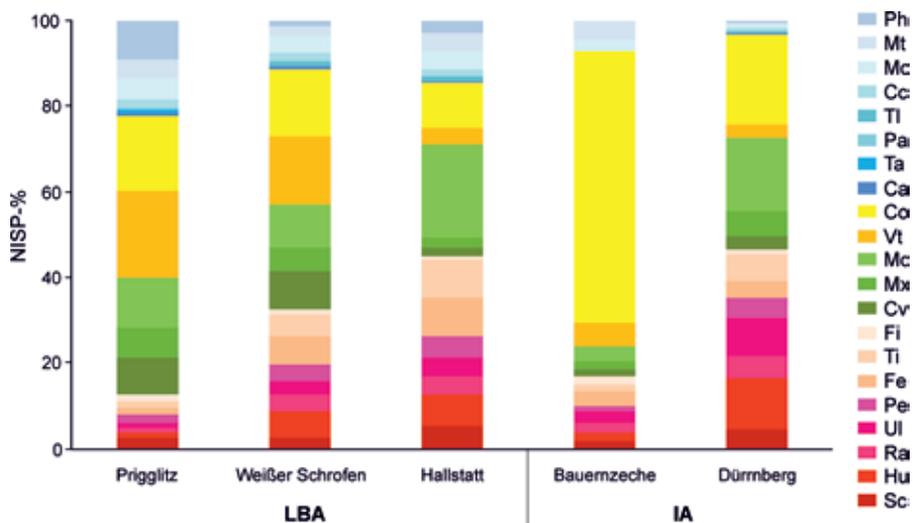


FIGURE 12

Skeletal element representation of pig (NISP-%). The normal distribution of body parts in Weißer Schrofen indicates that pigs were delivered as whole animals. In contrast, Bauernzeche exhibits a notable overrepresentation of ribs (Priggwitz n: 9126, Hallstatt n: 6438, Dürrenberg n: 1798).

Abbreviations: Cv: calvaria, Mx: maxilla, Md: mandibula, Vt: vertebrae, Co: costae, Sc: scapula, Hu: humerus, Ra: radius, Ul: ulna, Ca: carpalia, Mc: metacarpus, Pe: pelvis, Fe: femur, Pa: patella, Ti: tibia, Fi: fibula, Tl: talus, Cc: calcaneus, Ta: tarsalia, Mt: metatarsus, Ph: phalanges.

ed, whereas the mandibles were found at a very high percentage, since they were probably used for the transportation of the meaty regions (Pucher *et al.*, 2013). Dürnberg also exhibits a relatively low number of calvaria. At Weißer Schrofen, the head region is better represented and it illustrates a normal abundance relationship with the other bones; mandibles are slightly more common. In Hallstatt ribs and vertebrae were underrepresented. At Weißer Schrofen, all the bones, including metapodials and phalanges are present, suggesting that at least some individuals have been delivered as whole animals and probably were slaughtered at the site. The animal bones from LBA Rotholz were too few for statistical analyses. The Iron Age material from Bauernzeche shows in comparison with Weißer Schrofen a remarkable overrepresentation of ribs (Figure 12). All other bones are poorly represented.

The sheep remains from LBA Weißer Schrofen, show a normal distribution of all bones, with the exception of ribs, which are recorded at a significantly higher percentage (Figure 13). For this reason it is suggested that similarly to pigs, sheep arrived as whole animals, but “spare ribs” were delivered additionally. The distribution of sheep bones in the Iron Age mine Bauernzeche shows the

presence of almost all bones, indicating that also there whole animals arrived at the site (Figure 13). Similarly, to the sheep remains from Weißer Schrofen, ribs are overrepresented.

The body part representation for cattle can be interpreted only for Weißer Schrofen (Figure 14), since the material from Bauernzeche is too limited. The LBA material from Weißer Schrofen exhibits a similar distribution to the finds from Iron Age Dürnberg, indicating the presence of whole individuals.

Modifications: butchery marks

The data from the salt mining site of Hallstatt, where very specific butchery techniques were applied (Pucher *et al.*, 2013), shows that the study of cut and chop marks is important, especially in the context of mining settlements, where their analysis provided important insights into the economic organisation and provision networks (Trebsche & Pucher, 2013).

The cattle scapula, humerus, femur, tibia and metapodials from Weißer Schrofen were split longitudinally. Based on pressure marks on the surface of the proximal epiphysis of metapodials, it seems

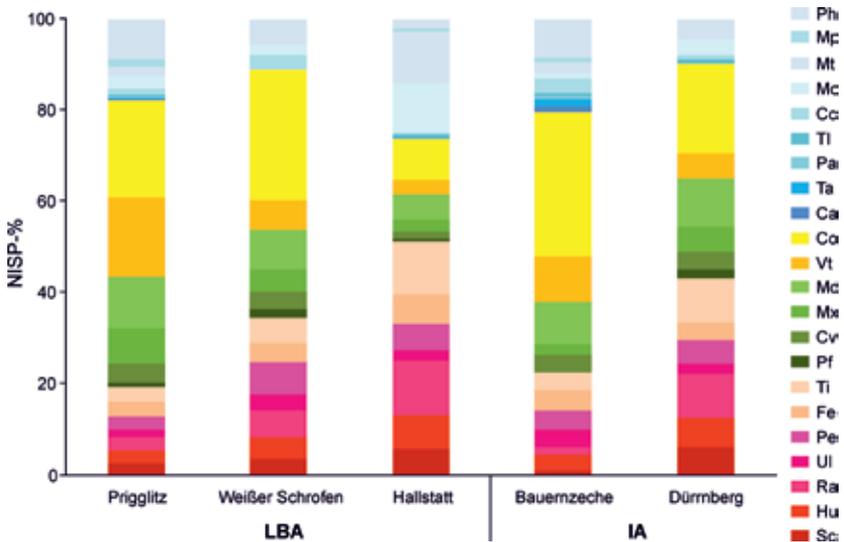


FIGURE 13

Skeletal element representation for sheep/goat (NISP-%). At both sites of Weißer Schrofen and Bauernzeche sheep arrived as whole animals. The overrepresentation of ribs could be related to additional supply of “spare ribs” (Priggwitz n: 3338, Hallstatt n: 2285, Dürnberg n: 1318).

Abbreviations: Pf: processus frontalia, Cv: calvaria, Mx: maxilla, Md: mandibula, Vt: vertebrae, Co: costae, Sc: scapula, Hu: humerus, Ra: radius, Ul: ulna, Ca: carpalia, Mc: metacarpus, Pe: pelvis, Fe: femur, Pa: patella, Ti: tibia, Tl: talus, Cc: calcaneus, Ta: tarsalia, Mt: metatarsus, Mp: metapodia, Ph: phalanges.

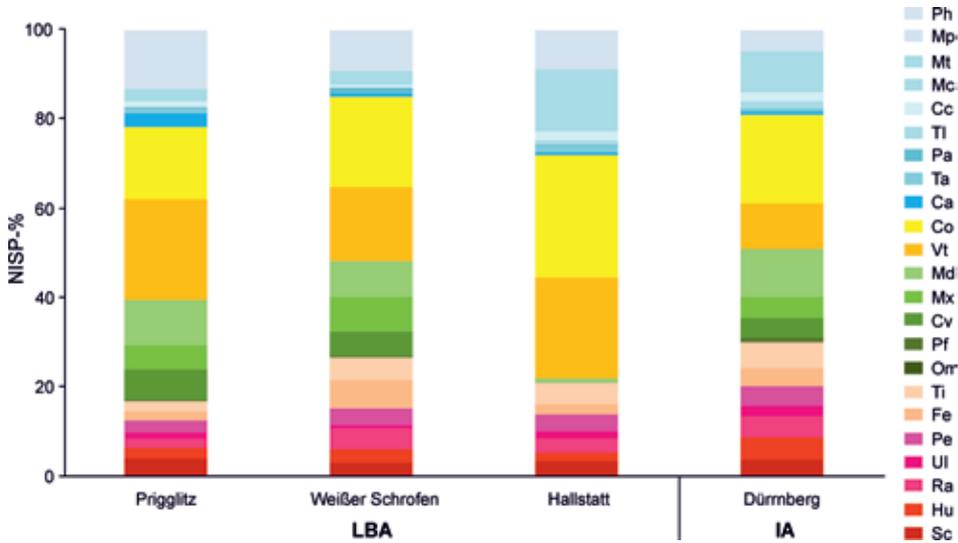


FIGURE 14

Skeletal element representation for cattle (NISP-%). The similarities to the cattle remains from Iron Age (IA) Dürnberg shows that cattle arrived as whole animals to Weißer Schrofen (Priggwitz n: 3786, Hallstatt n: 1869, Dürnberg n: 12223).

Abbreviations: Pf: processus frontalia, Cv: calvaria, Mx: maxilla, Md: mandibula, Vt: vertebrae, Co: costae, Sc: scapula, Hu: humerus, Ra: radius, Ul: ulna, Ca: carpalia, Mc: metacarpus, Pe: pelvis, Fe: femur, Pa: patella, Ti: tibia, Om: os malleolare, Tl: talus, Cc: calcaneus, Ta: tarsalia, Mt: metatarsus, Mp: metapodia, Ph: phalanges.

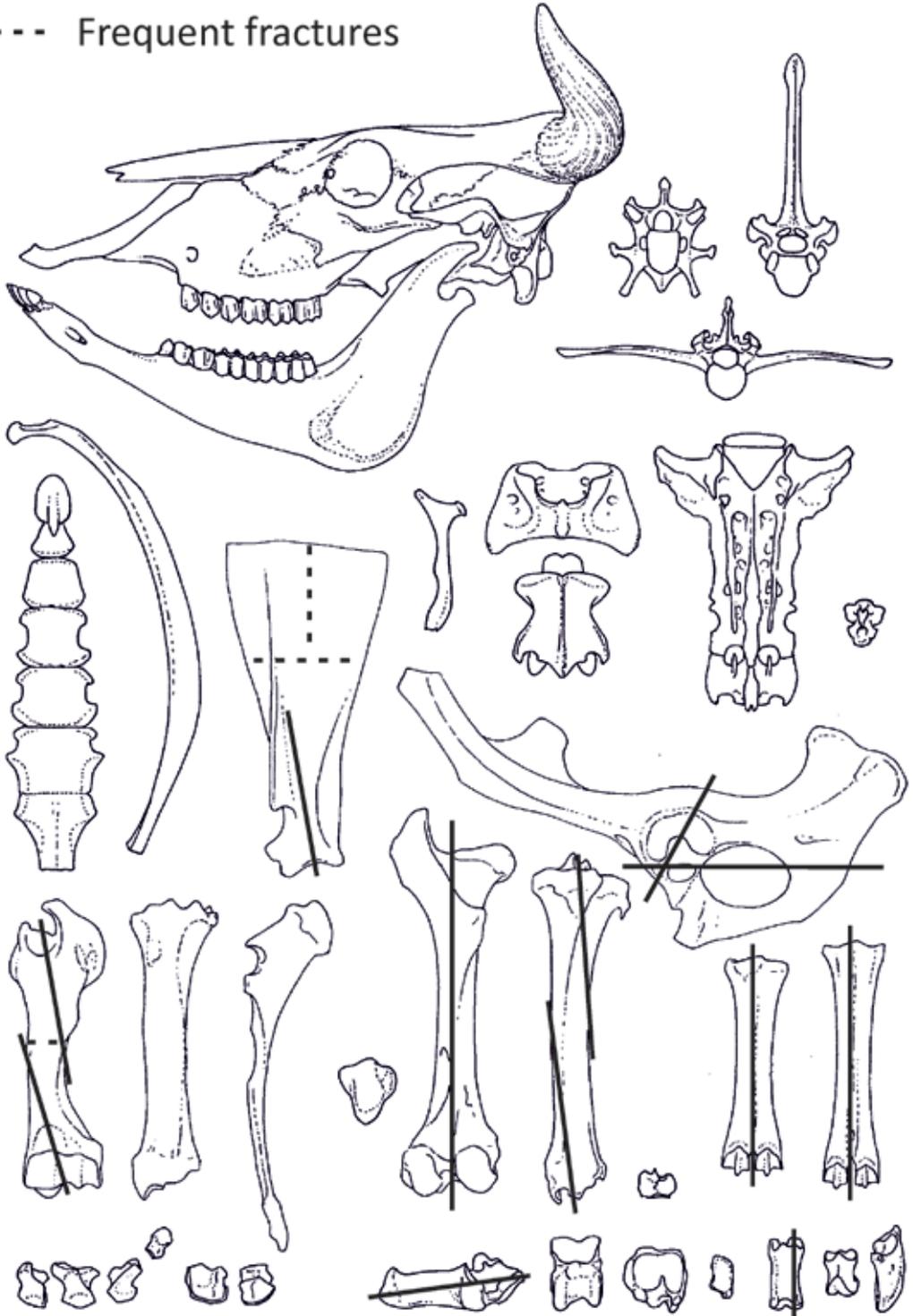
that they were stabilized at their proximal joint and they were split from distal. Smashing of long bones in general indicates marrow extraction. Pelvis bone was split through the acetabulum and then divided into smaller parts. Some small bones, like calcaneus, first and second phalanges were also split in longitudinal direction (Figure 15).

Sheep crania were split longitudinally (median-sagittal) and the horn cores were removed at their base. Another division was done from the side, in order to remove the maxillary row of teeth, under the zygomatic arch. The few finds show that removal of the head was achieved by chopping the first vertebra (atlas). The first and second vertebrae show transversal chopping. Other cervical vertebrae were absent. The thoracic vertebrae were split at their sides (parasagittal) to separate the ribs. The lumbar vertebrae were chopped at the middle of their bodies (median-sagittal) and some of them at the sides (parasagittal). The scapula, humerus, femur and tibia were transversally split, whereas radius and metapodials virtually exhibited no chop marks. Mandibles were chopped at the ramus mandibulae. Fissions can be seen behind the mandibular molar 3 (M_3) and the angulus mandibulae. Ribs were usually chopped from 5 to 15 cm long parts (Figure 15).

Similar butchery marks were documented on pig bones (Figure 15). The cranium was chopped

in the middle (median-sagittal) and the maxillary teeth were removed with a split under the zygomatic arch. Marks on the occipital condyles and the first cervical vertebra reveal removal of the cranium (Binford, 1981). The first two cervical vertebrae (atlas and axis) were split at the middle. Chops at the ramus mandibulae and the angulus mandibulae indicate separation and removal of the mandible. The lower jaw was additionally chopped along the symphysis. Pressure marks on the canini of the lower jaw indicate that the mandibles were chopped from basal. The thoracic and lumbar vertebrae were chopped from the sides (parasagittal). Ribs were chopped to portions between 5 and 15 cm; it is possible to observe characteristic filleting marks on their surface. Similar cuts on ribs were found on the material from Priggwitz-Gasteil (Trebsche & Pucher, 2013). The long bones of humerus, femur and tibia were transversally split, whereas radius remained whole. Small bones, like talus and calcaneus did not exhibit any marks. One scapula shows an incursion almost at the middle of the fossa supraspinata, which could be explained in several ways, such as a gnawing mark or as an indication for a hook or nail used for hanging this body part (Figure 16). The bones from Bauernzeche exhibit very similar marks like Weißer Schrofen.

— Chop marks
- - - - Frequent fractures



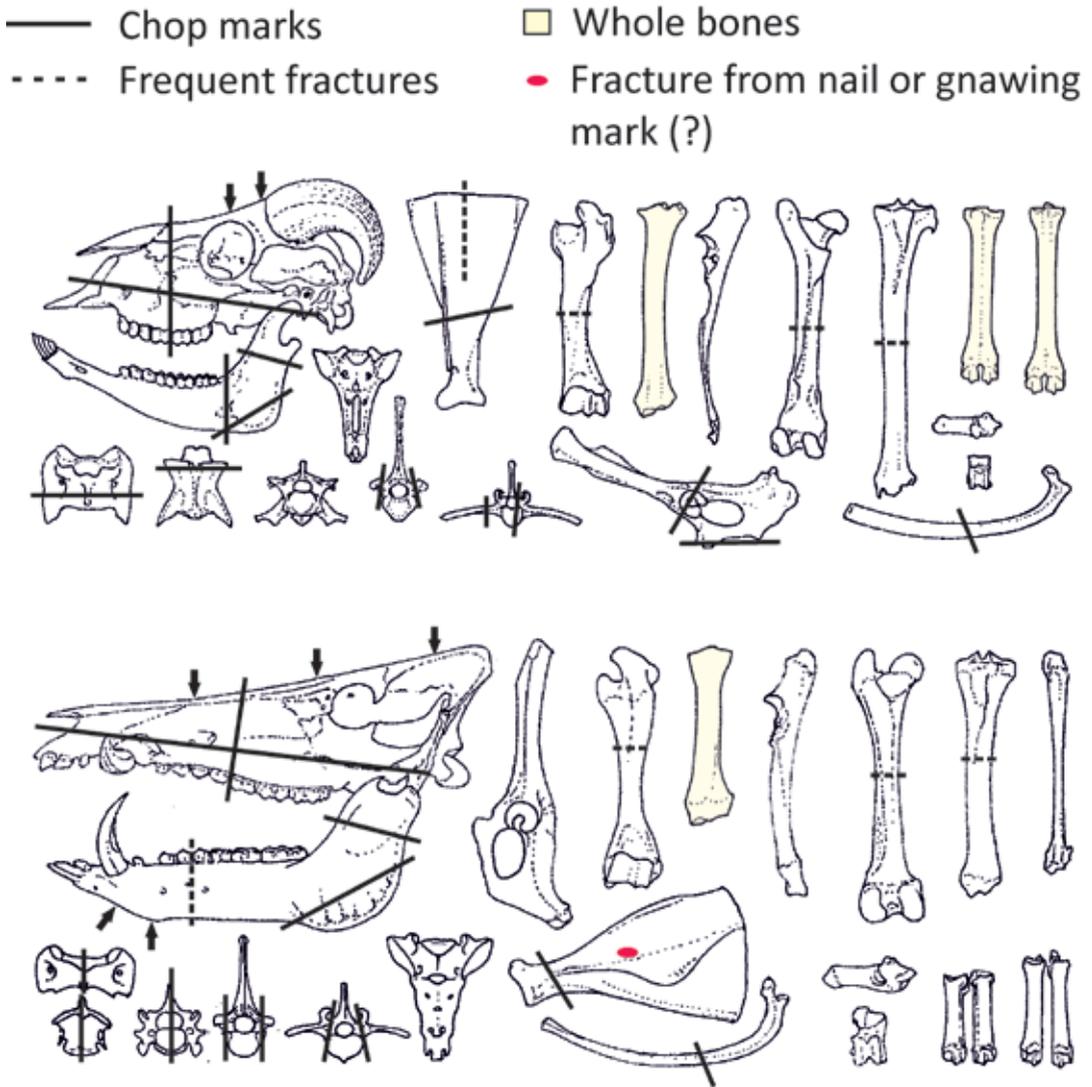


FIGURE 15

Chop marks and frequent fractures on cattle, sheep and pig from the LBA site Weißer Schrofen. The butchery marks indicate systematic and professional butchery techniques, as in other well-known mining sites of the LBA and Iron Age (IA).

A comparison with other sites of the LBA Urnfield culture indicates some slight variations. In all the cases, including Weißer Schrofen, the marks suggest a professional butchery technique, done by experienced people. Some differences are observed on sheep vertebrae in comparison with Hallstatt (Pucher *et al.*, 2013). In Hallstatt, the first two cervical vertebrae were chopped at the middle, but transversally at Weißer Schrofen. In Priggwitz-Gasteil, the radii were transversally

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chopped, whereas at Weißer Schrofen they remained intact.

These differences in the butchery marks could be explained in various ways. They might depict specific preferences for particular dishes e.g. “spare ribs” or they might be connected with different uses and/or functions of each site. For instance, in Hallstatt there was a very particular interest for the production of ham, which strong-



FIGURE 16

Pig scapula with incursion on the fossa supraspinata, cranial (left) and caudal (right) side.

ly influenced the butchery methods and the meat processing. Finally, such variations may also present normal cultural variety of local traditions and personal taste.

Modifications: gnawing marks

As mentioned above, long bones of pigs from Weißer Schrofen – with the exception of radius – bear transverse chop marks. Only two whole pig bones were retrieved and both bear gnawing marks, suggesting the presence of dogs. Two gnawing marks have been recorded at the cranio-proximal part of a humerus of an adult pig (Figure 17a). The distance between the two marks is about 14 mm, which indicates a relatively big-sized dog. The marks exhibit different size and depth and they strongly remind the paraconus of the maxillar pre-molar 4 (P⁴) and of the maxillar molar 1 (M¹). The tibia comes from a subadult pig and bears similar

traces (Figure 17b). Two puncture marks have been recorded at the lateroproximal side with a distance of 17 mm between them. Scratch marks on the tibia indicate that although the dog bit the bone, it slipped away.

The distance between the marks in both cases and the identification of the marks as the carnassial tooth and the following molar provided some indications concerning the size of the dog. Big-sized dogs with about 70 cm height at withers were found at the neighbouring EBA and LBA site of Brixlegg (Riedel, 2003; Boschin & Riedel, 2011). A dog maxilla from the EBA Brixlegg, which still had the P⁴ and M¹ teeth, would fit exactly with the marks of the humerus from Weißer Schrofen (Figure 18a). Additionally, material from the archaeozoological collection of the Natural History Museum was also used for comparison. The maxillary teeth of a Dobermann (Inv. Nr. A363), which was about 70 cm big, fit almost exactly.



FIGURE 17

(a) Pig humerus and (b) tibia from Weißer Schrofen with dog gnawing marks, probably caused by P⁴ and M¹.



FIGURE 18a

Dog maxilla from the EBA Brixlegg on the pig humerus from Weißer Schrofen.

Even if it is not clear how the dog bit the bones, some information derives from the marks on the humerus. It seems that the diaphysis was caught by the carnassial tooth (P^4) and the following molar, which suggests that the bone was posed oblique and at its long axis in the mouth of the dog, while the teeth of the lower jaw bit in muscles still attached to this part of humerus, without leaving any further marks (Figure 18b).



FIGURE 18b

Comparison of the gnawing marks with a Dobermann (NHM Vienna, Inv. Nr. A363), pointing to a quite large dog, responsible for the marks.

Morphometric analysis

Cattle

Concerning the size and shape of cattle three parameters are of key importance in the present study:

1. Statistical analysis is influenced by the number of measurements. For robust statistics a high number of samples is necessary, which is only rarely the case in archaeological contexts. However, low number of measurements allows for the recognition of tendencies. Additionally, slight differences with the comparative sites are often related to differences regarding sex distribution. With exception of Saalfelden, Bachsfall and Dürrenberg, where cows dominate, oxen have been documented in all sites included in this study.

2. Previously studied LBA cattle remains indicate a change in size, suggesting the appearance of a small-sized cattle population (e.g. Pucher *et al.*, 2013, Kyselý, 2016). In this context, the site of Brixlegg-Mariahilfbergl is of special interest for the evolution of cattle during the Bronze Age. There, faunal remains from the EBA to the LBA offer the opportunity to detect changes that took place concerning the size and shape of cattle in this period. Figure 19 compares talus measurements from sites dating from the EBA to the Iron Age. Tali are significant for the separation of cattle populations, since they are only slightly affected by sexual dimorphism (Pucher, 1999a).

Figure 19 shows that the EBA cattle bones from Brixlegg-Mariahilfbergl ($n=46$) exhibit a peak at 64-67.5 mm ($n=19$) with an average of 64.2, whereas the LBA material of Brixlegg-Mariahilfbergl ($n=8$) between 52-55.5 mm ($n=4$) with an average 55.8 mm. The talus measurements from Hallstatt ($n=8$) mainly fall between 56-59.5 mm ($n=4$) with an average 57.9, slightly higher than Brixlegg-Mariahilfbergl, probably due to the high number of oxen that might influence the range of variation. The measurements from the EBA/MBA site of Bachsfall ($n=15$) and MBA site of Saalfelden ($n=23$), with a peak at 60-63.5 mm and an average of 62.5 and 60.7 are between the EBA material from Brixlegg-Mariahilfbergl and the LBA assemblages. The earliest indications for the appearance of this small-sized cattle population have been found in the EBA/MBA context of Ledro in Southern Tyrol (Riedel, 1976; Pucher, 2019).

3. Cattle remains from the LBA show no significant differences in comparison with Iron Age cattle (Pucher, 1999a). Dürrenberg is one of the most important Iron Age sites, due to the high number of finds, allowing for many valuable measurements and statistical analyses (Pucher, 1999a; Abdel Karem, 2009; Schmitzberger, 2012; Saliari *et*

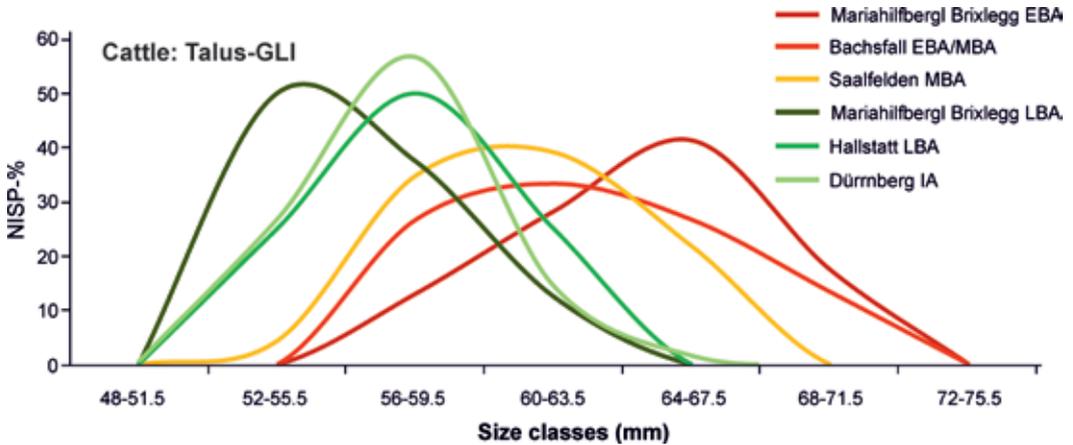


FIGURE 19

Size classes for cattle talus GLI (greatest length of the lateral half) measurement (in mm, NISP-%). Mariahilfbergl Brixlegg EBA (n=46), Bachsfall EBA/MBA (n=15), Saalfelden MBA (n=23), Mariahilfbergl Brixlegg LBA (n=8), Hallstatt LBA (n=8), Dürnberg IA (n=187). This figure shows the size change that took place from the EBA to the Iron Age (IA). During the LBA the size of cattle is very similar to the Iron Age.

al., 2016). The cattle talus data of Dürnberg, with an average of 57.4 mm, (n=187) is very similar to the LBA assemblages (Figure 19). This cattle population is probably related to the development of the mountain pastures. Previous research provides evidence for the adaptation of cattle to the Alpine environment (Pucher, 1999a).

The animal bones from Weißer Schrofen, Rotholz and Bauernzeche exhibited only a small number of measurements, which have however very important implications for the site itself and the broader context concerning the transition between the LBA and the Iron Age. The calculation of the height at withers for cattle was possible for one metacarpal of a castrated individual from Rotholz based on Matolcsi's factors (Matolcsi, 1970), which exhibited 112.8 cm. This value falls in the range of the Urnfield cattle population of Hallstatt, which according to the metacarpals there (n=12) showed values between 110.6 and 117.4 cm for castrated individuals.

The few Bd (greatest breadth of the distal end) measurements of radius (n=3) from Weißer Schrofen produced an average of 60.2 mm. The comparison with EBA and MBA sites indicates higher values. In Brixlegg-Mariahilfbergl (n=5) and in Wiesing (n=5) an average of 72.5 and 75.9 mm, respectively, was calculated. The EBA/MBA material from Bachsfall (n=2) and MBA material from Saalfelden (n=2) offered in total only four measurements, which exhibited an average of 64.5 mm and 66.3 mm, respectively. The LBA assemblages could not be compared

with Hallstatt, due to lack of data, but lower values have been recorded at the site of Kelchalpe (n=5) with an average of 58.5 mm and from Iron Age assemblages in Dürnberg (n=69) with 61.7 mm.

Bp (greatest breadth of the proximal end) measurements on radius support above trends in measurements. The EBA sites of Wiesing (n=6) and Brixlegg-Mariahilfbergl (n=4) gave an average of 78 mm. The EBA/MBA site of Bachsfall (n=4) and MBA site of Saalfelden (n=3) produced an average of 80.1 and 73.5 mm. LBA assemblages presented lower values, for example 67.9 mm in Kelchalpe (n=5), 71.5 mm in Hallstatt (n=5) and in Brixlegg-Mariahilfbergl (n=3). The radii from Dürnberg (n=100) with an average of 69 mm illustrate more similarities with the lower values of the LBA.

Weißer Schrofen and Rotholz, both with only a limited number of available measurements, exhibit very similar results, compared with other contemporaneous sites. Unfortunately, horn cores, which are very important for the identification of the population, were not found.

Similar observations concerning the morphometric analysis of cattle can be made for the Iron Age. In general, cattle remains of this period are very similar to those of the LBA. The GLP (greatest length of the Processus articularis) values of scapula from Bauernzeche (n=3) are between 50.5 and 54.5 mm, which is within the variation of Dürnberg (Pucher, 1999a).

Additionally, it has been observed that some of the measurements from Weißer Schrofen and Bauernzeche range at the minimum limits of the LBA and Iron Age faunal assemblages. In particular, a probable female tibia-Bd measurement from Weißer Schrofen is 46.5 mm, which falls at the lower values of Dürrnberg with a minimum of 45.5 mm (n=175), where the assemblage is highly dominated by cows. In Hallstatt (n=19), where oxen prevail, the minimum value is 48 mm. Concerning the GLP-scapula measurements from Bauernzeche, the value of 50.5 is lower than the range of the Dürrnberg variation (n=70), where the minimum value is 51.5 mm.

Preserved organic material, mainly from Hallstatt and Dürrnberg provides important additional information about the cattle population. Remains of hide from Hallstatt indicate that the colour of this cattle population was brownish (Ryder, 2007; Rast-Eicher, 2013; Reschreiter H., pers. commun.), while those from Dürrnberg exhibited a more colourful pattern (Groenman-Van Waateringe, 2002).

Sheep

The height at withers for sheep has been calculated based on Teichert's factors (Teichert, 1975). 21 measurements from the LBA sheep remains of Weißer Schrofen indicate an average height at withers between 61 and 62 cm (61.5 cm average calculated by radius, 61.6 cm average by meta-

carpus and 62.3 cm average by metatarsus). Three metatarsals could be used from the assemblages in Rotholz for the estimation of height at withers, indicating 58.3, 62 and 62.9 cm.

Similar values have been recorded from Hallstatt, where an average of 63 cm for the height at withers has been reconstructed (Pucher *et al.*, 2013). The LBA assemblages from Brixlegg indicate significantly higher values at 66 cm of the height at withers, similar with Dürrnberg. In Brixlegg, the material is very limited and thus this result is probably affected by the small statistical basis. In Dürrnberg, the average value probably has been influenced by the dominance of male and castrated individuals (Pucher, 1999a; Grömer & Saliari, 2018). Interestingly, one metacarpus from Rotholz indicated 68.7 cm for the height at withers, which is a high value. In general, the sheep population from Weißer Schrofen and Rotholz seems to be larger than the one in Northern Italy, where the average is commonly lower than 60 cm (Riedel, 1988). From the Iron Age assemblages of Bauernzeche one metacarpus exhibited 68.7 cm height at withers, similarly to Rotholz.

Pig

Concerning pig, the LBA remains of Weißer Schrofen indicate a height at withers between 65.3 and 83.9 cm with an average of 77 cm (n=28) based on Teichert's factors (Teichert, 1969). A rel-

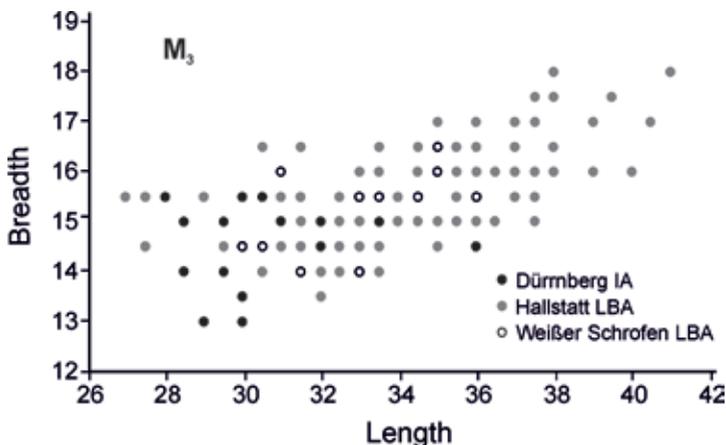


FIGURE 20

Scatter plot of length and breadth of M_3 (in mm) pig populations of Iron Age (IA) Dürrnberg (n=38), LBA Hallstatt (n=130) and LBA Weißer Schrofen (n=12). The measurements from Weißer Schrofen are mainly concentrated in the area at the middle and lower part of the Hallstatt values, indicating a homogenous population.

atively high value, which is probably influenced by the prevalence of male individuals. The EBA to LBA site of Brixlegg indicates relatively homogenous sizes of pigs during the Bronze Age. In Brixlegg, the average size is with 76.1 cm close to Weißer Schrofen. This value may have been also influenced by the high number of males and castrated. Similar results come from Hallstatt, where the average height at withers of pig reaches almost 80 cm. In this context, it is important to remember that the morphometric study of the Hallstatt pigs has exhibited mixed pig populations (Pucher *et al.*, 2013). A comparison of the length/breadth measurements of the M₃ (mandibular molar 3) from pig shows that those from Weißer Schrofen are slightly above the values from Dürnberg (Figure 20). Additionally, the clustering of the length/breadth measurements from Weißer Schrofen in the middle and lower part of Hallstatt measurements suggests a homogenous population (Figure 20).

The average height at withers of pig from Weißer Schrofen is close to that of Dürnberg, where the reconstructions range between 67 and 81 cm with an average of 75 cm (Pucher, 1999a). Two metatarsals IV from the Iron Age context of Bauernzeche yielded 82.2 and 76.9 cm for the height at withers. Their comparison with other Iron Age sites is challenging, due to the low number of data and the absence of measurements from other long bones.

DISCUSSION AND CONCLUSIONS

Archaeozoological evidence on the economic organisation

The bone material from two mining sites (LBA Weißer Schrofen and EIA Bauernzeche) and one smelting site (LBA Rotholz) in Schwaz-Brixlegg (Tyrol) provided significant information on aspects of organisation of the Bronze Age and Iron Age mining sites. Based on the age and sex profiles of the economically most important species – cattle, sheep/goat and pig – the miners had access to meat of very good quality. The animals arrived as whole individuals, whereas additional meat packages (especially ribs) were also documented. Interestingly, the two LBA sites of Weißer Schrofen and Rotholz

(even if the number of bones from Rotholz is relatively low) exhibit very similar faunal composition, probably indicating a functional and also contemporaneous relationship.

Additionally, the LBA faunal material from Weißer Schrofen indicates the presence of some big-sized dogs (around 70 cm), which raises questions about their role and function in the mines. This question becomes more interesting, when taking into consideration the particular big size of the dogs in mining contexts. Later sources, e.g. Agricola (1556) mentions that dogs carried bags out of pigskin in mines. Additionally, Weisgerber (1990) refers on dog skeletons found in the silver mining site of Oberzeiring in Judenburg, which was abandoned during the 14th century AD. However, archaeozoological evidence is still scarce. More material and future research are necessary, in order to gain further knowledge on the organisation of the Bronze Age mining societies.

The comparison of the Schwaz-Brixlegg district with other mining regions indicates a sustainable logistical balance between producers and consumers. The meat supply of the mining sites demanded a very well organised logistical system, with sustainable use of the animal resources for the benefit of producers and consumers (Pucher, 2014, 2015b). Important similarities seem to have existed in the dietary patterns concerning salt and copper mines (Trebsche & Pucher, 2013). Faunal and botanical remains indicate high food quality for the people working in the LBA and Iron Age mines (Boenke, 2005; Pucher, 2015a).

Even if the investigated mining sites of the same periods indicate minor archaeozoological variations, remarkable similarities were noted. One common phenomenon of mining settlements in the periods of investigation, including Weißer Schrofen, Rotholz and Bauernzeche is the low number or even the complete absence of wild fauna. The same is true for some domesticated animals, such as horse and dog (e.g. Riedel, 2003). Moreover, a rather surprising similarity is related to the butchery techniques. The butchery marks noted at the prehistoric mining sites in the Eastern Alps, point towards professional and systematic slaughtering techniques. Butchery experiments showed that similar butchery techniques are employed in the Austrian Alps until today, leaving very similar cut and chop marks, exhibiting a long lasting tradition (Pucher, 2009). These similarities, especially among the more investigated LBA

sites possibly indicate some standardised processes and exchange network among the miners and their suppliers, including people of different specialisations. Contact and a transfer of knowledge between different mining sites like Mitterberg and the Lower Inn Valley can be also observed by watching similarities in mining, beneficiation and smelting constructions, tools and techniques but also for example the use of slag sand as a temper surcharge inside the pottery.

Domestic faunal change across the Bronze Age – Iron Age boundary

The local archaeozoological record indicates a markedly change of the composition of the domesticated animals at the transition between the LBA and the beginning of the Iron Age (Pucher, 1999a). While pigs were the most important meat source for the Bronze Age miners, at the beginning of the Iron Age cattle and sometimes small ruminants (mainly sheep, like in Bauernzeche) became the most significant meat suppliers of the Iron Age miners (Pucher, 1999a; Saliari *et al.*, 2016; Schmölcke *et al.*, 2018). During the Bronze Age, cattle were the main milk suppliers and provided labour animals, but pigs by far dominated the meat supply at the mining sites. This important change in animal economy is accompanied by other organisational changes from Bronze Age to Iron Age mining, indicated by the archaeological record (Stöllner, 2009). The change documented in the archaeozoological data does not reflect only different dietary pattern, it is also part of a more general change that influenced the wider region of the Eastern Alps (Pucher, 2010a; Saliari *et al.*, 2016).

This change in animal economy is also evident at the three sites studied from Schwaz-Brixlegg, showing a decline of pigs and increase of sheep from Bronze Age to Iron Age. All three investigated sites at Schwaz-Brixlegg are geographically close, showing similar environments, therefore regional or environmental differences are not important. Additionally, animal economy is usually quite conservative especially in mountainous areas (Pucher, 2010b) therefore climatic change is a possible candidate as a factor.

Palaeoclimatic studies in the Swiss and Austrian Alps suggest that before the Roman occupation

eight cooling events (CE- 1-8) took place during the Holocene. The last phase CE-8 (*Göschener I*) is a central European cooling phase between 2900 and 2400 BP and can also be traced in Greenland, suggesting its global significance (Haas *et al.*, 1998). This cooling event is combined with changes in vegetation and an increase of the water tables in Switzerland (Burga & Sampietro, 2003). It has been suggested that probably the same cooling event caused the abandonment of the Urnfield period pile dwellings, situated close to lakes and swamps (Rösch, 1989).

This cooling phase could have influenced the fodder availability for pigs. Pigs are usually looking for fodder in forests with a preference for beech and oak forests. Based on forestry data of Austria (Schadauer *et al.*, n.d.) oaks are rarer than beeches, especially in western regions like Tyrol. Oaks are mainly found in Eastern Austria, where the climatic conditions are more favourable. Beeches are more widespread and they are better represented in Tyrol. Climatic cooling would have influenced the distribution of specific trees and thus a main fodder source of pigs. However, the cultural and technological advances related to the Bronze Age/Iron Age transition probably had an impact on many activities and thus possibly also on the animal organisation, supply and economy.

The high percentage of sheep at Bauernzeche is not surprising, since the existence of sheep in Tyrol is favoured in specific areas, such as the Alpine Dry Valleys (inneralpine *Trockentäler*). Furthermore, sheep keeping is usually easier than keeping of cattle, which are more demanding animals. Until today, there are sheep populations in Tyrol (e.g. *Tiroler Steinschaf*) which can be kept in rough conditions at high-altitudes that cattle cannot reach (Jaritz, 2015). Already during the LBA small ruminants and mainly sheep are quite common (around 20%) at some important mining sites such as Pichl (Early Urnfield culture) and Prigglitz Gasteil (Urnfield culture) (Trebsche & Pucher, 2013) which are however, in Styria and Lower Austria, respectively. Sheep keeping clearly would have had the additional important benefit of wool production. Textile finds made of sheep wool indicate that the Bronze Age and Iron Age wool technology and manufacture reached high levels (Grömer & Saliari, 2018; Schmölcke *et al.*, 2018).

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