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The Dürrnberg Miners during the Iron Age – New Results by Interdisciplinary Research

Keywords
Iron Age / Dürrnberg / Mining Archaeology / Social Structure / Archaeobotany / Pollen analyses / Nutrition / Parasitology

Abstract

Various analyses of Iron Age human palaeofaeces from the Dürrnberg salt mines provide a new insight into the diet, health conditions and seasonal aspects of a prehistoric population. Multiple data are used trying to answer the fundamental question of social status of the miners, but they often offer only an ambiguous explanation. The analysis of intestinal worms provides information not only on consumption habits but also on living and working conditions of the miners. Investigation of pollen and macrofossils in the faeces confirm the consumption of different meals based on cultivated plants, mainly cereals but also pulses and oil plants, as well as meat, spices and gathered fruits. The evidence of several zoogamous pollen taxa hint to the use of honey or honey products as well as to plants used as condiments or perhaps remedies.

The Dürrnberg as an Iron Age Centre

(Thomas Stöllner)

The Dürrnberg may be considered as one of the most important Iron Age research areas in Central Europe (Pauli 1978; Zeller 1995; Stöllner 1996/2002) owing to the quality and abundance of archaeological sources that have been investigated there since decades. Archaeological research has revealed a colourful and vivid picture of the prehistoric daily life, the economic progress of the Dürrnberg population, its far-flung trade relations and even its complex burial rites. The first settlements, mines and graveyards had been established during the first half of the 6th century BC. and were abandoned not later than the middle or first half of the 1st century BC. There is Roman activity in the 1st and 2nd century AD but it is actually unknown whether salt mining still was the main economic activity during that time.

By no doubt salt was the main reason for this remarkable concentration of economic prosperity mainly witnessed by well-furnished graves but also by an incredible variety of surface and underground sites. An outstanding monument in itself, the prehistoric salt mine is especially famous for its preservation conditions as salt favours the survival of all organic material. Therefore, medieval and post-medieval miners often came along with remnants of ancient prehistoric mining. The first written reports about the so-called "Old Man" date back to the 16th century.

The discoveries of salt pickled miners' corpses in 1577 and 1616 produced rumour and fame about the Dürrnberg mines (Stöllner 2002a; 2002b). These finds certainly can be acknowledged as the beginning of the archaeological and historical research at the Dürrnberg, although it took nearly another 400 years until systematic research started in the historic salt mines.

Plenty of research results have been produced since then. Research done by G. Kyrle and later by O. Schauberger, geologist of the Austrian saline company, shed light on aspects of prehistoric underground work (Schauberger 1968). Systematic archaeological research did not start before 1990 when the industrial salt exploitation ended. Due to the deformability of the Alpine salt deposits, exploitation galleries are being compressed constantly and many old galleries giving access to prehistoric find-spots now became rapidly inaccessible. From 74 reported subterranean find-spots, only six areas still can be visited today.

However, in 1990, a new research program has been launched to study the Iron Age salt mines and since then extensive excavations enabled scientific investigations of various aspects of Iron Age salt mining (Stöllner et al. 2003). The project focused on aspects of economy and technology, e.g. rock salt extraction, the usage of tools or the lightening of the galleries as well as the miners' equipment of various organic materials (textiles, skins, resins, wood). Outstanding discoveries right from the start have been numerous finds of prehistoric palaeofaeces, erroneously called coprolithes. Palaeofaeces occur in big quantities within the salty residues of the salt-mining processes called "Heidengebirge" ("pagan rock"). Originally, this material was the hewing debris of the salt extraction left in the mining chambers.

Human faeces are quite rare at European prehistoric sites and therefore provide a whole range of new information about the diet in general as well as special aspects connected to the question of seasonal mining in the Iron Age.

Since the examination of faeces also informs about diseases and even plagues, there was a manifold demand for new research when work on the Dürrnberg started again during the 1990ies.

Questions and state of research

(Thomas Stöllner)

One of the main problems when dealing with Iron Age social structure is the statistical value of burial sources. Numbers of graves differ considerably during various periods and in diverse cultural contexts. Facing this problem many attempts have been made to determine whether selective behaviour in history or the character of archaeological sources tend to falsify our assessment of the size of prehistoric populations. A methodological reflection will suggest that reliable data can only be expected if based on multiple sources, e.g. a comparison of working and dwelling sites. No doubt, the situation is complex because even under favourable conditions many parameters have to be considered: e.g. the calculation of the life span of houses as well as the estimation of the difference between the living population and its buried part (apart from a general ritual limitation to certain social groups). In any case, the chance for a reliable result increases with the number of data of different scientific sources.

At the Dürrnberg, research faces the problem, that an overall estimation based on graves only does not match the size of settlements nor the reconstruction of all necessary labour force regarding mining, the primary salt industries (such as salt pickling and skin-preservation) or further craft production (Stöllner 1998; 1996/2002). This fact clearly shows up from excavations in settlements as well as in the salt mines. Mining caverns had become quite large. In the Early La Tène period at least four to five large mines with huge mining chambers were operating. A rough calculation based on time span and work progress revealed labour forces of at least 50−70 miners to each mine (Stöllner 2002a; 2002b). This number also explains the huge quantities of faeces that excavations brought to light especially in the debris of rock salt extraction (Stöllner et al. 2003). The discussion still does not embrace all possible data and debate upon the time span and productivity of mining is not yet finished.

Looking at the size of the settlements as a further source, we are able to give rough calculations especially for the Ramsautal, a waterlogged craftsmen's settlement northwest of the central Dürrnberg area. By just counting the data of houses and dwelling areas, all around a number of nearly 400 buildings seems reasonable. Based on this, a general population size of nearly 2000 persons can be assumed as living at the Dürrnberg during its most prosperous period during the 5th−3rd century. Although there are various and multiple grave groups, such a population size cannot be reflected in the burials known from the Dürrnberg. Burials certainly represent only a minority, especially by taking into account that the frequency of burials decreased constantly from the end of the Early Latène to the Late Latène period (Stöllner 2007). The population-size was calculated on basis of the Acsádi/Nemeskéri-formula but also on the basis of the old palaeoanthropological data of the 1970ies (in detail: Stöllner 1998). New data are on the way (Wiltschke-Schrotta in preparation).

Although this reasoning has its limitations as well, it evokes a densely spaced and economically active community. If we presume similar conditions for earlier periods at Hallstatt, this seems to be doubtful according to recent studies. The Hallstatt cemetery is occupied far more densely than estimated before and a time-span longer than at the Dürrnberg can be estimated there for any individual mine. The discussion based on dendrochronological data is still under way, however. Regarding our research topic, it can be assumed that the cemeteries certainly do not represent the full social range especially at the Dürrnberg. Otherwise, we should also expect typical stress and muscle markers at the bones as have been recently detected on female skeletons from Hallstatt (Pany 2005). Further anthropological studies on the Dürrnberg material are necessary. However, those occupational stress markers need a careful interpretation, too.

Meanwhile it seems doubtful, especially at the Dürrnberg, that a bigger part of the miners is represented in the local burial grounds. Which part of the population is represented there remains elusive but some conclusions seem logical: foreign workers and part-time employees certainly cannot be expected in local cemeteries, as well as persons without a "ritual significance" for society.[1] What can be said yet, is that neither special burial rites nor special grave

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[1] Ritual significance is used in our respect for social groups whose appearance in graves was of importance for the Iron Age Society e.g. as transmitters to the other world or as legitimacy of social rank of the successors.

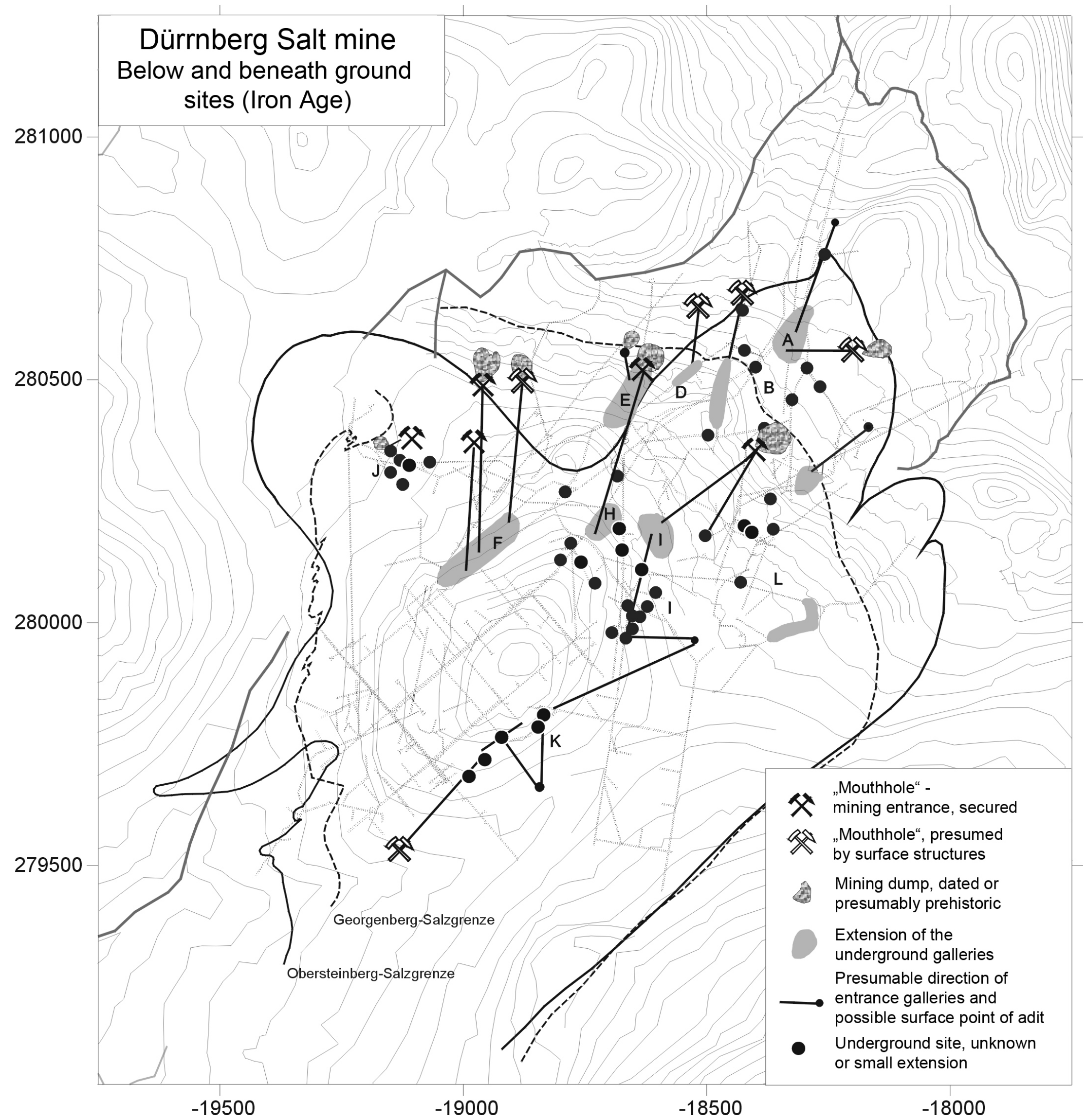

Fig. 1. *Dürrnberg salt mine: Mining areas plus tailings above ground and possible directions of main adit-galleries; the letters A to L describe the mining fields at the Dürrnberg.*

goods (such as tools) reflect a particular professional occupation.[2]

Certainly, there is no doubt, however, that faeces found in the mine in big quantities reveal first hand information about the working population. Different experts are involved to answer these questions by applying botanical, parasitological and archaeological methods. The work presented here was started in 1995 but is not finished yet.

III, Research in the prehistoric Salt mine

(Thomas Stöllner)

Modern excavation in prehistoric salt mines should gain a sufficient insight into structure, size and filling of ancient mining chambers (Fig. 1). According to results obtained during the last decades, mining caverns could reach considerable sizes. A conclusive picture of the different filling layers and thus chronological sequences often requires years of excavation and analysis (Stöllner 2002a; 2002b). The excavation of the ancient hollows itself is difficult as digging galleries have to be cut by pneumatic drills. In many cases, only a vertically orientated documentation is possible while full-scale stratigraphic excava-

[2] It is not yet clear whether two Late Hallstatt burials (351, 352) from an Iron Age mining tailing had been personally related to the mining work: Egg/Zeller 2005.

tions are nearly impossible or at least very expensive and time consuming.[3]

Large-scale excavations have been undertaken especially at the Obersteinberg, Georgenberg and Ferro-Schachtricht areas of the Dürrnberg salt mine. These modern galleries are cutting through ancient subterranean "Heidengebirge" deposits and thus provide access to them. The salty debris found there contains especially numerous organic artefacts and remnants disseminated all over different layers. The interpretation of dissemination patterns of different artefact groups is always limited by the small size of the excavation areas, thereby inhibiting statements that are more general. Certainly, the Ferro-Schachtricht excavation from 1994 to 1999 is the only one at the Dürrnberg from which such investigations tend to give a convincing pattern.

Our excavation galleries there have reached an extension of more than 60 m and were placed at the northern end of a prehistoric extraction gallery. According to stratigraphic observations, in Celtic times, two overlaying chambers had been cut in a southerly direction, always following the rich rock salt layers. Both extraction layers certainly belong to the same Late Hallstatt/Early La Tène mining period, verified by dendrochronological and radiocarbon dating (appr. 578–330 BC; Stöllner 2002a; Sormaz/Stöllner 2005). Connecting shafts between those two caverns favoured air circulation and allowed for the dumping of mining debris from the upper to the lower mining chamber in a younger phase. By no doubt the Ferro-Schachtricht mining system is one of the largest: As far as we know, its longitudinal measure exceeds 200 m with a width of nearly 30 m. Its pure rock salt content and the sheer length made it one of the most successful mines of the Dürrnberg.

The mining debris of the Ferro-Schachtricht site is salty enough to allow successful sieving of a part of the "Heidengebirge". Such a procedure provides a relatively exact amount of faeces per meter of the excavation area. We were able to sieve at least a quarter to a third of all prehistoric debris giving a sound basis for further dissemination analyses. In this way, we are able to calculate the weight of dried faeces per cubic meter of extracted "Heidengebirge" (Fig. 2) in general. A study of the spacing of weight rates within the whole debris should help to find latrines or at least areas preferably used as such.

Calculation of faeces weight rates in different "Heidengebirge" has just started and is as yet far from a conclusive result. It may be said, however, with due caution, that the rates per cubic metre seem higher than in Hallstatt. Dependent on the dating and excavation strategy at this place we can only compare the results from the Kernverwässerungswerk site (by F. E. Barth in 1989–1994).[4] The seemingly older deposits of the Hallstatt-Kernverwässerungswerk excavation obviously produced only a half to a third of the faeces in comparison with the Ferro-Schachtricht site. The rates we got from the Georgenberg site were comparatively high, especially at one spot of the "Heidengebirge", probably marking some kind of latrine in the vicinity of an Iron Age working or resting area. Although the rates are reduced by excluding these special deposits, the sieved total of the Georgenberg site seems far too small for a reliable statement. The spatial distribution of faeces within the mining debris of the Ferro-Schachtricht does not allow for the identification of latrines although some areas have been used more frequently. Additionally, a permanent process of re-deposition may have caused the more regular distribution of faeces.

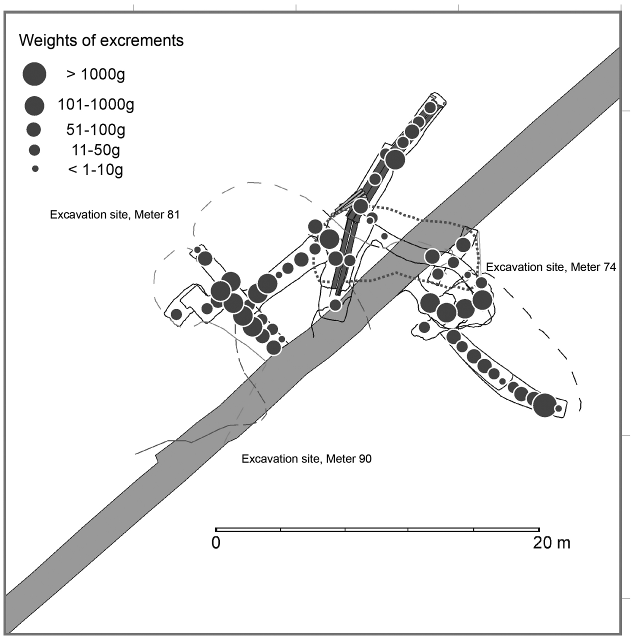

Fig. 2. Dürrnberg salt mine: Dissemination of faeces weights in the "Heidengebirge" layers of the Ferro-Schachtricht site (6th – 4th century BC).

This picture matches with the generally high faeces content at the Dürrnberg, giving the impression of more workers being integrated in the extraction process. This is surprising, as other artefact groups such as lighting tapers are found more frequently in Hallstatt. Since these tapers give a general impression about working time-span in the mine, it should

[3] Excavation underground is based on artificial galleries driven into so called pagan-rock fillings: documenting such excavations generally is resulting in vertical profiles and only seldom in areas being excavated according to the natural stratigraphy. One may call this a vertically orientated documentation.

[4] I am grateful to HR Dr. F. E. Barth and H. Reschreiter from the Natural Science Museum Vienna for their permission to study the collections in the late 1990ies.

be suggested that mining did not take as long as in Hallstatt, even if similar extraction methods had been practised. Taking the use of the more modern and perhaps more efficient iron pick into account, it seems even more likely that mining activities were generally based on larger working groups and shorter working stretches at the Dürrnberg. Here, more workers extracted probably more salt in less time than in Hallstatt, meaning also that each of the Dürrnberg miners individually worked less productively when compared to their colleagues in Hallstatt.

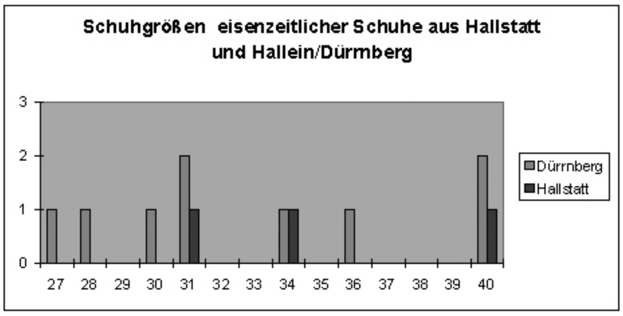

Fig. 3. *Hallstatt and Dürrnberg salt mines: Size of shoes from different sites (9th – 4th century BC).*

A possible explanation for this lower productivity could be a larger amount of child labour witnessed by the different sizes of shoes from the Dürrnberg salt mine. Here five out of ten shoes, respectively 50%, could be associated with children compared with only one out of three complete shoes in Hallstatt (Fig. 3). If we really can deduce a high level of child labour – which remains to be proved yet – we can at least suspect a higher number of persons obviously working (and living?) together in a narrow underground area. This might have had serious effects on the health status and ratio of infectious diseases: Further information on this has been gained by new studies on intestinal worms found in most of the faeces.

IV. Parasitological investigations on palaeofaeces from the Dürrnberg salt mine

(Horst Aspöck, Otto Picher, Thomas Stöllner)

During the new excavations at the Dürrnberg, numerous additional specimens of palaeofaeces have been brought to light. This study again reports of the results of parasitological analysis of 104 Iron Age human faecal specimens (Aspöck et al. 2002); additionally 72 further samples have been investigated at the University of Innsbruck.[5] Based on this evidence, some conclusions and considerations are presented, addressing the importance of parasitic illnesses in the Iron Age mining population of the Dürrnberg. 30 years ago, the present writer had the opportunity to conduct parasitological analyses of palaeofaeces from the Hallstatt period layers of both the Hallstatt and Dürrnberg salt-mines (Aspöck et al. 1973a; 1973b).

The term 'parasite' refers to all infective agents and vectors of disease that are not categorized as viruses, bacteria or fungi. This residual category is extremely heterogeneous, an assortment of very diverse organisms, which fall into three major groupings:

1. Protozoa (single celled, eukaryote, i.e. relatively high developed organisms, e.g. the infective agents in amoebic dysentery, malaria and sleeping sickness);
2. Helminths (intestinal worms, e.g. liver fluke, beef tapeworm, roundworm);
3. Arthropods (joint-legged creatures with exoskeletons, e.g. ticks, lice, bugs, fleas).

Hallstatt and the Dürrnberg are especially prolific sites as regarding the variety and quantity of palaeofaeces found there, by no doubt outstanding in European Iron Age. Multiple tests on parasites in palaeofaeces from both salt-mining sites have been conducted, successfully identifying the eggs of several helminths or intestinal worms, sometimes in large quantities. In a substantial proportion of the specimens, the eggs – despite having been buried in rock salt for some 2500 years – are superbly preserved and can be identified as plainly as if conducting a parasitological examination of a modern patient's fresh dejection specimen. Of 13 palaeofaeces specimens from Hallstatt ten tested positive for helminths; in ten specimens eggs of whipworm *(Trichuris trichiura)* were found and in one specimen, eggs of roundworm (*Ascaris lumbricoides)* could be identified (Aspöck et al. 1973a; 1973b). Out of 104 specimens from the Dürrnberg, 100 contained worm eggs, specifically 94 instances of *Trichuris trichiura,* 47 instances of *Ascaris lumbricoides*, three of beef tapeworm or pork tapeworm *(Taenia),* five of lancet fluke *(Dicrocoelium dendriticum)* and one of sheep liver fluke *(Fasciola hepatica*) (Aspöck et al. 2002). The same specimens could be identified by the Innsbruck investigations. Differences to our study only occur in respect to the combination in which they have been detected. The portion of non-infested faeces is slightly smaller. Striking is the considerable higher amount of samples in which alone *Trichuris trichiura*

[5] This second series represents a cross section of faeces investigated in Vienna in the Department of Medical Parasitology at the Medical University of Vienna by H. Aspöck, H. Auer and O. Picher, but also includes findings from other sites in the Dürrnberg salt mine. A final publication and discussion is envisaged in the near future.

have been found in the Vienna series: obviously, the Innsbruck investigations analyzed a higher portion of faeces with specimen combinations in contrast to single evidences of *Trichuris trichiura* (whipworm) (Fig. 4).

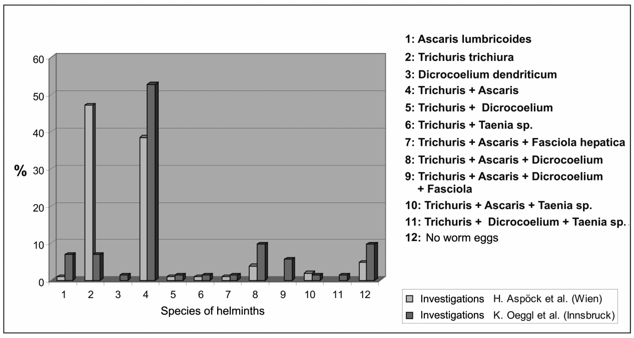

***Fig. 4.** Combinations of intestinal worms in the Dürrnberg palaeofaeces.*

The following conclusions can be derived from these findings: Both *Ascaris lumbricoides* and *Trichuris trichiura* (Fig. 5,3−4) are transmitted by oral ingestion of eggs, which have been excreted with faeces. However, the eggs are not immediately infectious but, depending on the ambient temperature, require a few weeks up to a few months exposure to atmospheric oxygen and a sufficiently humid environment. During this period, embryogenesis occurs followed by development into larvae capable of transmitting infection. The eggs, once excreted in faeces, must have remained in people's immediate surroundings for a considerable time span in order to become infectious. These unhygienic conditions must have been caused by completely inadequate disposal of human faeces. This is not only proved by the high rates of infestation (particularly in the Dürrnberg population) but also, and above all, by the high numbers of eggs detected in some specimens, indicating a massive level of infestation. One explanation for the last mentioned fact is theoretically possible, if somewhat improbable: It has been suggested that there might have been a steady influx of foreign workers to central European mines from the northern Apennine Peninsula where climatic conditions resulted in a higher level of infestation (as discussed by Aspöck et al. 1973a; 1973b).

Infestation with beef tapeworm or pork tapeworm (Fig. 5,2) – the eggs of the two species are morphologically indistinguishable – occurs by ingestion of the cysticerci (metacestodes = final larval stages) with raw or insufficiently cooked beef and/or pork. Faunal evidence of both cattle and pigs has been found at the Dürrnberg (Pucher 1999). Therefore, one must conclude that the prehistoric inhabitants cooked their meat insufficiently if at all. Even smoking of meat will not kill the larvae in this stage.

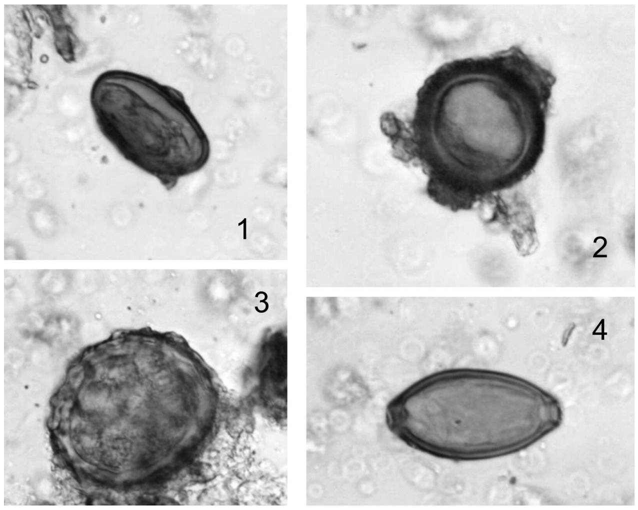

***Fig. 5.** Eggs of 1 Dicrocoelium (liver fluke), 2 Taenia spec. (tapeworm), 3 Ascaris (roundworm) and 4 Trichuris (whipworm).*

The numerous finds of *Dicrocoelium* eggs (Fig. 5,1) initially suggest that a proportion of the Dürrnberg salt-miners suffered from lancet fluke infestation. However, this presupposes oral ingestion of ants, the second intermediate host of *Dicrocoelium*, along with raw vegetation (infected ants clamp themselves by their mandibles to leaves). Since this is unlikely to happen frequently a more plausible possibility presents itself by the people of those days eating raw sheep liver, and by doing so ingested the liver fluke, which is predominantly a sheep parasite. However, the eggs contained in the liver fluke and those already released into the bile ducts of sheep livers would have passed through the human digestive tract without undergoing any particular transformation. Though their presence is apparent evidence of parasitic infestation, it is in fact specious, a phenomenon known as 'pseudoparasitism'. Whether the sole instance observed of *Fasciola* eggs is a case of parasitism or pseudoparasitism cannot be stated with certainty at present.

To summarize, numerous finds of worm eggs form reliable evidence that the prehistoric population of Central Europe must have suffered from worm infestation, especially by whipworm at least since the fourth millennium BC, by roundworm not later then 1500 BC and by tapeworm at least since the last millennium BC. Evidently, people did not take care to dispose of their faeces properly nor accorded enough importance to hygiene in general, probably through ignorance of its relevance to health. Likewise, there is compelling evidence that – at least in certain regions – the ingestion of raw (or very undercooked) meat had been commonplace.

The ailments from which people suffered in consequence primarily affected the digestive tract. Stomach pains and diarrhoea, highly detrimental to human productivity, must have been a routine experience. Diarrhoea, in turn, makes the safe disposal of faeces particularly difficult – at least in the absence of suitable sanitation. Probably, this vicious circle did often give rise to a huge build-up of worm infestation. Besides the various general ailments, there must also have been unspecified but frequent occurrences of serious and even fatal infections: Roundworms frequently enter the bile duct or the pancreatic duct, where they can e.g. trigger a life-threatening necrotizing haemorrhagic pancreatitis (inflammation of the pancreatic duct). Severe infestations with whipworm can cause anaemia and *prolapsus ani* (rectal prolapse). Pork tapeworm infestation can become life threatening if the eggs of the parasite are ingested, since the larvae that hatch from them infest the brain along with other organs possibly resulting in a dangerous neurocysticercosis.

There is good reason to suppose that prehistoric people did know about the connection between worm infestation and disease because certain helminths (roundworm, tapeworm segments) are large enough to be seen with the naked eye. It is also evident that those affected did attempt to cure themselves as shown by finds of unusually large quantities of butterbur (*Petasites hybridus)* in the collapsed Hallstatt salt mines, a plant used in folk medicine as a remedy for stomach pain (Aspöck et al. 1973a; 1973b; Kromer 1985). A similar antiseptic effect can also be presumed for sage (*Salvina officinalis*) evidenced by a DNA sample in an organic holder from the Dürrnberg salt mines (Burger et al. 2000, 81). Other plant remedies have been found regularly in the faeces perhaps as an intentional addition to the daily diet (e.g. *Artemisia*/mugwort). It is clear, however, that the Iron Age population must have been completely unaware of the routes by which disease was transmitted and thus was not able to take effective preventative measures against worm infestation.

Considering the fact of self-infestation by certain groups of miners (and perhaps their families) or even temporal worm diseases one would expect predicative dissemination patterns of Helminth species within the "Heidengebirge". Although the mapping does not contradict such an expectation, a clear pattern cannot be observed. Either the small number of special combinations does prevent any clear pattern, or re-depositing of debris layers has disturbed the original pattern. Obviously intestinal parasites had been disseminated in nearly the complete working group both on a high level and with the full variety of species. Modern molecular biological research should theoretically be able to identify single miners' faeces by help of a DNA-analysis. This potential approach would in the future certainly promote our understanding of radiation processes of parasitological diseases within specific mining groups.

V. Pollen Analysis of Human Palaeofaeces from an Iron Age Salt Mine

(Klaus Oeggl, Werner Kofler)

Introduction

Detailed information on the nutrition of prehistoric people is mainly based on macrofossil analyses of charred or uncharred animal and vegetal remains from archaeological excavations. Exceedingly rare but much more direct indications for dietary habits are human palaeofaeces rarely preserved in cultural layers under extremely favourable conditions. This is the case in the Iron Age salt mines at the Dürrnberg where numerous palaeofaeces were obtained in the course of archaeological excavations (Stöllner et al. 2003). Besides plant macro remains analysis (Boenke 2002) the identification and statistical analysis of pollen from these human palaeofaeces provides a big potential to study the diet of prehistoric miners and to contribute to palaeoenvironmental issues. This is possible because of the complex mixture of the pollen flora consisting of two distinct groups of pollen: economic and background pollen (Reinhart/Bryant 1992). The category of economic pollen comprises pollen adhering to food plants, which are ingested intentionally by the consumption of flowers, fruits or seeds, thereby providing supplementary information on prehistoric nutrition and diet. Background pollen encompass airborne pollen ingested unintentionally by respiration or by drinking water thereby enabling inferences on the environment, where and when the ingestion happened. In case of the palaeofaeces of prehistoric miners from the Dürrnberg salt mines both pollen categories are used to identify additional edible plants as well as to reveal clues to seasonal mining activities.

Methods

A hundred specimens of palaeofaeces mainly from the Ferro-Schachtricht site of the Dürrnberg salt mines were released to the authors for pollen analyses.[6] From each specimen a sample of constant weight (2 g) was taken. Before rehydration in a 0.5% solution of trisodium phosphate for 72 hours (Pearsall 1989), the samples were spiked with a solution of exotic marker pollen to enable the calculation of pollen concentrations (Maher 1981). Subsequently the liquid was screened through 500µ, 250µ, 125µ and 63µ steel meshes. The filtered solution (outwash) was kept for further investigation. Plant macro remains were picked out of the fractionated residues in the

[6] This research was funded by the Austrian Science Foundation (grant nos. P12901-BIO, P17372-B06). The authors acknowledge Dr. Hanna Schantl, University of Salzburg, for the use of the recent airborne allergenic pollen data of the city of Salzburg.

steel meshes. Finally, the residues of the steel meshes were added to the outwash of each sample, acetolysed (Erdmann 1969), washed in distilled water, covered with glycerine and afterwards kept in the drier at 100°C for twelve hours. For final analysis, samples were stained with fuchsine and mounted in glycerine. The light microscope investigations were carried out under magnifications of x750 and x1200 with the aid of phase and interference contrast.

Only samples with a counted sum of at least 500 pollen grains were considered for numerical analyses (correspondence analysis – CA; detrended correspondence analysis – DCA; principal component analysis – PCA), which resulted in an amount of 72 suitable samples. The counted pollen of arboreal and non-arboreal species exclusive spores provides the basic sum for calculation of the percentage values. Ordination of pollen percentage data sets was made with the software package CANOCO version 4.5 (ter Braak/Smilauer 2002). For all data sets, detrended correspondence analysis (DCA) with down weighting of rare species was used to measure the gradient length (ter Braak/Prentice 1988). Based on resulting gradient lengths a unimodal response model (CA; DCA) or a linear response model (PCA) was used for the ordination. Results were plotted using the program CANODRAW version 4.5 (ter Braak/Smilauer 2002).

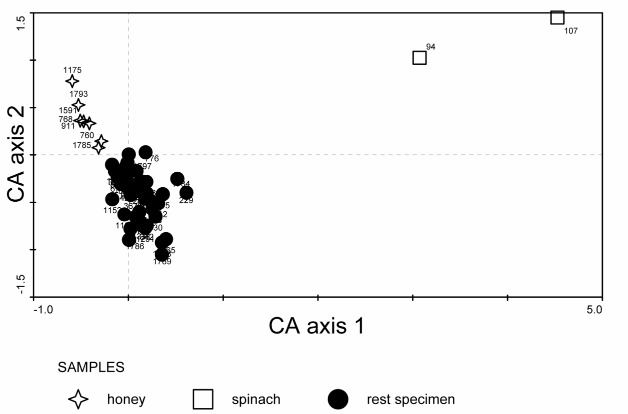

Fig. 6. Correspondence analysis of the relative pollen spectra of the palaeofaeces from the Dürrnberg mines to trace intentional ingested pollen from herbs. Pollen of cultivated crops (cereals, legumes) are excluded from the data set. Proportion of variance accounted for by the CA axes: Axis 1, 19.9%; and axis 2, 13.2%.

Results

Dietary Aspects: Economic pollen is principally identified through the pollen of crops, e.g. cereals of the *Hordeum*-, *Panicum*-, *Triticum*-type and the *Vicia faba*-type, which are common in the 72 samples, complemented by the spice *Nigella* (most probably *N. damascena* or *N. sativa*), evident in 10% of the samples. Additional information on economic pollen may be retrieved from zoogamous pollen. Since these contribute very little to the natural pollen downfall, pollen of insect-pollinated plants, which generate more than 2% of the basic pollen sum, are considered as intentionally consumed (Bryant/ Holloway 1983). This assumption provides the basis for a correspondence analysis conducted with the percentage pollen values of all samples. The analysis shows (Fig. 6) three clusters:

Two samples (nos. 94 and 107) are very rich in pollen of stinging-nettle (*Urtica* spec.) and of the goosefoot family (Chenopodiaceae) indicating a consumption comparable to spinach.

Seven samples (nos. 760, 768, 911, 1175, 1591, 1785, 1793) constitute a specific cluster, defined by pollen of insect-pollinated plant taxa (*Salix, Tilia, Achillea*-type, Asteraceae, Cruciferae, *Calluna vulgaris,* Campanulaceae, Caryophyllaceae, *Centaurea, Filipendula, Helianthemum, Heracleum, Hypericum perforatum, Mentha*-type, Papilionaceae, *Rhinanthus*, Rosaceae, *Trifolium* ssp., Umbelliferae), which are known as good honey sources for bees (Crane 1983, Vorwohl 1972) and thereby interpreted as indicating the consumption of honey or honey products.

The other samples do not show intentional consumption of pollen besides the above-mentioned cereal pollen.

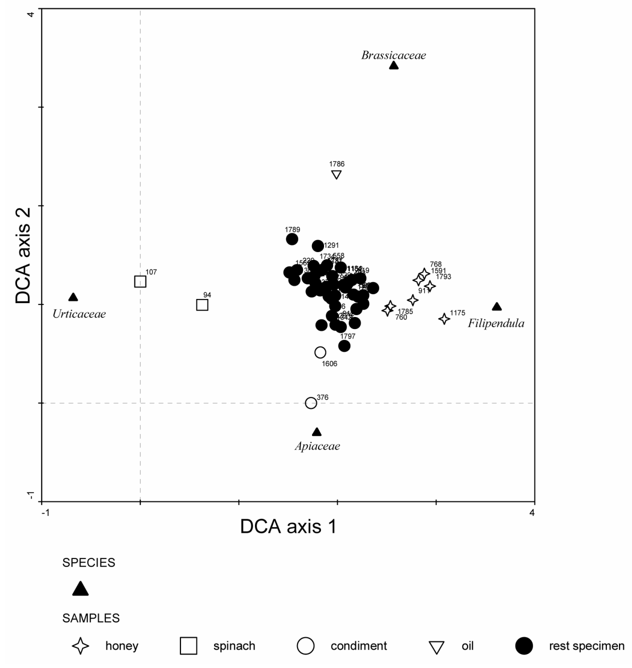

Fig. 7. Detrended Correspondence analysis of the relative pollen spectra of the palaeofaeces from the Dürrnberg mines and the pollen taxa identified to trace intentional ingested pollen from herbs. Pollen of cultivated crops (cereals, legumes) is excluded from the data set. Proportion of variance accounted for by the DCA axes: Axis 1, 19.9%; and axis 2, 5.8%.

For checking purposes, a detrended correspondence analysis (DCA) was done with all samples (Fig. 7). This DCA confirmed the clusters mentioned above, but resulted in two additional groups of faeces: One (no. 1786) is predominated by pollen of cruciferous plants (Brassicaceae), and a second by pollen of the carrot family (Umbelliferae), both suggesting the consumption via vegetables or spices.

Lastly, an ample group of palaeofaeces remains without any indication of intentional consumed pollen. To utilize the full potential of the data set and to trace any kind of information on consumed food plants a principal component analysis (PCA) was conducted with these samples. Expected were strong positive correlations between pollen taxa, which do not fulfil the above-mentioned 2%-assumption for intentional ingestion but were most probably pollen of intentional consumed plants. Surprisingly, the rest of the samples show a positive correlation (Fig. 8) between pollen of mugwort (*Artemisia*) and frequently detected eggs of human intestinal parasites (*Ascaris, Trichuris*). The Pearson-correlation coefficient represents 0.488, and therefore is highly significant ($p = 0.0007$). This may suggest an intentional absorption as a spice or as a remedy for these parasites.

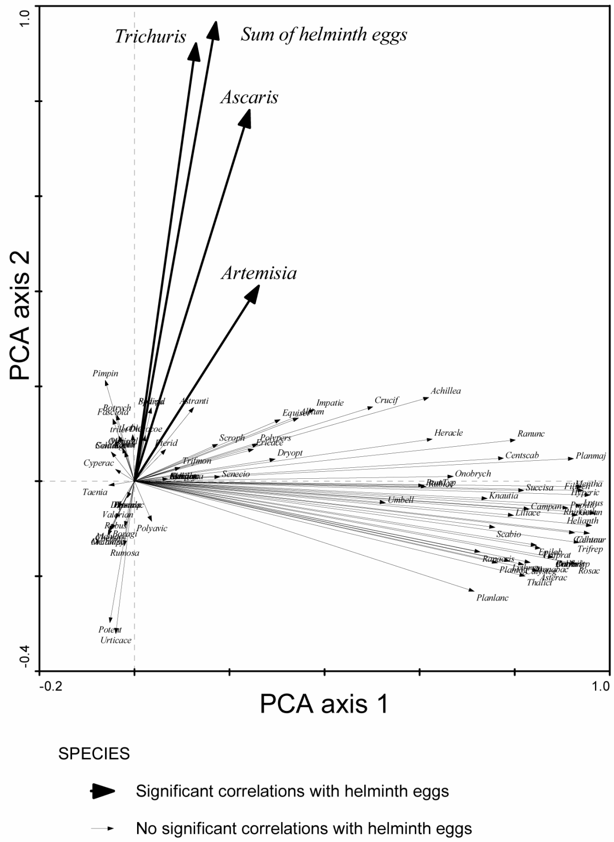

Fig. 8. Principal component analysis of the relative pollen spectra of the palaeofaeces from the Dürrnberg mines that show no indication of intentional consumed herbs to trace possible intentional ingested pollen by their correlation. Pollen of cultivated crops (cereals, legumes), spinach or vegetables, spices, honey or honey products mentioned in the text are excluded from the data set. Proportion of variance accounted for by the PCA axes: Axis 1, 46.9%; and axis 2, 23.5%.

Seasonal mining activities

Background pollen may reveal the season, in which the faeces were deposited in the mine and thus may provide clues regarding seasonal mining activities. To avoid biases with intentionally consumed pollen of food plants or honey, which can be stapled and used beyond the flowering season of the recorded plants, all pollen with an indication of intentional consumption (e.g. of cereals, honey, spices, etc.) were omitted from the data set. This then was subjected to a detrended correspondence analysis (DCA) with data of the recent airborne allergenic pollen monitoring data of the city of Salzburg, adjacent to the Dürrnberg area. Figure 9 shows two seasonal clusters of the recent airborne pollen data: one for winter/spring (respectively January until May) and another one for summer/autumn (in particular June until September). All pollen data of the faeces are consistent with the first mentioned cluster suggesting that mining activities took place during winter and spring.

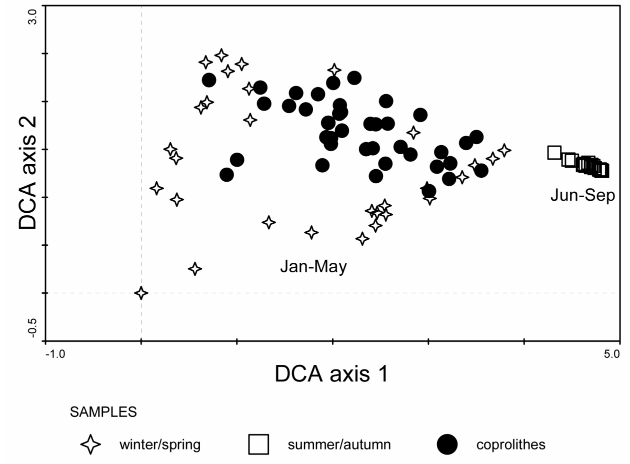

Fig. 9. Detrended correspondence analysis of airborne pollen monitoring data of the city of Salzburg (observation period 1992−1997) and the relative pollen spectra of the palaeofaeces from the Dürrnberg mines to trace seasonal patterns of the prehistoric salt-miners' activities. Pollen of cultivated crops (cereals, legumes), spinach or vegetables, spices, honey or honey products mentioned in the text are excluded from the data set.

Discussion

The numerical analysis of the human palaeofaeces reflects a mixed diet on a broad spectrum of species. Economic pollen of cereals (*Hordeum-*, *Panicum-*, *Triticum*-type) and legumes (*Vicia faba*-type) are recorded. They confirm the use of barley (*Hordeum vulgare*), broomcorn millet (*Panicum miliaceum*), emmer (*Triticum dicoccum*) and spelt (*Triticum spelta*) for human dietary purposes. Macro remains of these crops have frequently been found in the mines (Boenke 2002; Boenke in Stöllner et al. 2003) and in the cultural layers of the Iron Age Ramsautal settlement at the Dürrnberg (Swidrak/Schmidl 2002). The legumes – only broad bean (*Vicia faba*-type) is recorded − are underrepresented in the pollen spectra due to the fact that mainly the seeds are eaten. However, from plant macro remains analysis (Boenke in Stöllner et al. 2003) it is known, that the miners consumed broad bean (*Vicia faba*), pea (*Pisum sativum*) and lentil (*Lens culinaris*).

The meals were obviously flavoured with different condiments suggested by macro remains of fruits of caraway (*Carum carvi*), gold-of-pleasure (*Camelina sativa*), opium poppy (*Papaver somniferum*) and flax (*Linum usitatissimum*) in the cultural layers of the salt mine (Boenke in Stöllner et al. 2003). Since pollen adheres to fruits only in minor quantities, the occurrence of pollen of the carrot family (Umbelliferae) in faeces no. 376 (Fig. 7) is taken as a clue for the consumption of aerial vegetable parts of a plant of the carrot family (Umbelliferae). In contrast, the Brassicaceae pollen documented in high frequencies in faeces no. 1786 (Fig. 7) indicates the ingestion of gold-of-pleasure (*Camelina sativa*), which is confirmed by plenty of seeds in these faeces. New is the pollen evidence of fennel flower (*Nigella*) in seven samples most probably deriving from *N. damascena* or *N. sativa*, which was most probably used as a spice (cf. Heiss/Oeggl 2005) or as a remedy for dyspepsia.

Surprising is the indication for honey or honey product consumption by the miners through the evidence of pollen of insect-pollinated plants (*Salix, Tilia, Achillea*-type, Asteraceae, Cruciferae, *Calluna vulgaris,* Campanulaceae, Caryophyllaceae, *Centaurea, Filipendula, Helianthemum, Heracleum, Hypericum perforatum, Mentha*-type, Papilionaceae, *Rhinanthus*, Rosaceae, *Trifolium* ssp.) in quantities of much more than 2% of the basic sum. In this regard, the high number of *Filipendula* (presumably meadowsweet, *F. ulmaria*) needs special consideration. Although this species is widespread and common in wetland communities, its pollen is only sporadically recorded in honeys from the Alps (Vorwohl 1972). Apart from that, it has to be emphasised that earlier vernacular names of meadowsweet (*F. ulmaria*) refer to mead and not to meadow. In former times, the leaves and flowers were added to alcoholic beverages to give a pleasant taste (Hegi 1935, Dickson 1978). Since pollen of *Filipendula* adds up to more than 25 % in some of the "honey samples", we suggest that mead was consumed by the miners on the Dürrnberg.

Remarkable too is the consistent occurrence of human endoparasites (*Ascaris, Dicrocoelium dendriticum, Fasciola hepatica, Trichuris trichiura, Taenia*) suggesting that meat and fish had been a common part of the miners diet but also reflecting the absence of sanitation (Aspöck et al. 1973a, 1973b). In particular the infestation with *Ascaris* and *Trichuris* had been massive, the concentration of these helminth eggs often totalling several thousands per gram and faeces, thereby causing serious disorders of the digestive tract of the hosts (Aspöck et al. 1973a; see above). In this context, it is noticeable that several stomachica and anthelminthica are recorded amongst the pollen taxa. *Achillea, Artemisia* and *Drypteris filix-mas* are well known as a remedy for helminths from old herbals (Hegi 1935). Whereas *Achillea* and *Drypteris filix-mas* show no correlation with the eggs of the intestinal parasites, mugwort (*Artemisia*) pollen does (Fig. 8). However, a deliberate medication of the intestinal parasites is rather unlikely according to the relative low but highly significant correlation. A medication of the miners' dyspepsia seems to be corroborated by the occurrence of several taxa with laxative to purgative properties (*Frangula alnus, Prunus spinosa, Rosa canina, Trifolium arvense, T. pratense*). At least it has to be suggested that these herbs were added to the meals prompted by the empirical knowledge that they cause well-being in case of dyspepsia. After all, it is because of the content of sesquiterpenes why native *Artemisia* species are still used to flavour fat food (Bickel-Sandkötter 2001).

Finally, the analysis of seasonal activities of the miners has to be scrutinised seriously. Due to the mentioned biases arising from intentional consumed pollen, these were eliminated from the data set. Therefore, also pollen of *Artemisia* and *Urtica*, which bloom until September and may indicate autumn conditions, were omitted in case they exceeded the 2% assumption mentioned above. This led to only three specimens of palaeofaeces containing no intentionally consumed pollen amongst the herbs other than cereals. These samples seem to be too few for sound statistical analysis. Thus, only spring flowering taxa are considered in the given analysis and the result is governed by these intrinsic facts of the data set. Nevertheless, to contribute to the problem of the seasonal prehistoric miners' activities either other proxy-data have to be considered or more studies on palaeofaeces are needed.

VI. The social aspect of human nutrition

(Nicole Boenke)

Introduction

Interesting aspects towards the understanding of the miners' daily life are presented by the analysis of a large variety of archaeobotanical material from several excavations at the Dürrnberg. The plant residues vary from salt preserved material from the prehistoric mine (Boenke 2002, 2007a, 2007b, Oeggl/Kofler see above) to waterlogged samples from the Ramsautal settlement (Swidrak 1999, Swidrak/Schmidl 2002) and charred material from dwelling areas at the Putzenfeld, Putzenkopf and Ramsaukopf (Boenke in prep.). These studies gave clues to the use of natural resources as well as access to nearly all common cultivated plants in Celtic times (Boenke 2005).

The analysis of these organic samples offers a good chance to evaluate the prehistoric life beyond the material culture handed down in graves or settlements. Traditionally, the discussion of the prosperity of a population is based on these preserved artefacts – especially grave goods. In this context, inorganic finds like metals and ceramics are usually over-represented, whereas organic materials decompose. Therefore, it is often impossible to substantiate the role of the lower social ranks due to their lack of possessions. Various social models are discussed for the Iron Age settlement at the Dürrnberg with its obvious contrast between hard and dirty work in the mine and a large number of mainly rich or at least wealthy graves (Pauli 1978; Stöllner 1996/2002).

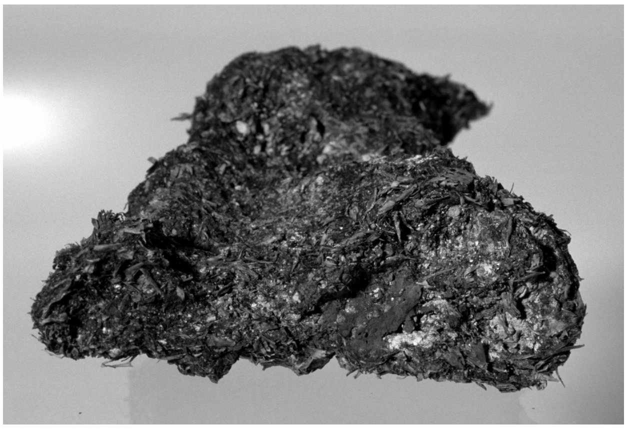

Fig. 10. *Dürrnberg, Salt mine: Rounded shaped piece of a human faeces.*

Fortunately, the excavation of the mines during the last decade provided an outstanding source for the study of Celtic everyday life in the form of human excrements (Fig. 10). Embedded in salty material and clay, the organic components were well preserved because the hygroscopic surroundings keep off most bacteria and microorganisms. The majority of the samples lost their original shape due to the pressure of the salt in the slow process of the closing of the ancient mine shafts.

Methods

From each portion of faeces one-half was used for pollen analysis (see Oeggl/Kofler), the other for the analysis of macro remains. For the latter procedure, the excrements were solved in (warm) water, and then put through a 0.25 mm sieve. Additionally, a part of the solving water was separated in order not to loose microscopic information. The sieved botanical macroremains were then examined under the microscope at 8x−40x magnification, counted and identified morphologically. In some cases 40x−100x magnification was used to look at fibers, cell structures on fruit surface fragments or cell patterns in cereal grain fragments.

For the identification, the reference collection of the archaeobotanical department of the former KAL Institute Wiesbaden[7] was used as well as the current literature (see below).

Results

The faeces contained thousands of organic, mainly botanical fragments showing a diet consisting of various cereals, pulses and fruits. Frequently found cereals were hulled barley (*Hordeum vulgare*), broomcorn millet (*Panicum miliaceum*) and spelt (*Triticum spelta*). Sometimes horse bean (*Vicia faba*), pea (*Pisum sativum*) or lentil (*Lens culinaris*) was added. Investigation under the binocular shows muscle fibres and little bone fragments, indicating the frequent presence of meat in the meals. Added to this, fruits like sloe (*Prunus spinosa*), apple (*Malus sylvestris*), pear (*Pyrus pyraster*), blackberry (*Rubus fruticosus*), wayfaring tree (*Viburnum lantana*) or common hawthorn (*Crataegus monogyna* and *C. laevigata*) had been consumed.

Discussion

Regarding our aim of a social interpretation, it is important to emphasise the fact that in our case a single piece of excrement represents the intestinal content of one person and his or her nutrition, whereas a latrine contains a mixture of several faeces. At first it had to be ascertained, whether the faeces had been those of the miners or of animals (pack animals or perhaps dogs) since they contained large amounts of roughage, including several glume fragments of cereals. This suggested initially that the food represented therein might not have been suitable for human consumption.

The association with animals, however, now seems unlikely. Nearly all the plants represented in the faeces are cultivated crops or wild fruits; there are no traces of hay or of other forms of animal fodder. This did not rule out the possibility of animal origin, because pack animals working in the mines might have been given high-quality food to increase their strength. However, the frequent occurrence of bone fragments and muscle fibers negates this possibility. Definitely, the excrements had been produced by an omnivore. The way the bone fragments are preserved excludes dogs or similar animals, because the tiny pieces were rounded on the surface and not broken with sharp edges (Kowalski et al. 1976). Inasmuch as omnivorous pigs are not used as pack animals, we may conclude, that the faeces discovered in the Dürrnberg mine are of human origin. This had

[7] Now Landesamt für Denkmalpflege Hessen, Abt. Naturwissenschaften.

been confirmed already by parasitological analysis (Aspöck et al. 1973a, 1973b, Aspöck et al. 2002, Aspöck 2003).

What kind of nutrition do these human excrements represent? Changing percentages of plant material allow a differentiation between various kinds of "dishes". An interpretation could not only be based on the number of plant remains, since nobody is consuming numbers of seeds, which can be of different weight and size or just can be the relic of a much bigger fruit/plant after digestion. Therefore, in a first step, the number of seeds was transferred into the number of fruits (Boenke 2007a). Owing to the unknown factor of food processing and digestion, even this will not show us the real quantities, but probably will hint to the ratio of consumed plants. We know from medical research that food processing influences digestion (Ledden Hulsebosch 1899, Schmidt/Strasburger 1905). Therefore, the different digestion of each individual limits the quantitative analysis of faeces. Unfortunately, it is not possible to distinguish between faeces of children (except suckling babes) and adults.

There are three main combinations of plant remains (Fig. 11), the first containing solely cereals, the second comprising cereals and fruits and the third combining cereals and pulses, sometimes added by fruits as well (Boenke 2007,). Other components are rare excepting the frequent occurrence of a few bone fragments in all groups. Fish and bird have each been detected once. Fish scales are also known from the settlement layers.

The fragmentation of the cereal remains indicates the consumption of a kind of soup or stew. However, bread is possible, too. As far as we know (Behre 1991, Hansson 1995, 1996) bread in ancient times still contained a lot of substance like glume fragments or species which today are not considered proper bread cereals like barley (*Hordeum vulgare*).

Only in some cases, the small size of the particles definitely points to flour for bread. In these cases, wheat (*Triticum* spec.) is dominant, not automatically meaning white bread, though. Hulled wheat species like einkorn, emmer and spelt (*Triticum monoccocum*, *T. diccocum* and *T. spelta*) are possible as well. In all other cases, hulled barley (*Hordeum vulgare*) and broomcorn millet (*Panicum miliaceum*) are dominant, known as suitable species for preparing soups and matching well with the varying use of pulses. Pulses in the soup had not substituted meat, however, as it is often suggested for "poor" or ordinary people. On the contrary, meat frequently occurs in correlation with horse bean (*Vicia faba*), pea (*Pisum sativum*) or lentil (*Lens culinaris*). As mentioned by F. E. Barth (1992) these ingredients still belong to the present-day "Ritschert", a traditional dish in the southeastern Alps. This region is also represented in the artefacts from the Iron Age graves.

Sometimes, oilseeds are added to the soup or stew as spices. In one sample, gold-of-pleasure (*Camelina sativa*) occurs in very high numbers. Oilseeds of flax, poppy and gold-of-pleasure (*Linum usitatissimum*, *Papaver somniferum* and *Camelina sativa*) are found in other food combinations as well.

"Vegetables" were not important for the miners' nutrition. A common topos in archaeological food studies is the assumption that prehistoric cuisine did not only include cultivated cereals and pulses, which char and therefore preserve well in the archaeological context, but also a wide range of plants that do not char and hence are not preserved. The Dürrnberg faeces are neither totally lacking e.g. leaf fragments, nor are the documented pieces unusually large or indigestible. Quite the contrary: even fragile leaf fragments are preserved. Therefore, a massive or even frequent consumption of leaf vegetables or salad should have been possible to detect. Probably the few fragments indicate the use of some herbs as spices or for medical purposes.

Fruits had been eaten very often. A high fruit content of the faeces is signalised by a dark matrix in which seeds and fruits are embedded. Large quantities of kernels are also documented from the layers inside the mine as well. The fruits could have been collected in the vicinity (Boenke 2005).

Mediterranean imports such as figs and grapes are known from other Celtic settlements (Stika 1999, Kreuz/Boenke 2001), but do not appear in the miners' diet. Indeed, at the Dürrnberg settlement only a single grape seed has been found so far (*Vitis vinifera* ssp. *sylvestris*) which probably came from a locally gathered fruit (Swidrak/Schmidl 2002).

The fruit consumption shows no evidence for seasonal mining. The majority of species found in the excrements like sloe (*Prunus spinosa*) could have been dried and used for months. Nevertheless, there are other finds as well: strawberries (*Fragaria vesca*) ripen in summer, are not as easy to preserve and had to be consumed fresh. The occasional character of fruit finds supports the argument. If someone treats a fruit to preserve it, it will probably be done in large quantities. The more or less isolated find of a fruit indicates that it had been eaten occasionally.

After the botanical remains, the consumption of meat has to be considered. Initially, the low numbers of bone fragments in the faeces and in the mine appeared to contradict the analysis of the large faunal assemblage in the settlements. On further consideration, however, the data present no such interpretive difficulty. As witnessed by the archaeozoological studies, cattle had been driven up to the Dürrnberg to be slaughtered there and people processed large amounts of beef on-site. The best parts were probably preserved with salt for trading as the bones of these parts are underrepresented. Off cuts might have been all that was usually left for the miners (Pucher 1999, Stöllner et al. 2003).

The analysis of the botanical remains has shown that the meat was probably cooked in soups. In this form, it would be quite easy to digest in contrast to roasted meat. If the miners had been eating roasted meat, there should have been higher rates of visible muscle fibers in the samples. Other archaeological evidence supports the idea that roasted meat was not a common part of the workers' diet. More or less complete bones, commonly left after the consumption of roasted meat are rare finds in the Dürrnberg mines. In addition, spits for roasting primarily occur in the same context as drinking vessels for (imported) wine or other luxury goods: in rich graves. Consumption of big pieces of roasted meat appears to have been reserved for special occasions such as funerals or other opportunities to demonstrate wealth.

Although the miners did not consume the best parts of meat, they did not lack of animal protein, but according to the frequency of tiny bone fragments in the excrements ate meat regularly.

Cultivated plants had dominated the miners' nutrition. Food had to be acquired mainly through trade. Although agriculture is possible on the Dürrnberg, the mountainous area lacks the space for fields to supply a large community. Additionally, meat and fruits are frequent components of the meals. While sufficient calories and proteins could have been obtained by buying cultivated crops, vitamins probably had to be procured from the local sources. The comparison of the Dürrnberg data with contemporaneous archaeobotanical data from other European areas (Boenke 2005) indicates, that the miners had access to all of the foods that were common in Iron Age Central Europe and that there was neither lack of plant food nor of meat.

VII. Discussion

(Thomas Stöllner)

By discussing the Dürrnberg miners, it became fairly clear that this group can only be grasped by indirect evidence: There are no graves directly linked with them. Principally, one could argue as L. Pauli did: his idea was that of a wealthy society which had produced on its own account (Pauli 1978). The demonstration of wealth in the graves would therefore reflect only the other side of a coin that was earned by hard work in mines and by economically successful enterprises. Along with the progress of archaeological fieldwork above and below the ground, however, a disproportion became obvious. The relation between the population represented in graves and that which could be estimated based on settlements and economic activities is not balanced any longer: at the most only a fifth of the total population is represented by the calculated total of graves (see e.g. Stöllner 1996/2002; 1998). Therefore, the question arises, whether these burials represent only an upper social stratum or rather a cross-section of the local inhabitants.

To answer this question, it seemed to be useful to look at the somewhat elusive miners, who can be especially traced by faeces. The most significant results were obtained by analysing intestinal parasites found in nearly all faeces. Noteworthy was the higher infestation ratio as well as the larger variety of worm-species in comparison with the older salt mines at Hallstatt. Without going too far into details, one would conclude a worse health status caused by living and working in larger groups underground. Some recent results, however, prove the use of remedies against intestinal parasitic diseases, e.g. sage or mugwort. A positive statistical correlation between mugwort and whipworm or maw worm is no surprise, since both worm species have been found in nearly all faeces, a fact liable to produce a heuristic error.

The ordinary health status is revealed, too, by larger quantities of faeces found in the "Heidengebirge" at the Dürrnberg in comparison with Hallstatt. Would this mean that a larger work force was employed consisting of some specialists being supported by a larger group of part time workers or even children? Far more undetermined is the aspect of standardization of equipment and miners' nourishment: How much of it is accounted for by a generally expectable labour-division and how much by an increase of efficiency with negative effects on labour conditions?

Therefore, it is worthwhile to consider the miners' nutrition. Methodologically, the analyses of pollen and macro remains reflect different aspects of human nutrition. While macro remains in the faeces result from intentional intakes, the interpretation of pollen is more problematic because of its origin. Apart from that, pollen analysis offers valuable details on a bigger range of species than the macrofossils do, relating to the surrounding vegetation as well as the intentional intake.

High numbers of pollen grains in the faeces e.g. may indicate an intentional intake. It finally remains a question of interpretation whether insect pollinated plants have been consumed only as mead or honey. An example perhaps is *Filipendula* (meadowsweet) occurring in some "honey" samples in high quantities thus indicating intentional intake. Still, there is but a comparatively small portion in a part of the other faeces. Would this mean they had been taken in by water from the nearby wetlands where it grows (e.g. the dwelling site in the Ramsautal)? This ambiguous relation could be another effect of background pollen.

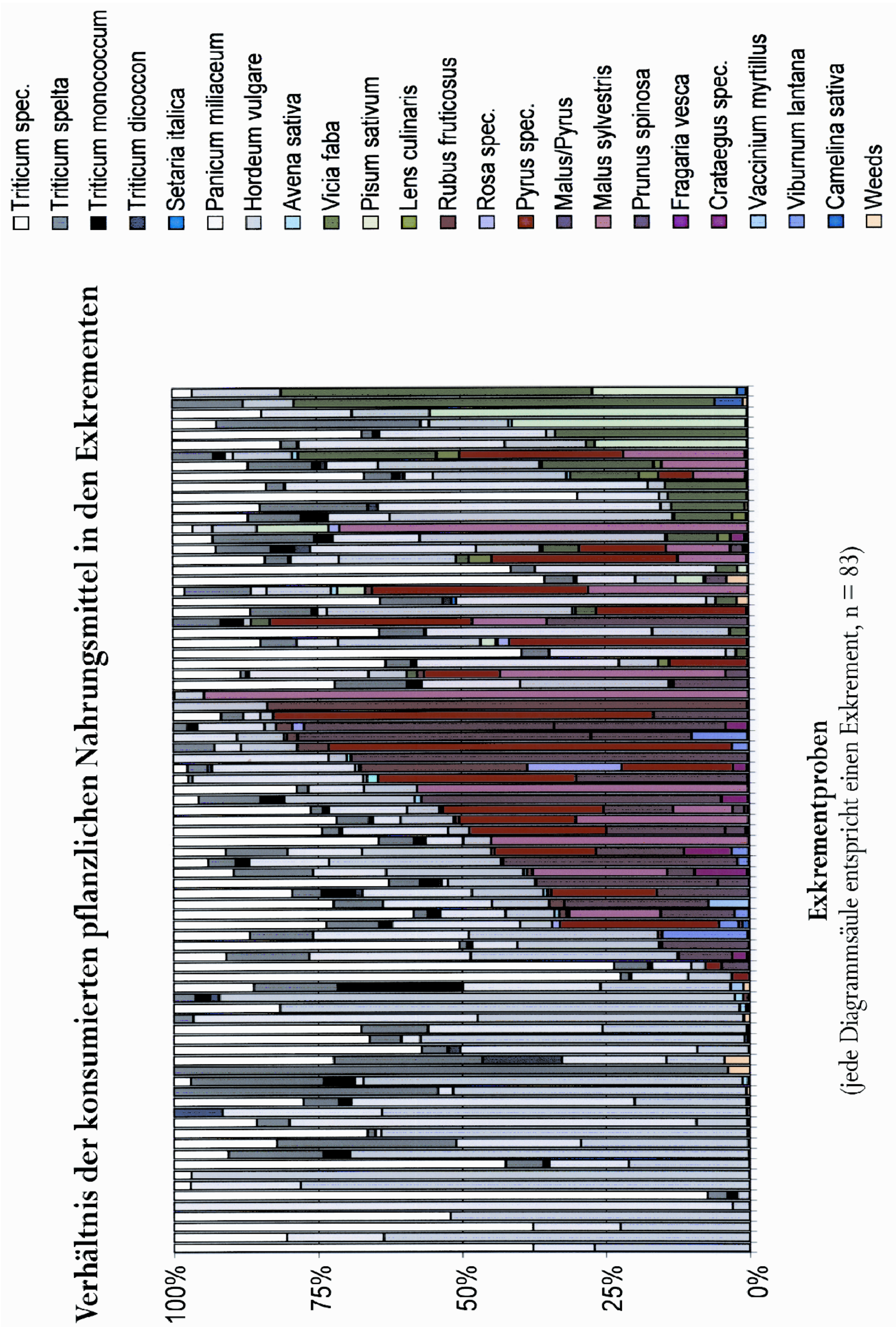

Fig. 11. Relation of plant consumption on basis of the composition in palaeofaeces. Grey: cereals, red: fruits, green: pulses).

When looking at the nutrition in general there is no doubt, that a well-balanced daily diet has been consumed by the miners: There even is a constant occurrence of meat fibres and small bones as well as (once) fish and bird remnants. Meat obviously was cut in small slices and served without bones as witnessed by the few occurrences in the mine in general (Stöllner et al. 2003, esp. 164−170). There are only a handful of pig bones, mainly ribs, and fragments of cattle bones, mainly remains of butchering such as legs and tales. In turn, this scanty faunal evidence does not match the level of meat consumption known from other evidence. Infestation circles of intestine worms such as *Dicrocoelium* or *Taenia* indicate a common consumption of insufficiently cooked cattle or pork meat and especially entrails like sheep liver. Moreover, the butchering techniques reveal a very advanced system perhaps resulting in the complete separation of bones and meat, techniques well known from the contemporary Mediterranean world. There is plenty of evidence for the consumption of spices and vegetables; some of them certainly used as remedies against painful worm diseases. The high quantities of fruits detected as kernels and fruit stones in the mine debris and in faeces indicate a well-balanced supply with vitamins.

Piecing these facts together, there is no need to sketch a picture of exhausted slaves. Of course they were capable workers and important for the flourishing economy at the Dürrnberg and it was important to sustain their physical power. Socioeconomic position and legal standing are linked but not necessarily congruent, so faecal analysis cannot prove what the miners' legal status was. Probably the miners participated in the Celtic client system (Dobesch 1996, 2002, see also Karl 2006). The relationship between chieftains and clients was one of interdependence: The miners' work guaranteed the growing prosperity of the settlement, and it is clear that political elites and/or traders profited from it. On the other hand, the miners being unable to produce their own food were provided with food and probably other goods as well. In a complex society, there probably are social positions between the upper and the lower end of the social scale.

Apart from the social interpretation of nutrition, the seasonal aspects of mining have to be considered. The macro-remains indicate three main compositions: solely cereals, cereals with fruits or cereals combined with pulses and sometimes also fruits. Certainly, there is no proof for seasonal food as they could also represent different dishes being prepared with dried or otherwise preserved ingredients. On the other hand, there is no argument against seasonal food composition and even the ambivalent pollen data do allow different views. It may be worthwhile further on, to consider the relation of economic and background pollen under seasonal aspects. If we exclude all pollen of species that could have been consumed we neglect the possibility of both the accumulation by consumption (by water or food) or by vegetation in general. This may be the case with *Filipendula* as well as with plants that can also be found in honey. If Artemisia really was used intentionally − certainly a fascinating hypothesis – this cannot in fact be proved statistically by correlating it with *Ascaris* and *Trichiura*-worm species. Therefore, the question remains unanswered, because there is reason to doubt on the other hand that *Artemisia* was taken in as background pollen all over the year contrary to the spectra of tree-pollen and herbs especially blossoming in early spring.

The consumption of fruits gives only poor evidence towards or against seasonal mining, because many of the eaten species could have been processed for storing and consumption at need (e.g. large amounts of blackberry or sloe). Although the latter starts getting delicious after the first frost in autumn or winter, rare finds of the mainly summer ripened strawberry could give a hint towards mining in summertime.

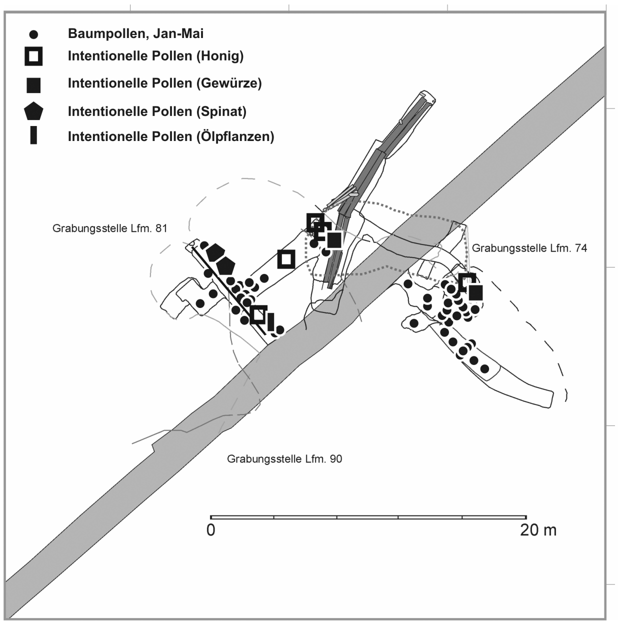

Fig. 12. *Pollen data of "intentionally" consumed and tree and herbal pollen and their dissemination in the "Heidengebirge" layers of the Ferro-Schachtricht site (excavations 1990−1999).*

Pollen-investigations on hairy animal furs and bark gave evidence of spring pollinating trees and herbs as well as summer blooming plants such as cereals (Groenman van Waateringe/Stöllner 2001). An activity all year round could be based, too, on the distributionof faeces in the rock-salt debris of the Ferro-Schachtricht site: Faeces containing most probably intentionally consumed pollen were found separated from those being dominated by pollen-spectra of January−May (Fig. 12).

A cautious interpretive approach is clearly necessary even if there is evidence for all year round mining. There is no more reason to assume that winter mining was technically necessary because of ventilation problems in summer, because there is evidence for air circulation favored by shafts on different levels. The matter, however, holds many questions and outstanding possibilities in store for further investigation and scientific approaches of the future.

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Abbildungsnachweis

Fig. 1: after Stöllner 2002a. – Fig. 2: after Stöllner.– Fig. 3: after Stöllner et al. 2003. – Fig. 4: after Aspöck/Oeggl/Stöllner. – Fig. 5: after H. Aspöck. – Fig. 6–9: after Kofler/Oeggl. – Fig. 10: after N. Boenke in: Stöllner et al. 2003. – Fig. 11: after Boenke 2005. – Fig. 12: after Stöllner.