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THE ECONOMY OF DÜRRNBERG-BEI-HALLEIN: AN IRON AGE SALT-MINING CENTRE IN THE AUSTRIAN ALPS

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For the first time in English, we present a summary of the international programme of excavation work carried out between 1990 and 2001 in and around the Iron Age salt-mining complex of the Dürrnberg region, south of Salzburg. First we describe the results of excavation in the prehistoric adits, and of work to locate and survey associated settlements. This is followed by a series of specialist reports embracing floral and faunal remains, palaeodiet and parasitology, leather and woodworking and other crafts. The evidence suggests that a complex inter-relationship existed between the Dürrnberg and other communities in the Alpine foreland. It is assumed that the Dürrnberg was under the control of an elite – perhaps a local dynasty whose wealth is reflected in the graves.

INTRODUCTION

The ancient salt-mining complex of the Dürrnberg is one of the most important archaeological sites of the European Iron Age. This fascinating site has long attracted scholars because of the outstanding survival of a range of archaeological material and flora and fauna, presenting a panoramic picture of the economic life of a complex society over a period of more than 500 years.[1]

Bad Dürrnberg is located near the small town of Hallein, situated south of Salzburg, in Austria. Geologically the region is part of the Northern Calcareous Alps. The Alpine salt deposits of the Dürrnberg (which have been the subject of new studies since 1996[2]) are mostly Permian in age and represent precipitates laid down in a marine basin surrounded by alluvial fans and mudflats in a rift arm of the north-west Tethys Ocean (see figs 1, 2 and 3). Arid conditions are necessary for the development of such evaporites.[3]

In parts, these salt layers were forced upwards as a result of Late Jurassic tectonic movements during the early formation of the Alpine anticlines.[4] As a result of this upward movement, Alpine salt deposits (known as *Haselgebirge*) now extend from the Tyrol in the west to the Viennese woods in the east. They consist of a mixture of 40 to 95 per cent sodium chloride (NaCl) together with clay and anhydrite or gypsum. The whole deposit is covered by a 20 to 40m layer of clay (basically leached-out Haselgebirge), which protects the salt deposits against further leaching by freshwater.

On top of these malleable and movable salt deposits, and causing an even tectonic pressure on the salt, there are a number of calcareous outcrops, of which the most prominent is the Hahnrainkopf (1,026m: see fig 4). At the foot of the Hahnrainkopf, salt dissolved by water emerges in the form of brine springs, and these offered the prehistoric settlers of the region a clear indication that salt deposits lay beneath the surface.[5]

Many such springs are known in the Northern Calcareous Alps, but only in the Alpine Haselgebirge does the geology allow the underground salt to be mined. The clay residues of the

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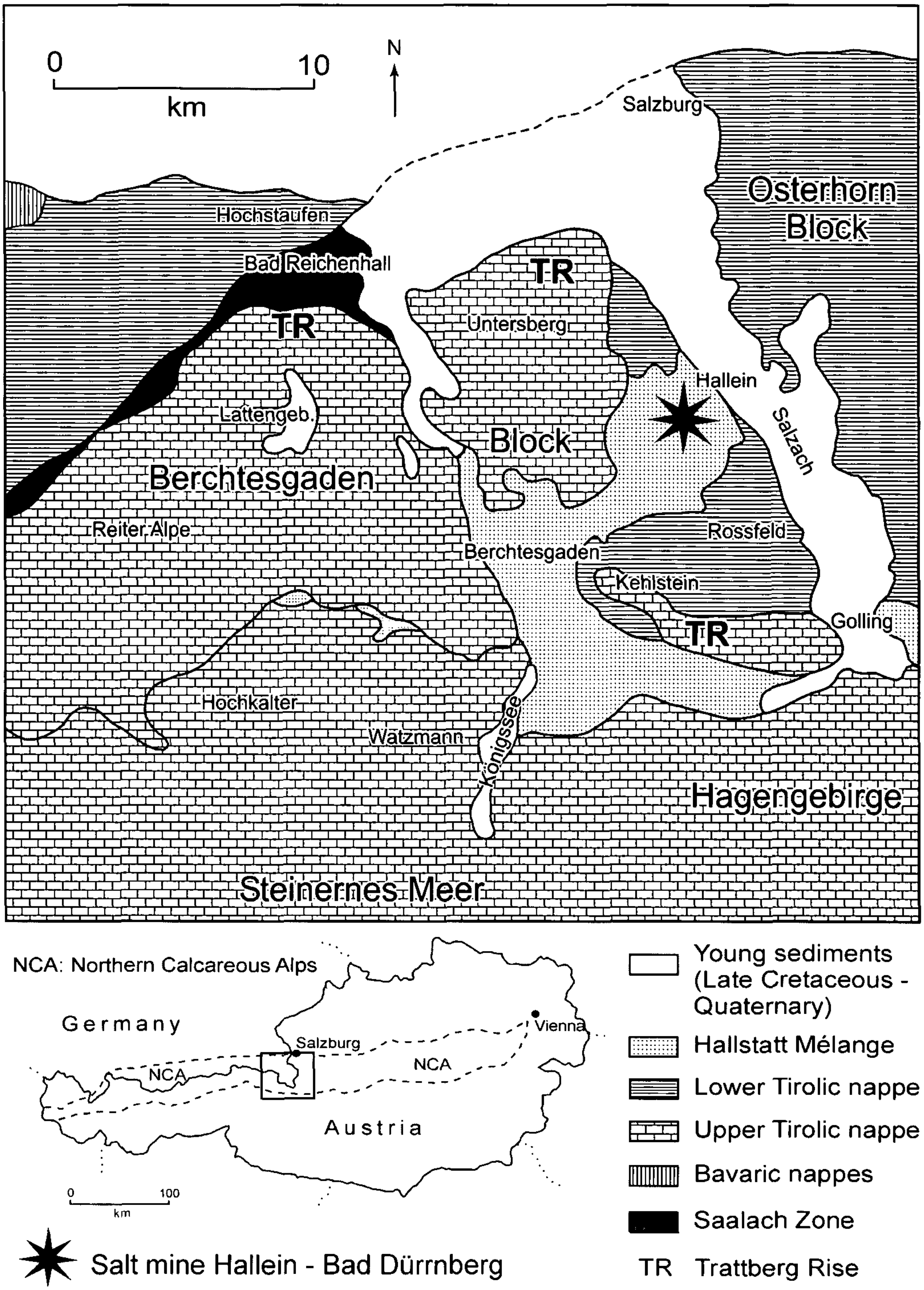

Fig 1. The geographical and tectonic position of the Hallein–Bad Dürrnberg salt mines (after Missoni *et al* 2001, Frisch and Gawlick 2001). *Drawing*: H-J Gawlick

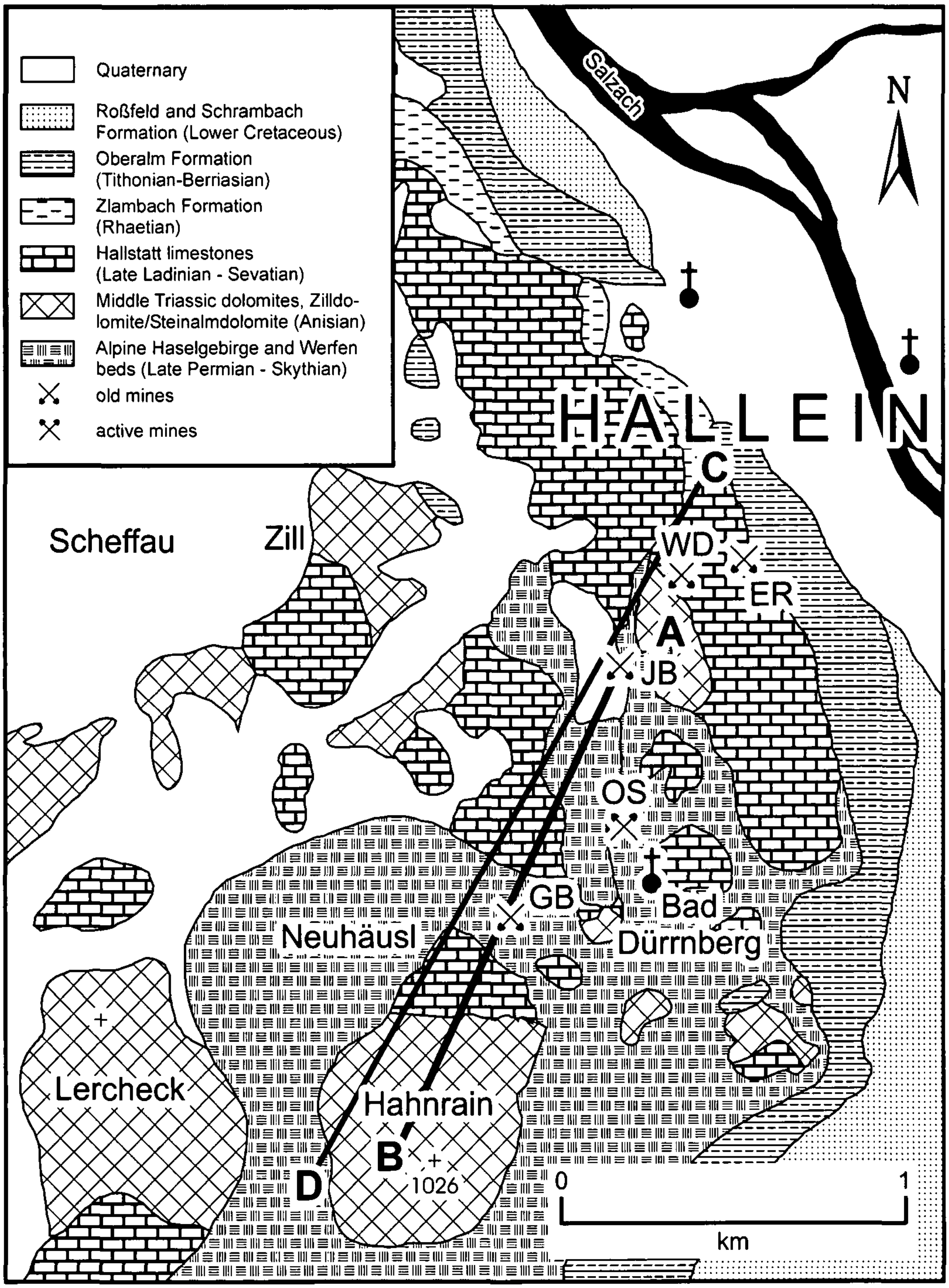

Fig 2. A simplified geological map of the Hallein–Hallstatt Zone in the area of Bad Dürrnberg. Cross-sections A–B: Jakobberg horizon (see fig 3a); C–D: Wolfdietrich horizon (see fig 3b); GB: Georgenberg horizon; OS: Obersteinberg horizon; JB: Jakobberg horizon; WD: Wolfdietrich horizon; ER: Egglriedel horizon (map after Pichler 1963, Plöchinger 1955, 1987 and 1996, and Pytel in Gawlick *et al* 1999a; stratigraphic data from Gawlick and Lein 1997 and 2000, and Gawlick *et al* 1999a). *Drawing*: H-J Gawlick

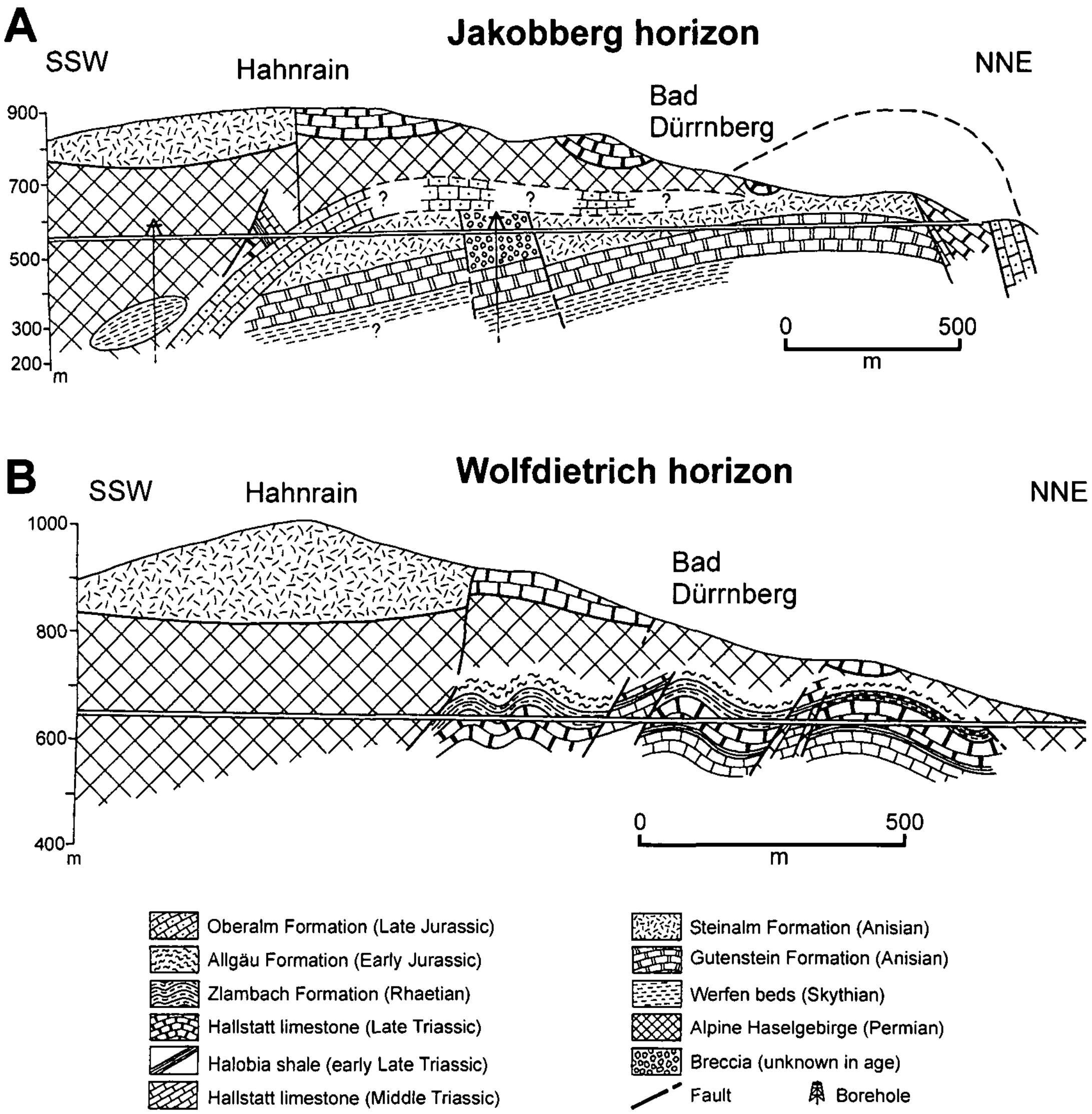

Fig 3. Cross-sections of the Hallein–Bad Dürrnberg salt mine (see fig 2). A: on the line of the Jakobberg horizon; B: the line of the Wolfdietrich horizon (after Gawlick and Lein 2000). *Drawing*: H-J Gawlick

Fig 4. The Hahnrainkopf peak, located above the salt deposits: a view from the west. Significant sites in the location are marked. *Photograph*: Bayerische Landesamt für Denkmalpflege, Archive-Nr 8344/005, SW 3453–12 (O Braasch)

Alpine Haselgebirge are easy to work by following first the fault line of the contact carbonates and then the actual salt layers themselves.

Mining activities have occurred in several periods. Despite stray finds suggesting local knowledge and usage of brine springs extending back to the Neolithic,[6] in Hallstatt below-ground archaeological finds confirm a Late Bronze Age date for the beginning of salt extraction. On the Dürrnberg there is no confirmed evidence for mining older than the sixth century BC. A second intensive stage of mining took place from the start of the twelfth century AD.[7]

Access to the salt deposits was achieved by cutting shafts diagonally down from the surface. The need to remove the considerable overburden lying above the salt deposits demanded the investment of a considerable period of time before the mines became economically viable. Against the background of what is known of ancient mining, it seems clear that the mining of rock salt required a fairly developed and stable political system, as well as technical know-how, and that it took place within powerful communities who were able to guarantee a permanent supply of food and raw materials.

Miners' skills must have been developed to a certain extent prior to the Iron Age. In the eastern Alps Bronze Age copper mining seems to offer a basis for the techniques later employed in salt mining. Indeed, rock salt extraction was developed in Hallstatt in the thirteenth and twelfth centuries BC, while copper mining continued as a successful enterprise contemporaneously in the Salzach Valley.[8]

The importance of the Dürrnberg rests on the unique wealth of its archaeology and the outstanding preservation of organic material. Yet, it cannot solve all the research problems of the European Iron Age. It is not, as Ludwig Pauli also suggested in his pioneering discussion of the site, some kind of a *deus ex machina*.[9] The very uniqueness of the Dürrnberg militates against using it as a general model. Even so, it was and still is an extraordinary test-bed for trying out various theoretical models for understanding Iron Age society and economic relations.

This was one of the main reasons for the initiation, in the 1990s, of a research programme based on a number of key, but so far largely unanswered, questions. What do the salt-mining activities represent in social and economic terms? Did the attendant settlement have a hierarchical society, with an élite whose wealth was based on exploitation of poorer and more dependent people, or was there some kind of broader-based pattern of wealth distribution within a society exploiting the salt for its own mutual profit? (CD, H-JG, RL, TS)

PREHISTORIC SALT MINING: DATA FROM BELOW AND ABOVE GROUND

One of the earliest records of research into the ancient salt mines of the Dürrnberg is found in Franz Dückher Haslau zu Winckl's *Salzburgische Chronika* of 1666,[10] where he records that two miners' bodies – popularly known as the *Männer im Salz*, the 'men in the salt' – were discovered in AD 1577 and 1616. These discoveries were directly linked to the mining activities of the time. Just as it was a mining official – the renowned J G Ramsauer – who was one of the first to realize the antiquity of Hallstatt, so it was another mining official – Andreas Seethaler – who was the first to offer an overview (in 1831–3) of the prehistoric sites in the Dürrnberg.[11] K K Berg and Forstrat A Miller, also a mining officer, tried to draw the attention of the museums in Linz and Salzburg to archaeological finds from the mines by sending them recently discovered artefacts. And in the course of the preparation of the 'Salinenkonvention' – a treaty between Austria and Bavaria drawn up in 1829 – systematic documentation of sites in the mines by mining surveyors was introduced for the first time.[12]

But despite a couple of attempts to establish regular archaeological investigation on the Dürrnberg, there was no systematic research to compare with the situation in Hallstatt. Not until the later nineteenth century did interest in the archaeological potential of the region revive, when local scientific societies started to look at the Dürrnberg again.[13] While prehistoric salt mining was widely acknowledged to have been very important for the welfare of the Iron Age communities of the Dürrnberg, regular research was not established within the mines until the cessation of commercial activities in 1989.

With the ending of modern salt production in 1989, old shafts in the ever-moving and malleable Alpine salt formations rapidly began to collapse and archaeologists had only a short time to study them. Research in the Eastern Alpine salt-mining complex had shown that the structures and galleries were likely to be so widespread and so complex that complete excavation would not be possible. As a result, it was recognized from the start that sampling would be necessary in order to allow a reconstruction of the whole.

In order to locate the ancient mining entrance areas, intensive surveying was carried out over a couple of years around the centrally positioned Hahnrainkopf. The immediate result was the realization that geomorphological and archaeological features could not be distinguished without detailed investigation. A combination of different methods proved to be the most successful, largely based on drilling and the geophysical examination of likely areas.[14] Contemporary Alpine pastoral economies do not normally provide good conditions for archaeological surveying, so drilling was used to gain more information about the soil history and such human-influenced features as settlement deposits, waste dumps resulting from mining activities, and erosion. The identification of waste dumps has proved highly effective in helping to locate old mining entrances. The stratigraphy of such dumps is immediately recognizable, and consists of a highly intermingled mix of topsoils and clays – the latter mainly of leached-out Haselgebirge mixed with mining waste, such as wood chips and other artefacts. It has been possible to understand the stratigraphical sequence of the mining dumps and their chronology by subjecting the waste wood they contain to Carbon-14 dating (see Sormaz below). As figure 5 shows, this intensive surface work has led to an understanding of the surface structures associated with mining processes, but there remain a number of unanswered questions with respect to the mining entrances (see further discussion below).

Mining archaeology in Austria is founded on a long research history, of which underground research has been always an important part. Because of the current situation in the Dürrnberg salt mines, only six ancient mining areas out of a total of seventy-four locations can still be reached and since 1990 in only three of them has it been possible to work intensively (fig 6).[15] The results of mining archaeology at Hallstatt made clear the need to learn something about the extensions of the different galleries in order to answer crucial questions about the scale of the exploitation of the salt mines as a whole, the time-span during which the mine was worked and the number of miners engaged on these projects.

What can currently be said is that – as with the Iron Age mines at Hallstatt – large mining chambers were progressively widened in the course of salt exploitation. Excavation in the Obersteinberg gallery between 1994 and 1999 (mining area A) has considerably advanced our ability to reconstruct the sequence of rock salt exploitation. The whole mine was destroyed by a mud avalanche sometime after the middle of the fourth century BC, an event that, fortunately for mining research, preserved parts of the old chambers from subsequent tectonic action. This allowed the clearing-out of the accumulated clay in order to reveal the original surface of the prehistoric walls, which in turn allowed the further identification of tool marks and other aspects of mining activities.

Most interesting were a couple of parallel steps running along the roof in the direction of the main extension of the shaft. These steps are in line with the main eastern wall of the shaft. Dendrochronological data and the general direction of work suggest that the excavation was located at the youngest end of the exploitation, which proceeded in an easterly direction.[16] Putting all these observations together, it can be deduced that a couple of miners with picks ('hewers') were working eastwards side by side – a systematic way of extracting large lumps of rock salt (fig 7).

According to old plans of the area, it is possible to get some idea of the general size of this working chamber, which must have reached some 120m in length and roughly 30m in width. The miners must have carried the salt lumps out, but how exactly this was effected cannot yet be ascertained. The mining technique observed on the Dürrnberg is closely comparable to that found in the Ostgruppe at Hallstatt, a mining area exploited between the eighth and the sixth/fifth centuries BC. This similarity of mining practice suggests that miners and the necessary technological know-how were brought from the older mines at Hallstatt to the new salt mines at the Dürrnberg in the sixth century BC. But at the younger mines of the Dürrnberg one can clearly see technical developments based on a knowledge and use of surveying techniques, and on an improved tool-kit using mainly iron implements.[17] The implements of the Dürrnberg miners consisted of handles and iron picks with distinctive right-angled wooden hafts, whetstones, and tools such as axes and adzes for woodworking (fig 8). These working

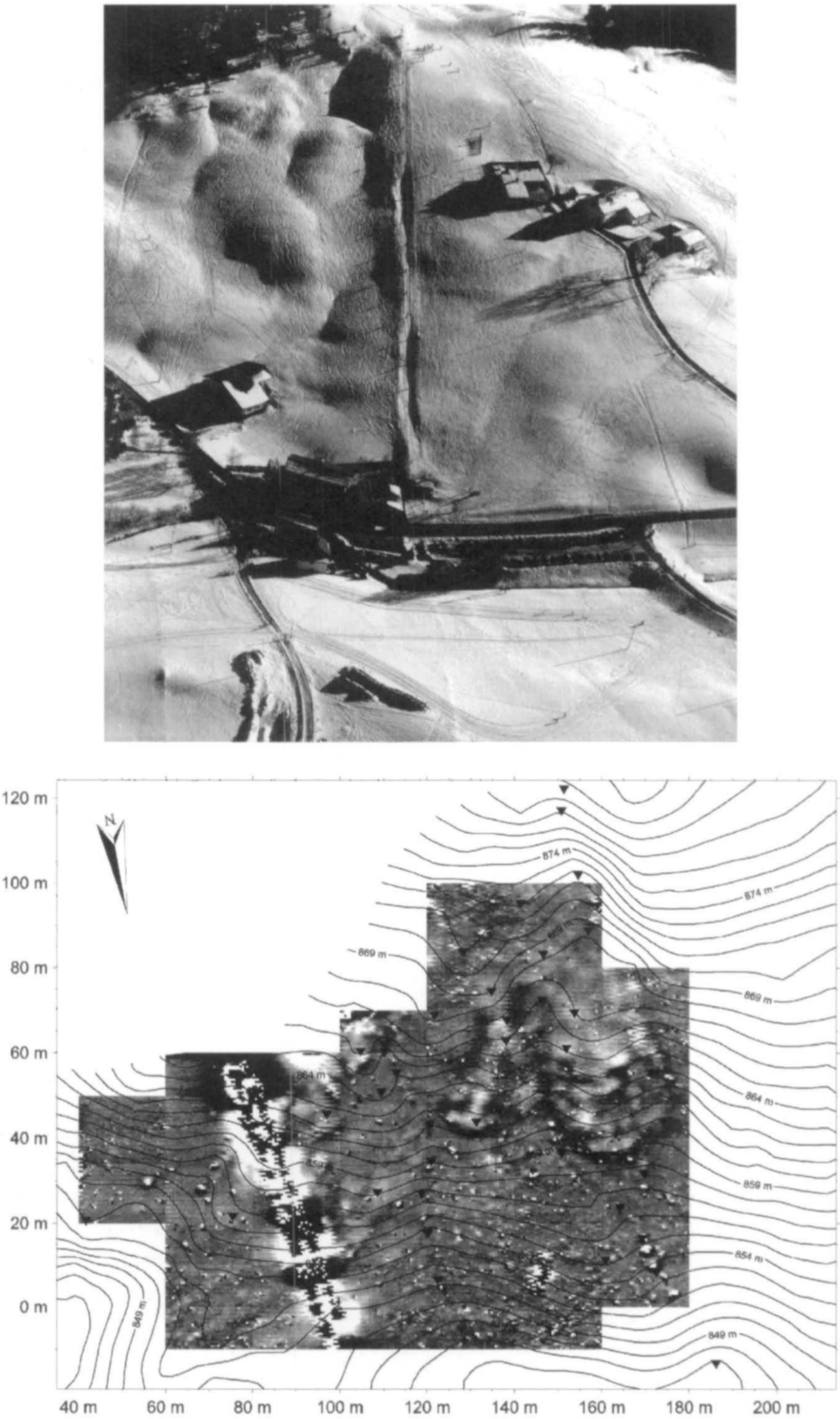

Fig 5. The north face of the Hahnrainkopf in winter, showing an entrance area with a massive tailing and a depression orientated north–south. *Photograph*: Bayerische Landesamt für Denkmalpflege Archive-Nr 8344/005; SW 4815–19a (O Braasch). The plot below shows the results of geophysical prospecting (by B Zickgraf, PZP Marburg/Frankfurt). *Source*: after B Zickgraf in Dobiat and Stöllner 1997

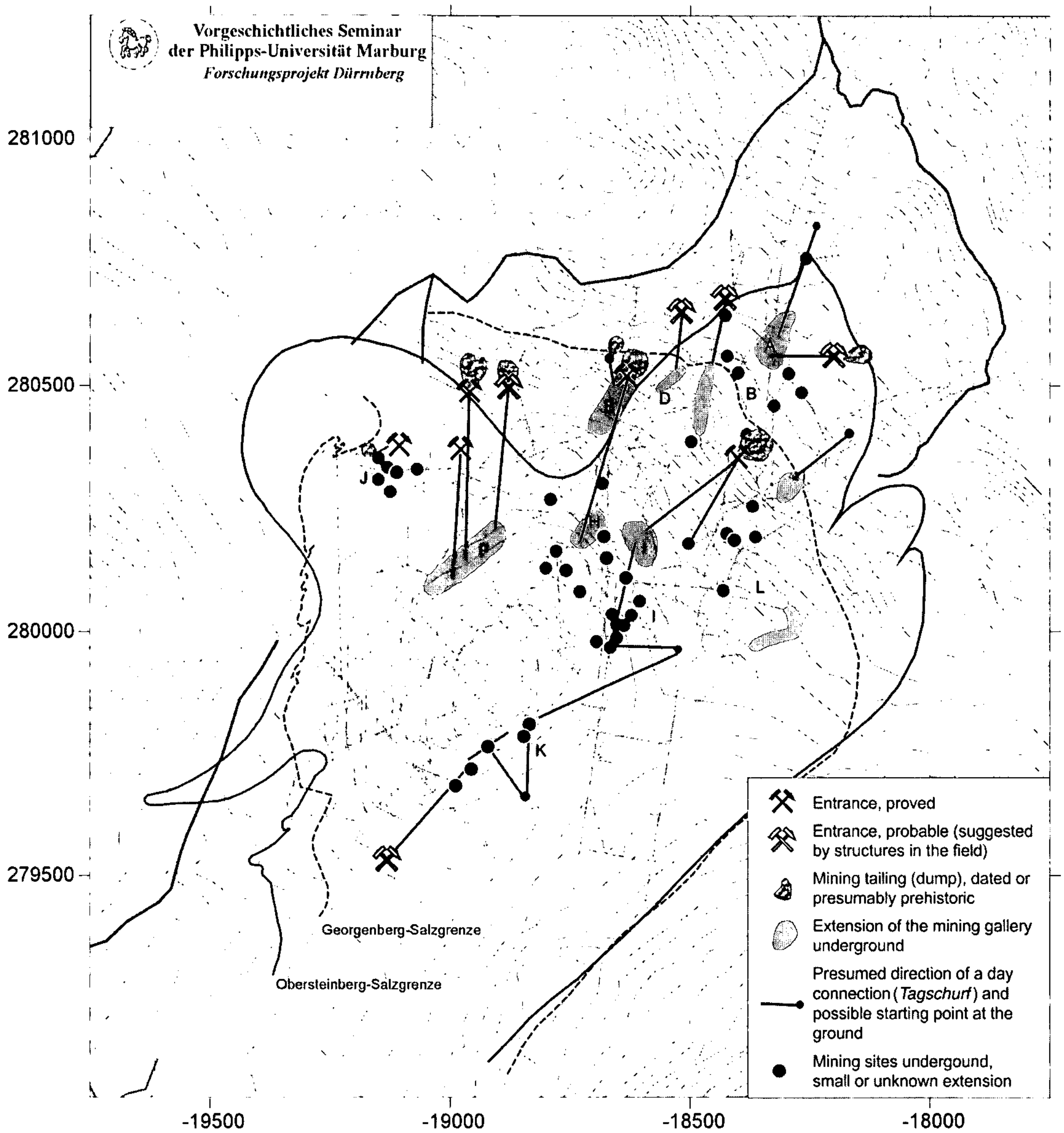

Fig 6. Prehistoric mining on the Dürrnberg. Interconnecting mine galleries (grey shading) and single sites (black dots) are located in relation to modern mines. Entrance areas are marked by a hammer and chisel (those securely dated in black; those not securely dated as open symbols). Tailings are indicated with grey stipple, and solid black lines represent the presumed direction of adits. *Scale*: grid intervals at 500m. *Drawing*: B Schroth and T Stöllner

Fig 7. The Obersteinberg (zone A): an early La Tène mine at the eastern end of the zone. Note the large lump of rock salt *in situ* in the roof. *Photograph*: T Stöllner

processes, and the implements used, provide evidence for workmen with distinct skills, such as hewers, haulers and carpenters.

The excavations in the Georgenberg mine (area E) have produced other important insights into the mining process and its development over time.[18] Here the ancient deposits have been cut through by modern mining, and it has been possible to gain some idea of how large prehistoric mining galleries were. In the case of the Georgenberg, the shafts were more than 30m in width, some 5m in height and around 100 to 150m in length (fig 9). The profile also shows how mining normally proceeded. It is clear that the ancient miners mined the lowest salt-rich Heidengebirge level first, which meant that their first task was to locate these layers. Mining progressed from the lower to higher levels with a resultant decline in the quantity and quality of salt extracted.

As with the Obersteinberg mine, the Georgenberg shafts were flooded by an inundation of mud and water. This presumably occurred co-terminously in the second half of the fourth century BC. According to a seventeenth-century source, one of the 'men in the salt' was found in the surroundings of the Georgenberg – perhaps this ancient miner died as a result of some such disaster.[19] Surprisingly, the mine was reopened again some seventy years later, presumably

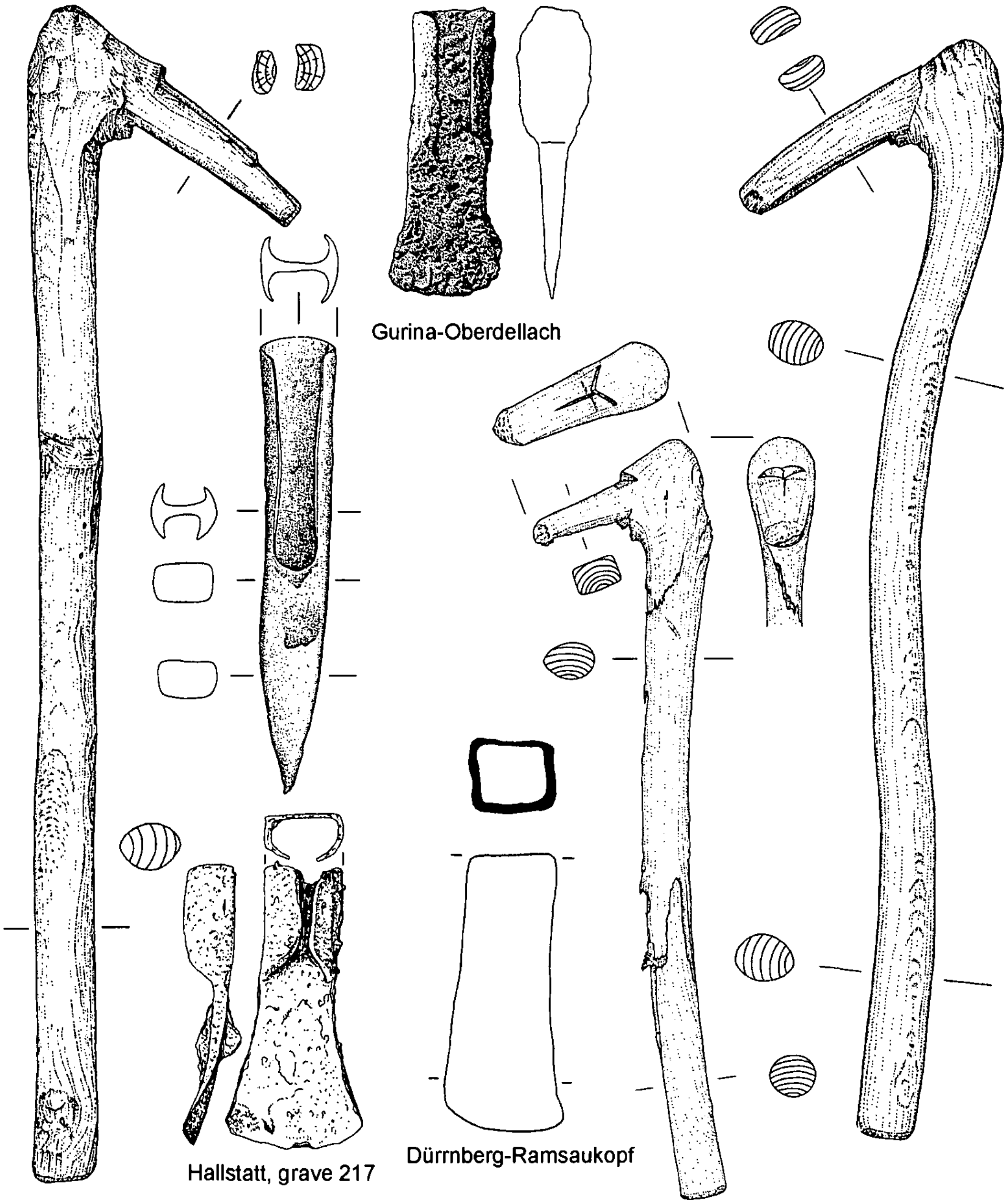

Fig 8. Tools of the Dürrnberg miners: iron-headed picks, axes (not from the mines) and adzes with beechwood handles (scale 1 : 3). *Drawings*: M Krause, Marburg; Gurina after E F Mayer; Hallstatt after K Kromer; Ramsaukopf after W Irlinger

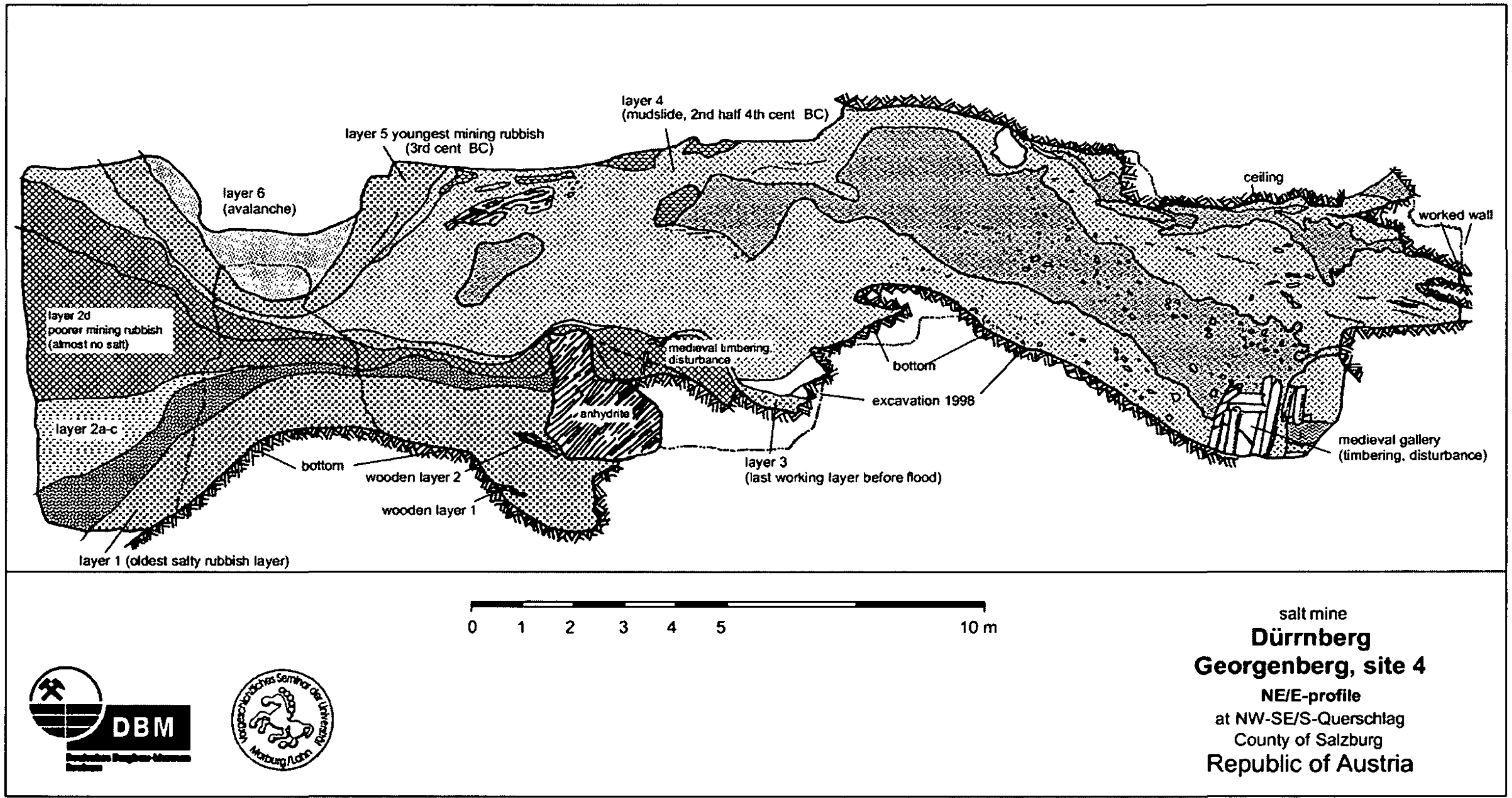

Fig 9. The Georgenberg: a generalized profile of site 4, a mine shaft in zone E (state of excavation in 2000). The profile shows the progress of mining in the fifth and fourth centuries BC; some time after 330 BC, the shaft was destroyed by a mudslide but it was later reopened in the middle La Tène period. *Drawing*: T Stöllner

in areas that had not been affected by the mine's flooding. This event seems to belong to a revival of salt mining in the middle La Tène period, when new mining areas were established and some old ones reworked.

In the Ferro-Schachtricht mine (area F) the new mining techniques used at Dürrnberg, as distinct from Hallstatt, can easily be understood.[20] Although the whole shaft has been deformed by subsequent tectonic movement to the degree that not one area retains its original form, it is possible to reconstruct the mine based on other parts of the Dürrnberg and even to estimate the approximate height of the individual chambers. A system of two overlying working galleries has been discovered, dating to within a range of 150 years during the fifth and fourth centuries BC. In some places these two galleries were interconnected to assist the hauling of mined material as well as air circulation.

Besides natural ventilation, there is evidence for artificial thermal ventilation resulting from the heating of the air by the lighting of fires, as well as by the thousands of wooden tapers that provided the main source of illumination below ground.

In both galleries the miners hacked out all of the rich rock salt deposits and nothing of the poorer salt-bearing clay layer between. This kind of efficient working can be followed over a considerable area more than 200m in length and some 25m wide. The miners seem never to have worked the less productive zones.

Surface survey has provided some additional clues concerning the shaft entrances. These include the identification of a main entrance (the local term is *Mundloch* – literally 'mouth hole'), with a huge attendant waste dump (fig 5). There is evidence for at least one more entrance at a point some 20m higher above sea level – a position high enough to support natural air circulation within the mine.

Taken together, stratigraphical observations and deductions about the extraction techniques used inside the mines suggest that systematic and regular work practices were employed, and that these were presumably dependent on large gangs of miners. This data has to be confirmed by quantitative estimates of the size of the groups working the mines. Two possibilities present themselves. Firstly, a series of dendrochronological dates indicates that all three of the mining areas discussed here were mined within a period of not more than 100 to 150 years in the fifth and fourth centuries BC (fig 10). Secondly, one can observe that there is three times the amount of human palaeofaeces per cubic metre of Heidengebirge in the Dürrnberg mines in the early La Tène phase than there is at Hallstatt in the seventh century BC (fig 11). An interim conclusion is that more workers extracted more salt in a shorter time at Dürrnberg than at Hallstatt, but that individually each of the Dürrnberg workers worked less productively when compared with their colleagues in Hallstatt.

One can estimate that some twenty miners would have been needed in the Ferro-Schachtricht shaft to do the actual extraction work. In addition to those working at the rock face, one might calculate that in a mine the size of Ferro-Schachtricht, there would have been groups of fifty to a hundred men working, including haulers, carpenters and those attending to the tapers. In addition to the skills required for work in the mines, a full-time class of craftworkers, as well as labourers and unskilled workers, must be assumed. Extrapolating from this, the total number of miners on the Dürrnberg site would have been around 200.

Two other facts support this proposition. Firstly, analysis of the miners' palaeofaeces gives information about the specific plants that formed the ingredients of the miners' daily meals and are indicative of a seasonal-influenced diet, showing that mining was a permanent, year-long occupation. This runs counter to earlier ideas of mining being a seasonal activity. There is also the fact that 98 per cent of the mining population was infected with parasites – that is more

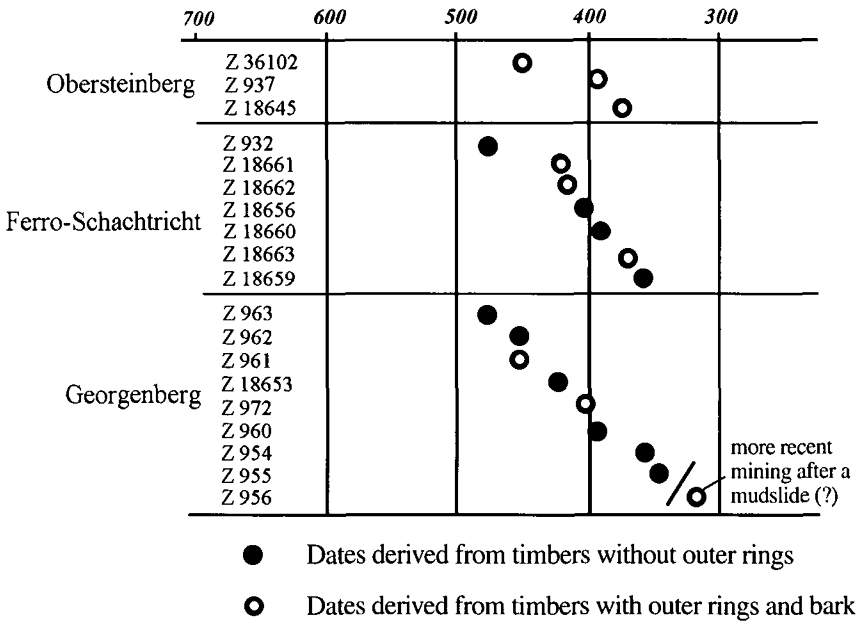

Fig 10. Prehistoric mines dated by dendrochronology

	Average quantity of excrement in 1 m³ (g)	Without latrine (g)	Total weight (g)	Latrine (g)	Sieving quantity (m³ of 'pagan rock')
Hallstatt-Kernverwässerungswerk, eighth–seventh century BC (collected by sieving)	15.93	7.41	1,434	767	90
Georgenberg, fifth–fourth century BC (collected by sieving)	267.04	70.8	1,337.03	983	5
Ferro-Schachtricht, fifth–fourth century BC (collected by sieving)	48.6		1,885.74		38.8
Ferro-Schachtricht, total (different methods of sieving and collection)	34.3		4,335.51		85

Fig 11. The amount of palaeofaeces ('pagan rock') found in the mines of Hallstatt and Dürrnberg (seventh–fourth centuries BC) based on information available up to 1999

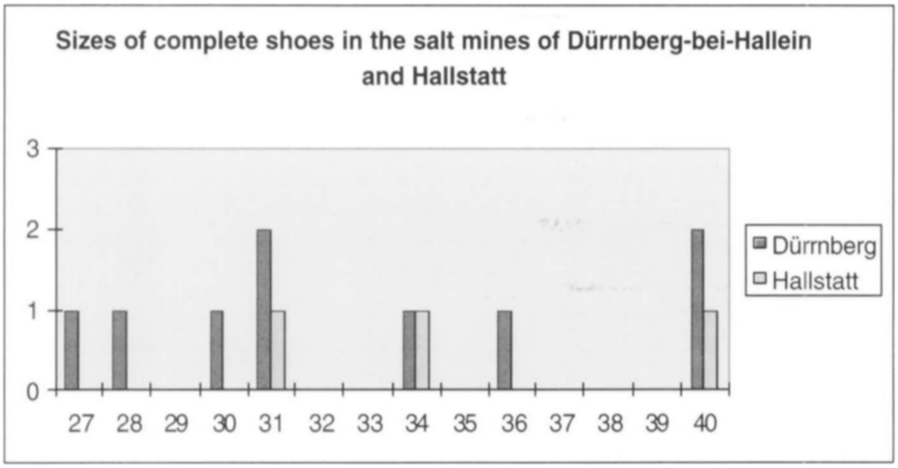

Fig 12. Sizes of all known shoes from the Austrian salt mines. Sizes between 27 and 31 are likely to represent those belonging to children

than in Hallstatt, and the high percentage is typical for large working groups living and working in unhygienic conditions.

Examination of the shoes found in the mines provides a possible explanation for the seemingly inefficient work pattern. Around 50 per cent belong to children under ten years of age (fig 12), showing that the employment of children in mines has a long history.

This permanent group of mining workers had to be provided with food all year round. To feed 200 workers with an average ration of meat it would have been necessary to butcher one of the 'Dürrnberg cattle', of the type known from excavations on the Ramsautal (with an average weight of 300kg) each day. As has been observed by examination of animal bones in the mines, consumption of large joints of meat was unusual. On the contrary, it was much more common for smaller cuts to be boiled and eaten as a stew (see Boenke; Pucher and Stöllner below).

What has been learnt of the mines so far is that there was an almost industrialized mining system supported by a professional group of miners – including children and, perhaps, women. This picture contrasts with that proposed by L Pauli, who tried to explain salt mining on the Dürrnberg in terms of models based on medieval evidence in which the miner is represented as a wealthy and much sought-after specialist.[21] Over the timescale with which we are concerned, it is clear that the mines, and thus the whole salt production industry, were highly successful, especially in the early La Tène period. (TS)

SALT-MINING DUMPS AS ARCHIVES FOR ECONOMIC PROCESSES

In addition to an extensive surveying programme above the ground, excavation was undertaken in some of the most promising areas. The main goal of this subsidiary programme was to obtain detailed information about the different working processes that must have been carried out in the vicinity of the prehistoric entrances.[22] One process most likely to have taken place here was the preparation of the rock salt hauled up from the salt mines. Other processes may be assumed, such as the butchery known from Hallstatt in the late Bronze Age.[23] In the light of the specialized cattle processing that has been observed in the Ramsautal, one can also imagine similar processes at, or near, the mine entrances and the related waste dumps. Previous to the current research project only one entrance had been investigated, though never fully published. In 1936, F Morton, during his excavation of the La Tène settlement at the Dammwiese in the Hallstatt mining complex, discovered a complete La Tène period *Tagschurf* (literally 'day entrance'). This was associated with mining operations in the so-called Westgruppe.[24]

On the Dürrnberg, our field surveys have located Iron Age entrance areas distributed around the Hahnrainkopf, especially on its north-eastern and eastern slopes (fig 6). Some of these areas are readily visible, with their massive dumps and depressions behind. One of the main problems, however, is dating. There are no surface scatters of artefacts because the local pastoral economy involves the continuous clearing of surface levels. As a result, stratigraphic sequencing is based on the radiocarbon dating of organic material recovered in the course of systematic boring of the area. Fragments of wood, notably from the ubiquitous tapers used to light the mine galleries, have provided reliable dating material.

The best indications for a well-preserved entrance were obtained close to the Dürrnberg playing field (*Sportplatz*). In 1998 and 1999 excavation was undertaken of this suspected mine entrance and of the main tailings nearby. While at the beginning of the excavation no absolute dating was available, the mine's possible medieval origins should cause no surprise, since neither the prior survey nor the subsequent excavation yielded any contrary evidence. Notwithstanding, the site represents the first modern archaeological examination of a salt mine adit. The timber construction of the entrance was surprisingly well preserved, with its regular pattern of side and cross-beams held together by mortice-and-tenon joints (fig 13).[25] These timbers were eventually dated by dendrochronology to AD 1248–50. Some younger dates indicate that the whole complex was slowly filled in from the 1270s.

Since other entrances have been in more or less continuous use into modern times, this short-lived entrance was a lucky find as it has provided new insights into thirteenth-century working processes. It furthermore allows an interesting comparison with prehistoric entrances. Small finds consisted mostly of shavings and other off-cuts from construction work. There was a marked lack of wooden spills or tapers both in the tailings and in the filling of the adit, although they are a common feature of prehistoric dumps and entrance areas. Similar observations have been made at other medieval tailings, such as the dump of the Raitenhaslach adit in the south-eastern part of the mining complex. This seems to indicate that other sources of light must have been used, such as the *Unschlitt* – or tallow – lamps, well known from a number of historic mining sites.[26]

In 1999 and 2000 further soundings were carried out of two prehistoric dumps in the western and central parts of the salt-mining complex. At the Brandner-Lehen, surveying work has produced evidence for a prehistoric mine entrance. Although house building has considerably altered the area, a couple of tailings were recognizable. Drilling cores have provided additional evidence of sediments typical of the Iron Age. Near the prehistoric dump, some very well-preserved tailings with a very poor representation of waste wood are presumably of medieval and/or recent date.

A cutting through the prehistoric dump measuring 10m in length and 3m in depth has provided secure insights into the stratigraphy for the first time (fig 14). Above the ancient land surface, mainly a brownish moraine clay, a sequence of some seven layers was detected. These mostly contained mixed greyish-blue Haselgebirge. Charcoal layers interspersed with moraine gravel suggest a more complex periodization of these tailings, including a reworking of the entrance area or of the actual adit. There may also have been a local fire.

Fig 13. Dürrnberg-Sportplatz: the entrance or *Mundloch* running north–south with fully preserved timbering. In the foreground is the small entrance hut and an access way paved with pebbles. Towards the rear, the timbering of the adit uses the *Mann-am-Mann* technique, with cross-beams at top and bottom as well as side supports fixed by mortice-and-tenon joints. *Photograph*: T Stöllner

The chronology of the entrance was fixed by a couple of wheel-turned fragments of graphite ware dating to the fourth or third century BC. This fits well with the Carbon-14 dates from archaeological sites below ground, and thus suggests a connection with the so-called Western Schauberger Group (zone J). Unfortunately it has not been possible to investigate the actual entrance, which probably lies in a depression behind the mine tailings and which, unfortunately, has recently been filled with building waste. The western group of mines (Westgruppe) belongs to minor activities on the fringes of the Dürrnberg. These activities belong to a period when new mining projects were recommenced after a couple of mudslides in the fourth century BC had destroyed some of the larger mining areas.

It is conceivable that other areas survived these phases of destruction and may have been exploited more or less continuously. Based on the below-ground research, the traces of prehistoric mining in the so-called Werk Platz (zone H) could be among the most promising pieces of evidence in favour of a continuous sequence. To date there is evidence for a late Hallstatt to early La Tène phase and a second phase in the middle to late La Tène period. As it is no longer possible to reach the underground working areas, the surface tailings are the only way to answer these questions.

Fig 14. Oberau-Brandnerlehen: this section from the 1999 excavations gives a good overview of the tailings of the early to middle La Tène dump, which are related to the western group (zone J) of the prehistoric salt-mine complex. *Photograph*: T Stöllner

It was very rewarding, therefore, to be able to excavate the Hallersbichl site, a massive dump near the central settlement area. This looks to be a prime contender for the entrance to this particular underground area (fig 15). In the rear part of the tailings there is a considerable depression, presumably representing the entrance itself. Initial geophysical and geological survey work and analyses of core sampling took place in 1998, and further soundings were carried out in 2000 to determine the area's chronology.

Because of the depth and instability of the mine waste it was not possible to reach the natural soil in the central parts of our trench. Contrary to investigations in other tailings, the complex and confused sequence of layers was striking: topsoil and vegetation were mixed with a greyish-blue, leached-out Haselgebirge, while hill-wash was mixed with rubble and a number of wooden tapers. The special structure of the strata may be due to the location of the excavation trench near the edge of the dump where it may be expected that small quantities of waste material would have been dumped one on top of the other. A most interesting feature was a ditch near the dump edge that was dug into the natural moraine gravel and was later filled with waste material. There is so far no convincing interpretation for this ditch, but notwithstanding the compact moraine gravel, the digging of the ditch seems to have formed a border to the dump.

A number of archaeological artefacts were recovered (fig 16). Some were clearly related to the salt-mining processes and included the wooden handles of mining picks, tapers, whetstones

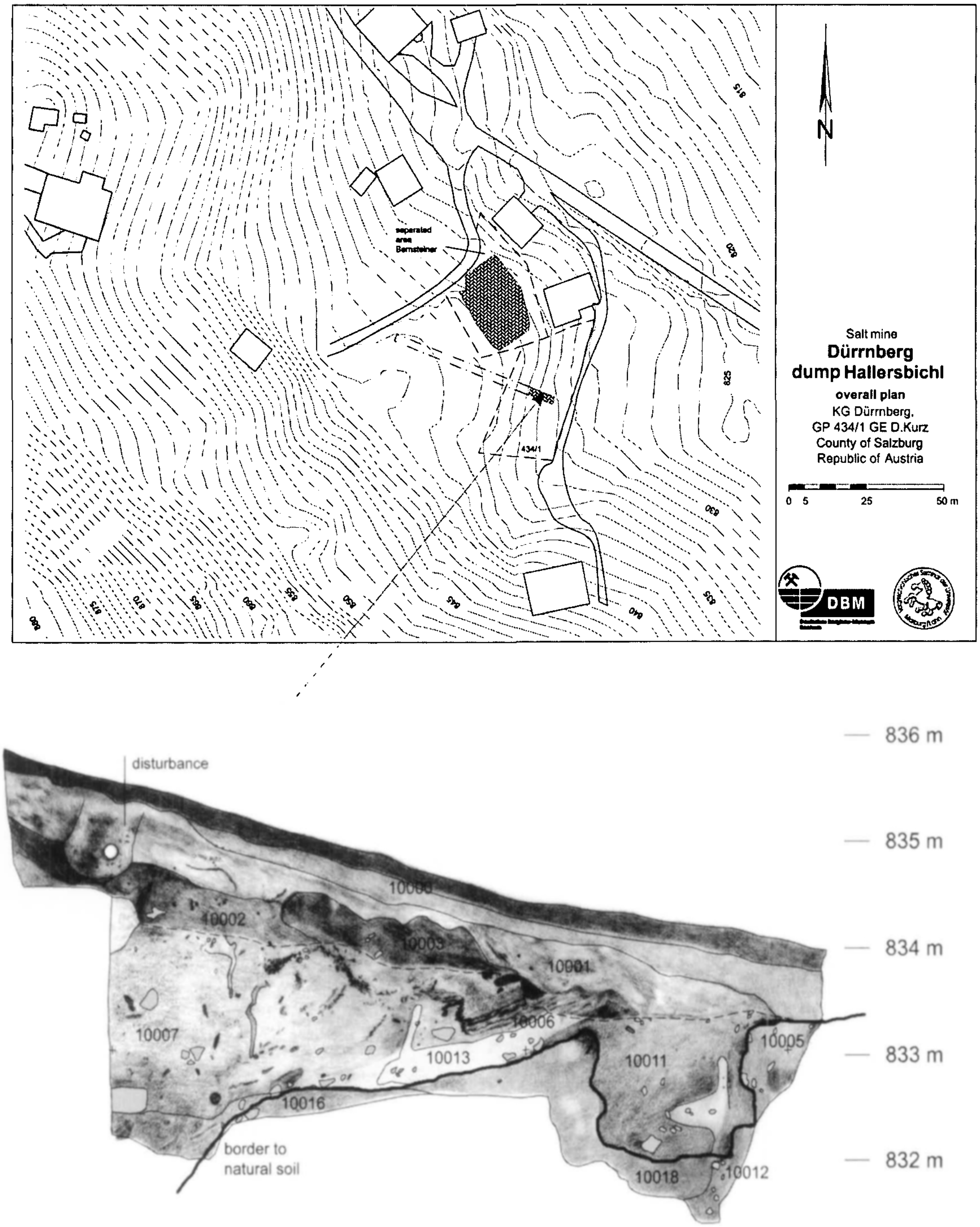

Fig 15. Map of the Hallersbichl area, with the prehistoric dump and the section dug in 2000. *Drawing*: G Steffens (survey by T Stöllner and A Friedrich)

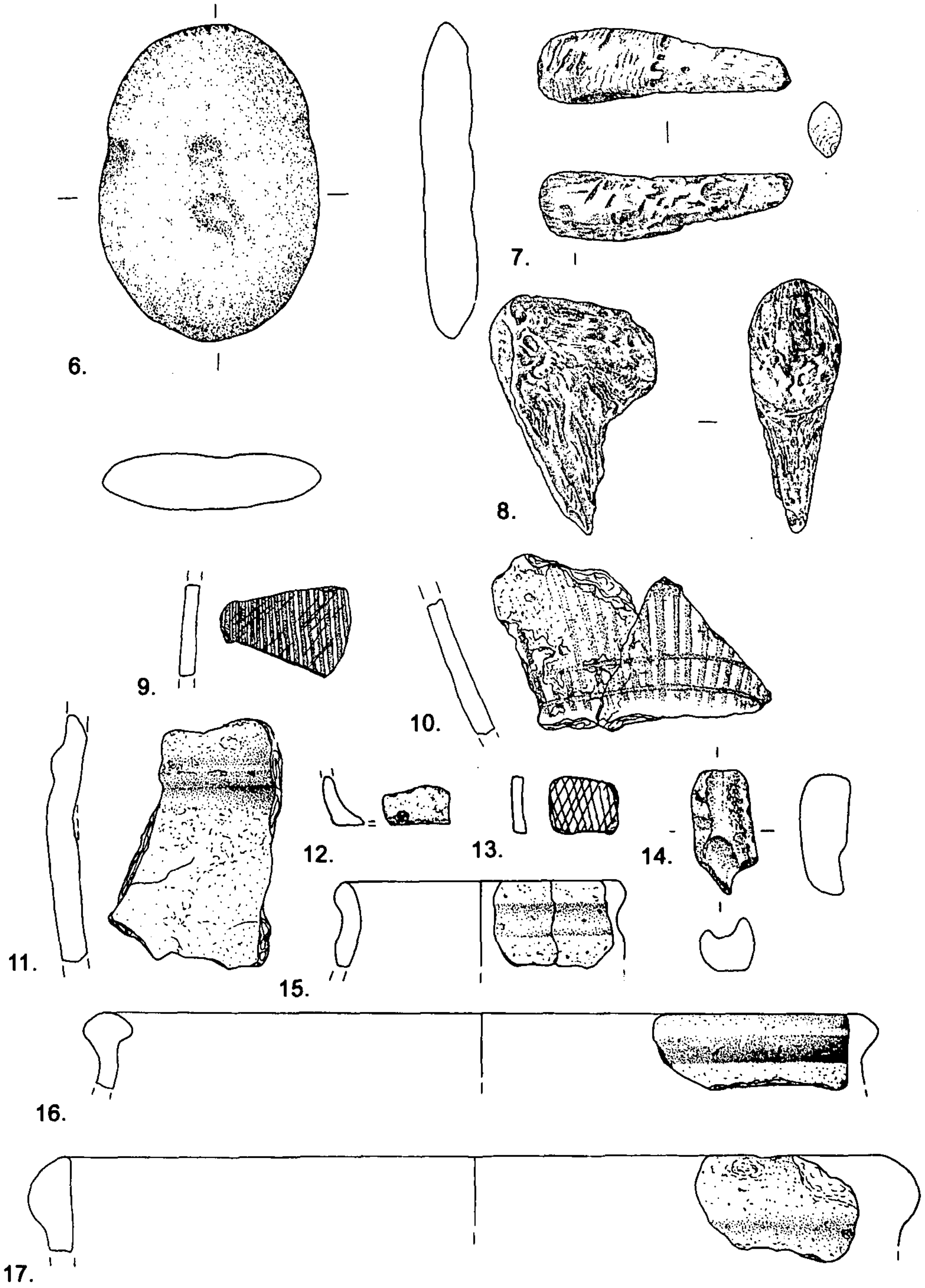

Fig 16. Pottery, whetstone (6) and wooden artefacts (7–8) from Hallersbichl (excavations of 2000). Scale 1 : 2. *Drawings*: D Miles-Williams and J Garner

and discarded planks formerly used as timbers in the mine. Marks caused by natural pressure from the overlying strata are unambiguous evidence for their use within the mine. Pottery and Carbon-14 dates confirm a chronological position for the area between the early and middle La Tène periods.

Similar chronological results were also provided by a rescue excavation carried out by the Österreichisches Forschungszentrum Dürrnberg in the autumn of 2000, during which two late Hallstatt graves were discovered in the upper strata of the tailings a little way from our trench, both with excellently preserved organic material, including wooden burial chambers. This means that parts of the mining waste material should date back to the sixth century and thus the late Hallstatt period.[27] The discovery of two graves in the waste sediments is certainly somewhat surprising; but other graves previously detected make it clear that the dump and its surroundings were used as a burial ground, especially in the late Hallstatt period. That those who had been buried belonged to a special social group cannot be excluded at the moment, and there are some remarkable differences and particular features when compared with other Dürrnberg graves.[28]

Other features of this rescue excavation, including a possible working platform, are raising further questions as to the precise significance of this area. Generally it seems to reflect a complex mining history between at least the sixth to the third century BC. Thus, the Hallersbichl dump has the potential to answer many questions, including the periodicity of the central area of the Dürrnberg mines – and not least questions concerning the start of the development of the salt-mining process, which is currently placed in the sixth century only as the result of what we know of the area's settlement history. (VM, GM, TS)

DENDROCHRONOLOGICAL AND CARBON-14 DATING

Wooden material has been found in the course of excavations carried out at Hallstatt and Dürrnberg since the first half of the nineteenth century (fig 17). Previous publications have identified different wood species.[29] In 1974 E Hollstein analysed four samples using dendrochronology for the first time.[30] Twenty years later, following an invitation from F E Barth (then based at the Naturhistorisches Museum, Vienna, and engaged in a long-term project investigating the ancient mine shafts at Hallstatt), it became possible to investigate forty samples in Hallstatt and Vienna using a digital camera and an endoscope, a method of tree ring measuring first applied to a Romanesque wooden ceiling in the church of Zillis, in the Swiss canton of Graubünden.[31]

These investigations were continued in 1994 as a project of the Swiss National Foundation (Schweizerischer Nationalfonds).[32] Altogether, 110 samples were measured from the salt mines at Hallstatt, complemented by a further 70 samples that had remained in store in the Rheinisches Landesmuseum in Trier.[33] Further investigations, including samples from the Dürrnberg salt mines, were carried out at the invitation of T Stöllner as part of the Dürrnberg project. Finance in 1995–2000 was provided mainly through the Raphael Program and the German Research Council (DFG).[34]

The main goal was to work out a general chronology for Upper Austria and the Salzburg region in order to provide a broader framework for the dating of archaeological features of the eastern Alpine salt-mining complex. In addition, some more recent wood samples were measured, namely two Norway spruce (*Picea abies*) felled in 1989–90 and eighteenth-century timbers used in house construction at Hallstatt.[35]

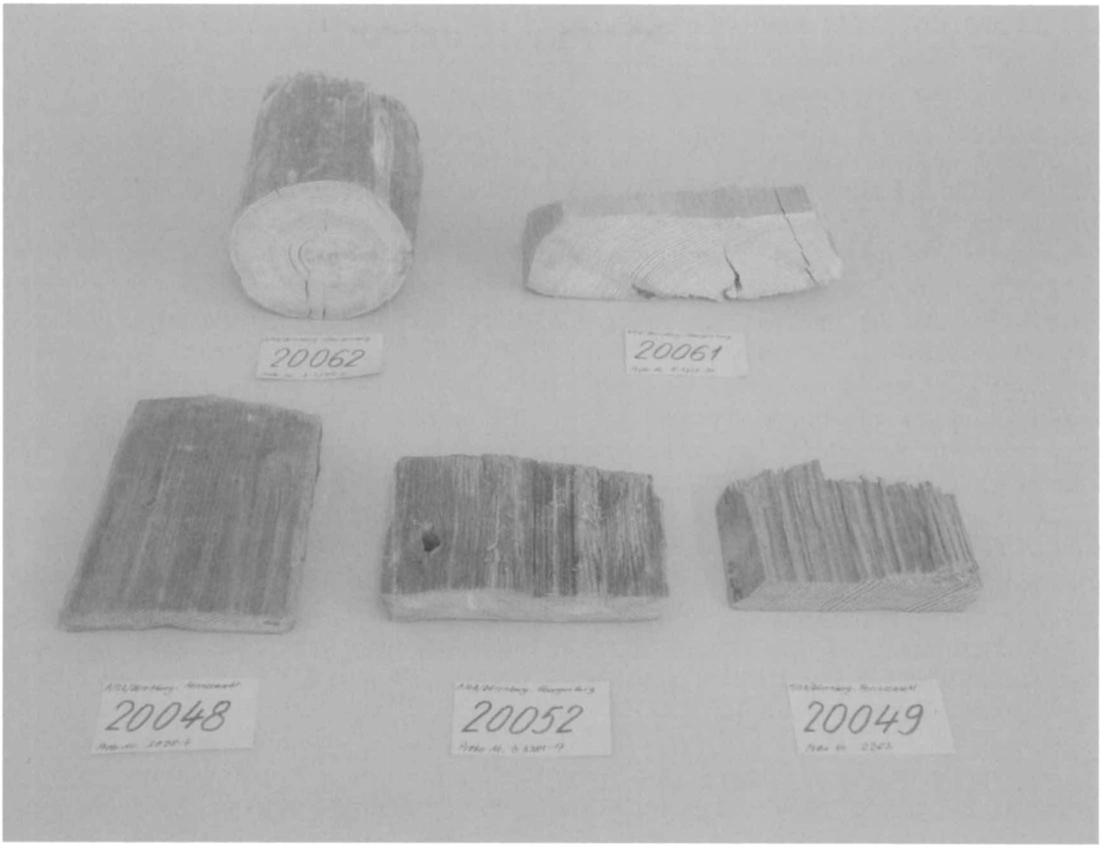

Fig 17. Various wood samples from the Dürrnberg salt mines. The tree rings are clearly recognizable. Sample 20061 shows the original outer bark (to the left) and dates to the year AD 1501. *Photograph*: T Oertle

As a result of this work, two comparatively long mean curves have been correlated, one for the Urnfield period and early Hallstatt period (based on samples from Hallstatt), and the other for the early and middle La Tène periods (Dürrnberg samples) and the late La Tène period (Hallstatt-Dammwiese samples). In addition, a more or less closed mean curve has been constructed comprising the time between the thirteenth and the twentieth centuries AD. Carbon-14 measurements of samples from sealed contexts have also been used to provide fixed dendrochronological dates. The greater part of the Carbon-14 estimates cited here were obtained by AMS (accelerator mass spectrometry) and undertaken by the Institute of Particle Physics at Zurich's Eidgenössische Technische Hochschule.[36]

Amongst the timbers examined, the high proportion of poorly ringed trees means that trees were felled and used early in their life cycle – a clear sign of intensively used forests with a minimum of older trees. Over 80 per cent of the analysed samples exhibit autumn and winter outer rings, meaning that most of the trees were cut in winter. Pollen analysis suggests that most of the wood was derived from the immediate surroundings, a typical mountainous *Fagus-Abies-Picea* zone. Conifers such as spruce (*Picea abies*), fir (*Abies alba*), larch (*Larix*) and pine (*Pinus*) are dominant. The deciduous species used for timbering in the mine, such as beech

(*Fagus*) and ash (*Fraxinus*), are much rarer. More detailed analysis of timber used in the settlements and in the mines has been undertaken by Boenke (forthcoming) and Oberhuber (1994). Their work, which has included sampling off-cuts as well as timber used for special purposes, shows a broader variation than that reported here.

In addition to a range of dates from the eastern and northern mine groups of the Hallstatt complex,[37] further samples have been analysed as part of the Raphael-sponsored project. Unlike most of the samples from the salt mine, this work has included two planks with plenty of tree rings. These planks form part of the permanent exhibition at the local museum in Hallstatt, and they were excavated at the La Tène settlement at the Dammwiese in Hallstatt. They were measured, correlated with each other and (without difficulty) fitted into a mean curve of 252 years' duration, with an unambiguous dating in the last quarter of the second century BC.

To the dates already published for the Dürrnberg,[38] further samples from below- and above-ground excavation (including the Iron Age mining dump and the medieval mining entrance) have been subjected to extensive Carbon-14 dating, and these dates have been correlated with the dendrochronological curve. There is now a master curve from the thirteenth century AD up to modern times, and this has allowed the dating of a couple of medieval and younger mining complexes between the thirteenth and the seventeenth centuries. As for timbers of Iron Age date, the database now extends from the beginning of the fifth to the end of the third century BC, including almost twenty dates for the ancient mine shafts of the Obersteinberg, Georgenberg and the Ferro-Schachtricht. Other complexes have also been dated, including the wooden chamber of a La Tène B grave from the cemetery on the Römersteig, excavated in the early 1980s.

Summing up, investigations to date have laid solid foundations for the construction of a local tree ring calendar extending back to the beginning of the first millennium BC. It is clear that a considerable number of further systematic analyses will be necessary in order to complete an unbroken local standard chronology based on fir (*Abies alba*) and thus to provide an absolute history of both the Hallstatt and Dürrnberg salt-mine complexes. At present, a couple of smaller mean curves have been established, and continuing research has already reached some important provisional results. (Tr So)

ORGANIC RESOURCES: FOOD SUPPLY AND RAW MATERIALS

Besides stable cultural and political structures, the availability of resources is essential for the organization of a complex project such as the mining of rock salt. In this context the analysis of botanical plant material plays an important role, because, in contrast to later societies, prehistoric people were much more dependent on organic materials and their natural occurrence. The archaeobotanical analysis[39] of findings from the mine is principally concerned with wood (timber and tools) and human faeces (miners' diet, plant cultivation and trade). Both are in an excellent state of preservation due to their being embedded in salt.

In order to interpret the data from the mine it must be stated that practically nothing got into the mine by chance (fig 18) – indeed, everything found there had served a specific purpose. On the other hand, evidence of the surrounding vegetation is missing, contrary to what one might expect in open settlements. So the documented seeds and fruits or trees mainly represent the location of the origin of food and other raw materials and only secondarily can one draw conclusions about the general environment of the Dürrnberg as a whole.

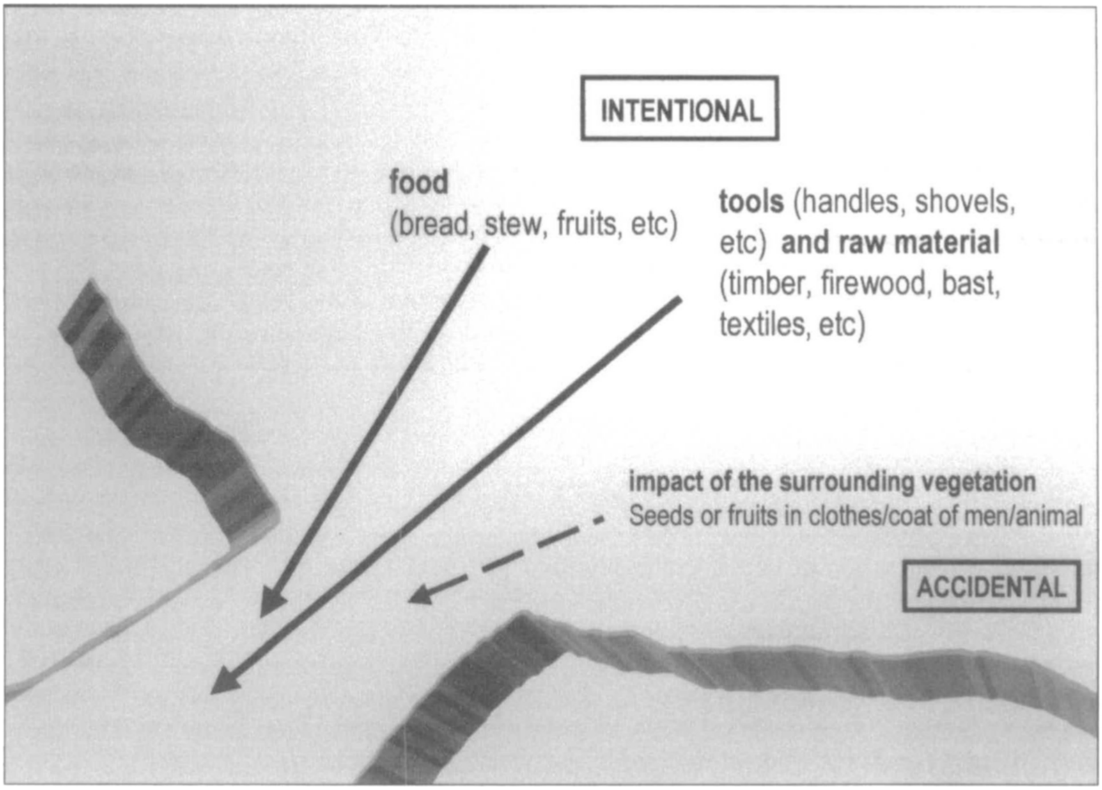

Fig 18. Schematic representation of the embedding of organic material in the Dürrnberg salt mines during the prehistoric period. *Drawing*: N Boenke

More than 5,000 samples of timber and tools have been analysed. The timber from the Dürrnberg consisted mainly of coniferous wood (86 per cent), made up of Norway spruce (*Picea abies*, 42 per cent) and silver fir (*Abies alba*, 44 per cent). These conifers have a high degree of stability and elasticity. In contrast to these percentages, coniferous wood accounts for only around 50 per cent of all timber in the Ramsautal settlement.[40]

Also made of coniferous wood were the long, narrow tapers split from logs, which were produced in large numbers. Because of its high resin content, coniferous wood burns readily. Amongst the tapers, silver fir is much more common than Norway spruce, representing 88 per cent of the sample. It is not known why the wood of silver fir was preferred. Probably the brittle wood was easier to split. Another possible reason is that it gives a steadier flame because of its lower resin content.

The third important category of wooden finds consists of various tool handles, shovels and more than 500 goose-necked pick handles made of common beech (*Fagus sylvatica*), a timber that is both hard and fine-grained. Oak, maple and elm are rare. Surprisingly, even ash (*Fraxinus excelsior*), which has similarly good tool-making properties to beech, was far from common. All the species mentioned above, with the addition of hazel (*Corylus avellana*) are represented among the waste wood, off-cuts and firewood.

If one compares these wood species with the expected composition of the Alpine forest, it is clear that the Dürrnberg miners selected the most common species. Alpine forest vegetation, as

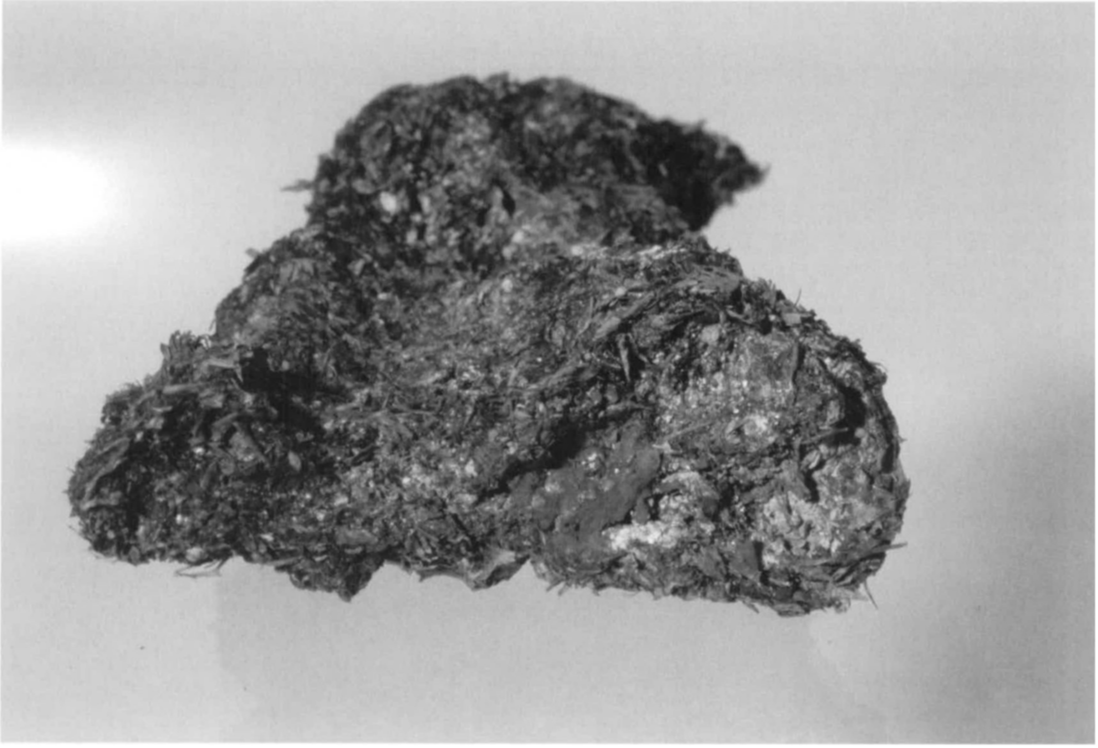

Fig 19. Human faeces (width 54mm; length 67mm). *Photograph*: N Boenke

reconstructed for the later prehistoric period,[41] consisted of mixed forest of mainly beech, spruce, fir, ash and maple, while hazel grew on the forest margins and alder stands were found in the vicinity of streams and rivers.

Quite probably, the miners' timber needs could all have been met from the surrounding area, without the need for any long-distance timber transportation. Large amounts of hazel twigs and fruits collected from hedges or the edge of the forest indicate that more or less open hazel stands or bushes existed near the miners' settlement. Also worth noting is the lack of any evidence for the devastation of the forest cover in the vicinity of the mines. This suggests that the wood supply was managed by rotational cutting, and not by importation from other regions, as was the case in the Middle Ages. Iron Age forest use was clearly less intensive than in medieval times,[42] when developed mining techniques required higher amounts of wood for timber and when the salt-processing works at Hallein, below the Dürrnberg, additionally consumed a remarkable amount of firewood.

Another important aspect of the archaeobotanical work has been the analysis of seeds and fruits contained in human faeces (fig 19). The exceptional preservation conditions in the mine permitted the investigation of more than one hundred faecal samples. In contrast to material from the settlement,[43] which gives an impression of the cultivated plants present as well as the vegetation cover of the Ramsautal, the samples of faeces indicate which species were actually consumed by the miners.

Analysis of the faeces content shows a rich diet based on cereals, legumes and fruits. The most commonly consumed dish was a kind of soup or stew. This may have been eaten with bread like that from an Iron Age context found in the Ipweger Moor, a bog in northern Germany.[44] The main cereals present were hulled barley (*Hordeum vulgare*), millet (*Panicum miliaceum*) and spelt (*Triticum spelta*). Sometimes beans (*Vicia faba*), peas (*Pisum sativum*) or lentils (*Lens culinaris*) were added. Additionally, blackthorn (*Prunus spinosa*), blackberry (*Rubus fruticosus*) or common hawthorn (*Crataegus monogyna* and *C. laevigata*) fruits were consumed. Changing percentages of plant material allow one to differentiate a range of dishes.

The miners of the Dürrnberg had available to them everything that was commonly consumed in Iron Age times. The menu seemed to change regularly, and sometimes the presence of spices may be identified. The oil plant 'gold-of-pleasure' (*Camelina sativa*) was used as a spice, as were the seeds of the opium poppy (*Papaver somniferum*) and flax (*Linum usitatissimum*). A surprise discovery was the occurrence of aniseed (*Pimpinella anisum*) and caraway (*Carum carvi*), which are not recorded commonly north of the Alps until Roman or medieval times. According to T Stöllner, contamination with younger material can be excluded, except for one of the layers in which these exotic finds occurred. The Iron Age context of these spices can be confirmed by the fact that aniseed occurs at two of the three different excavation sites in the mines: the Georgenberg and Ferro-Schachtricht.

In addition to their characteristic taste, the seeds of both species have good medicinal properties, particularly in the treatment of diseases of the digestive system. It is possible that Celtic people used them in connection with the problems caused by intestinal parasites.[45] While caraway occurs naturally in Alpine meadows and could thus have been collected locally, aniseed was probably imported from the Mediterranean. Contacts with the world south of the Alps are well known from objects found in the rich graves on the Dürrnberg.

A second point concerning nutrition is that food had to be provided for a large number of people. Summer crops with a short-term vegetation period, such as millet, could probably have been cultivated at the Dürrnberg altitude of 650 to 800m above sea level. But while it is possible to find arable land for plant cultivation in the surroundings of the Dürrnberg, it might not have been sufficient to cater for a large community. This suggests the existence of other communities capable of producing a surplus of food to trade with the people of the Dürrnberg. The nearest potential source of such food would have been the northern part of the lower Alpine foreland. In addition to profitable long-distance trade in salt (as demonstrated by rich archaeological finds from the Dürrnberg graves), the surrounding area probably participated in the general wealth as well through a more restricted regional trade in food. (NB)

PARASITOLOGICAL INVESTIGATION OF EXCRETA PRESERVED IN SALT

It has been known for some time that among the layers of rock that constitute the Heidengebirge, human excrement was found interspersed with other traces of human activity associated with the once-flourishing Iron Age salt mines. These salt-preserved excreta should not strictly be described as coprolites since they are neither hard nor stone-like in shape. They are simply 'palaeofaeces' of a consistency characteristic of desiccated faecal material (fig 19).

Thirty years ago, the present writer had the opportunity to conduct parasitological analyses of palaeofaeces from the Hallstatt period layers of both the Hallstatt and Hallein salt mines.[46] During the new excavations on the Dürrnberg, numerous additional specimens of palaeofaeces have been brought to light. This study reports the results of parasitological analysis of 104 human faecal specimens.

Species of helminths, single* or combined	Number of occurrences per faecal specimen
*Trichuris trichiura**	49
*Ascaris lumbricoides**	1
*Dicrocoelium dendriticum**	–
*Taenia sp.**	–
*Fasciola hepatica**	–
Trichuris trichiura + *Ascaris lumbricoides*	40
Trichuris trichiura + *Dicrocoelium dendriticum*	1
Trichuris trichiura + *Taenia sp.*	1
Trichuris trichiura + *Fasciola hepatica*	–
Trichuris trichiura + *Ascaris lumbricoides* + *Dicrocoelium dendriticum*	4
Trichuris trichiura + *Ascaris lumbricoides* + *Taenia sp.*	2
Trichuris trichiura + *Ascaris lumbricoides* + *Fasciola hepatica*	1
No eggs of helminths detectable	5

Fig 20. Evidence of helminth eggs in 104 samples of palaeofaeces from prehistoric miners in the Dürrnberg salt mines (fifth and fourth centuries BC)

Due to the high salt content of the Hallstatt and Dürrnberg sites, everything discarded in the mines by prehistoric miners has been superbly preserved, including fragments of clothing and – most importantly – excreta. Multiple tests have been conducted for parasites on palaeofaeces from both salt-mining complexes. In so doing, the eggs of several helminths or intestinal worms have been successfully identified, sometimes in large quantities. In a substantial proportion of the specimens, the eggs – despite having been buried in rock salt for some 2,500 years – are superbly preserved and can be identified as plainly as if one were conducting a parasitological examination of a modern patient's fresh stool specimen. Of thirteen palaeofaecal specimens originating recently 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*).[47] 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 species*), five of lancet fluke (*Dicrocoelium dendriticum*) and one of sheep liver fluke (*Fasciola hepatica*) (fig 20).[48]

Both *Ascaris lumbricoides* and *Trichuris trichiura* are transmitted by oral ingestion of eggs that have been excreted with faeces. The eggs are not immediately infectious, requiring a few weeks to a few months exposure to atmospheric oxygen, depending on the ambient temperature, and to a sufficiently damp environment. During this period, embryogenesis occurs, followed by development into larvae capable of transmitting infection. What this means is that the eggs, once excreted in faeces, must have remained in people's immediate surroundings for some considerable time in order to have become infectious. This reveals a picture of extremely unhygienic conditions, characterized by wholly inadequate disposal of human faeces. Proof of this is found not only in the high rates of infestation (particularly in the Dürrnberg population) but also in the high numbers of eggs detected in some specimens, indicating a massive level of infestation.

Infestation with beef tapeworm or pork tapeworm (the eggs of the two species are morphologically indistinguishable) takes place by ingestion of the final larval stages with raw or insufficiently cooked beef and/or pork. It is known that the prehistoric inhabitants of the Dürrnberg kept both cattle and pigs, since faunal evidence of these animals has been found.[49] One must therefore conclude that they undercooked their meat, if they cooked it at all.

An initial conclusion suggested by the numerous finds of *Dicrocoelium* eggs is that a considerable 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 to leaves by their mandibles). For this to happen with such frequency is unlikely. A more plausible possibility is that the miners ate raw sheeps' liver, and in so doing ingested the liver fluke (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 of *Fasciola* eggs observed here is a case of parasitism or pseudoparasitism cannot at present be stated with certainty.

The fact that people of the Hallstatt period were infested with lice is demonstrated by evidence from textile remains.[50] Apart from the psychological and, in cases of severe infestation, the physical ill-effects induced by body lice (*Pediculus humanus*), the health implications of ectoparasites largely depend on what infective agents they transmit. The infective agent of epidemic louse-borne typhus (*Rickettsia prowazekii*) is of particular relevance. That said, it is simply not known whether louse-borne typhus occurred in Central Europe in the pre-Christian era.

The parasites found at the Hallstatt and Dürrnberg sites are consistent with those known from numerous worm egg finds throughout the whole of Central Europe. The prehistoric population suffered from massive worm infestation from at least the fourth millennium BC. Whipworm and roundworm were especially prevalent during at least the last 1500 years BC; so too was tapeworm, at least in the last millennium BC. Evidently, the people of the period took insufficient care to dispose of their faeces properly, and accorded little 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 was commonplace.

The ailments from which these people suffered primarily affected the digestive tract. Stomach pains and diarrhoea must have been a routine part of daily life, and highly detrimental to human productivity. Diarrhoea, in turn, is a condition that – at least in the absence of suitable sanitation – makes the safe disposal of faeces particularly difficult. This produced a vicious circle, which probably often gave rise to a huge build-up of worm infestation.

Besides the various general ailments, there must also have been repeated occurrences – the extent of which remains unknown – of serious and even fatal infections. Roundworms frequently enter the bile duct or the pancreatic duct, where they can, for example, 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, sometimes resulting in a dangerous neurocysticercosis.

There is good reason to suppose that prehistoric people made the connection between worm infestation and disease because certain helminths (roundworm and tapeworm segments) are large enough to be seen with the naked eye. It is also evident that those affected attempted to treat themselves. Finds in the collapsed Hallstatt salt mines of unusually large quantities of butterburr (*Petasites hybridus*), a plant used in folk medicine as a remedy for stomach pain, provide clear evidence of this.[51] A similar antiseptic effect can be also presumed for sage (*Salvina officinalis*), evidenced by a DNA sample in an organic holder from the Dürrnberg salt mines.[52] It is plain, however, that the Iron Age population must have been completely unaware of the routes by which disease was transmitted, which is why they were not in a position to take effective preventative measures against worm infestation.

Infestation with ectoparasites, especially with lice and fleas, will probably, at least in some population groups, in some regions and in some periods, have represented a significant source of physical discomfort. Equally, the occurrence of these parasites is closely related to poor personal hygiene and insanitary living conditions. (HA)

TEXTILES FROM THE DÜRRNBERG SALT MINES

Hundreds of different fragments of textiles have survived deep down in the Dürrnberg salt mines. Most were found in direct connection with mining activity, so it seems logical to suppose that those textiles originally had a certain function and meaning within the process of salt mining.

One very telling find for the interpretation of the textile remains in the salt mines came to light almost a hundred years ago.[53] It is a colourful woollen band with a chequered pattern, which was wrapped around the wooden shaft of a pickaxe. The shaft had split during work and the textile was used to fix it on the spot. This find makes it clear that the majority of the Dürrnberg textile remains were probably brought into the mines for technical purposes and are not necessarily parts of the miners' clothing.

Before the systematic excavations of the Dürrnberg salt mines from the early 1990s onwards, the number of textiles found in the mines had been relatively small. This changed quickly, and more than 600 textile finds or fragments have since been recorded and studied by the present author.[54] A representative sample of the Dürrnberg textiles has also been analysed by M L Ryder (the detailed results of his analyses will be incorporated in the final study on the Dürrnberg textiles).[55]

Most of the textiles can be dated with the help of other finds in the same complex (rubbish heaps, for example), such as iron tools (which are dated stylistically) or wooden implements (for which a dendrochronological date can be established). The textiles themselves show certain characteristics typical of textiles of the late Hallstatt and early/middle La Tène periods in Central Europe.[56]

Thanks to the preserving properties of salt, most of the textiles uncovered in the Dürrnberg salt mines still possess their material quality, so wool still looks like wool after 2,500 years. Next to the woollen textiles, which make up the majority of the finds, there are also textiles consisting of flax or hemp. Only rarely can a combination of plant and animal fibres be observed. Two finds of silk from the mining areas consist only of single threads, so their final interpretation has to be left open for the time being until further examinations have been carried out.

From other, more local, raw materials the Dürrnberg weavers created a number of different and, in some cases, most artistic weaves. There is first of all tabby (coarse and fine), but also rep (a fabric with a narrow ribbed effect) and different variants of twill – mainly 2-by-1 twill and 2-by-2 twill (fig 21). There is also a group of tablet-woven textiles made out of very fine dark blue wool, as well as some tablet-woven borders.

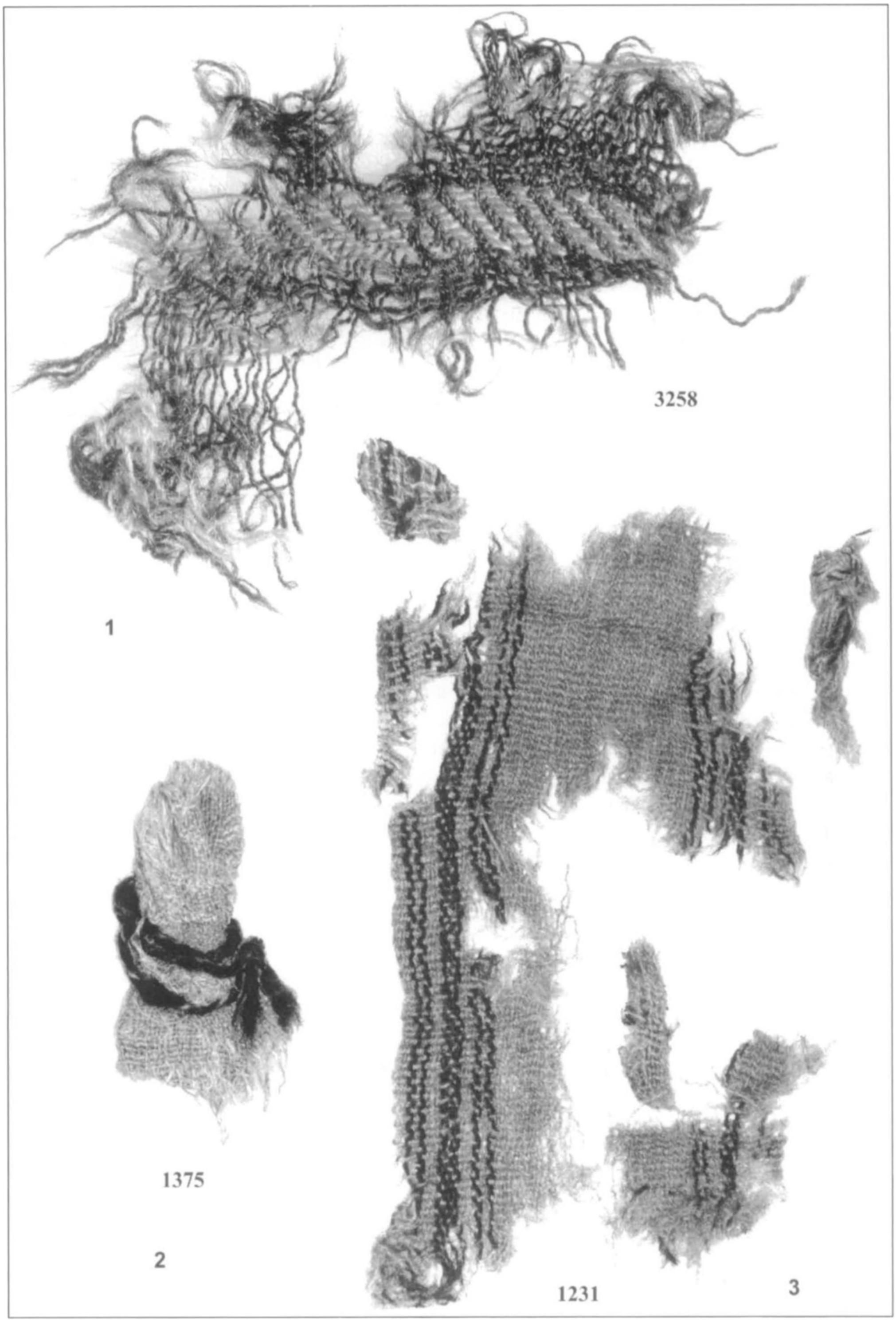

Fig 21. 1: 2-by-2 twill with light brown stripes in dark brown textile (*Textil Nr 3258, Ferro*); 2: beige linen tabby with dark brown wool cord used as bandage for a finger injury (*Textil Nr 1375, Ferro*); 3: tabby band in light brown wool with dark and reddish-brown stripes (*Textil No 1231, Ferro*). Scale 1 : 2. *Photograph*: V Ilic

The salt has not only preserved the materials of the textiles very well, it has also preserved the colours. For the first time it is possible to get a glimpse of the colours and patterns preferred by the Iron Age people of the Dürrnberg. There are several different shades of blue – mainly a blue-green that is very dark because, in most cases, it was brown wool that was dyed. But one can also find pure green, a dark and a more yellowish variety, and red. Dr J Wouters has carried out analyses of the dyestuffs used for the Dürrnberg textiles at the Instituut voor het Kunstpatrimonium at Brussels. He found out that the Dürrnberg people knew a number of natural dye sources, which they used very expertly. Some of the dyestuffs had even been imported from the Mediterranean.

The threads dyed in different colours were then used to create patterns in the textiles. Most of the patterned textiles are made of wool (maybe because it is more difficult to dye flax or hemp). There are stripes – often alternating wide and narrow ones – and also chequered patterns in different colours. Sometimes only the borders of the textiles are patterned. One small textile fragment even possesses an elaborate ornamental pattern consisting of small S-forms, triangles and rectangular ornaments in three different colours, created with the help of a complicated weaving technique.[57]

Although the state of preservation of the textiles is excellent, most of them have only survived as fragments. Many originally belonged to garments. There are seams joining different textiles, hems and other traces of sewing. In some cases one can surmise that the textile formed part of a sleeve, or the decorated hem of a tunic, or a torn-off pocket, but it is almost impossible to reconstruct the original textiles to which the fragments once belonged.

Many of them have been torn from bigger pieces – probably intentionally. Obviously it was useful to have a certain amount of rag below ground, which could be used for different purposes: fixing pickaxes in their hafts, or cleaning one's hands or face. Some of the textiles were used as bandages, as one example shows very clearly: the rectangular textile had been wound and fixed around a finger, then fell off, still preserving the shape of the finger (fig 21).

Bands, made of wool or flax, occur in a couple of (possibly standardized) widths (fig 21). These narrow or wide bands could have served a number of different purposes: hoisting up or lowering loads down into the mines, fixing and mending broken tools or protecting the limbs and wrists of the miners. Some of those textiles have been deliberately woven as bands, while others have been torn or cut from bigger pieces of cloth. Often different bands are linked by knots. Sometimes several knots in a single band indicate that something had once been attached.

This short summary of the textiles from the Dürrnberg salt mines gives an idea of the wealth and variety of Iron Age textiles. The fragments excavated in the salt mines obviously reflect the kinds of textiles produced and used in daily life. They show how far advanced and important the craft of weaving must have been, even if rags are all that remains today. (K v K)

POLLEN DATA FROM HAIR AND BARK

It has recently been shown that animal coats may contain pollen, partly from the time when the animal roamed through the landscape and partly from the time when the hide or skin was used after the animal's death.[58] It therefore seemed worthwhile carrying out pollen analysis of the hair or wool present on the excavated hide and skin fragments from the Dürrnberg. Some of the many bark samples found in the mines were also examined for their possible pollen content.[59]

Only six out of some twenty samples of hair or wool contained pollen, and of these only three samples had enough pollen to allow the calculation of percentages based on a sum of arboreal and non-arboreal pollen (fig 22). This low pollen presence cannot be due to preservation in general, because the quality of the pollen that could be detected was good. The mineral content of most of the samples, however, was high, which made analysis difficult – and identification virtually impossible in some cases.

Four of the six samples were of sheep's wool, one came from a cow and one was identified as dog's hair. The amount of pollen in the cow hair sample was the lowest. This could point to washing as the driving agent for the loss of pollen. Sheep's wool is curly and pollen is better protected against a stream of water, whereas cow hair is smoother.

As can be expected with domestic animals grazing in open fields, the amount of arboreal pollen was extremely low, apart from sample 5, in which it is makes up around 40 per cent of the surviving pollen, and is mostly of oak. The landscape must in general have been quite open, since one would have expected higher arboreal pollen percentages from small, enclosed pastures.

Although their arboreal pollen content was too low for percentage calculations based on arboreal pollen alone, samples 4 and 5 did contain a fair amount of herbaceous pollen. Specifically, sample 5, the dog hair, showed a great number of herbaceous pollens and many taxa not occurring in any of the other samples. It differed considerably in this respect from the pollens in the sheep's wool. One can imagine that a dog would visit a greater variety of environments and types of vegetation than sheep and cattle, which are restricted to their pastures – although it is true that these should in themselves be herbaceous-rich. The relatively high amounts of cereal pollen in the sample can easily be explained as the result of the dog visiting farmyard areas where grain was processed and where pollen would be released through such activities as threshing.

Most of the bark samples (fig 23) contained pollen, although not enough for percentage calculations in about half of the samples. The ratio of arboreal to non-arboreal pollen is high, the percentage of arboreal pollen varying between around 50 and 90 per cent.

According to Firbas,[60] the Alpine foreland, in which the Dürrnberg is situated, can be characterized in the sub-Atlantic climatic period as a *Fagus-Abies-Picea* area with beech (*Fagus*) in the lower, drier areas between 200 and 950m. Oak (*Quercus*) and hornbeam (*Carpinus*) were present in limited quantities, and there were few or no conifers in higher and wetter areas between 300 and 1300m, except for fir (*Abies*) and spruce (*Picea*).

The arboreal percentages are rather high, pointing to a dense forest cover. High conifer and beech percentages are to be found in samples 2 and 3 (fig 23), while samples 1 and 4 (fig 23) have rather high hazel (*Corylus*) percentages and are probably from a forest margin. However, in those cases where one taxon seems to be over-represented, the possibility cannot be excluded that the pollen comes from the tree or shrub itself. For example, sample 4 has a high *Corylus* percentage in combination with a rather high NAP (non-arboreal pollen) percentage. This fits well in a forest margin situation, whereas sample 1 with its extremely low NAP percentage does not fit this context so well. In the latter case one may instead assume that the piece of bark analysed is from an actual hazel tree. A similar situation is probably represented by sample 5 (fig 23), with an extremely high percentage for willow (*Salix*), and by sample 6 (fig 23), with the highest beech (*Fagus*) percentage of all samples. All three species had a specific use in the mines.[61]

The percentages for cereal pollen and other cultural indicators are much lower than in the hair samples. In the light of the provenance of the bark samples from a woody environment,

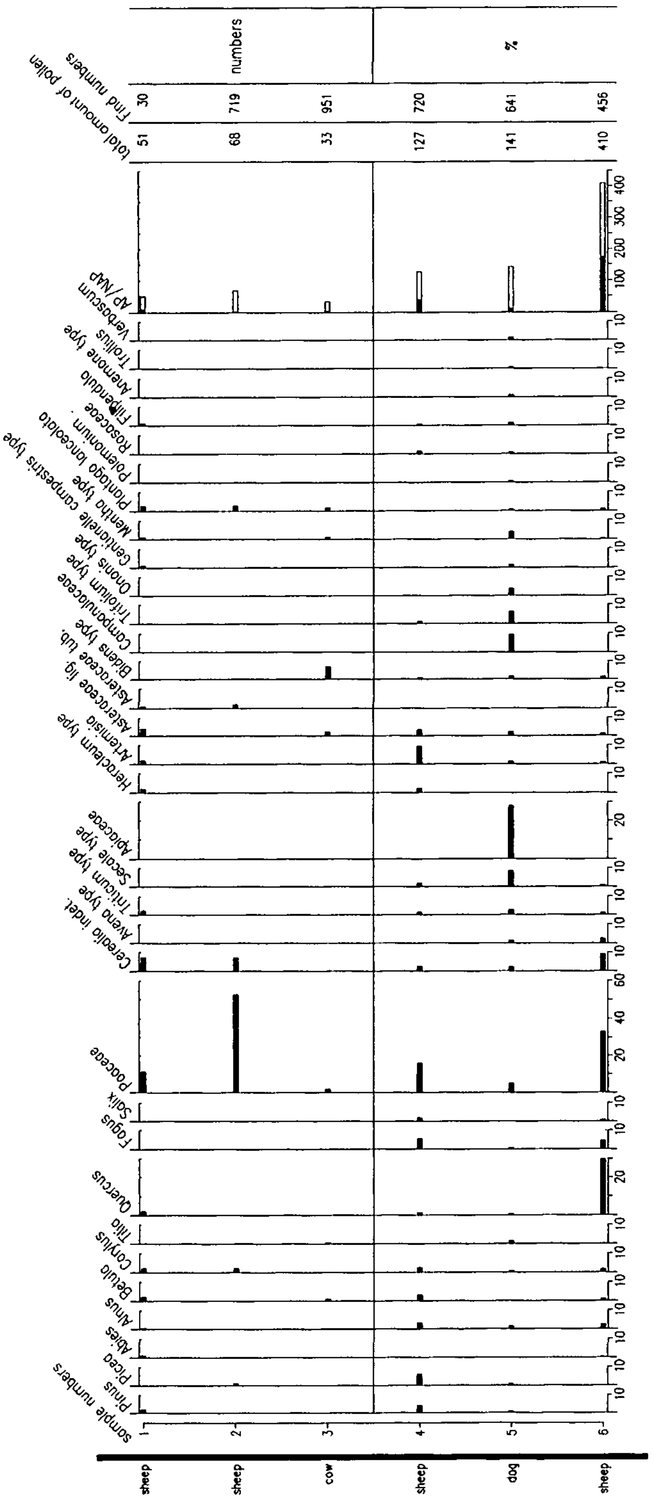

Fig 22. Dürrnberg: pollen analyses (individual totals and percentages) from hair samples; a selection of curves (based on Groenman-van Waateringe and Stöllner 2001, fig 2)

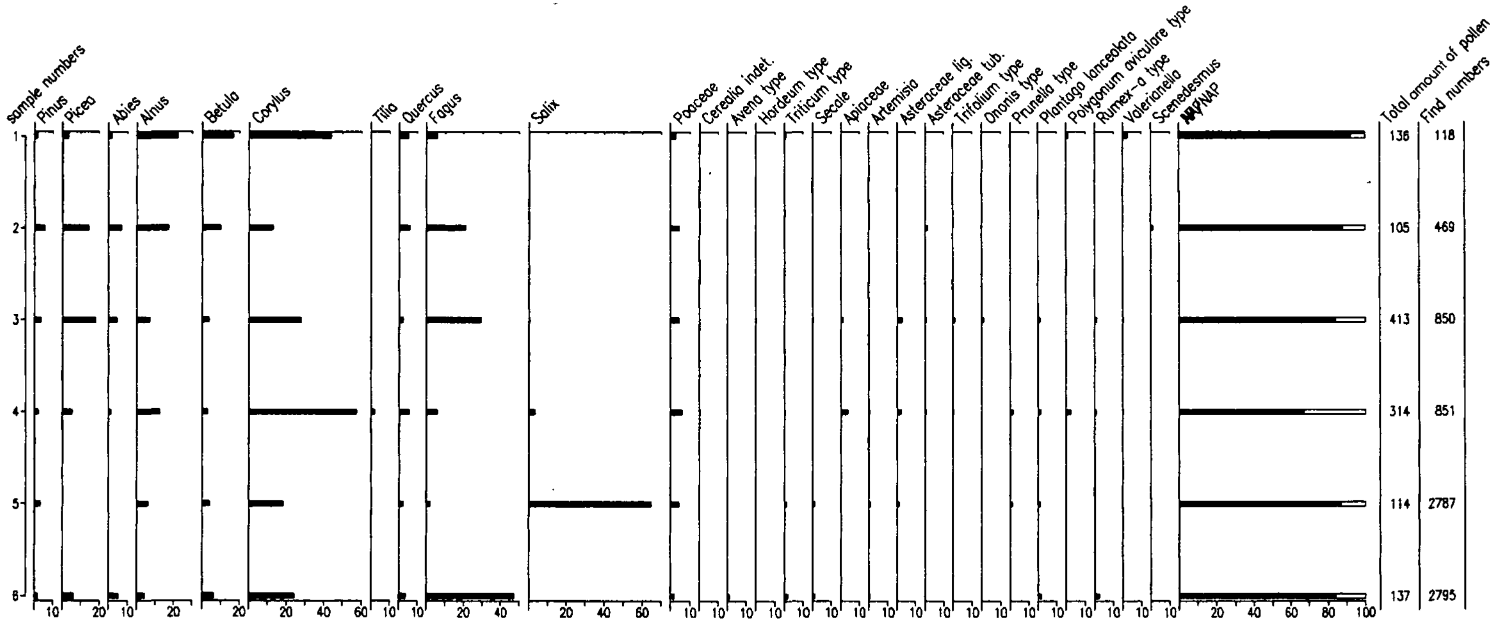

Fig 23. Dürrnberg: pollen percentage data from bark samples; a selection of curves (based on Groenman-van Waateringe and Stöllner 2001, fig 3a)

this is what one would expect. That such pollen is present at all must be due to the storage, working and using of wood in the settlement.

Four types of cereal pollen have been identified: wheat (*Triticum* type), oats (*Avena* type), barley (*Hordeum* type) and rye (*Secale*). *Triticum* and *Secale* are the most common. Since *Secale cereale* is a wind-pollinated species, it produces much more pollen by comparison with the other three. Thus, equal percentages of *Triticum* pollen and *Secale* do not mean that both types would have been represented equally in the actual crops grown. The percentage of *Secale* is still rather low, and one cannot therefore conclude from it that *Secale* played an important role in crop husbandry as early as the Iron Age. Rather, the origin of the cereal pollen has to be found in the third of the sources of pollen noted above, that is, in the settlement itself, since the dense woods from which the sampled bark originally came were not a suitable environment for cereal growing.

In summary, the pollen data from the hair and wool samples point to fairly extensive open grazing areas. However, this environment is not necessarily the same as that of the settlement where the miners lived, since Pucher[62] (see below) has found no evidence that the miners were breeding domestic animals locally. The same holds true for the cereal pollen, since there is no evidence for cereal cultivation in the area. It must be supposed that cattle, sheep and grain were supplied externally and thus that the Dürrnberg had to be supported economically from outside its immediate area.[63] Based on what is known of the local climate and soil conditions, only millet (*Panicum miliaceum*) could have been cultivated locally. Remains of this cereal were regularly found in the archaeological deposits. However, *Panicum miliaceum* cannot be separated by pollen analysis from the larger species of wild grass pollen. (WGvW)

WOODWORKING AND CRAFTS IN THE RAMSAUTAL SETTLEMENT

Our knowledge of the Dürrnberg settlements is mainly – but not exclusively – based on excavations carried out in the waterlogged area of the Ramsautal, a small valley located in the eastern part of the Dürrnberg, and in its immediate surroundings. Here and on the plateau of the Moserstein there is evidence of a striking concentration of crafts – iron and bronze-working, glass-production and carpentry, as well as traces of fine metalwork.[64] Unfortunately, owing to the restricted nature of the more recent excavations and to inadequate documentation of the older work in the area, the Ramsautal excavations offer only a partial view of these specialist activities.

In 1988–9, because of a projected drainage programme, it was necessary to carry out rescue excavations in order to document in greater detail the settlement layers recorded by earlier excavations.[65] In these two years an area in excess of 230m² was explored. Because of the constant flooding action of the Glannerbach, a stream that accumulates at a geological threshold, the area has developed into a wetland with consequently optimum conditions for the preservation of organic materials. The drainage ditches dug in the La Tène period – and which subdivide the house areas into virtual islands – proved to contain large quantities of the best preserved of this material.

The excavations carried out between 1988 and 1989 rendered possible for the first time an understanding of the complete stratigraphic and developmental sequence of this large-scale settlement, dating from the fifth to the second century BC. Analysis of the features[66] and the creation of a Harris Matrix resulted in the recognition of nine settlement horizons and some seven partly multi-phase houses, comprising some twenty-four building phases in all. The occupation of the larger part of the Ramsautal settlement lasted from Dürrnberg II A[67] or La Tène A to Dürrnberg II C or La Tène C. Only one settlement area – house 3 – in fact lasted right to the end of this period, while late Hallstatt features were absent.

Within the settlement, multiphase drainage ditches and levels of flooding were found that show that the occupation of the area in prehistoric times was very hazardous. The ditches were reinforced with wattle fences and offered some protection to the houses against flooding. The drainage ditches also served as disposal areas for butchery waste and general domestic debris – and perhaps also as latrines. Because houses were erected on the same spot time and time again, it is possible to recognize similar features formed in a dense sequence of building and flooding layers.

Of primary interest are the houses themselves, which were well preserved. The most common design is that of a log building with stamped clay floors that are sometimes very thick. Judging from their contents and their general layout, it can be assumed that the local population lived and worked under one roof. With lengths of up to 15m, these large houses had room for both specialized activities and domestic life.[68] One fifth-century BC house gives further evidence of life in the Ramsautal: it had two hearths and a corridor between, leading to an upper floor. The room on the left-hand side contained quantities of shavings, a couple of carpentry tools and, outside, a quantity of lathe-turned wooden vessels closely resembling classical Greek pyxides in form. This is likely to have been the workshop of a lathe-turner (fig 24).

Some ten human foetuses were uncovered at various occupation levels in the vicinity of this house, having been placed as foundation offerings in the course of various phases in the house's construction history. How these foetuses met their fate remains so far unknown.[69] Certainly, hygiene conditions must have been as bad in the settlements as in the mines. A rough estimation of the number of houses (300) and of the population in the Ramsautal suggests that between 1,000 and 1,200 people lived here as a minimum, and so the living areas were probably very crowded and unhygienic.

The use of the settlement as a craft centre is indicated, for instance, by finds of blue glass beads. Most come from the most recent levels. A single 1mm-diameter bead was found in a somewhat older flooding layer. The massing of glass finds in the north-western corner of the excavations appears to be the result of flooding, in as much as there are no signs of glass smelting in this part of house 1, even though the majority of glass finds from the site did actually originate from the flooding layers and drainage ditches around house 1. Blue beads appear in the settlement from the transition of La Tène B2 to C1 and on to the developed phase of La Tène C. Three armlet fragments also come from this period. The sole early bead was of the 'Schichtaugenperle' type; otherwise only blue beads dating to the middle La Tène period were found.

One bead from a flooding level in the vicinity of house 3 is of special interest because it shows traces of a sharp-edged implement, used to push the bead off the pontil rod. Another bead shows traces of an applied – probably white – glass thread forming a zigzag pattern; parts of the waste material that adhered to the rod are still to be found in the suspension hole. On the basis of this evidence, and of additional finds of 'gobs' or rough-shaped blue lumps of raw glass, we can conclude that the production of glass beads – and probably other glass products as well – formed one of the skilled activities practised in the Ramsautal settlement.

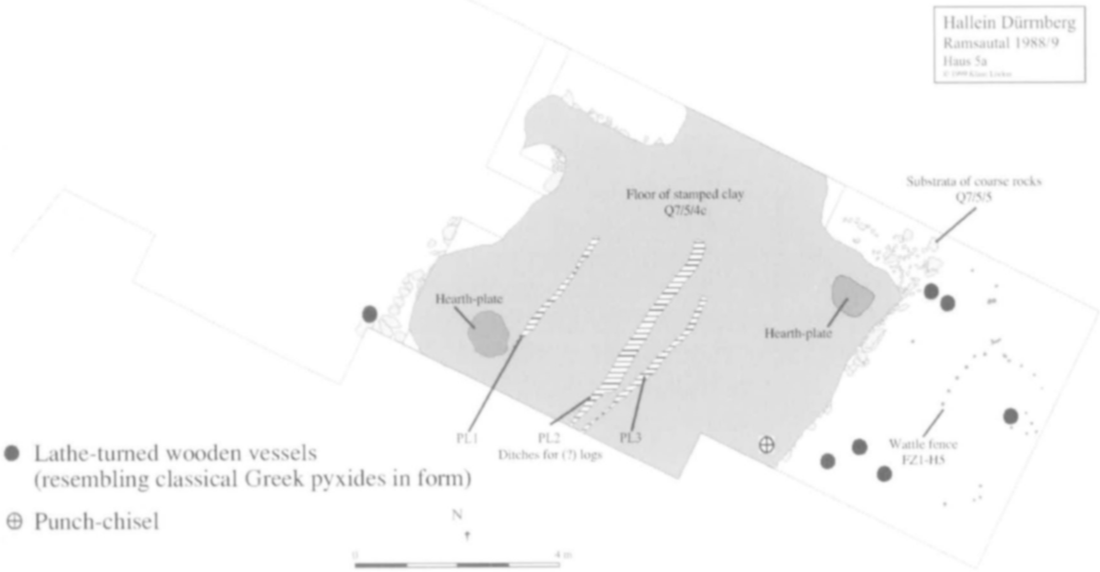

Fig 24. Top: an overall view of the Ramsautal 1988/9 excavation. *Photograph*: K Zeller; bottom: the 'house of the lathe-turner' (no. 5a, settlement horizon 2) with tools and fragments of lathe-turned wooden vessels. *Drawing*: K Löcker and T Stöllner

A cut iron bar, found in a flooding layer associated with house 3b, provides further evidence for the settlement's use as a craft centre. The discovery of a mould fragment in the substructure of house 3b might indicate metal production in the same area. Numerous finds of slag throughout the entire excavation site certainly offer additional evidence that there must have been a smithy somewhere in the settlement area. Further, a chisel-like iron tool found in the drainage ditch around house 5b could have been used as a blacksmith's punch. Alternatively, it might have been used by a stonemason. The tool shows distinctive impact traces, which indicate that it was used to shape metal or stone, rather than softer materials such as wood. The blade of the tool has been welded to the handle and may have been hardened.[70]

The unusually good state of preservation of the organic materials in the Ramsautal settlement also allows some insights into the woodworking techniques of the time, especially those used in house construction. In some houses, substantial parts of upright looms survived.[71] As well as whole logs, there were planks and timbers that had been shaped with an adze or chisel (fig 25). In addition to houses with a timber foundation, built using a mixture of log and post construction, there were also buildings constructed on a pole frame. The variety of constructional techniques represented in one small area was eye-opening, and offers hope for the future development of a chronological sequence of construction methods.

The normal forms of joinery represented here included slots, tongued grooves, mortice-and-tenon and dovetail joints. Toothed as well as dovetail joints were also used at the corners of the buildings (fig 26). The most important tools employed were axes, adzes, chisels and scribers.[72] In general, woodworking activity on the site seems more varied than one might expect of normal domestic handicrafts.[73] Parts of tools, such as hafts, offer the strong likelihood that tools were made – or at least stored – here for use in the mines. As already noted, a number of finished wooden pyxides have also been found in the settlement area.[74] To what extent these or other particular objects were made locally cannot yet be ascertained. Study of waste products of various carpentry processes – such as off-cuts and shavings – might eventually throw light on this question.

It is natural to assume that from the Neolithic onwards, local populations selected timbers that rendered construction as simple as possible, while at the same time guaranteeing optimum life for their houses.[75] In general, it is noticeable that a majority of that part of the building timber used on or close to the ground surface was manufactured from fir. Phleps[76] characterizes the fir as follows: 'It grows up to 60m high, with a less upward tapered trunk than the spruce and reaches an age up to 450 years. Its wood is reddish or yellowish-white and shows like the spruce no difference in colour between core and sapwood. It has clearly visible tree rings, is resin-poor, very flexible and very fissile. The wood of the fir grown in the mountains is better than from a wet and soft soil. As far as durability goes, it is inferior to the resin-rich spruce by far'. Thus it remains an open question why inferior wood was used for building – unless it was simply the ease with which fir can be worked.

To sum up, the activities of several business enterprises can be detected within the small area of the Ramsautal settlement so far excavated. There is evidence for carpentry and glass processing as well as for a forge and/or a general metalworking workshop. The making and working of leather, sapropelite and jet working, pottery making and butchery most probably took place in the Ramsautal as well.[77] The finds from the settlement offer important insights into the activities of skilled craftsmen in the La Tène period. The wooden finds especially should help add to our knowledge of Iron Age house construction. (WL, KL, TS)

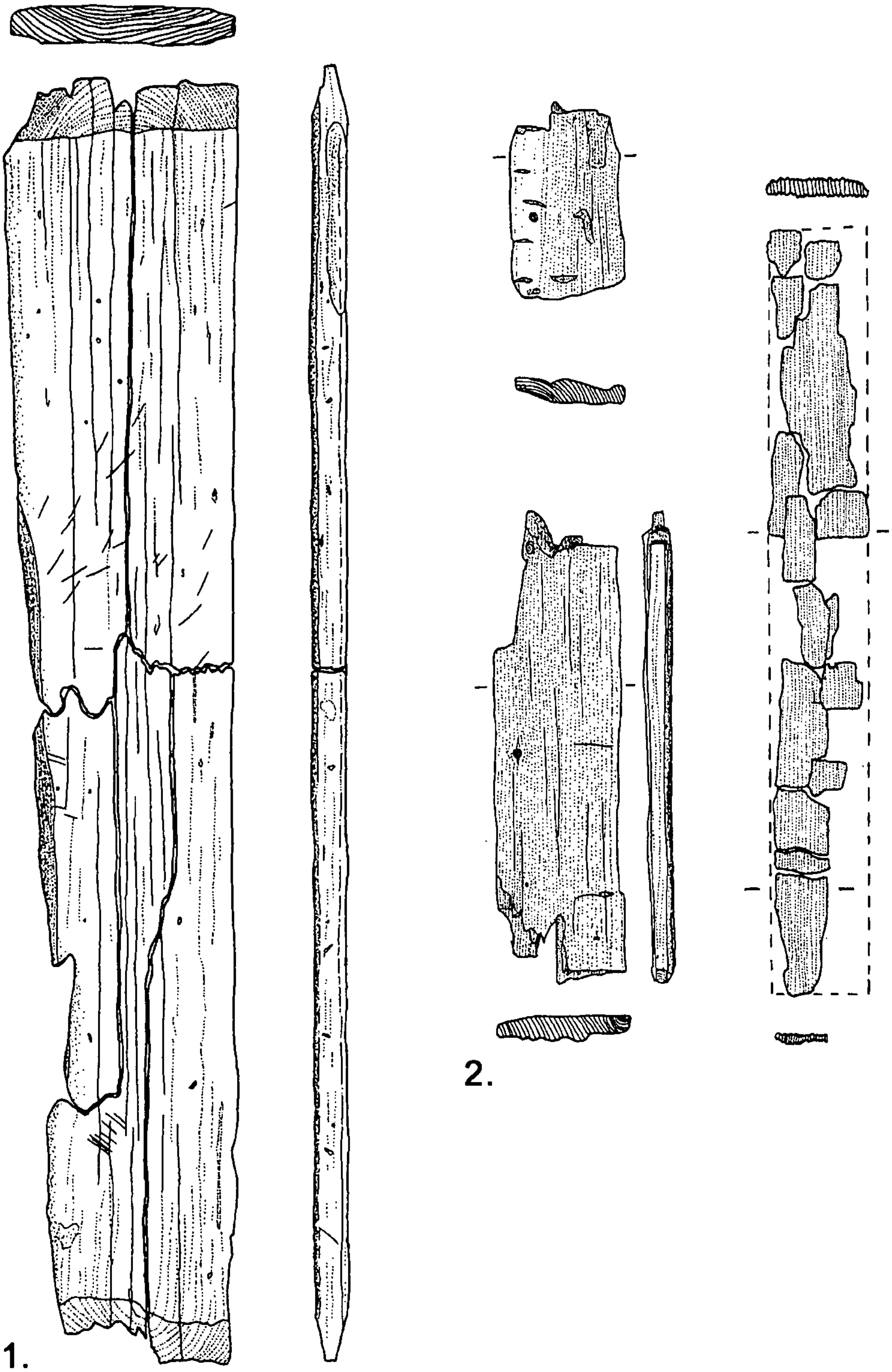

Fig 25. Planks from the Ramsautal settlement (scale 1 : 10). *Drawing*: C Schmidt

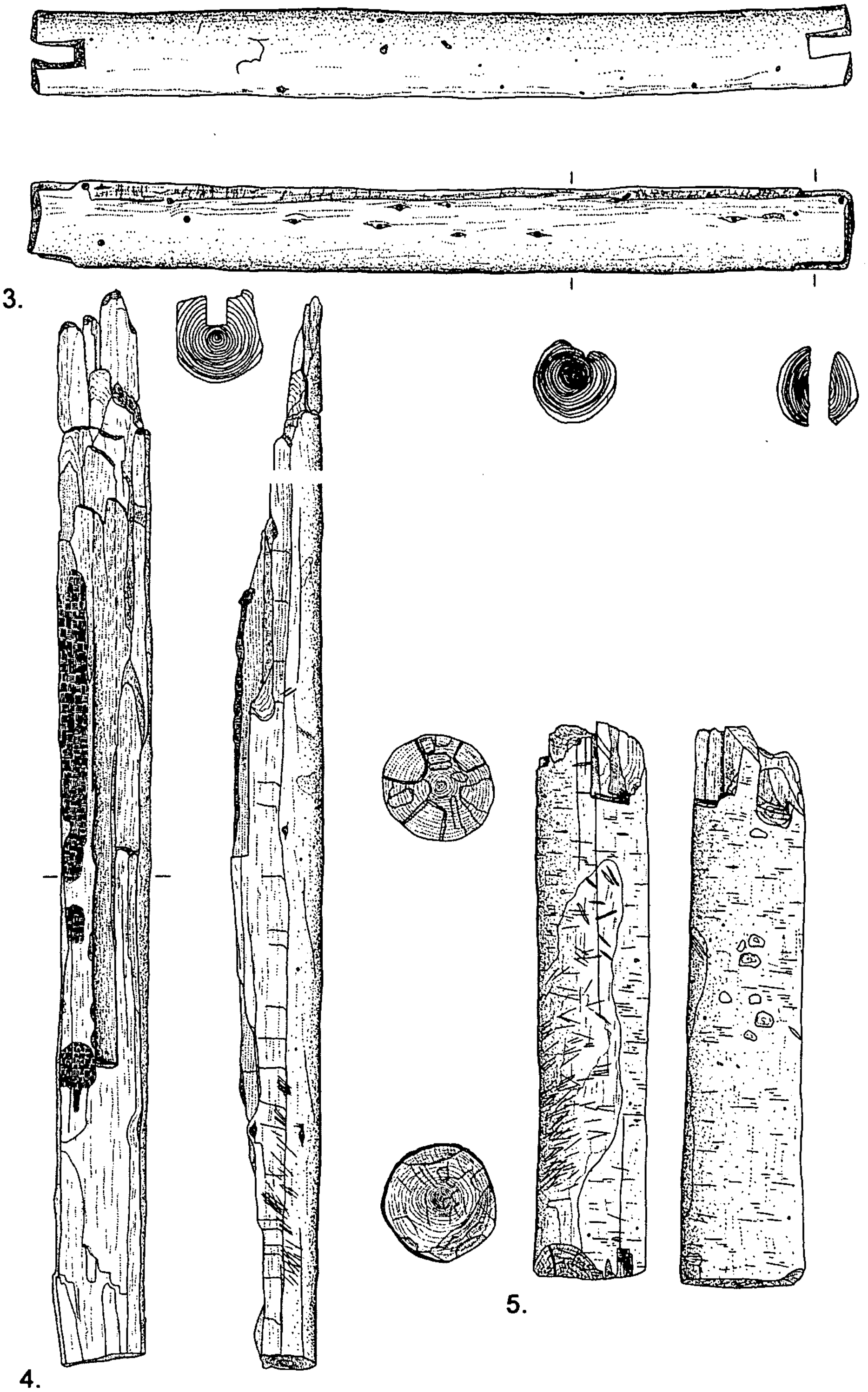

Fig 26. 3: foundation section of a wall from house 1; 4: fragment of threshold from house 3; 5: part of a post from house 2 (scale 1 : 10). *Drawing*: C Schmidt

MEAT PROCESSING ON THE DÜRRNBERG

The excavations carried out at the Celtic mining and manufacturing settlement in the Ramsautal have yielded a total amount of 15,589 identifiable animal bones, which have enabled us to undertake a detailed archaeozoological study.[78] As a result of their deposition and the humid soil conditions at the site, the bones were not only well preserved, they could also be separated into four strata (H1 to H4). A chronological differentiation into a number of short periods was thus possible, none of the periods lasting longer than a hundred years. The whole assemblage dates from La Tène A to La Tène C (450/400–200/150 BC) centring on La Tène B, thus covering the chronological gap between the well-studied sites of Heuneburg and Manching in neighbouring southern Germany.

The faunal composition of the Dürrnberg sample is shown in figure 27. At first glance it is clear that game contributed very little to the bone deposits (0.7 per cent of the total 'Number of Identified Specimens', or NISP). Nevertheless, the list of game is surprisingly varied and even contains rare species, including bison, chamois, elk and a number of bird species. The great majority of finds (78.4 per cent of NISP) were cattle bones. Pig bones and the bones of small ruminants appear far less frequently. No other species occur in any significant quantity.

Cattle were the animals most frequently represented by bone finds and the most important animal for butchering, the meat of pigs and sheep playing only a subsidiary role. In Central European Iron Age sites the frequency of cattle bones is usually high, but the extreme predominance of cattle bones at the Dürrnberg site is unparalleled (fig 28). Other samples, whether from large-scale settlements or from rural sites, show only a moderate preponderance of cattle bones, ranging between 40 and 60 per cent of the total NISP. Apart from the considerable variations in the sheep : pig ratio, they display general similarities in the composition of the remaining species.

If one looks for a comparable predominance of a single species, there are very few examples in the eastern Alpine area. All such sites – like the Dürrnberg itself – are linked by specialized mining activities and the necessity of maintaining a well-organized external food supply.[79] In the Late Bronze Age mining sites of Kelchalpe and Hallstatt,[80] pig bones predominate in the samples – representing 60 per cent of NISP. Both sites are located at altitudes above 1,000m, amidst almost impassable mountainous terrain where local stockbreeding can be excluded for a number of reasons.

These mining settlements must therefore have been able to rely on an adequate supply from animal breeders in the neighbouring valleys. For Hallstatt, recent investigations indicate that, on the whole, only carcasses relieved of their entrails and other parts poor in meat were carried to the site, probably to avoid the transportation of unnecessary weight. This seems not to have been the case for the more accessible Dürrnberg, where different parts of the skeleton were represented in the proportions one would expect from the use of whole animals. Therefore, one can assume that whole herds, particularly of cattle, were brought to the Dürrnberg for slaughtering and processing on site. It is still a matter for conjecture whether the beef was used solely to supply the mineworkers and others in the settlement, or whether some of it was cured for export using salt from the mines.

A very interesting detail concerns the nasal bones of the cattle. Unusual cracks are visible in seventeen of thirty-four nasal bones, progressing from the oral incisure to the centre of the bone. In most cases these signs of trauma have healed over, but in other cases the nasal bones have split again. Only more or less contemporary material from Inzersdorf ob der Traisen[81] includes split nasal bones of the same kind. There may be some connection with harnessing

	Species	NISP	NISP%	MNI	MNI%
domestic animals	Cattle	12,223	78.4	156	45.5
	Sheep	283	1.82	(28)	(8.16)
	Sheep or Goat	948	6.08	46	13.4
	Goat	87	0.56	(13)	(3.79)
	Pig	1,798	11.5	91	26.5
	Horse	38	0.24	5	1.46
	Dog	102	0.65	11	3.21
	Fowl	6	0.04	5	1.46
wild animals	Bison	12	0.08	3	0.87
	Chamois	3	0.02	2	0.58
	Red Deer	52	0.33	7	2.04
	Elk	6	0.04	3	0.87
	Roe Deer	2	0.01	1	0.29
	Wild Boar	10	0.06	3	0.87
	Brown Bear	3	0.02	2	0.58
	Beaver	11	0.07	3	0.87
	Mute Swan	1	0.01	1	0.29
	Red-breasted Merganser	1	0.01	1	0.29
	Raven	1	0.01	1	0.29
	Pike	1	0.01	1	0.29
	Cyprinids	1	0.01	1	0.29
	Total	15,589	100	343	100

Fig 27. Number of identified specimens (NISP) and minimum number of individuals (MNI) for the complete sample

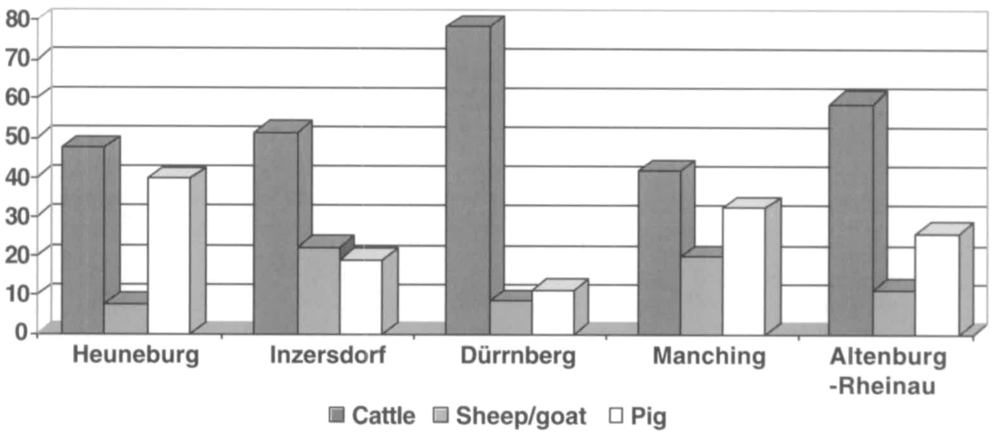

Fig 28. Proportions of dominant species of animals in some Iron Age samples (y-axis = per cent of total NISP)

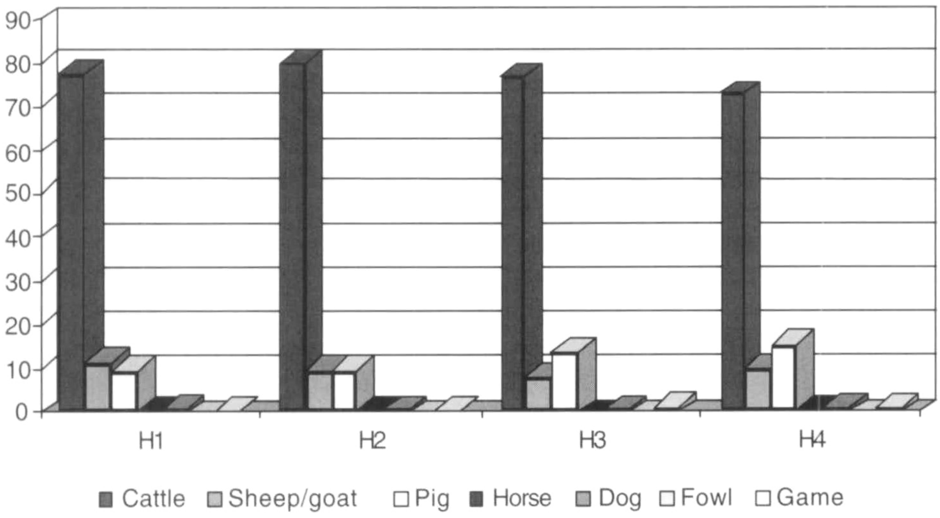

Fig 29. Diachronic changes in the faunal composition of the total NISP

practices – such as the use of nose-rings – but in the absence of known parallels amongst modern material, a definite explanation remains elusive.

Figure 29 shows the very slight diachronic changes traceable within the 250 years of site occupation documented by the four strata (H1 to H4). It is clear that the most characteristic feature of the sample, namely the huge predominance of cattle bones, never falls below 72 per cent. The even more pronounced predominance of cattle in the sample that cannot be assigned to a particular chronological horizon (H?) indicates that the proportion of cattle to other animals in the well-separated strata is probably underestimated. Some moderate changes are visible between H2 and H3 – the frequency of pig and game bones increasing in H3 – whereas the proportion of cattle, sheep and goats decreases slightly.

Some insights into the economic structures of the Dürrnberg are offered by analysis of the 12,223 cattle bones. The sex determination of pelvic bones, horn cores and metapodials provides surprisingly similar results from each strata. The sex ratio of the complete sample is roughly 75 per cent cows, 22 per cent oxen and 3 per cent bulls. Diachronic changes observed include a doubling of the proportion of oxen from levels H1 to H4. Age determination based on tooth wear is shown in figure 30. The abundance of young cattle with deciduous dentition (M4o–M4+++) is strikingly low; a decrease over time of calves starting at 24 per cent in H1 to 4 per cent in H4 is clear. In contrast, cattle with M3 o and M3 + stages (sub-adult and young adult) increase from 26 per cent to 50 per cent while medium stages (M3 ++) predominate. Extensive tooth wear (M3 +++) is only frequent in H3.

This lack of young animals, becoming more pronounced from H1 to H4, supports the assumption that the food supply came from outside the immediate area of the Dürrnberg. Under normal rural conditions the abundance of young tooth wear stages is usually much higher than these results show. On the other hand the predominance of cows and medium stages of tooth wear closely fits with what is known of the Alpine Iron Age practice of concentrating on milk production. The maximum ratio of older cattle in H3, and the further increase of oxen, points to a growing demand for beef. Probably the stockbreeders could only meet these demands if they raised more castrates for additional meat production. All these

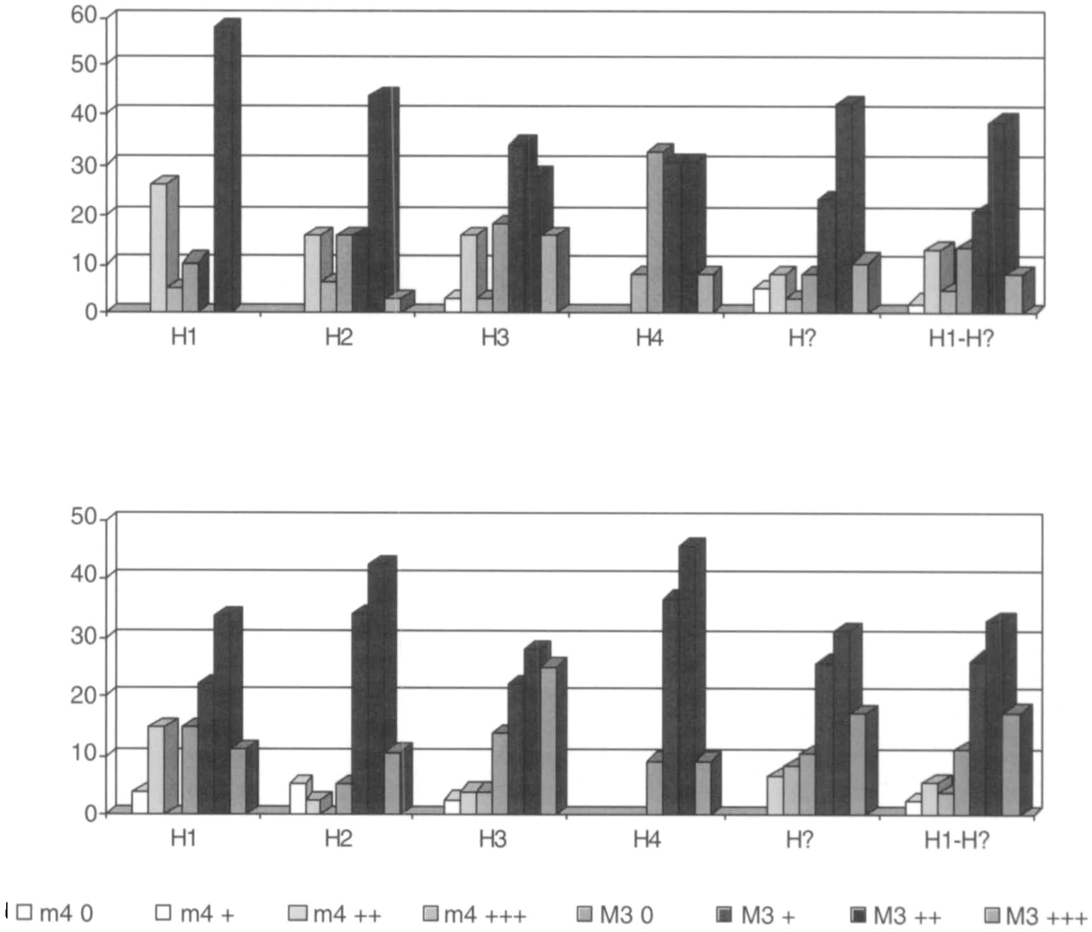

Fig 30. Cattle age determination based on tooth wear stages (0–+++) divided in strata (maxilla above, mandibula beneath. *y*-axis = per cent of unit)

factors, and the methodical butchering techniques, suggest that meat processing had reached a level of effectiveness comparable to that known for the Mediterranean.

The anatomy of the Dürrnberg cattle is typical of the small, short-horned Iron Age cattle of Central Europe, a type well known from extensive samples from sites in southern Germany.[82] The Dürrnberg sample is completely free from later disturbance, and the population is even more compact and uniform than the late La Tène bones from Manching, which include some later Roman intrusions. The variation in height at the shoulders, based on ninety-six metapodials and calculated following the factors defined by Matolcsi,[83] ranges from 949 to 1,225mm, with a mean of 1,066mm. The mean value of fifty-eight cows is 1,044mm, of thirty-three oxen 1,107mm, and of five bulls 1,056mm. Comparisons of the small measurements, such as articular width, confirm the position of the Dürrnberg sample as being within the normal range for the Iron Age cattle population.

Osteological – particularly craniological – features of the Dürrnberg cattle closely resemble those of the Styrian or Ennstaler Bergschecken breed, extinct since 1986.[84] These animals have

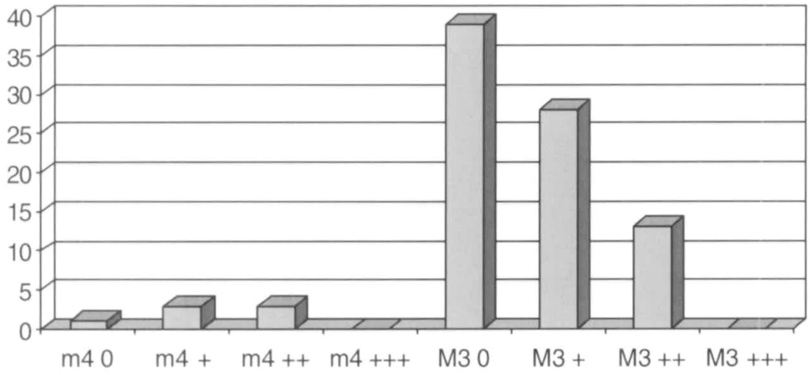

Fig 31. Pig age determination based on tooth wear (0–+++) – whole material amalgamated (maxilla + mandibula. *y*-axis = numbers)

been described by Wilckens, Zacharias and others as being very small as well as hardy and resistant to the severe mountain climate.[85] Of the nineteenth-century individuals described, only a few were more than 1.10m high. The cows weighed some 350kg, with slender limbs, pointed muzzles and small, turned-up horns. The coat was reddish or yellowish, sometimes with black spots or dots along the flanks leaving the rest of the body, particularly the head, neck and belly, white in colour.[86] The milk and meat quality of the Bergschecken was much appreciated, but their yearly production of scarcely 1,500 litres of milk would be considered insufficient for twentieth-century needs. Widespread medieval – as well as recently discovered Roman – faunal evidence for this unique breed[87] supports the thesis of its ultimate ancestry in the East Alpine and Danubian area.

Within this zone a distinct break is detectable in the graph showing measurements of cattle bones between the Middle Bronze Age and the Late Bronze Age.[88] The cattle of the Early and Middle Bronze Age are only slightly smaller than the tall cattle of the Danubian Neolithic and occasionally even taller than the medium-sized cattle of the Alpine late Neolithic.[89] But with the beginning of the Late Bronze Age, measurements from urnfields (*c* 1300 BC) suddenly drop to the much-reduced range of Early Iron Age cattle. From then on cattle size reduces gradually to that common in the La Tène period. The causes of this sudden change are not yet resolved.

The remains of the other less frequently occurring animals have not yielded the same amount of information. Sheep bones are three or four times more frequent than goat bones. In sheep the sex ratio is more or less equal, while females predominate amongst pigs. The horn cores of the rams resembled those of mouflon, but were a little smaller and had a semicircular cross-section. Most of the ewes were without horns, but some of them had rudimentary horn cores. With caprids and pigs, jaws exhibiting deciduous dentition are extremely rare, and young adult to medium-aged specimens are predominant (fig 31). Again, this suggests that the slaughtered animals were not raised on the Dürrnberg itself – or only exceptionally so – but were rather supplied on the hoof from outside the area. Sheep had a 660mm mean height at the shoulders (Teichert's factors[90]), somewhat taller than the Iron Age populations of South Germany, and more closely resembling sheep from south of the main Alpine zone. A mean shoulder height of 750mm[91] establishes the Dürrnberg pigs as one of the tallest breeds of their period. This height factor can also be seen in the Dürrnberg dogs, which have a mean height at the shoulders of 590mm (Harcourt's factors[92]).

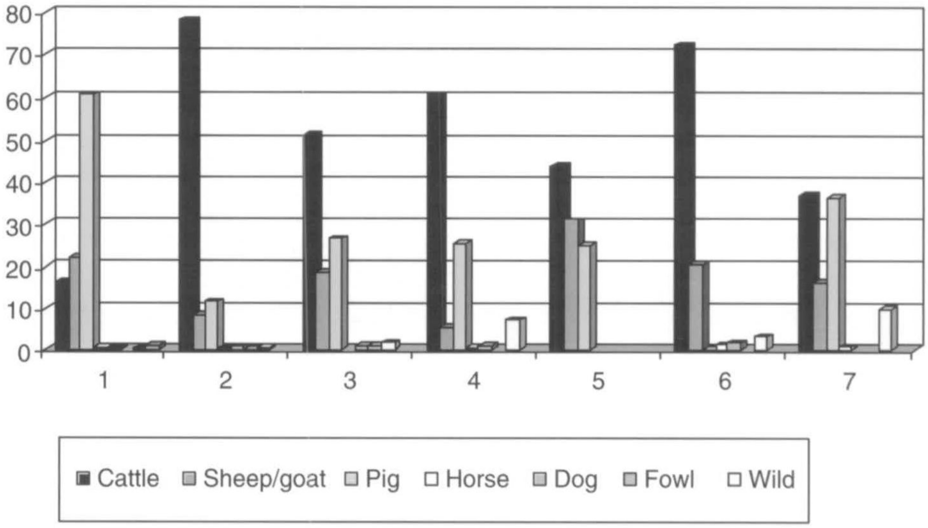

Fig 32. A comparison of the percentage of the most important domestic animals in different Urnfield to Iron Age settlements at the Dürrnberg and in its surroundings (Hallstatt and Hellbrunnerberg). Key to settlements: 1: Hallstatt (Urnfield period) (Pucher 1999b); 2: Vorderramsau (Pucher 1999a) (number = 15,589); 3: Hinterramsau (Megaw 1990) (number = 117); 4: Ramsaukopf (J Boessneck in Irlinger 1995) (number = 201); 5: Dürrnberg graves (M Stork in Moosleitner, Pauli and Penninger 1974) (NISP = 16); 6: salt mine skins (Groenman-van Waateringe 1998c) (number = 241); 7: Hellbrunnerberg (G Wipplinger in Stöllner 1996b) (NISP = 143)

Similar results are obtained when comparing the Ramsautal evidence with that from other parts of the Dürrnberg settlement (fig 32). At the Ramsaukopf and in the Hinterramsau, cattle again dominated, if at a lower ratio: cattle bones make up 60 per cent and 51 per cent of the total, respectively, compared with 78.4 per cent in the Ramsautal, whereas pig bones are more frequent at 25 to 26 per cent as compared to 11.5 per cent.

Fowl and horse remain at a constant, if minor, level while sheep and goat vary anywhere between 5 and 19 per cent. The other known settlement complexes are too small and have produced too little faunal material to allow a detailed interpretation. The dominance of cattle is striking, however. This underlines the general importance of cattle for meat processing and of the maintenance of a regular supply to the Dürrnberg community. At the neighbouring princely settlement of the Hellbrunnerberg (Hallstatt D) some 15km to the north, on the outskirts of present-day Salzburg, cattle and pig populations are nearly equal. Here too there is a higher percentage, and a greater variety, of wild animal remains. This compares closely with other late Hallstatt princely sites, such as the Heuneburg.[93] At the Hellbrunnerberg a higher percentage of younger animals were being slaughtered as compared with the Dürrnberg. Even more remarkable is the clear demonstration of the importance of hunting for the daily meat supply. In view of the comparable numbers of wild animals on the Ramsaukopf, this may point to activities directly related to a particular social class. Unfortunately, the absence of comparative evidence from other settlements in the Salzburg basin severely limits any firm conclusions about animal husbandry in the smaller Iron Age settlements of the area.

The Ramsautal settlement seems to have played an important role in animal husbandry, which fits well with its position at the top of the main entrance to the Dürrnberg, via the Raingraben valley. One can imagine that cattle were driven up to the Dürrnberg to be slaughtered and butchered there.[94]

Further ideas about on-site production and usage can be gained by looking at animal skins. Skins and hides were used in the mines for protective clothing (such as shoes and caps) and for technical purposes (such as ropes and bags).[95] Cattle skins are again dominant among the surviving materials. Most retain their colour, giving a good impression of the light brown to dappled yellow coat of the so-called 'Dürrnberg cattle' (fig 33).[96] This dominance offers good evidence for the interdependency between the mines and the craft centres of the Ramsautal settlement.

Besides leather working, one might imagine that beef was produced in the Ramsautal on a scale sufficient for the miners' needs. However, the very small quantity of animal bone found in the mines offers no support for this assumption. Only a handful of pig bones have been found (mainly ribs) and only fragments of cattle bones (mainly butchery off-cuts, such as tails).

This scanty faunal evidence does not match the level of meat consumption known from other evidence. Parasites found in the miners' faeces indicate the consumption of a variety of raw or inadequately cooked meat, including offal, such as sheep's liver. The butchering techniques point additionally to a very advanced system that may have resulted in a complete separation of bones and meat – techniques that are well known from the contemporary Mediterranean world.[97] Perhaps this explains the lack of bones within the mines.

Finally, one can arrive at some indication of the scale of stock rearing in general if one calculates the average number of individual cattle represented by the remains found in the occupations layers of the Ramsautal. Although it is not possible to extrapolate a finite number of individuals from the NISP, a large number of cattle appear to have been slaughtered during the settlement period. In fact, the quantities are such as to suggest the presence of specialized butchers. Further evidence for this is supplied by the frequent occurrence of standardized cut-marks.

One may thus imagine that the cattle management in the Ramsautal was geared to raising sufficient stock for the year-long operations of the mines. Perhaps the meat was cut into small pieces (possibly separated from the bone) and it may be that offal in particular was boiled to produce a stew. The bones associated with the more select cuts are not found in the mines; perhaps these joints were not consumed by mining groups. On the other hand, there is clear evidence of particularly choice portions of meat being found as grave gifts.[98] The latter might reflect burial customs rather than a regular eating pattern, but it points to a possible difference between the diet of the miners and that of the upper social groups represented in the graves.

A similar situation can be observed for Hallstatt in the Late Bronze Age, where there was intensive pig breeding, and where the pigs slaughtered in the valley were carried to the Salzberg above the Hallstatt lake and processed there.[99] This husbandry had the aim of producing sufficient stock for the miners for the whole year, especially in the early spring, but only the off-cuts of butchering were cooked for feeding the miners – evidence of superior cuts of meat has never been found in the mines. It might follow, then, that the Dürrnberg community did not just produce meat for themselves but also perhaps for the local market and for export. Strabo (IV, 3, 2 192, 197) remarks that in Italy the preserved pork of the Sequani was highly appreciated, preserved meat being a well-known article of commerce. (EP, TS)

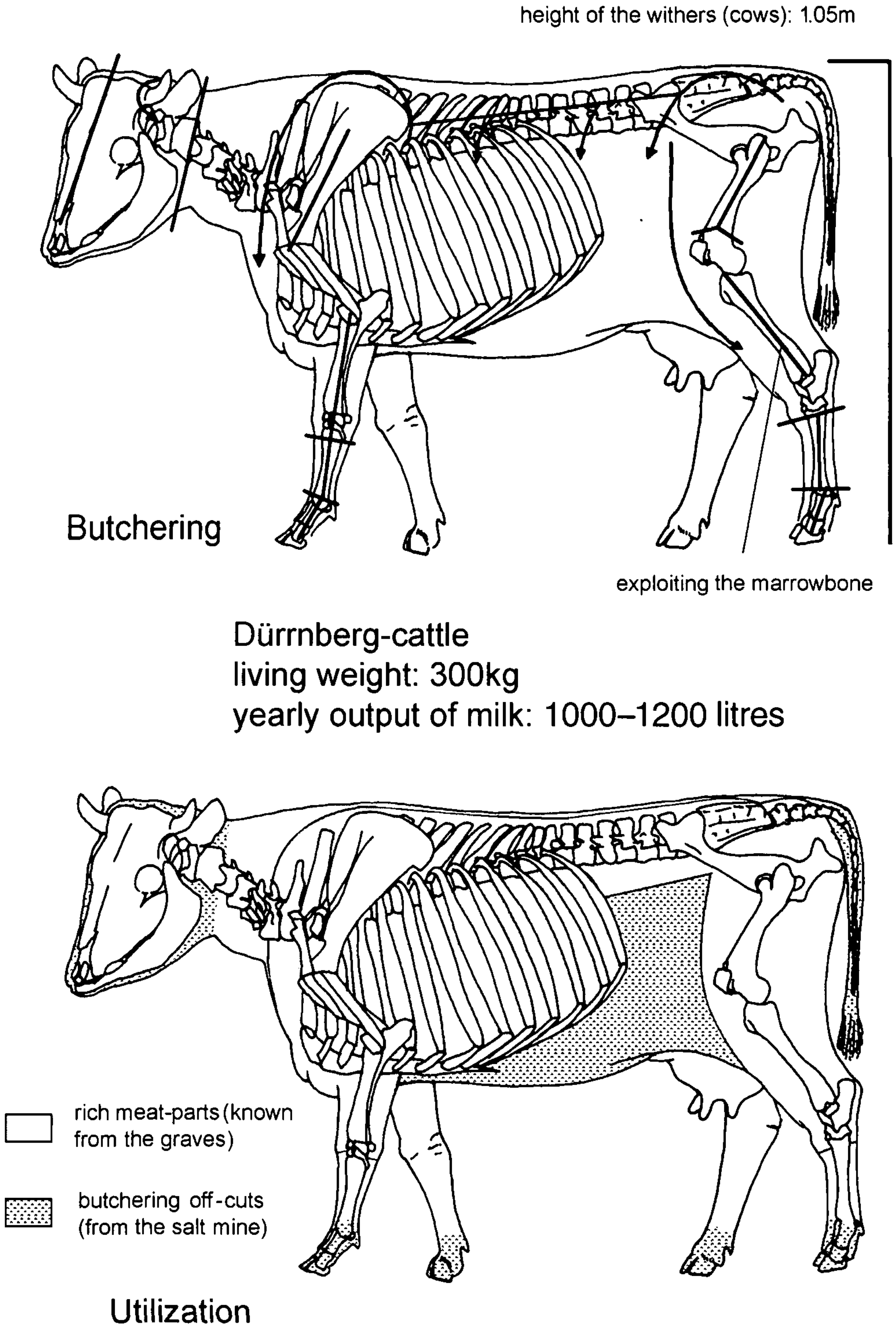

Fig 33. The Dürrnberg cattle: butchery patterns and the occurrence of different joints in the mines and graves. *Drawing*: T Stöllner

IRON AGE LANDSCAPE USE ON THE BAVARIAN SIDE OF THE AUSTRIAN-GERMAN BORDER

The contemporary landscape of the Dürrnberg, with its woods, meadows and open settlements, is essentially medieval in origin. When the Archbishop of Salzburg and several monasteries in the region decided to reopen the salt mines in the thirteenth century, they resettled the Dürrnberg in order to assure an adequate labour force. It is likely that an existing pattern of Alpine pastures belonging to the Abbey of St Peter in Salzburg was now utilized for more permanent settlement. The whole area of the Dürrnberg was subdivided into individual plots allowing mostly poor farmers to make a living both from farming and mining, something that made the Dürrnberg attractive for new settlers.

The Celtic period seems to have been completely different. Prehistoric activities were concentrated on the central part of the Dürrnberg, especially around the so-called Moserstein. Not only was the richest and most outstanding early La Tène cemetery located on this geographically important point, it was also the location of the central area of settlement on the Dürrnberg throughout the Iron Age from the beginning of the sixth century BC on. Geophysical survey has revealed a dense settlement pattern, especially between the St Joseph Sanatorium and the Ruedl-Kopf, a small hilltop at the south-eastern end of the plateau. Furthermore, most of the surrounding parts of the Moserstein – such as the Ramsautal and the Ramsaukopf – were densely settled in the La Tène period[100] by contrast with the sparser settlement patterns of the historical period.

One of the crucial questions at the outset of the current project was therefore to attempt to expand our knowledge of putative fringe settlements. Two main areas were selected for further survey and excavation: the German part of the main salt-mining area west of the Hahnrainkopf and, north of the mines, the Zill/Scheffau basin.

Collaboration with the Bayerisches Landesamt für Denkmalpflege made it possible to start the survey with a programme of systematic aerial photography, which was carried out by K Leidorf. Sorties were flown around the year, but especially in early spring. A sampling programme was also employed using metal detectors to find potentially interesting anomalies in several of the wooded hilltops lying around the Zill and the Wildmoos marsh (see fig 34).

These preliminary programmes were followed by a more detailed survey involving a series of boring or coring lines, as well as geophysical measuring at various localities.[101] The main focus of the latter programme was to identify mining entrances and related structures. All these activities have assisted in the construction of a rough outline of Iron Age activities in the Hahnrainkopf and Scheffau areas.[102]

In the north-western part of the Hahnrainkopf, traces of prehistoric settlement activity are very rare. Coring confirms that the wet Wildmoos swamp was never settled, although there is a scattering of sherds in the area.[103] As the whole area is a basin, coring has also provided evidence that Holocene erosion action could have destroyed some of the prehistoric settlements situated in higher parts of this area. The Wildmoos area has been used for agricultural purposes since medieval times, and occasional intensive ploughing must have accelerated local erosion processes. Carbon-14 dates from the eastern edge of this area support this assumption, by showing that there has been considerable soil covering since medieval times. However, a possible settlement was identified on the Karner property, where borings and geophysical measuring produced evidence for pits and other anomalies.

Since this location is close to the entrance of the western group of mines, it was decided to extend our knowledge of the area by undertaking a small excavation in 2000, designed to locate

Fig 34. An east–west view of the Wildmoos area. In the background is the area of the Iron Age entrance with tailings (see fig 14); in the foreground is the site of the marsh, with the presumed Iron Age settlement on higher ground. *Photograph*: T Stöllner

the pit-like anomalies. Instead, all that was found were layers of accumulated hill-wash, though these did contain Iron Age finds – a fragment of a blue glass bead and some small sherds of *Graphittonkeramik* ('graphite ware') – indicating a date in the La Tène period. The settlement area itself will have to be looked for in a higher position up the hill.

The area has thus provided some slight indication for Iron Age settlements, even if their exact locations are as yet unknown. Certainly, mining activity can clearly be seen in the contemporary landscape on this side of the Hahnrainkopf. Similar results were also obtained in the south-western part of the Hahnrainkopf, but although survey work has located at least one further mining entrance relating to the southern group of the prehistoric mining network (field K), it was almost impossible to find any traces of Iron Age settlement.

The mines around the Hahnrainkopf are linked to another potential settlement area in the Scheffau by a track using an erosion gully called the Nesseltal. This track gives access to the Dürrnberg, less than half an hour distant. The Scheffau is quite different from the Dürrnberg and consists of a basin-like landscape, surrounded by two areas of high ground used in recent times as locations for farmhouses, while the swampy centre of the basin had been a small lake in post-glacial times. The mountains surrounding this basin are, on average, 100m lower than in the vicinity of the Dürrnberg and, due to a more favourable climate, the area has a greater potential for plant growth.

Coring produced evidence for sedimentation reaching back to the seventh millennium BC. Again, it proved difficult to find evidence of Iron Age settlement in this area, even though aerial photographs taken in the 1980s and 1990s had indicated a couple of burial mounds in the eastern part of the Scheffau called the Zill. Further aerial survey followed by geophysical measuring confirmed the existence of at least two burials that can be identified by their stone chambers, while others can be identified by their profiles.[104] Further isolated finds from the general area can be closely related with this small cemetery. They include one early La Tène brooch[105] and sherds spanning the whole La Tène period (fig 35). Some other stray finds from the location of the Kraxenberg might date back to the late Hallstatt period. This is important evidence because it underlines the permanent usage of this small, perhaps mainly agricultural, area during the whole period of the large settlement of the Dürrnberg.[106]

Most of the sites that have produced Iron Age material are located on the surrounding heights. One is the Kühloch cave, first identified by Ferdinand Birkner in 1921, a rock shelter perhaps only occupied temporarily. The discovery on the Kraxenberg of a grinding stone offers clear evidence for more permanent settlement activity. The same goes for sherds found on the south-western edge of the area during drainage operations along the modern road; the range of forms represented offers a time-span between the early and middle La Tène period indicative of a long-term settlement somewhere in the vicinity.

Excavation in the summer of 2001 produced more information concerning a location first noted in the 1980s. In the course of ditch-digging with a back-hoe a passer-by reported the discovery of wooden structures, charcoal and graphite ware. Here there seemed to be clear evidence for some kind of waterlogged structure. After removing the topsoil a trial trench brought to light a waterlogged wooden construction with a width of around 2m flanked by wood off-cuts and branches.

Further careful cleaning of the timbers allowed a more precise description and interpretation: above a foundation of logs and planks, a couple of small tree logs had been carefully laid down (fig 36). Altogether, this suggests the existence of a wooden trackway, perhaps for crossing the wet ground in the middle of the valley. There are comparable prehistoric trackways in Ireland that include, particularly in the Iron Age, shorter lengths or 'puddle *toghers*' used simply to

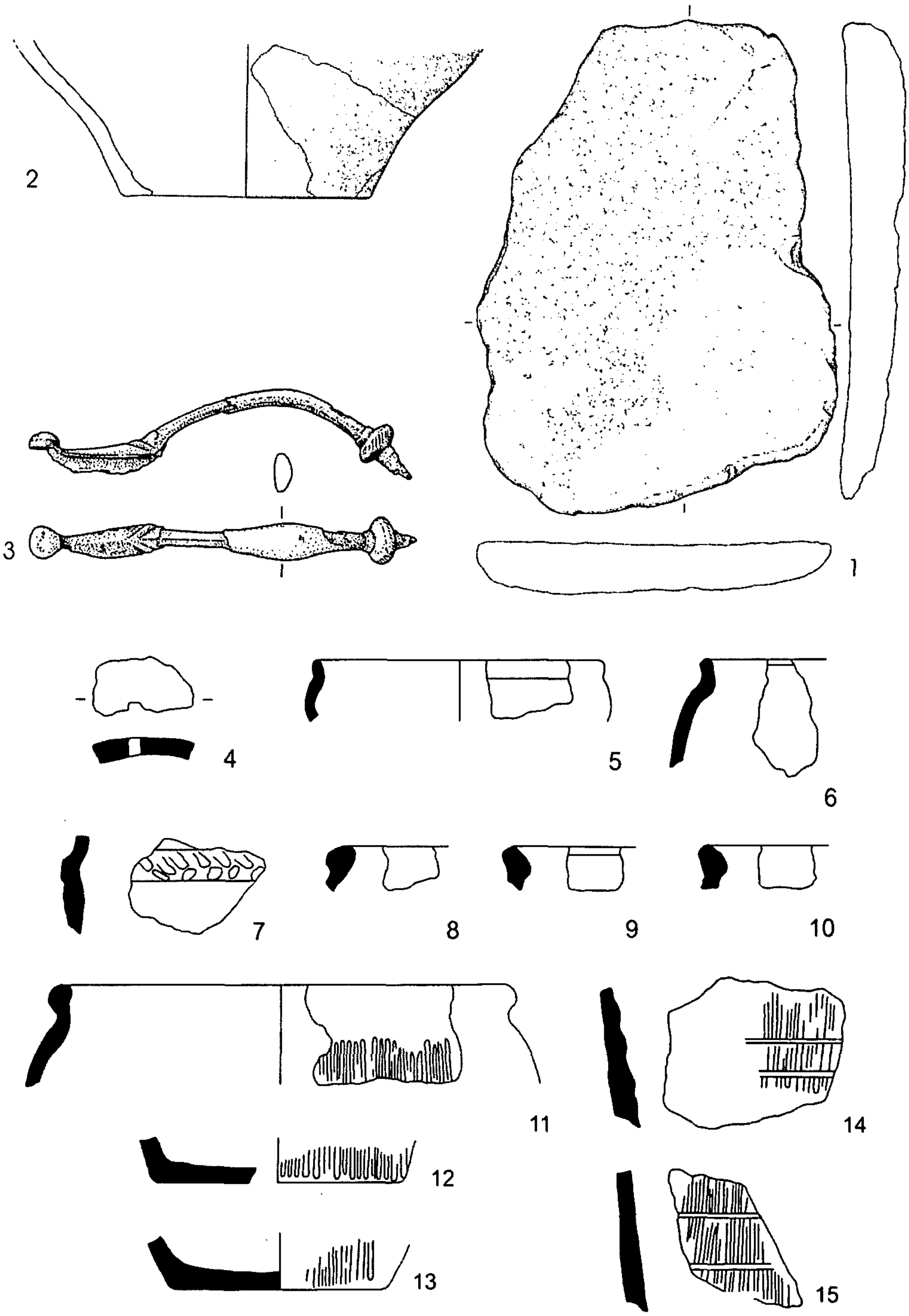

Fig 35. Scheffau, Marktschellenberg: stray finds found on the Kraxenberg (1 and 2), on fields and heights near the Hirschbichllehen (3) and near the Malterlehen (4 to 15) (scale 1 : 3; brooch scale 2 : 3) (after Irlinger 1995). *Drawings*: M Krause, Marburg (1–2); after Bayerisches Landesamt für Denkmalpflege (3); after W Irlinger (4–15)

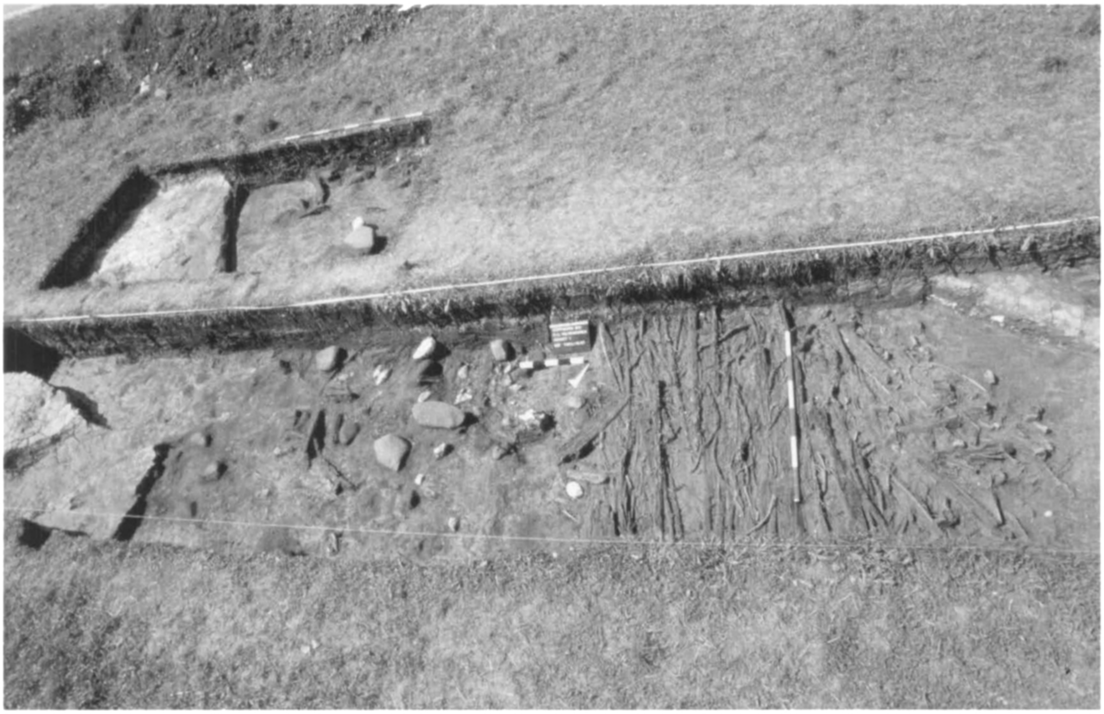

Fig 36. Excavation of a medieval trackway near the Wilhelmlehen in 2001. *Photograph*: T Stöllner

prevent cattle from sinking into marshy areas, constructions that continue into the present day.[107] Continental parallels include the 'Via Claudia' in the Tyrol.[108]

On both sides of the Scheffau trackway, branches and waste wood had been dumped in no particular order, perhaps to stabilize the surrounding muddy soil. In the vicinity of the trackway were found Iron Age pottery, a wheel-turned wooden bowl and a pair of iron horseshoes. Although an Iron Age or Roman dating for the horseshoes has been advanced,[109] they could equally be placed in the medieval period. Another fragment of a horseshoe and two other nails found on the surface of the trackway has now offered a clear chronological and functional context to the trackway. Counter-arguments for an Iron Age dating, a Carbon-14 measurement carried out in Zurich, finally places the feature in the twelfth or thirteenth century AD (cal AD 1156–1283). While this feature belongs to the medieval renaissance of salt mining, it also provides some information on the Iron Age settlements, because the whole area was covered by a sedimentary accumulation mixed with charcoal and Iron Age pottery. The absolute dating of the medieval trackway gives a *terminus post quem* for this sedimentation, which should be dated to the thirteenth–fourteenth century AD. It provides clear evidence that intensive medieval agricultural working of the Scheffau might have caused considerable – if not total – degradation of the Iron Age soils, and might well have destroyed at least part of the Iron Age settlement structures.

To summarize our current stage of knowledge, there is no doubting the existence of an extensive Iron Age settlement in the Scheffau, even though the exact localities of such settlements remain unknown. The fertile agricultural soil may point to crop production in the *rural hinterland, which was in close contact with the main settlements on the Dürrnberg.* Proof of this lies in the archaeological material – the pottery and the early La Tène brooch already mentioned have direct parallels on the Dürrnberg and may indeed have been made there.

Recent research in the fringe zones around the Dürrnberg has clearly shown that more attention needs to be paid to the hinterland of the salt-mining centre – such zones clearly cannot be ignored if one wants to understand the economy of the salt-mining process in general. (WI, TS)

THE DÜRRNBERG: CENTRE FOR CRAFT SKILLS OR IMPORTER OF LUXURY GOODS?

Examination of the often spectacular finds from graves on the Dürrnberg is beyond the scope of this paper,[110] but a number of questions present themselves with regard to the organization, distribution and supply of both exotic raw materials and fine metalwork that need to be taken into consideration when attempting a reconstruction of the Dürrnberg's social and economic systems. Furthermore, we should ask if the Dürrnberg was a magnet for artists and travelling artisans – was the site itself a producer of skilled metalwork that spread to other parts of Central Europe?

It is some considerable period of time since one of the authors of this paper first raised the possibility that artisans engaged in producing fine metalwork might have been largely itinerant.[111] Subsequently – in a detailed study of the Basse-Yutz (Moselle) find – we commented that the pair of early La Tène bronze-beaked flagons might have been the result of 'close collaboration between craftsmen of different specializations and, quite possibly, different regional traditions in the production, whether under patronage or as a co-operative enterprise ... of exceptional objects for a very special spiritual or temporal purpose'.[112]

Detailed examination has demonstrated technical similarities between the Basse-Yutz beaked flagons, a flagon that is regarded as the *chef d'oeuvre* of Iron Age art on the Dürrnberg, discovered in 1932 by O Klose in the chariot grave (112), and one recovered in 1995 from barrow 1, grave 1 below the Glauberg (Wetteraukreis). Such similarities might be thought to support our hypothesis.[113]

Certainly this is in contrast to the claims of L Pauli and F Moosleitner that the Dürrnberg flagon was, in the words of the latter, *als Erzeugnis einer hochqualifizierten Werkstätte, die im Dienste der Salzherren tätig war, bezeichnet werden* ('to be regarded as the product of a highly qualified workshop that was in the service of the salt lords').[114] If there was such a workshop it clearly did not work exclusively in the Dürrnberg region.

As we have previously pointed out following Moosleitner, there are a number of copies in pottery and wood[115] of the typical concave-profiled bronze-beaked flagon, of which one comes from settlement material on the Moserstein and another from Hallstatt grave 21 (1938). More recent discoveries have swelled the number of pottery beaked flagons to more than forty examples, though only a handful centred on the Alpine foreland copy the presumed concave-profiled metal prototype. The latter include particularly fine, wheel-turned examples from settlement deposits at Gilgenberg am Weilhart (Upper Austria), from the Ehrenbürg (Oberfranken) and, the furthest northern example, a barrow find from the Middle Rhine at Sien, Kreis Birkenfeld.[116] While there are no conclusive fabric analyses, it seems only reasonable to regard the majority of the pottery flagons as local products fulfilling the same assumed status position as the other two classes – but not exactly in every detail, in view of the fact that pottery flagons occur in settlement contexts. That they occur at all would indicate that, while the form of the beaked flagon was uniformly prized, the ability to command the necessary skills to produced an ornate metal flagon lay largely outside the Alpine area.

What, then, may be deduced from the presence of exotic materials on the Dürrnberg, such as amber, coral and marine shells, all of which, as has been pointed out, signal 'accumulating and controlling power through the acquisition of restricted raw materials'[117] and which must have involved on-site storage in their unworked state?

Firstly, as to amber, by far and away the commonest of the exotic materials brought to the Dürrnberg, there seems little reason to doubt that the primary – and possibly for the Alpine region, the sole source – was the Baltic.[118] On the Dürrnberg, where amber appears from the very beginning of Iron Age settlement, the local use of lathe-turning – already noted in woodworking (see above) – can be assumed for the manufacture of, for example, beads from imported raw material.

We have already queried the 'on-site' production of the bronze flagon from Dürrnberg grave 112. While tools are not unknown from the settlement areas, and although Pauli has drawn attention to the high quality of bronzes found on the Dürrnberg, unequivocal evidence for localized fine metalwork production is sparse – although various traces of blacksmith's work (iron bars, iron anvils, metal and slag) have now been found over the whole area.[119]

No mould fragments have been found so far that might be related to the more than a hundred early La Tène decorated bronze brooches found in the graves on the Dürrnberg and produced by the lost-wax process. However, the large number of such brooches found to date – far more than are known from any other single site – and their stylistic parallels with southern German examples might suggest a locally based stylistic group.

We still believe that one may interpret the available evidence as supporting skilled itinerant craftsmen producing on-site prestige goods. This view has been challenged by those who would argue that craftsmen would be tied to localities where raw materials could readily be obtained.[120] Certainly there is further support for the Dürrnberg as a 'central place', as will be suggested in the concluding section. The Kleiner Knetzberg[121] on the other hand is not a major settlement or industrial centre, despite the discovery there of an unfinished mask-shaped brooch (*Maskenfibel*) and fifteen complete brooches, including one in the shape of a shoe with an upturned toe-piece.

It is quite possible that another high-quality find from Dürrnberg (grave 44/2) – the bronze 'pilgrim flask' with its compass-constructed and scribed decoration on the body and four anthropomorphized feet, each shod with a pointed-toed shoe, here embellished with a pair of eyes – may have been made on site. The pilgrim flask owes its form to trans-Alpine prototypes, but its decorative elements are wholly local and the site has produced the scribers that would be necessary for producing compass ornament, although compasses are known only from later contexts.[122]

It may be observed that less than forty of the graves so far excavated are identifiable as being those of a 'warrior'. This represents around 10 per cent, a small proportion of the total and hardly enough to constitute a warrior caste – though remaining consistent with the idea of an elite.[123] Archaeology is overloaded with *ex silentio* arguments, but just as there are no graves (as yet) identifiable as those of miners, so one can but speculate on the absence (so far) of evidence for those responsible for the splendours of the craftsman's skill that set the Dürrnberg apart as something unique in the early La Tène world.

As well as strong evidence of long-range trade involving raw materials, it is clear that there are 'long-range' stylistic elements too. This is hardly surprising if one accepts our view of La

Tène 'art' as representing a form of symbolic visual communication that may well have acted as an overarching phenomenon linking the various disparate communities making up much of Iron Age Central and Western Europe.[124] Links between the art of the various regions – and the relationship between such centres as the Glauberg, the Middle Rhine, the Dürrnberg and, further east, the Traisental – need to be further explored.[125] For the present, while the answer to both parts of the question posed in our title should be in the affirmative, the supporting proof for each assertion still remains tantalisingly weak. (VM, RM)

THE DÜRRNBERG AS AN ECONOMIC SYSTEM – A SUMMARY

Recent work at the Dürrnberg has provided evidence that salt mining flourished between the end of the sixth and the middle of the fourth centuries BC (confirmed by dendrochronological dating). These results have also generated some ideas about the production history of individual mining districts, each of which lasted 100 to 150 years. Large-scale salt extraction seems to have been combined with a large labour force – conclusions that were drawn from the amounts of meat consumed, the amounts of faeces occurring in different layers of the Heidengebirge and the generally high infestation by parasites (both higher than in the older mines of Hallstatt). As well as skilled miners, we also have evidence for greater use of child labour than at the latter site.

Besides the primary task of mining rock salt, it is possible to distinguish other economic activities that were related directly to salt extraction and preparation. Meat and skin processing were probably linked, and they presumably made use of poorer quality salt from the mines for preservation. The high percentage of cattle bones found, especially in the Ramsautal, can be explained as the result of bringing special consignments to the Dürrnberg from the rural hinterland. Meat was probably cured to produce sufficient reserves for year-round activity in the mines. Nevertheless, the small quantity and the nature of the off-cuts from butchering found in the mines – most likely cooked in some kind of stew – suggest that the miners themselves did not consume all the meat represented by the Ramsautal bone deposits.

It is likely that the Dürrnberg community – like that found in Late Bronze Age Hallstatt – reserved better cuts of salted meat for regional and long-distance trade. This conclusion begs questions concerning the character of the Iron Age salt trade itself, and the possibility must be considered that it was the cured meat that would have been traded rather than the salt.

Hides and skins were used for miners' clothing and tools (bags, wedges and binding for iron picks, for example) – but we lack clear evidence for the actual steps taken in their production.[126] Meat- and skin-processing activities might have taken place near the entrances, where salt debris was dumped in considerable quantity – but the evidence is too scanty to allow this to be more than a strong suspicion.

The directly related processes of salt production, butchery and leather working seem to have served as the primary source of income that underpinned the social welfare and economic structure of the Dürrnberg community (fig 37). Success in mining was the basic coin that financed other working processes as well. Crafts such as pottery, fine metalwork (brooches and other costume articles) or textile production formed a secondary economy that was important in the establishment of a regional market. Although only small parts of the settlements have been documented so far, there are considerable concentrations of different crafts in and around the Ramsautal and at the Moserstein. Woodworking also played an important role, perhaps with some form of woodland management.

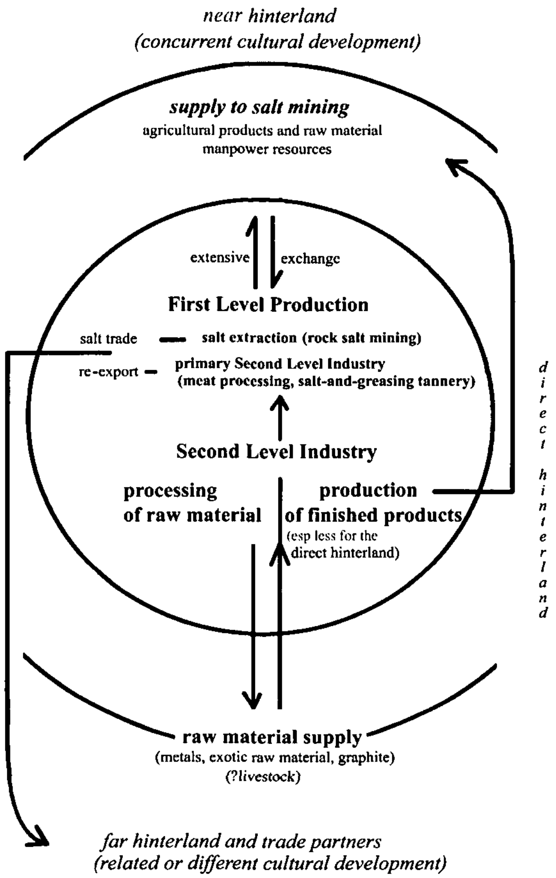

Fig 37. Dürrnberg: theoretical model of the economy of the salt-mining centre

More difficult to explain are the fine art products found in high quantity in the Dürrnberg graves. Although it is difficult to offer complete proof for the local manufacture of some of the outstanding objects like the *Schnabelkanne*, or beaked flagon, from grave 112, the Dürrnberg region does undoubtedly constitute an original stylistic province, which integrated foreign and local influences. But the bird's-head and 'Certosa' brooches typically found in the Dürrnberg graves – as well as other classes of object – seem to have a moderately restricted distribution.[127] Although we have evidence for considerable local craft activities in terms of actual artefacts (slag, anvils, bars, crucibles, tools, incomplete castings), it seems logical to include itinerant specialists as part of the craft and cultural dynamics of the Dürrnberg.

With regard to the large quantity and high quality of textiles found in the mines, one may ask if these textiles also represented a key industry on the Dürrnberg or whether, at the very least, they played an important role in secondary production. The quality and the quantity of linen found here is surprising – linen produced from flax and hemp represents around 30 per cent of all the textiles recovered to date. At Hallstatt, by comparison, the absence of linen is accompanied by more complicated, domestic-style weaving techniques and patterns.[128] This may indicate a considerable change between the Hallstatt and La Tène period. In later periods textile production seems to have been standardized, as is the case with other developments on the Dürrnberg.

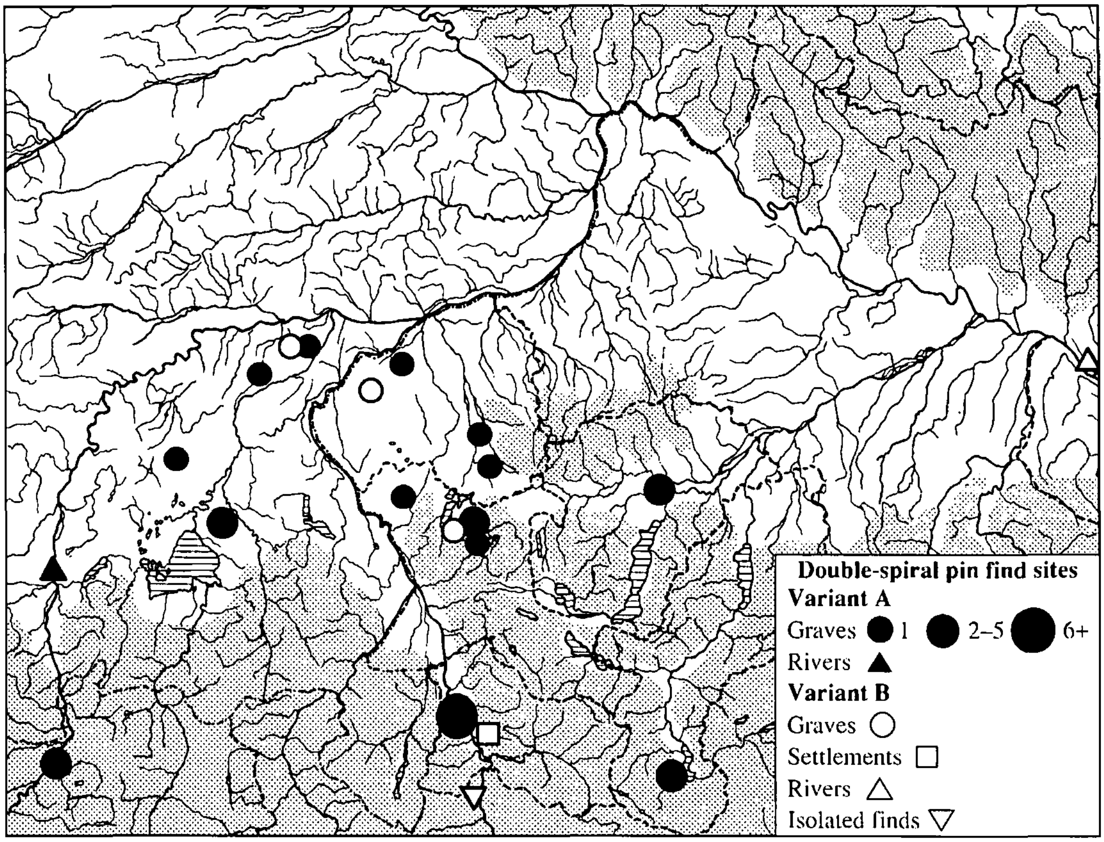

Fig 38. Inn-Salzach area (scale: 10mm = 18km): distribution of locally typical costume articles such as the double spiral pins (after Stöllner 1996c and 1999)

In the course of time the Dürrnberg evolved into a regional centre with a considerable and varied accumulation of craft industries. Furthermore, its products gained in importance in the surrounding hinterland. The Dürrnberg and its northern neighbour, the Inn-Salzach region, are thus culturally linked. These links are manifested in burial customs, such as specific grave goods in female burials, and in a generally comparable material culture (fig 38).[129] Although there were strong relations even with the southern Alpine hinterland, the latter never assumed a similar role in cultural development, as was the case for territories to the north and west. This supports the argument that sites like the Dürrnberg were, in fact, established by groups from the northern Alpine foreland.

Dependency on local and regional supply is another field where the current project has produced a sound basis for further discussion. As this is an issue that was previously treated more speculatively – determined more by hypotheses than by hard facts – our new evidence may be considered to be of particular value. It is fairly clear that the Dürrnberg had to be supported economically from outside – perhaps from southern Bavaria and Upper Austria. As has been seen, this is proven by the results of pollen and faunal analyses and the palaeobotany of different plants found in faeces from the mines. The dominance of cattle, the lack of young animals, and rational butchering techniques are reasons to believe in an external cattle-breeding programme and delivery of the surplus to the Dürrnberg. The morphological comparison between the cattle from Manching and the Hellbrunnerberg indicates that these breeds could have been based in the northern Alpine foreland, or even further away.

The analysis of the faeces shows that the miners' diet was seasonal and contained different percentages of corn in relation to the general nutritional value of their diet. Beyond that, there is clear evidence that spelt (*Triticum spelta*) was sown for winter grain during October and November. Together with the existence of some specific weeds, this clearly shows that most of the grain consumed by the miners was planted in lowland regions such as the Salzburg basin and beyond,[130] as it is only possible to cultivate millet in mountainous regions like the Dürrnberg.[131]

This pattern of summer and winter crops speaks for a complex agricultural system rather than for a rotation of mining and farming carried out by the same population. Further support for this interpretation is supplied by archaeobotanic results, which confirm that mining was a full-time, year-round pursuit. Besides the question of seasonal nourishment, there is evidence for small quantities of plants being gathered in spring and early summer, such as strawberries. These seem not to have been collected in large quantities, which would have required some form of preservation, and further underlines the fact that mining was taking place during the plants' fruiting period.

As at Hallstatt, it seems that fresh leaves of butterbur (*Petasites hybridus*) were used as a remedy for stomach pains – another pointer that mining occurred during the time when the butterbur was flourishing.[132] It also offers alternative evidence for specialization within the whole salt-mining community. Taken together, all this evidence encourages us to envisage a constant supply of grain, sheep and cattle for the purpose of feeding miners working the whole year around.

This may be the reason why economical and cultural development between the centre and the direct hinterland of the Inn-Salzach region is closely connected. Theoretically, one can divide the whole region into an area within one day's journey – roughly the whole of the Salzburg basin – and other more loosely connected areas in the Alpine foreland (fig 39). For the population of these areas the Dürrnberg served as a regional market where craft products, such as metal objects, pottery or even textiles, could be traded.

In the context of understanding regional interactions in the Iron Age, a pivotal site is the settlement on the Hellbrunnerberg, located close to the River Salzach, only 15km north of the Dürrnberg. As a result of excavations carried out by M Hell in the 1920s and by F Moosleitner in the late 1970s, there is good evidence for a rich late Hallstatt settlement.[133] Based on the archaeological evidence, it is possible to reconstruct widespread cultural contact with the western Hallstatt province and with south-eastern Alpine cultures as well as with the Middle Danube region to the east. These contacts with the Hellbrunnerberg seem to have been based on the salt trade – certainly the settlement was founded at the beginning of the sixth century, in the same period as the Dürrnberg salt mines were opened. The economic, and perhaps even the political, role of the area as a 'princely site' was possibly due to the dependence of the mining community on an external supply of food and raw materials. The interaction between the Hellbrunnerberg and Dürrnberg is clearly demonstrable. One may postulate an important settlement in the Salzach valley that served as trading post, market and administrative centre and was significant also for the foundation of the Dürrnberg mining complex.

At the beginning of the fifth century BC the Hellbrunnerberg settlement vanished – just at the time when the settlement of the Dürrnberg was flourishing, concentrated around the Moserstein and in the Ramsautal. Here, as seems most likely, was an example of regional

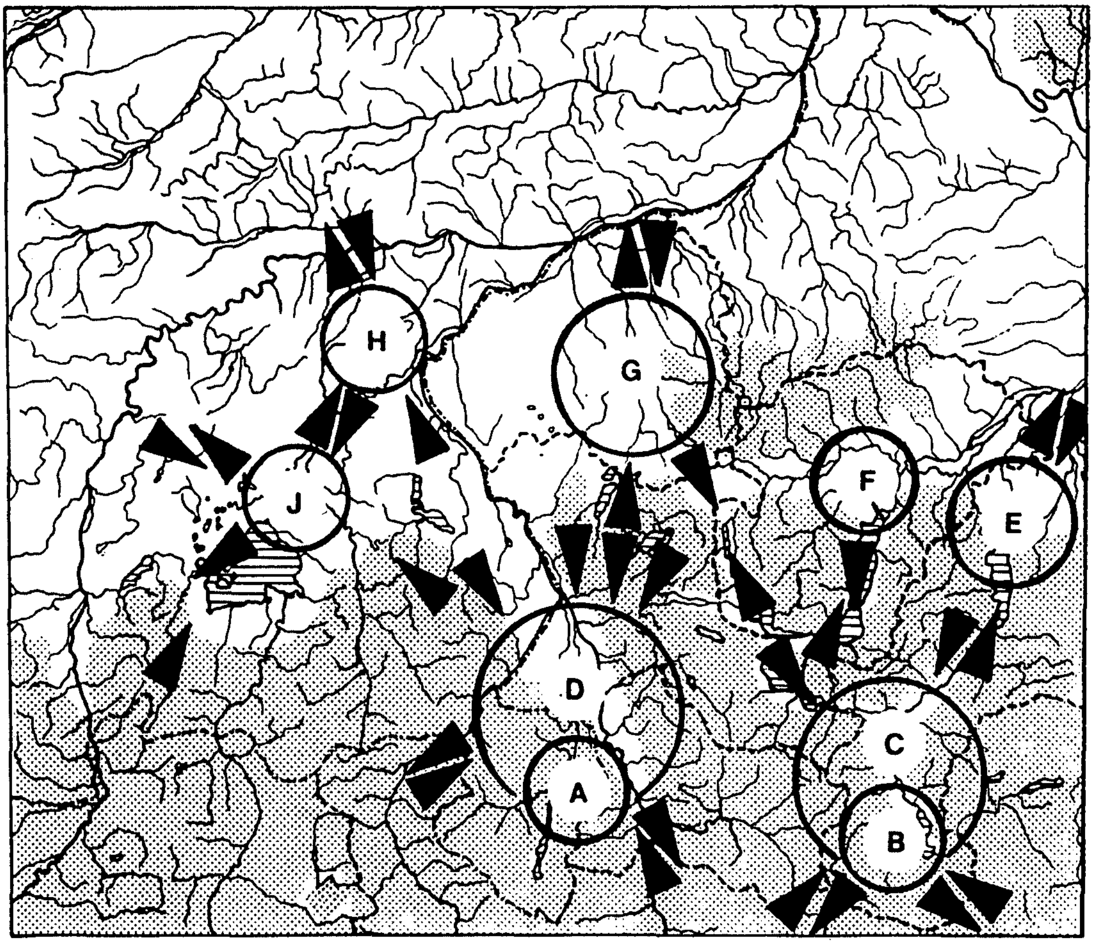

Fig 39. Inn-Salzach-area (scale: 10mm = 18km): diagram of the salt-mining centres of Dürrnberg and Hallstatt, their directly connected hinterland and the more distant but culturally and economically linked regions in the Alpine foreland. A: Dürrnberg; B: Hallstatt; C: Ischl and Goisern basin; D: Salzach basin and Rupertiwinkl; E: Gmunden-Wels area; F: Vöcklabruck area; G: western Innviertel area; H: Alzterrasse; J: the northern Chiemsee area. *Drawing*: T Stöllner

resettlement, supported by connections in the settlement dynamics of the Salzburg basin and beyond.[134]

It is obvious that the whole regional economy could not have developed to the degree it did without long-distance trade. Various luxury goods give us an impression of the trading network of the Dürrnberg: for example Attic pottery, Etruscan flagons and stamnoi,[135] a coin from Massalia,[136] silk, spices such as aniseed, coral,[137] amber, cowries,[138] and the Mediterranean red dye, *kermes vermilio*, used with textiles from the Dürrnberg mines. These remarkable finds are only a small reflection of the wealth that accrued to the salt trade. The provenance of these various raw materials also provides the best evidence for those regions to which salt was being exported. Not surprisingly, these are the same regions that were significant in medieval (not to mention early modern) times.[139] One key reason for the great success of the Dürrnberg and Hallstatt is simply the fact that the Alpine sources of rock salt are surrounded by an area of some 500km that is totally without salt.

In grave 44/1 on the Moserstein a little golden boat, found in one of the richest of the La Tène warrior graves of the Dürrnberg, allows an insight into ancient transport systems. Its form is closely comparable to the flat-bottomed craft that can still be seen today on the lakes and rivers of the region. It may be evidence for the way in which salt was transported on the River Salzach to northern consumers in Bavaria and Bohemia, such craft being depicted (in the mid-eighteenth century) on the walls of the *Fürsten-zimmer* (princely apartments) of the *Pflegerhaus* (guardian's house) (now the Keltenmuseum) in Hallein.[140]

What conclusions can now be drawn with regard to local social and political systems from the evidence of mining, economy, settlement history and diet? While one must exercise due caution, it seems there are strong arguments in support of a well-organized and politically stable core area, dominated by a powerful elite.[141] This situation is not unlike the technologically more developed *poleis* of the ancient world and their agriculturally orientated hinterland. The large populations of these city-states were dominated by a relatively small elite, even in democratic Athens of the fifth century. It is in the trading economy based on this network – and in the colonization of the eastern and western Mediterranean – that one can see wide-ranging connections at their best. Did a comparable situation exist in the eastern Alpine salt centre of the Dürrnberg? What is the significance of the rich graves that have hardly been considered in this paper? What do they really show us? At the simplest level they might seem to display the universal wealth that accrued to the whole Dürrnberg community. But how does this fit with the large-scale intensive activities of the Dürrnberg mines in which even child labour was involved?

Some 400 graves were excavated from all over the Dürrnberg up to the end of the 2001 season – graves that range in date from Hallstatt C to La Tène C. Based on this evidence one can use demographic formulae to calculate an overall population for the Dürrnberg at any one time of around 180 adults and some 90 children.[142] By contrast, it may be recalled that the population of the Ramsautal settlement was potentially estimated to be 1,000 people – and Ramsautal is only one of the settlements located on the Dürrnberg. In order to reconcile these seemingly disparate figures, one is led to an alternative interpretation of the rich burials of the Dürrnberg. They can be regarded as representing a kind of preferential rite or, just possibly, a cross-section of all the existing social groups. Neither of these last two explanations seems wholly satisfactory. It is more likely that most of the graves are those of the upper echelons of a highly stratified Dürrnberg society.

We can imagine that the wealthy upper class – represented by the chieftain (as surely he must have been) of grave 44/2 – was not centred on one individual but rather on a larger group of persons representing an aristocracy or oligarchy (perhaps consisting of inter-related families, since rich women's graves are known as well as those of men). The major demands of organizing specialist crafts and trade, as well as mining and the processing of salt, make it impossible that power would have been concentrated in one person. Rather there must have been a larger group, whose members might have had several and differing functions within the community.

So, in considering the fluctuating fortunes of the Dürrnberg economy one can fit together the incomplete mosaic that represents the outcomes of the project to date to form if not a complete picture, then one of which the main features are clear. For English readers there may seem to be some points of comparison with the social models that have evolved out of the Danebury project.[143] Graves, as well as evidence from the settlements, show us that the Dürrnberg economy flourished from the end of the sixth century to the fourth century BC. The apogee is reached in the early La Tène period or during the fifth and beginning of the fourth century BC. It is hardly surprising that it is just in this period that evidence is clearest that the Dürrnberg was connected to all areas of the Celtic world.[144]

As the Megaws have discussed in the previous section, Dürrnberg was a magnet for artisans, traders and even adventurers who sought a quick economic return. Some of them may have travelled from centre to centre or have been invited – or perhaps commanded – to come here by the Celtic nobility. It is hardly surprising, then, if key works of early Celtic craftsmanship such as the beaked flagon from grave 112[145] and the recently discovered beaked flagon from the Glauberg should demonstrate the formal and technical relations between the Dürrnberg and other important centres of the period that seem to be a mirror of these times.[146] Debate on these questions continues, but the Dürrnberg may be claimed as one of the starting points of La Tène art.[147]

All economic peaks are followed by a downturn. In the second half of the fourth century, mud-slips within the mines – perhaps caused by climatic changes or by insufficient control and over-exploitation of the natural resources – caused a minor break in this increasing development. The Dürrnberg revived again in the third and second centuries BC, but never again reached the wealth of the preceding period. The whole Iron Age operation on the Dürrnberg is like a tiny window opening on to a broader prehistoric reality. It shows that one cannot overestimate the significance of such ancient mining centres, which might have been far more than the term 'mine' might indicate. (TS)

ACKNOWLEDGEMENTS

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From 1995 the Dürrnberg project itself has been largely funded by grants from the Deutsches Forschungsgemeinschaft, supplemented by the Vorgeschichtliches Seminar, Philipps-Universität Marburg, and from 1998 by the Australian Research Council, the Flinders University Research Budget, the School of Archaeology and Ancient History of the University of Leicester, the British Academy and the Society of Antiquaries of London. Further support has come from the European Commission, the Stiftung Berchtesgaden and the Deutsches Bergbau-Museum, Bochum. The success of the project has depended largely on the dedicated on-site work carried out by undergraduate and postgraduate students from Australia, Austria, Germany and the United Kingdom; full acknowledgement must await the final publication.

NOTES

1. Pauli 1980; Moosleitner 1985; Zeller 1995.
2. Gawlick and Lein 1997; Gawlick 2000; Gawlick *et al* 1999a; Gawlick *et al* 1999b.
3. For a detailed description of a facies model and the sedimentary environment, see Spötl 1989.

4. Schauberger 1986; Scherreiks 1995, 20.
5. Gawlick in Dobiat and Stöllner 2000, 77.
6. Hell 1926; Moosleitner 1969.
7. Koller 1979.
8. Barth 1998; Stöllner 1999.
9. Pauli 1978.
10. Dückher 1666; Willvonseder 1931.
11. Penninger in Pauli 1980, 150.
12. Stöllner 1999, 15.
13. An excellent first summary: Kyrle 1913.
14. Zickgraf and Stöllner in Dobiat and Stöllner 1997, esp 592; Boenke *et al* in Dobiat and Stöllner 2000, esp 74.
15. For research history, see Stöllner 1999, esp 27.
16. Stöllner 2002c.
17. Stöllner 1999, fig 22.
18. Stöllner 2002c.
19. Schatteiner and Stöllner 2001.
20. Stöllner 2002a; Stöllner 2002c, figures 73–74, 105.
21. Pauli 1978, 505–20.
22. Excavations between 1998 and 2001 were financed to a great extent by a joint programme supplementary to the Dürrnberg project in which the partner institutions were the universities of Marburg, Flinders and Leicester, and later, due to Thomas Stöllner's move to Bochum, the German Mining Museum as well; for important additional funding, see Acknowledgements on p 185.
23. Barth and Pucher 2000.
24. Morton 1939.
25. Stöllner *et al* 1999, 12–20; Megaw *et al* 2000; Stöllner *et al* in Dobiat and Stöllner 2000, 65–84.
26. Weisgerber in Dahm *et al* 1998 (esp 184ff).
27. Unpublished; pers comm K W Zeller, Keltenmuseum Hallein.
28. Some three graves were known before. Grave 88, discovered in 1823 and first described in 1829 by A Seethaler, was that of a female and contained a decorated bronze axe: Moosleitner *et al* 1974, 57 and pl 154A:1. The other graves were published in Penninger 1972, 59, pl 22C–23, 74 (grave 22), and preliminarily in Zeller 1992, 35–50, esp 38 (grave 306).
29. Hofmann 1926; Hofmann and Morton 1928; Schauberger 1960; Schauberger 1968.
30. Hollstein 1974; Hollstein 1980.
31. Ruoff *et al* 1997.
32. Project No. 12–33859.92: 'Correlation of soft-wood and fir-samples in combination with the analyses of prehistoric settlement structures'.
33. Thanks are due to Mechtild Neyses, Rheinisches Landesmuseum Trier, for making this source of funding available to us.
34. Project No. 96/AD2: 'The Celtic salt mines at the Dürrnberg and prehistoric economy in the Iron Age'.
35. W Lobisser, Hallstatt, kindly made these samples available to us.
36. This dating was carried out under the supervision of Prof Dr G Bonani, Zürich-Hönggerberg; we are most grateful for his generous co-operation.
37. Barth *et al* 2000. For the Nordgruppe and Tusch-Werk, see Barth 1998.
38. Ruoff and Sormaz 1998.
39. Boenke in preparation.
40. Oberhuber 1994.
41. Küster 1995, 41.
42. Schatteiner 1995.
43. Swidrak 1999.
44. Behre 1991.
45. Cf Aspöck below.
46. Aspöck *et al* 1973.
47. To the older investigations: Aspöck *et al* 1973.
48. Aspöck *et al* 2002.
49. Pucher 1999a; see below.
50. Hundt 1960, esp 148; Hundt 1987, esp 285.
51. Aspöck *et al* 1973; Kromer 1985.
52. J Burger *et al* in Dobiat and Stöllner 2000, 81.
53. Klose 1926.
54. Stöllner 2002c.
55. For example, M L Ryder's first full report on the fibres found in the Iron Age salt mines at Hallstatt in Austria: Ryder 1990; von Kurzynski in preparation.
56. Cf von Kurzynski 1996; Bender-Joergensen 1992; Banck-Burgess 1999.
57. Cf von Kurzynski 1998; state of the examinations at that time.
58. Groenman-van Waateringe 1992; Groenman-van Waateringe 1998a.
59. Groenman-van Waateringe 1998b.
60. Firbas 1949.
61. Groenman-van Waateringe and Stöllner 2001.
62. Pucher 1999a.
63. Stöllner 2002b.
64. Brand 1995.
65. Moosleitner and Penninger 1965; Zeller 1984a; Zeller 1984b.
66. For interim accounts of the Ramsautal, see Stöllner 1991b; Stöllner 1996a, esp 228–35; Lobisser and Löcker 2002.
67. Following the local system of Pauli 1978.
68. Zeller 1984b; Stöllner 1991b.

69. Wiltscke-Schrotta and Stöllner in Pucher 1999a, 11 and 113.
70. A planned metallographical analysis of these objects is unfortunately still pending.
71. Stöllner 1991b, 257; Stöllner 1996a, 228.
72. Similar scribers were found in the settlement areas.
73. Zeller 1984b, 199.
74. Stöllner 1996a, 234.
75. Schweingruber 1976, 36.
76. Phleps 1942, 47.
77. Zeller 1984b; Stöllner 1996a.
78. Pucher 1999a.
79. Pucher 1999b.
80. Amschler 1939; a detailed publication by F E Barth, E Pucher and others is in preparation.
81. Pucher 1998a.
82. For example, Boessneck *et al* 1971.
83. Matolcsi 1970.
84. Avon 1990.
85. Wilckens 1876; Zacharias 1903.
86. Pucher 1998b, figs 1–2.
87. Pucher and Schmitzberger 2001.
88. Pucher 2001.
89. Pucher 1994.
90. Teichert 1975.
91. Following the norms established by Teichert 1969.
92. Harcourt 1974.
93. But even at the Heuneburg during the later phases of its occupation one can note a change to a greater reliance on cattle as a transportable source of meat: Ekkenga 1984.
94. Stöllner in Pucher 1999a, 9ff.
95. Stöllner 1999.
96. Groenman-van Waateringe 1998c.
97. Similar techniques are mentioned by Athenaios, Cato and Plutarch (*De agricultura* 162; Gal. VI 745; Plutarch IV 4,3, 669; V 10,3 685). See Docter 1997, 150–4, mentioning amphorae as containers for meat and fish.
98. Stork in Moosleitner *et al* 1974, 191–4.
99. Pucher 1999a; Barth and Pucher 2000.
100. Irlinger 1995; Brand 1995.
101. Irlinger and Stöllner 1997.
102. Some palynological investigations have also been carried out by Prof Dr K Oeggl of the University of Innsbruck; one core was taken from the area of the Wildmoos. This will allow reconstruction of the Iron Age vegetation in the north-western part of the Dürrnberg; the results are not as yet published.
103. Irlinger 1991, 165.
104. Irlinger in Dobiat *et al* 1997, 106.
105. Irlinger in Dobiat and Stöllner 1997, 593 and fig 8.
106. See further Irlinger 1991.
107. Raftery 1994, ch 5; Raftery 1996, esp 411–13.
108. Raftery 1996, ch 4; Walde 1988.
109. See Walde 1988, esp pls 36, 65
110. For recent discoveries and theories, see Zeller 1995 and Stöllner 1998.
111. Megaw 1979; Megaw 1985.
112. Megaw and Megaw 1990, esp 90.
113. Moosleitner 1985; Herrmann and Frey 1997, esp 43–67; Bosinski in Baitinger 2002, esp 139ff.
114. Moosleitner 1985, 91.
115. Stöllner 1998, 121ff, fig 15.
116. Pauli 1978, 291–3; Megaw and Megaw 1990, 39 and fig 17; Abels 1992; Gruber 2001; conclusively for the Inn-Salzach region: Stöllner 2002b, 174ff.
117. Henderson 1991, 107.
118. Pauli 1978, 406–7; Pauli 1997; see in general Beck and Bouzek 1993; for Moravia: Čižmař 1997; for Switzerland: Beck and Stout 2000.
119. Pauli 1978, 400–1; Brand 1995, 112–15, pls 35–37, 67–69, esp pl 68.7; Megaw 1990, 534–5, fig 20:6 and pl 21.
120. Henderson 1991, esp 118–19.
121. Pauli 1980, cat no. 115; Megaw 1985, 176 and fig 9.6; Binding 1993, cat nos 92–106.
122. Lenerz-de Wilde 1977, cat nos 42 and 7 and fig 5; Pauli 1978, 340.
123. Stöllner 1998, esp 126–41; see also further below.
124. Megaw 1994; Megaw 2001, esp 16–23; Echt 1999, esp 285–92.
125. Megaw, Megaw and Neugebauer 1989; Neugebauer 1992, esp 100–7; Frey 1996; Frey 1998.
126. Groenman-van Waateringe in Dobiat and Stöllner 1998, 568.
127. Stöllner 2002c, 420.
128. von Kurzynski 1996, 31.
129. Stöllner 1996b; Stöllner 2002b.
130. Boenke in preparation; Swidrak 1999; for a general economic scheme, see Jacomet *et al* 1989, 222, fig 74.
131. Groenman-van Waateringe and Stöllner 2001
132. Kromer 1985; the arguments of Langer 1940 (1999), 126, Schauberger 1960, 4, 15, and Schauberger 1968, 22, have mainly been influenced by the idea that underground mining was only feasible in winter due to the superior natural ventilation possible at that time of the year thanks to a system with

one main entrance. In the light of our current state of knowledge, however, it is clear that there is usually more than one entrance for each mine system, allowing for year-round working. Together with the system of illumination, heating of the air by fires would have supported air circulation. Other insights into the seasonality of life in the mines come from pollen analyses of excreta currently being carried out by Prof Oeggl of Innsbruck. These clearly support other evidence for continuous activity in the mines.

133. Stöllner 1996b, 145ff.
134. Stöllner 2002b.
135. Pauli 1978; Stöllner 2002b, 151ff.
136. Stöllner and Tadic 1998.
137. Pauli 1978, 407; Champion 1985; Megaw and Megaw 1990, 39–43 and appendix 5; Krausse 2000; branches of coral travelled as far north as the Trou de l'Ambre, Eprave (Namur), as noted by Mariën 1970, 139, nos 303–9, fig 30 and pl 1.
138. Pauli 1978, 149 and 453; Reese 1991; Banghard 2000.
139. Koller 1994, esp 144.
140. Dopsch *et al* 1994, 142–5 and figs 70–71 on pp 234–5; for an attempt to reconstruct trading routes according to historical conditions: Pauli 1974; Pauli 1995; recently conclusive Stöllner 2002d.
141. Hodson 1990; Stöllner 1998, 124; Stöllner 2002b.
142. Stöllner 1998, 138.
143. Cunliffe 1995, esp 89–103.
144. Pauli 1978.
145. Hundt in Penninger *et al* 1974, 125; Moosleitner 1985.
146. Herrmann and Frey 1997; Megaw and Megaw 2001, 76–8, 257–8; Bosinski in Baitinger 2002, esp 139ff.
147. Stöllner 2002b.
148. The English texts provided by the individual authors have been revised by VM.

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