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A MINING SUBSIDENCE EVENT AROUND 920 BC IN THE LATE BRONZE AGE COPPER MINE OF PRIGGLITZ-GASTEIL (LOWER AUSTRIA)

The Prigglitz-Gasteil »Cu I« site (Bez. Neunkirchen, Lower Austria/A) is an extensive Urnfield-period mining settlement where chalcopyrite was mined, beneficiated, smelted and processed into bronze products. Archaeological excavations took place here in 1956 and 1958 under the direction of archaeologist Franz Hampl and mineralogist Robert J. Mayrhofer (Hampl/Mayrhofer 1963) and again between 2010 and 2014 under the direction of archaeologist Peter Trebsche, in cooperation with geologist Günther Weixelberger [1]. The period of activity of the site falls within the younger phase of the Urnfield Period (Ha B2-3), as confirmed by a series of radiocarbon dates and some chronologically significant bronze finds (Trebsche 2015). The excavations on the excellently preserved settlement terraces, which were established on waste dumps immediately adjacent to the copper ore mine, provide detailed insights into everyday life, diet, and various activities related to metal production [2]. The site offers a unique insight into the living and workshop areas, the division of labor, and the organizational structure of a relatively small copper-producing settlement on the edge of the Eastern Alps.

The abundant features and finds uncovered by the recent excavations were investigated by an interdisciplinary team within the framework of the research project »Life and Work at the Bronze Age Mine of Prigglitz«, funded by the Austrian Science Fund FWF from 2017 to 2021 (project number P30289-G25). Complementing the excavations, non-destructive and minimally invasive prospections were also carried out at the site as part of the research project, in order to clarify some questions that could not be addressed in the excavations of 2010-2014 and the accompanying initial coring prospections (2013-2014) [3]. First, geophysical measurements and deep core drilling were carried out to determine the total thickness of the dump layers, which was at least 11 m at the apex of the dump, based on the findings of the pile core probing (Trebsche 2014a, 40; 2014b, 19; 2014c, 17). Second, the geological bedrock and the location of the mineralization zone were explored; these were covered by slope debris and dumps in the area of the site and therefore nowhere directly exposed. Third, clues were sought as to the location and type of Late Bronze Age mining at the site, whose existence had hitherto been only indirectly proven by associated primary waste dumps and tools (antler hammers and picks; Trebsche/Pucher 2013, 132-133 fig. 20).

The field work was divided into three stages. First, extensive geophysical prospecting (electrical resistivity, induced polarization, and seismic surveys) took place at the site between 16.-18.10.2017, under the direction of Ingrid Schlögel (Applied Geophysics Department, Central Institute for Meteorology and Geodynamics, Vienna). After preliminary interpretation of the measurement results, two points were selected for core drilling to complement and verify the geophysical prospections (23.10.-9.11.2017). Finally, the geophysical profiling was densified in a second prospecting campaign (2.-5.7.2018).

In this paper, we evaluate the results of the core drilling (cores KB01 and KB02) with respect to the questions formulated above. The focus is on interpreting the stratification revealed by the cores, reconstructing the mining activities, and dating them with the help of dendrochronological investigations and ^{14}C analyses. A surprising result of the investigations was the detection of a mining subsidence event in the form of a mighty sliding scree which took place around 920 BC and can be reconstructed from evidence encountered in both cores. In the last section of the paper, the impact of this event on settlement and copper mining in Prigglitz-Gasteil will be briefly discussed. For reasons of space, conclusions regarding the overall extent of the copper mine, reconstructed in conjunction with the geophysical prospections, will be published elsewhere (Trebsche / Schlögel / Flores-Orozco in prep.).

TOPOGRAPHY

The site is located on the eastern slope of the Gahns mountain, in the area of Gasteil farmstead No. 7 (**fig. 1**). Below the timberline, on the surface of meadows now used as cattle pastures, several massive dump bodies are clearly recognizable, sloping from west to east. They are particularly visible in the embankments of the state road, which runs north-south, and the roadway above the farmhouse. Hampl and Mayrhofer distinguished three dumps (**fig. 1b**, I, II and III), of which the smallest and stratigraphically youngest, dump II, is associated with what is probably a modern exploratory iron-ore mine (whose shaft is entered from terrain terrace T6). South of dump II is dump III, whose base is on terrace T1 (elevation approx. 745 m a. s. l.), now covered by dense young forest. The entire area to the east, i. e., downhill from dumps II and III, consists of further dumps, which merge into each other and are therefore not readily differentiated, and which were collectively identified by Hampl and Mayrhofer as dump I. Their total extent is easily recognizable from the archaeological profiles documented in the road embankments at A, C and D (**fig. 1b**). In our opinion, however, at least two dump cones can be identified in the western embankment of the state road (**fig. 1b**, C): the larger dump cone of Hampl's dump I is located directly to the east of and below the »sand pit« (**fig. 1b**, A), while a separate, shallower dump, dump IV, can also be identified, whose top lies east of excavation area 1/7/8 on terrain terrace T4. As far as the chronological sequence is concerned, dump III seems to overlie terrace T7 and thus dump I; nothing certain can be said about the relationship of dumps I and IV.

The massive mine heap I was partially destroyed by the so-called »sand pit« created during the extraction of material used for buildings and road construction in the 1950s. Some areas of the steep dumps were artificially leveled in modern times to form terraces on which to build the existing farmhouse Gasteil No. 7 and a timber storage area with a storehouse (in the former »sand pit«). Other clearly pronounced leveling episodes are directly traceable to the Late Bronze Age, as demonstrated by archaeological excavations on terraces T7 (excavations Hampl 1956, 1958; Hampl / Mayrhofer 1963), T3 and T4 (excavations 2010-2014; Trebsche / Pucher 2013; Trebsche 2015). These excavations provided an initial chronological approach for dating the dumps I, III, and IV; according to the stratigraphy, they must date from the Late Bronze Age (or earlier).

The total volume of the dumps was estimated by Hannes Mohr, as early as 1958, to be at least 60,000 to 80,000 m^3 (Mohr 1958). After the first pile core probing campaigns in 2014, Weixelberger arrived at an estimated volume of 75,000 to 110,000 m^3. In view of the considerable dump volume, it is astonishing that no corresponding mass deficit, for example in the form of a large hollow or a fall shaft, is recognizable in the terrain today. It has therefore not been possible, so far, to clarify the method of mining – surface or underground – at Prigglitz-Gasteil.

In 2017, core-drilling sites KB01 and KB02 (KB = German »Kernbohrung«, English core drilling) were selected on terrain terraces T2 and T7 (**fig. 1b**), because this was where the greatest thickness of waste rock was likely to be, according to the results of the initial pile core probing. The drill points were placed as close as possible to the intersections of the longitudinal and transverse geophysical profiles.

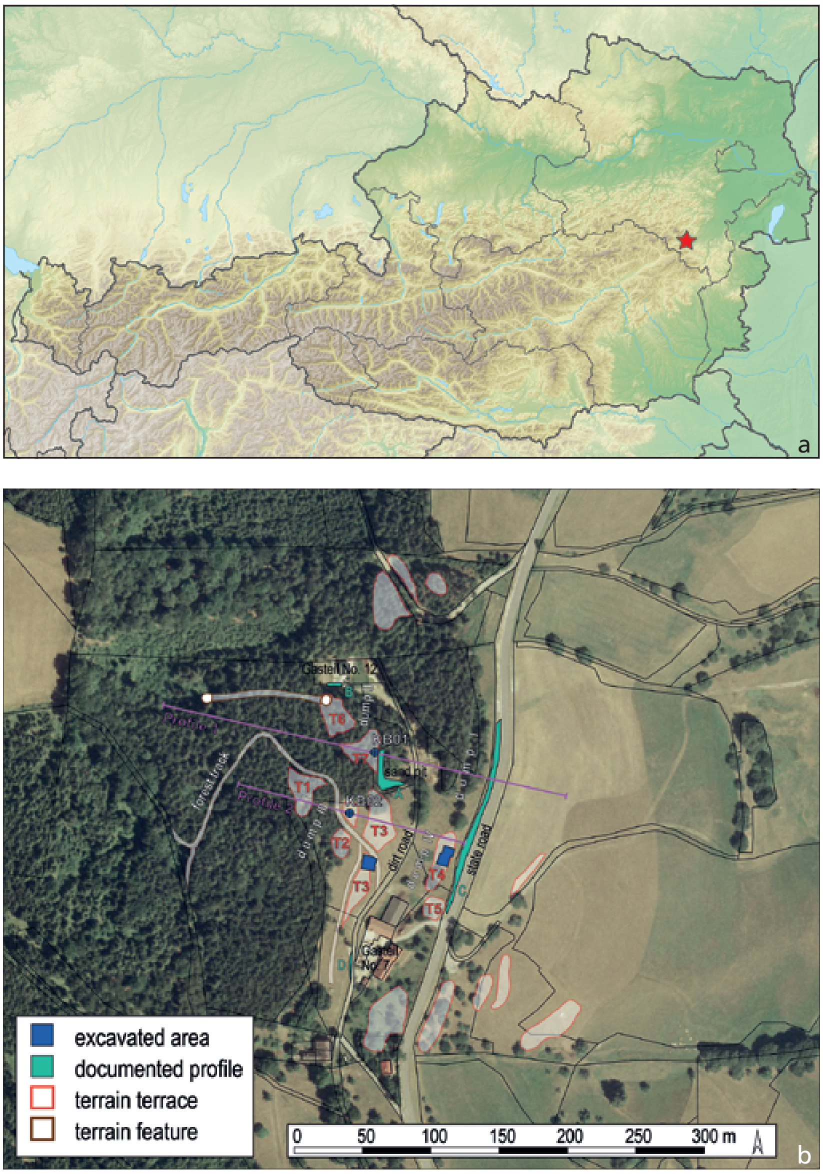

Fig. 1 Prigglitz-Gasteil: **a** location in Austria and **b** plan of the site showing terrain terraces (T), dumps, excavation areas, and core drilling sites (KB). – (a map © BEV, 2021; b orthophoto © Land Niederösterreich; with additions by P. Trebsche).

KB01 was located at an elevation of 726.25 m a.s.l. on terrain terrace T7 (»Planum B« after Hampl/Mayrhofer 1963, fig. 11) between the dumps II and III. The drilling point was located on the forest road above the »sand pit«, which is now occupied by a newly constructed storehouse. KB01 is therefore comparable to the approximately 5.5 m profile of the »sand pit«, immediately to the east, which was documented by Hampl in 1956 (P. Trebsche, Fundberichte aus Österreich 53, 2014, D2870 fig. 1; D2873; Hampl/Mayrhofer 1963, figs 15-16). KB02 was located at an elevation of 732.16 m on the second-highest artificial terrain terrace, T2, which intersects dump III (**fig. 2a**).

PRESENTATION OF THE STRATIGRAPHY

The core drilling was carried out by the company Urban Brunnenbau- und Tiefbohr-Gesellschaft m.b.H. (Klosterneuburg) using a fully hydraulic rotary drilling DSB rig made by the company Nordmeyer (drill diameter 219 mm, core diameter 180 mm; **fig. 2b**). In the first borehole (KB01), the drill was initially rotated,

Fig. 2 Prigglitz-Gasteil: **a** aerial view of the site from the southeast with the yellow core drilling rig in the center of the image. – **b** close-up view of the core-drilling site KB02. – (a photo R. Weßling; b photo P. Trebsche).

which meant that drilling was relatively slow, leading to considerable »smearing« or »burning« of the drill cores, which was a hindrance to further description. From a depth of 10 m, therefore, the drilling method was changed to pile-driving, which allowed faster progress and resulted in the recovery of larger blocks of intact sediment. Using this method, a depth of 32 m was reached. In the second borehole, KB02, the pile-driving method was used from the start, reaching the bottom at a depth of 37.5 m. Attempts were made to drill even further into the underlying bedrock using water flushing and rotary drilling, but the water caused the borehole to mud up, so that no more of the core could be recovered.

Core Borehole KB01

In the 32 m core from borehole KB01, 48 stratigraphic units (SE = German »stratigraphische Einheiten«; SE 01-01 to 01-48) were documented, which could be roughly grouped into four stratigraphic complexes (**fig. 3**): first, the »hanging« waste dump (SE 01-01 to 01-25, depth 0-12.51 m); second, the layer of material originating from the mining subsidence event (SE 01-26 to 01-30, depth 12.51-19.63 m); third, the »lower« waste dump (SE 01-31 to 01-47, depth 19.63-31.60 m); and fourth, the underlying bedrock (SE 01-48, depth below 31.60 m).
The »hanging« dump, which was about 12.5 m thick in total, lay immediately below the forest humus (SE 01-01), which was only 0.15 m thick. This upper dump complex consisted of numerous deposits of mining waste that could be distinguished from each other by differences in color and grain size, and in some cases by zones of claying. Up to a depth of 11.03 m they all consisted of relatively fine dumps resulting from ore processing, which contained only a few traces of copper ore (chalcopyrite), although in some layers there were quite a few pieces of iron ore (siderite). SE 01-22 and 01-23 (depth 11.03-11.88 m), on the other hand, consisted of coarse spoil with large blocks of phyllite, i. e., the dead rock surrounding the ore veins. Interspersed between the layers of fine, processing waste were several cultural layers, indicating the deposition of settlement waste or the construction of terraces or working podiums on top of the dumped waste. A dark brown cultural layer (SE 01-05) was encountered at a depth of 1.29-1.47 m, containing a compact, reddish-brown, burned clay slab (hearth?) resting on a leveling layer or substructure of yellow sandy loam (SE 01-06). Another thin cultural layer (SE 01-08) was recorded at a depth of 3.00-3.06 m, and a third was located at a depth of 5.08-5.30 m (SE 01-10), consisting of rich, compact, chocolate-brown, loamy material with evidence of a working podium, along with a ceramic sherd and pieces of purple fired clay (kiln remains, roasting bed?). This cultural layer lay on top of a homogeneous, light-gray, loamy-sandy leveling layer (SE 01-11). At a depth of 9.40-9.70 m, a dark-gray layer, approximately 0.3 m thick (SE 01-17), consisting of small pieces of crushed ore (most measuring up to 2 cm, a few up to 6 cm) was embedded between layers of fine material. SE 01-20 was a layer of pure clay with bands of ochre and light-gray that had probably been washed in between the layers of fine waste (depth 10.25-10.49 m) and which contained some charred pine needles and uncharred wood chips.
Beneath this finely stratified »hanging« dump was a 7.12 m-thick layer consisting of material that had slipped off the former slope edge. At the very top of this layer, at a depth of 12.51-12.83 m, was the old soil horizon (SE 01-26), 0.32 m thick. Below this was nearly 2 m of calcareous slope debris (SE 01-27 to 01-29) and a nearly 5 m-thick layer of the local metaquartz-wacke (SE 01-30), in which the original microstructures of phyllite and quartz veins were still easily recognizable, clearly distinguishing the landslip layer from the worked and redeposited dump layers. The lower edge of this layer, corresponding to the shearing zone of the landslide, was located at a depth of 19.63 m.
The dump complex below the landslip layer, which was about 12 m thick in total, was again composed of layers of fine processing waste (SE 01-31, 01-32, 01-34, 01-36, 01-38, 01-42, 01-43, 01-45, 01-46), some

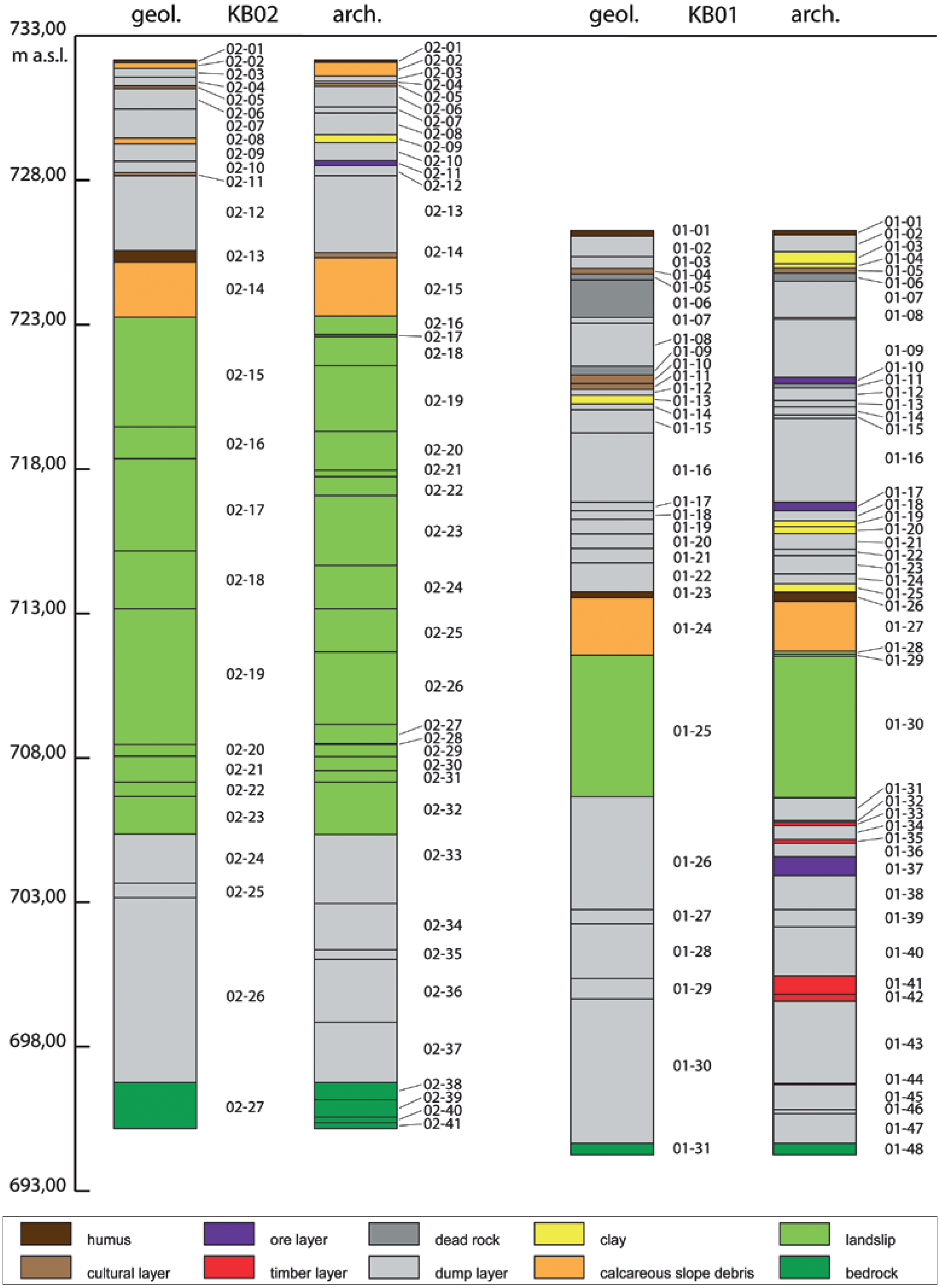

Fig. 3 Prigglitz-Gasteil. Stratigraphy of cores KB01 and KB02. Archaeological and geological description of the stratigraphic units. – (Diagrams P. Trebsche / G. Weixelberger).

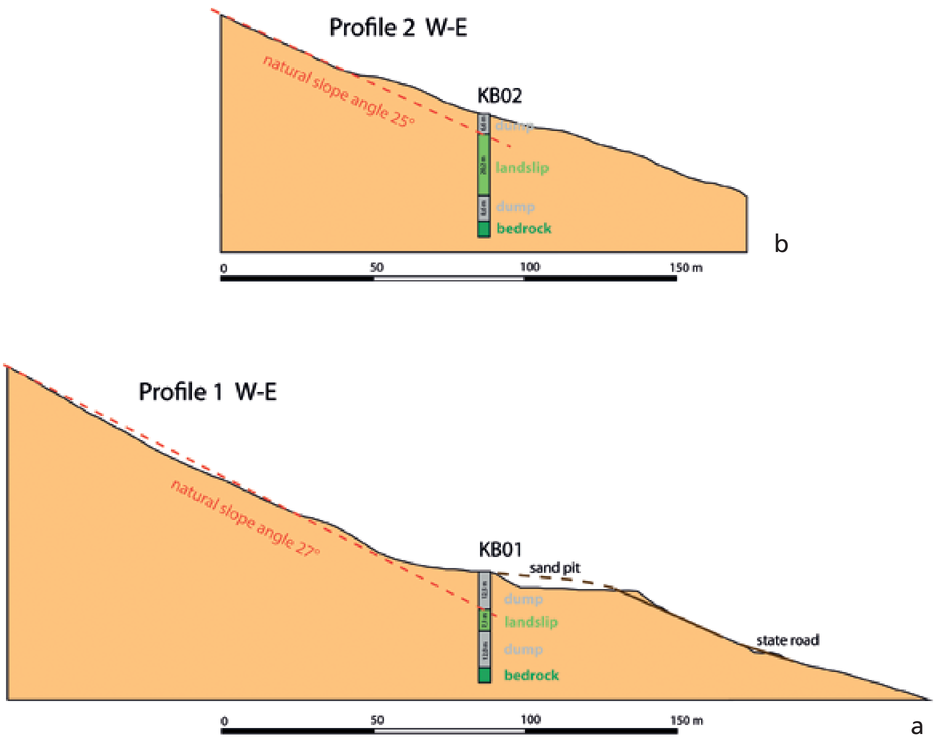

Fig. 4 Prigglitz-Gasteil. Terrain profile and schematized drawing of KB01 and KB02. For the location of the profiles see **fig. 1**. – (Drawings P. Trebsche).

with a considerable siderite content (SE 01-37), and deposits of coarse waste rock (SE 01-39, 01-40, 01-47). The sediments below the landslip layer were wet, and actual groundwater or slope water was reached at a depth of 30.70 m. Due to the more or less constant water regimen, numerous timbers were preserved in the »lower« dump (see below). Several layers consisted of logs, some just a single log, others with up to a maximum of seven (SE 01-33, 01-35, 01-41, 01-42, 01-44), each separated from the others by layers of waste material.

At a depth of 31.60 m, the underlying bedrock of metaquartz-wacke was reached. It was noteworthy that there was no ancient soil formation between the *in-situ* bedrock and the lowermost dump layers. Moreover, the great depth – about 19 m below the expected surface of the terrain (calculated by extension of the slope line dipping at an angle of 27°) – indicated that this was not the original surface of the bedrock, but a Bronze Age excavation edge, possibly originating from a large open-pit or deep-mining operation (**fig. 4**, a).

Core Borehole KB02

The stratigraphy of the core from borehole KB02 was quite similar to that of KB01, with 41 stratigraphic units (SE 02-01 to 02-41) which could also be roughly grouped into four stratified complexes (**fig. 3**): first, the »hanging« spoil heap (SE 02-01 to 02-13, depth 0-6.67 m); second, the landslip layer (SE 02-14 to 02-32, depth 6.67-26.82 m); third, the »lower« spoil heap (SE 02-33 to 02-37, depth 26.82-35.40 m); and fourth, the underlying bedrock (SE 02-38 to 02-41, depth less than 35.40 m).

The upper dump complex, overlain by thin humus (SE 02-01) and slope debris (SE 02-02), was about 5.1 m thick and consisted of fine deposits of processing waste (SE 02-03, 02-04, 02-07, 02-08, 02-10) and coarse mining spoil (SE 02-06, 02-12, 02-13). There was also a cultural layer (SE 02-05, depth 0.81-0.92 m), a thin layer of clay (SE 02-09, depth 2.58-2.86 m), and a layer of black iron-ore fragments (SE 02-11, depth 3.48-3.65 m) that had apparently been deliberately sorted from the mining waste material.

Below this followed the material from the landslide, which was about 20.15 m thick. Its uppermost stratigraphic unit SE 02-14 (depth 6.67-6.85 m), the old soil layer, also showed signs of being a cultural layer, having, for instance, a high charcoal content. A stone bedded in pink burnt clay may have belonged to a hearth. Beneath the old soil layer SE 02-14 was a layer of calcareous-alpine slope debris (SE 02-15), about 2 m thick. The remaining slip layers (SE 02-16 to 02-32) were predominantly phyllitic, with primary bedrock structures; some veins of siderite and presumably manganese ores also appeared in this section of the core (SE 02-29).
Below the slip material was another anthropogenic dump package with a total thickness of 8.6 m. Here, too, finer deposits of processing waste (SE 02-33, 02-35, 02-37) alternated with coarse mining spoil (SE 02-34, 02-36). As in KB01, there was no evidence of the formation of soil over the underlying base rock (metaquartz-wacke), which was reached at a depth of 35.40 m. The excavation edge lay about 29 m below the expected former ground surface, assuming a uniform slope gradient of about 25° (**fig. 4**, b).
In contrast to KB01, no wet sediments were encountered in KB02.

RECONSTRUCTION OF THE MINE AND THE MINING SUBSIDENCE

Three observations are crucial for the interpretation of the cores. The first is the fact that in both cores the surface of the base rock was encountered far below the expected level (at least 19 m deep in KB01, 29 m deep in KB02). Secondly, neither soil formation nor natural slope debris could be detected immediately above the bedrock, which in this topographic situation must be considered as further evidence of an anthropogenic stratigraphic edge. Thirdly, based on the composition, grain size and documented inclusions, the »hanging« and lower strata can clearly be identified as anthropogenic deposits of mining or processing waste, filling a trough-shaped hollow on the slope of the Gahns mountain. Since both cores – despite being at a horizontal distance of 48 m apart – show an analogous stratigraphic sequence, we interpret the lower edge of the anthropogenic strata as the bottom of a single pit, whose extent in a N-S direction was at least 48 m. This trough at the foot of the calcareous slope probably represents an open-pit copper-ore mine that is no longer superficially visible today.
Copper-ore extraction took place to maximum depths of 694.7 m a.s.l. and 696.8 m a.s.l. (Adriatic sea level), respectively, in the areas of core-drilling sites KB01 and KB02. The mine floor slopes downwards from N to NNE by about 2 m over the distance between the two boreholes (about 48 m). Until further, sufficiently deep explorations can be carried out, no more precise statements can be made about the actual extent and total volume of this open pit.
Late Bronze Age extraction probably stopped at the proven depth because barren rock had been reached. However, it is also conceivable that further excavation was impossible for technical reasons. Obviously, copper-ore extraction was then continued further uphill and, in the process, the open pit left by the earlier mining operations was filled with overburden material up to a level of 706.7 m a.s.l. (KB01) and 705.4 m a.s.l. (KB02). The thickness of this spoil layer is thus approx. 12 m in KB01 and 8.6 m in KB02.
The materials of the lower dump body are mainly coarse spoil. This obviously means that waste rock was dumped here directly from the mine face. Since no, or hardly any, fine, processing waste was encountered, it is reasonable to assume that the ore-bearing rock pieces were transported to a different site for further crushing and processing. The material extraction further uphill resulted in the formation of a very steep mine face with a height of more than 20 m. Given the geological and tectonic conditions at the site, an excavation wall of such height and steepness would not have been permanently stable.

For this reason, a major mine failure must have occurred, resulting in an inflow of rock from above the mine face into the open pit below and thus onto the dump body. Based on our experience, such an event would be the result of a sudden and spontaneous rock failure rather than a slow slide in the form of slope creep. Whatever its nature, this mining subsidence event resulted in the deposit of a large overburden on top of the horizontal body of mining waste.

The thickness of the landslip intrusion was 7.1 m in KB01, and an appreciable 20.2 m in KB02. A minimum length of 48 m was verified by the distance between the boreholes. At present, no statements can be made about the width and the exact position of the uphill break-off edge, which was probably obliterated by subsequent mining activities.

After this mining subsidence event, copper ore mining continued. Initially, it supposedly took place along the site of the landslip, which probably revealed fresh ore veins. Further mining activity is evidenced by the dumping of new waste-rock piles directly on top of the landslip material. The thickness of the core material representing this »hanging« dump complex reached 12.5 m in KB01 and 6.6 m in KB02, indicating that, far from being halted by the subsidence, mining activities continued intensively.

However, material extraction now took place further away from the two boreholes, both laterally and in terms of elevation. For that reason, only a small amount of coarse debris, i. e., the waste rock surrounding the ore veins, was deposited in the »hanging« spoil heap. For the most part, the waste now being dumped consisted of fine tailings produced during the secondary manual processing of the mineralized rock fragments. This operation involved crushing the ore-bearing blocks and separating and sorting the copper ore from the surrounding, non-ore-bearing rock. The rapid succession of cultural layers and relatively thin layers of processing waste observed in the layer package of the »hanging« dump in both cores essentially corresponds to the stratification that was archaeologically investigated (although only to a depth of a maximum of 2.5 m below the present ground surface) in the two excavation areas on terraces T3 and T4 between 2010 and 2014 (cf. Trebsche / Pucher 2013; 2014a; 2014b; 2014c; 2015).

ABSOLUTE DATING OF THE WOOD FINDS

Suitable samples for the scientific dating of the cores were taken from the above-mentioned wood finds from KB01 and from some charred plant remains and animal bones. The remaining finds were either of no value or inconclusive from a chronological point of view. From KB01 3 pottery fragments of local Late Bronze Age fabric, 1 fragment of burnt clay, 1 burnt stone, 34 charcoal fragments and 1 charred fir needle were recovered, and numerous sediment and ore samples were taken. 3 animal bone fragments and 29 charcoal fragments were recovered from KB02, along with numerous ore samples.

Fortunately, thanks to moisture caused by slope water, 17 timbers were preserved in the area of the KB01 borehole, where they were found at a depth of about 20.5-29.5 m in the »lower« dump core material (**tab. 1; fig. 5**)[4]. Although the substance of the timber was well preserved throughout, most pieces, because they had been severed by the drill (19 cm in diameter), were mechanically deformed and partially frayed at the cut edges.

Their classification relied mainly on comparable finds from prehistoric mines in the Eastern Alps. Larger ensembles of wooden features were found, for example, at the Bronze Age underground mines of Mitterberg (Bez. St. Johann im Pongau / A) (Thomas 2018), the Bronze Age processing plants at Mitterberg (Stöllner et al. 2010; Pichler et al. 2018; Stöllner 2019) and the Kelchalm (Bez. Kitzbühel / A) (Pichler et al. 2009), the Bronze and Iron Age mine workings of Hallstatt (Bez. Gmunden / A) (Grabner / Reschreiter / Klein 2009; Grabner et al. 2014; 2015), the Late Bronze and Early Iron Age fire-set pits in the Schwaz-Brixlegg

SE	timber	find number	depth (m)	type	wood species	bark preserved	measured year rings	radiocarbon samples
01-33	Timber 01	2547	20.48-20.60	split timber	fir	yes	45	GAST25; GAST26; GAST80
01-33	Timber 02	2549	20.50-20.56	split timber	fir	yes	25	
01-35	Timber 03	2551	21.08-21.22	round log	fir	bast	41	GAST27; GAST28
01-38	Timber 04	2556	22.33-22.38	lighting taper?	fir	no	4	
01-41	Timber 05	2562	25.80-26.00	split timber	conifer	no	not invest.	
01-41	Timber 06	2569	26.00-26.14	split timber	conifer	no	not invest.	
01-41	Timber 07	2566	26.12-26.26	split timber	conifer	no	not invest.	
01-41	Timber 08	2570	26.22-26.30	split timber	fir	yes	39	GAST29; GAST30; GAST81
01-41	Timber 09	2574	26.15-26.32	split timber	fir	yes	25	
01-41	Timber 10	2571	26.00-26.12	split timber	conifer	no	11	
01-41	Timber 11	2573	26.00-26.12	split timber	conifer	no	not invest.	
01-41	Timber 16	2568	26.00-26.10	wood chip	not det.	no	not invest.	
01-42	Timber 12	2579	26.45-26.65	split timber	fir	no	10	
01-42	Timber 17	2580	26.63-26.68	lighting taper	not det.	no	not invest.	
01-43	Timber 13	2581	27.00-27.18	split timber	fir	no	9	
01-43	Timber 14	2582	27.00-27.24	split timber	fir	no	34	GAST31; GAST32; GAST82
01-44	Timber 15	2589	29.52-29.56	split timber	fir	no	12	GAST33; GAST83

Tab. 1 Prigglitz-Gasteil. Description of the wood finds from core hole KB01. The SE (stratigraphic unit) refers to the archaeological units in **fig. 3**. The columns »wood species« and »measured year rings« are taken from the report by Michael Grabner (2017). All finds are kept under inventory number UF-22692 at the Landessammlungen Niederösterreich depository in Asparn an der Zaya.

area (Bez. Kufstein/A) (Pichler et al. 2013; Nicolussi/Pichler 2013), the Iron Age underground mines at the Dürrnberg (Bez. Hallein/A) (Stöllner 2002; Boenke 2005; 2015; 2020) and the contemporaneous industrial settlement in the Ramsau Valley (Bez. Hallein/A) (Lobisser 2005; 2015).

For classifying the pit timbers from Prigglitz-Gasteil, the categorization designed by Peter Thomas for the pit timbers from Mitterberg was particularly suitable (Thomas 2018). Among the Prigglitz finds were 1 round log (Timber 3; **fig. 5a**), 13 split timbers (**fig. 5b-c**), including 4 which had been radially split and 8 which had been tangentially split (in the case of one piece, the method of splitting was not precisely determinable), as well as 2 lighting tapers (Timbers 4 and 17) and 1 wood chip (Timber 16) (**fig. 5; tab. 1**). A detailed analysis of the wood finds is planned for separate publication (Jakobitsch et al. in prep.). Since the pit timbers were not in any recognizable construction context, their intended use can only be surmised. In an open-pit mine like Prigglitz-Gasteil they could conceivably have been used to support the pit walls, as cladding for the overburden heaps, or to construct working platforms or stairs. It was remarkable to find two lighting tapers in the context of an open-pit mine. So far, prehistoric lighting tapers have usually only been found in large numbers in underground mines, thanks to their special preservation conditions, although they have occasionally also been found in other contexts (Eberschweiler 2004, 162. 164 fig. 220; Thomas 2018, 145).

Michael Grabner (Institute of Wood Technology and Renewable Materials, University of Natural Resources and Life Sciences, Tulln, Austria) kindly undertook wood species determinations and dendrochronological analyses of the timbers at the end of 2017. He identified 10 timber samples as fir, while the others could only be generally identified as conifer. In the case of eleven samples, he was able to measure tree-ring

Fig. 5 Prigglitz-Gasteil. Selected wood finds from KB01: **a** Timber 3. – **b** Timber 9. – **c** Timber 14. – (Photos Landessammlungen Niederösterreich, N. Weigl).

sequences ranging from 4 to 45 years; however, absolute dendrochronological dating was not successful (Grabner 2017; see **tab. 1**). Radiocarbon samples were therefore taken from the five timbers with the longest tree-ring sequences for wiggle matching.

A total of 29 radiocarbon dates were obtained for cores KB01 and KB02, both from these timber samples and from other organic samples of shortest possible age. All the radiocarbon dates were determined by Accelerated Mass Spectrometry (AMS) at the Poznan Radiocarbon Laboratory (PL) and calibrated with OxCal 4.4 (Bronk Ramsey 2009) using the IntCal 20 calibration curve (Reimer et al. 2020). The uncalibrated results are given by order of sample name in **table 2**.

sample number	core	SE	find number	material	depth (m)	determination	lab number	radiocarbon age	remark	calibrated date (1σ)	calibrated date (2σ)
GAST20	KB01	01-05	2505	charcoal	1.36		Poz-100990	2705 ± 30		895 BC (27.0 %) 866 BC; 856 BC (41.2 %) 817 BC	908 BC (95.4 %) 807 BC
GAST21	KB01	01-14	2521	charcoal	6.13		Poz-100991	2880 ± 35		1114 BC (68.2 %) 1008 BC	1194 BC (7.9 %) 1143 BC; 1132 BC (83.7 %) 971 BC; 960 BC (3.8 %) 936 BC
GAST22	KB01	01-20	2534	charred fir needles	10.46		Poz-100992	2810 ± 30		1000 BC (68.2 %) 925 BC	1050 BC (95.4 %) 895 BC
GAST23	KB01	01-21	2537	charcoal	10.88		Poz-100858	2790 ± 35		996 BC (68.2 %) 903 BC	1018 BC (95.4 %) 839 BC
GAST24	KB01	01-23	2539	charcoal	11.40-11.44		Poz-100890	2885 ± 30		1111 BC (68.2 %) 1017 BC	1193 BC (6.9 %) 1143 BC; 1131 BC (87.8 %) 976 BC; 952 BC (0.7 %) 946 BC
GAST25	KB01	01-33	2547	Timber 1, fir, year ring 3	20.48-20.60	M. Grabner	Poz-100993	2900 ± 30		1123 BC (68.2 %) 1024 BC	1207 BC (16.6 %) 1141 BC; 1134 BC (78.8 %) 1004 BC
GAST80	KB01	01-33	2547	Timber 1, fir, year ring 25	20.48-20.60	M. Grabner	Poz-128471	2795 ± 35		998 BC (68.3 %) 906 BC	1045 BC (2.0 %) 1032 BC; 1019 BC (93.5 %) 834 BC
GAST26	KB01	01-33	2547	Timber 1, fir, year ring 44	20.48-20.60	M. Grabner	Poz-100995	2770 ± 35	0.4 mg C	974 BC (10.6 %) 957 BC; 941 BC (38.3 %) 891 BC; 879 BC (19.2 %) 846 BC	1001 BC (95.4 %) 835 BC
GAST27	KB01	01-35	2551	Timber 3, fir, year ring 2	21.08-21.22	M. Grabner	Poz-100996	2855 ± 30		1056 BC (60.0 %) 973 BC; 958 BC (8.2 %) 940 BC	1115 BC (95.4 %) 928 BC
GAST28	KB01	01-35	2551	Timber 3, fir, year ring 39	21.08-21.22	M. Grabner	Poz-100997	2855 ± 30	0.8 mg C	1056 BC (60.0 %) 973 BC; 958 BC (8.2 %) 940 BC	1115 BC (95.4 %) 928 BC
GAST29	KB01	01-41	2570	Timber 8, fir, year ring 3	26.22-26.30	M. Grabner	Poz-100998	2820 ± 30		1006 BC (68.2 %) 929 BC	1055 BC (95.4 %) 899 BC
GAST81	KB01	01-41	2570	Timber 8, fir, year ring 21	26.22-26.30	M. Grabner	Poz-128472	2860 ± 30		1107 BC (5.4 %) 1096 BC; 1081 BC (6.1 %) 1068 BC; 1056 BC (53.2 %) 981 BC; 947 BC (3.7 %) 939 BC	1122 BC (95.4 %) 927 BC
GAST30	KB01	01-41	2570	Timber 8, fir, year ring 37	26.22-26.30	M. Grabner	Poz-100999	2740 ± 30		906 BC (68.2 %) 841 BC	971 BC (2.3 %) 960 BC; 937 BC (93.1 %) 816 BC

Tab. 2 Prigglitz-Gasteil. Overview of radiocarbon dates from cores KB01 and KB02, arranged by archaeological strata. Radiocarbon ages and remarks from the laboratory reports of the Poznan Radiocarbon Laboratory (PL). Calibrated with OxCal 4.4 (Bronk Ramsey 2009) using the IntCal 20 calibration curve (Reimer et al. 2020).

sample number	core	SE	find number	material	depth (m)	determination	lab number	radiocarbon age	remark	calibrated date (1σ)	calibrated date (2σ)
GAST31	KB01	01-43	2582	Timber 14, fir, year ring 6	27.00-27.24	M. Grabner	Poz-100891	2895±30		1118 BC (68.2 %) 1022 BC	1207 BC (13.5 %) 1141 BC; 1135 BC (81.9 %) 998 BC
GAST82	KB01	01-43	2582	Timber 14, fir, year ring 24	27.00-27.24	M. Grabner	Poz-128473	2855±35		1107 BC (4.0 %) 1097 BC; 1080 BC (4.4 %) 1069 BC; 1056 BC (50.3 %) 974 BC; 954 BC (9.6 %) 934 BC	1125 BC (95.4 %) 913 BC
GAST32	KB01	01-43	2582	Timber 14, fir, year ring 34	27.00-27.24	M. Grabner	Poz-100892	2870±30		1110 BC (6.7 %) 1097 BC; 1092 BC (61.5 %) 1003 BC	1127 BC (95.4 %) 931 BC
GAST33	KB01	01-44	2589	Timber 15, fir, year ring 1	29.52-29.56	M. Grabner	Poz-100936	2850±35		1055 BC (55.3 %) 971 BC; 961 BC (12.9 %) 935 BC	1117 BC (95.4 %) 918 BC
GAST83	KB01	01-44	2589	Timber 15, fir, year ring 11	29.52-29.56	M. Grabner	Poz-128301	2795±30		991 BC (68.3 %) 907 BC	1043 BC (0.8 %) 1036 BC; 1016 BC (86.0 %) 892 BC; 880 BC (8.6 %) 837 BC
GAST54	KB01	01-46	2594	charcoal	30.43-30.57	A. G. Heiss	Poz-108335	2980±35		1261 BC (45.1 %) 1188 BC; 1181 BC (12.8 %) 1157 BC; 1146 BC (10.3 %) 1129 BC	1374 BC (2.1 %) 1356 BC; 1301 BC (92.8 %) 1076 BC; 1065 BC (0.6 %) 1058 BC
GAST55	KB02	02-11	2627	bark, 0.001 g	3.48-3.65	A. G. Heiss	Poz-109169	2785±30	0.2 mg C	980 BC (68.2 %) 900 BC	1007 BC (95.4 %) 845 BC
GAST34	KB02	02-12	2629	animal bone fragment, 4.37 g	3.92-3.94		Poz-100650	2810±30	4.4 % N, 12.8 % C, 8.4 % collagen	1000 BC (68.2 %) 925 BC	1050 BC (95.4 %) 895 BC
GAST35	KB02	02-14	2639	animal bone fragment, 4.01 g	6.74		Poz-100652	2840±35	1.8 % N, 6.3 % C, 2.4 % collagen	1045 BC (51.3 %) 970 BC; 961 BC (16.9 %) 935 BC	1111 BC (95.4 %) 914 BC
GAST36	KB02	02-14	2641	animal bone fragment, 2.60 g	6.80		Poz-100653	2780±30	2.4 % N, 7.5 % C, 3.5 % collagen	980 BC (68.2 %) 896 BC	1004 BC (95.4 %) 844 BC

Tab. 2 (continued)

sample number	core	SE	find number	material	depth (m)	determination	lab number	radiocarbon age	remark	calibrated date (1σ)	calibrated date (2σ)
GAST37	KB02	02-33	2667	charcoal	26.90		Poz-101000	2810 ± 35	0.45 mg C	1004 BC (68.2 %) 919 BC	1054 BC (92.0 %) 891 BC; 880 BC (3.4 %) 847 BC
GAST38	KB02	02-33	2668	charcoal	27.40		Poz-101001	2960 ± 30		1219 BC (68.2 %) 1125 BC	1263 BC (95.4 %) 1056 BC
GAST39	KB02	02-34	2671	charcoal	30.05		Poz-101002	2850 ± 30		1051 BC (59.2 %) 974 BC; 957 BC (9.0 %) 941 BC	1111 BC (95.4 %) 927 BC
GAST40	KB02	02-34	2673	charcoal	30.73		Poz-101003	2865 ± 30		1109 BC (5.4 %) 1098 BC; 1091 BC (62.8 %) 996 BC	1123 BC (95.4 %) 930 BC
GAST41	KB02	02-37	2677	charcoal	34.15		Poz-100893	2980 ± 30		1260 BC (46.6 %) 1190 BC; 1179 BC (11.2 %) 1160 BC; 1145 BC (10.4 %) 1130 BC	1372 BC (1.1 %) 1359 BC; 1297 BC (94.3 %) 1112 BC
GAST42	KB02	02-37	2681	charcoal	35.10-35.20		Poz-101005	2890 ± 50	0.16 mg C	1190 BC (3.3 %) 1179 BC; 1160 BC (4.7 %) 1145 BC; 1130 BC (60.2 %) 1001 BC	1217 BC (95.4 %) 929 BC

Tab. 2 (continued)

Radiocarbon Dating of Samples from Core KB01

19 radiocarbon dates were measured to determine the absolute chronology of core KB01 (**fig. 6; tab. 2**). The lowermost organic finds suitable for radiocarbon dating were charcoal fragments from SE 01-46 (GAST54; depth 30.43-30.57 m). The worked timbers preserved in the moist sediments below the subsidence-event layers were sampled for »wiggle matching« (Bronk Ramsey/van der Plicht/Weninger 2001) as their dendrochronological sequences were not datable in absolute terms. Tree rings with known time gaps were cut out of five timbers, three of which (Timbers 1, 8 and 14) each provided three radiocarbon dates, and the remaining two (Timbers 3 and 15), two each. The sediments from the subsidence-event deposit did not contain any organic material. The layers above the subsidence material provided no short-lived organic material apart from charred fir needles (GAST22) from SE 01-20 (depth 10.46 m). Four undetermined charcoal fragments therefore had to be chosen from different depths, ranging from 1.36-11.40 m (GAST20, 21, 23, 24).

Wiggle matching of the preserved timbers from the lower mining debris yielded good results for every single timber (see **tab. 3** with calibrated ages and agreement index). Their felling dates did not correspond with the depth of deposition and showed that they were not deposited in chronological order, with Timber 14 being older than Timber 15, and Timbers 3 and 1 being older than Timber 8. Obviously, the timbers were discarded in secondary positions and did not represent intact building structures, a fact that was also confirmed by their different alignments. Because of their secondary (re-)deposition, their felling dates did not correspond with the operating period of the opencast mine evidenced in KB01. Instead, they were obviously deposited *after* (this part of) the mine working had been abandoned. The discarded mining debris encountered in KB01 means that mining activities must already have shifted to another location further uphill. The operation period of these higher-level mining activities is reflected by the chronological range of the investigated timbers, which extends from ca. 1030 BC (Timber 14) to ca. 920 BC (Timber 8).

The only organic finds that were potentially associated with the operation of the original opencast mine were several charcoal fragments (GAST54) from a wet-sieved sample that was taken from below the preserved timbers, only approximately 1 m above the lower edge of the copper mine (identical with the surface of the bedrock). This charcoal sample was considerably older (1264-1127 BC, 1 sigma) than the preserved timbers, but an old wood effect cannot be excluded. The only possible way of directly dating the operation of this part of the copper mine in future would be to extract further cores from near the bedrock surface and retrieve some short-lived organic samples.

The precise dating of the mining subsidence event was likewise difficult, as no organic finds were associated with the event itself. At best, its dating can be narrowed down by the youngest find from the underlying layers (as a *terminus post quem*) and the oldest finds from the overlying layers (as a *terminus ante quem*). At present, the *terminus post quem* is represented by the youngest timber sample, Timber 8, whose wiggle matching result (973-960 BC [14.2 %], 933-905 [54.0 %]; 1 sigma) showed a peak in the probability distribution at ca. 920 BC.

The calculation of a *terminus ante quem* proved to be less simple, as KB01 yielded only four charcoal and one short-lived sample from the layers overlying the subsidence material. Of these, charcoal samples GAST21 to GAST24 were even older than both Timber 15 and Timber 8, which provides the *terminus post quem* (ca. 920 BC). This can be explained either by the old wood effect or by redeposition. The debris layers containing the charcoal could have accumulated older residues or they could have slid down along with the underlying sediments. Only the uppermost sample, charcoal sample GAST20 from cultural layer SE 01-05 (depth 1.36 m) with an age of 898-812 BC (1 sigma), was definitely younger than the subsidence event.

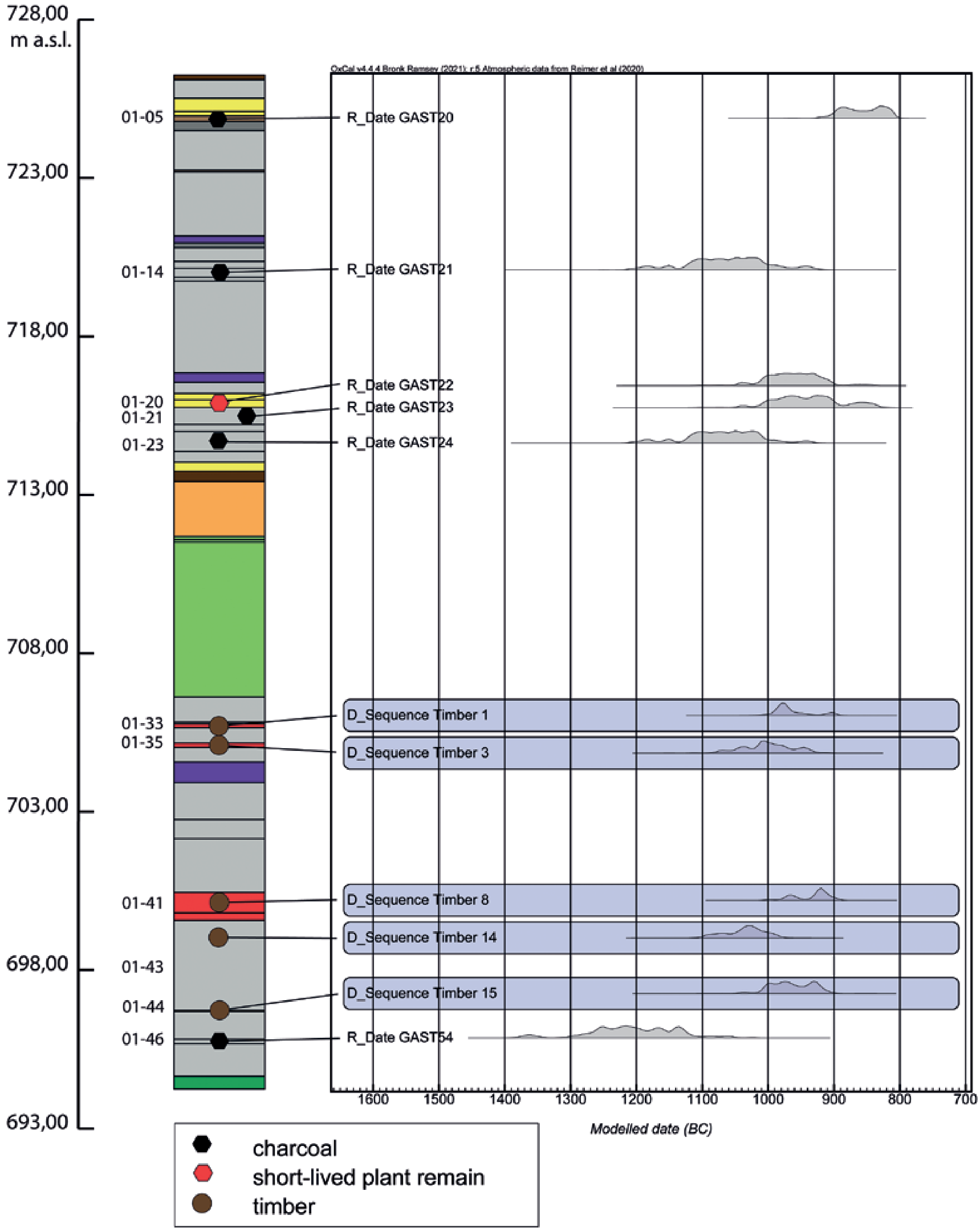

Fig. 6 Prigglitz-Gasteil. Calibration model of the radiocarbon data from KB01. Calibrated with OxCal 4.4 (Bronk Ramsey 2009) using the IntCal 20 calibration curve (Reimer et al. 2020). – (Diagrams P. Trebsche).

timber	calibrated date (1 σ; 68.3 %)	calibrated date (2 σ; 95.4 %)	peak	index A_{Comb}
Timber 1, year ring 44	994-956 BC	1010-931 (83.4 %), 921-893 BC (12.0 %)	980/975 BC	69.6
Timber 3, year ring 39	1046-1030 (11.3 %), 1021-970 (51.4 %), 952-943 BC (5.6 %)	1077-932 BC	1005 BC	110.7
Timber 8, year ring 37	973-960 (14.2 %), 933-905 BC (54.0 %)	984-891 BC	920 BC	55.1
Timber 14, year ring 34	1052-995 BC	1096-986 BC	1030 BC	132.1
Timber 15, year ring 11	1005-958 (47.4 %), 942-922 BC (20.8 %)	1016-905 BC	930 BC	112.1

Tab. 3 Prigglitz-Gasteil. Result of wiggle matching for the timbers from KB01. Calibrated with OxCal 4.4 (Bronk Ramsey 2009) using the IntCal 20 calibration curve (Reimer et al. 2020).

Radiocarbon Dating of Samples from Core KB02

Ten radiocarbon dates were measured to determine the chronology of KB02 (**fig. 7**). This core provided four short-lived organic samples for radiocarbon dating from the upper mining-dump layers and the old humus layer (SE 02-14) directly above the subsidence-event material, while the lower dump layers only provided six charcoal samples from undetermined tree species. As in core KB01, the subsidence layers in-between did not contain any datable material.

The six charcoal samples (GAST37 to GAST42) from the mining debris below the subsidence material were obviously either not deposited in chronological order or affected by old-wood effects. For the purposes of the calibration model, they were grouped together in one phase. The lower mining debris with the six charcoal samples thus constituted the first phase, two animal bone samples from SE 02-14 (GAST35 and GAST36), the old humus layer covering the subsidence material, represented the second phase, and the remaining two samples from cultural layers SE 02-12 (GAST34, animal bone) and SE 02-11 (GAST55, bark fragment) represented the third phase. The resulting calibration model yielded a very good Agreement index A_{model} = 104.5 % with a start boundary of between 1237-1128 BC (1 sigma, peak of probability distribution 1165-1145 BC) and an end boundary of between 952-872 BC (1 sigma, peak at 910 BC).

The first phase in the calibration model, represented by the dump layers below the subsidence material, dated from the period 1200-979 BC (according to the maximum ranges of the 1 sigma results). This period is older and longer than the date range obtained for the felling dates of the timbers from the corresponding layers in KB01 (ca. 1030-920 BC according to the peaks of the wiggle matched results, 1052-905 BC according to the maximum ranges of the 1 sigma results from wiggle matching), a discrepancy which is certainly a consequence of the old wood effect affecting the charcoal samples.

As for the second phase, the two short-lived animal bone samples from the old humus layer (SE 02-14) above the subsidence material clearly dated from the first half of the 10^{th} century BC (GAST35: 1002-946 BC, 1 sigma, peak at 980; GAST36: 998-953 BC, 1 sigma, peak at 965 BC).

The buried humus layer was already covered with a layer of mining debris about 3 m thick when the next occupation phase started. The two short-lived samples GAST34 (971-922 BC, 1 sigma, peak at 935 BC) and GAST55 (950-902 BC, 63.4 %, peak at 920 BC) from cultural layers SE 02-11 and 02-12 roughly correspond with the felling dates of the youngest timber samples (Timbers 8 and 15) found below the subsidence material in KB01.

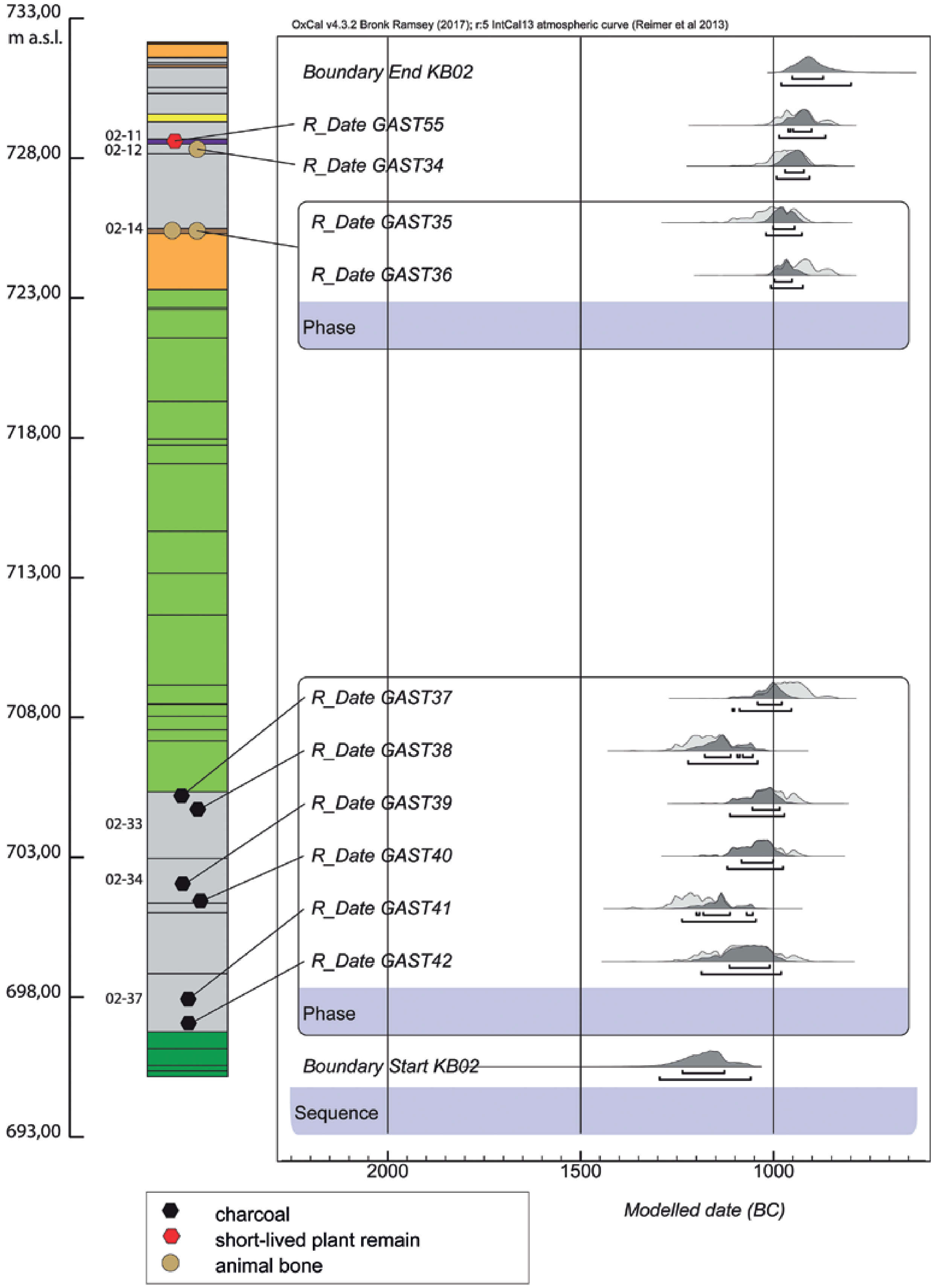

Fig. 7 Prigglitz-Gasteil. Calibration model of the radiocarbon data from KB02. Calibrated with OxCal 4.4 (Bronk Ramsey 2009) using the IntCal 20 calibration curve (Reimer et al. 2020). – (Diagrams P. Trebsche).

DISCUSSION

According to the dating of the youngest timber sample, Timber 8, found below the subsidence material in KB01, the subsidence event must have occurred after 973-960 BC (14.2 %) or 933-905 (54.0 %) and probably after 920 BC, the point where the probability distribution reaches its peak. According to the calibrated data from KB02, however, the subsidence event occurred after 1200-979 BC (1 sigma) and before 1002-953 BC (1 sigma). This discrepancy requires further consideration.

One possible explanation is that two different episodes of mining subsidence occurred at Prigglitz-Gasteil, the first affecting the area around KB02 on terrace T2 and the second affecting the area around KB01 on terrace T7 some decades later. The alternative explanation assumes only one large subsidence event shortly after ca 920 BC, extending over both terrace T2 and terrace T7. In this case, either the layers immediately above the old humus layer covering the subsidence material contained older, redeposited finds or these layers were redeposited intact during the subsidence event.

With these taphonomic considerations in mind, the animal bones (GAST35 and GAST36) embedded in the old humus on top of the subsidence material in KB02 were probably dislocated during the subsidence event, because domestic activities like slaughtering or food consumption immediately on top of the landslip material seem rather implausible. Thus, the above-mentioned bone samples indicate a *terminus post quem* for the mining subsidence event rather than a *terminus ante quem*. Similarly, the mining debris and the cultural layer above the subsidence-event material in KB02 could have been redeposited at the lower level, together with the finds it contained (GAST34 and GAST55). Perhaps the superimposed load of these layers even triggered the subsidence.

At this point, we should return to the radiocarbon dates from the upper mining debris in KB01 which were also older than the *terminus post quem* for the underlying subsidence material. In the case of KB01, the reverse dates could be explained by the old wood effect of the charcoal samples. In KB02, however, the same phenomenon can be observed in the case of the short-lived radiocarbon samples. At the present state of research, we prefer the hypothesis of a single subsidence event shortly after ca. 920 BC, taking into account the almost identical stratigraphic sequences, the corresponding altitudes and the analogous distribution of (reverse) radiocarbon dates in both drilling cores, indicating intensive processes of redeposition in the mining area. However, only future core drillings between KB01 and KB02 will be able to provide a definite solution to the problem of whether the two subsidence-event layers encountered in the two boreholes represent the same or two different events.

Finally, it should be mentioned that occupation of terrace T3 did not end with layers SE 02-12 and 02-11 (GAST34 and GAST55) but continued with the deposition of mining and beneficiation debris (thickness ca. 2.5 m) and another cultural layer (SE 02-05) that did not yield any datable organic material.

RESULTS AND OUTLOOK

The two core drillings carried out in 2017 in the area of the Late Bronze Age mining site of Prigglitz-Gasteil provided decisive clues about the technology of the prehistoric mining operations and, at the same time, an explanation for why no traces of them can any longer be seen on the surface of the terrain. Copper ore mining took place in an open pit, the floor of which is more than 32 m below the present ground surface and at least 19 or 29 m below the assumed ancient ground surface. Its north-south extent is at least 48 m. Its overall extent can only be reconstructed with the help of the geophysical prospections, for the interpretation of which, in turn, the results of the core drillings are essential (Trebsche / Schlögel / Flores-Orozco in prep.).

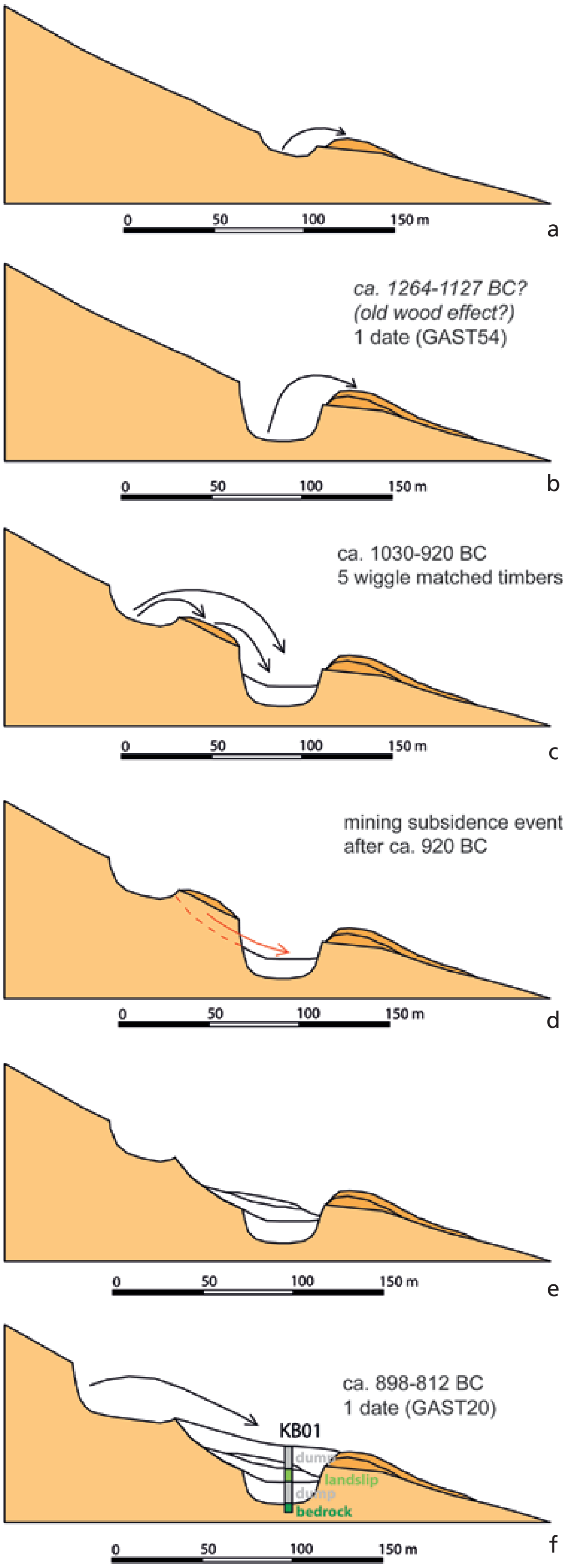

Fig. 8 Prigglitz-Gasteil. Schematic reconstruction drawing of the open pit and its backfilling stages, interrupted by a mining subsidence event. – (Drawings P. Trebsche).

Bronze Age open-pit mines are known from several countries in Eurasia (e.g., the copper mines of Great Orme in Wales [Conwy County Borough/GB]; O'Brien 2015). So far, they have only rarely been attested in the Alps, although it is generally assumed that underground ore mining originated in most cases from an open-pit mine (e.g., O'Brien 2015, 169. 200-203). A good example is the Early Iron Age »Bauernzeche« copper ore mine in the Großkogel mining district (Gem. Reith im Alpbachtal, Bez. Kufstein/A) in the Tyrolean Lower Inn Valley, which certainly started from surface ore outcrops and developed into an underground mine with a depth of about 50 m (Staudt et al. 2019, 122-124 fig. 9). For the Mitterberg region, there is evidence from geophysical prospections that the Brandergang mine also began as an opencast mine (German »Pingenbau«; Stöllner et al. 2006, 123-129; Thomas 2018, 398-399). In general, the mining approach depended, of course, on the nature of the deposit and the bedrock. In the case of Prigglitz-Gasteil, the deposit was a ramified vein of chalcopyrite and siderite, embedded in metaquartz-wacke that was relatively easy to mine, with the veins presumably traversing the bedrock in a tightly meshed manner. This type of mineralization would make a surface or large-volume mining approach preferable to following the individual vein branches.

Prehistoric open pits are probably underrepresented in the Alps because ancient copper mining was mainly discovered and documented as a result of modern underground mining, starting in the 19th century. Another reason is that even fairly large open pits may have been completely filled in and therefore leave no trace on the surface of the terrain. This is exactly what happened in the case of the Prigglitz-Gasteil pit. The backfilling process documented in the drill cores provides a detailed insight into the operation of the mine. The open pit (**fig. 8a-b**) was partially backfilled with a 12 m thick deposit of waste material, including 17 redeposited pit timbers that were preserved under moist conditions (**fig. 8c**). This dump material could not have come from the above-mentioned pit itself but must have come from a second pit (probably also an open pit) at a higher elevation than the one that had been abandoned. The mining process was interrupted by an extensive mining subsidence event (**fig. 8d-e**), the displaced material of which is documented in both drill cores. Massive subsidence in the high valley of Hallstatt also led to the destruction of Bronze and Iron Age mines in 1062 BC and 662 BC (Rohn et al. 2005; Reschreiter/Grabner/Ehret 2010; Grabner et al. 2021). In contrast to the catastrophic events at Hallstatt, which caused the death of the famous »man in the salt« (Barth 1993) and which necessitated a spatial relocation of the mining works, mining at Prigglitz-Gasteil continued without any discernible temporal interruption. Further massive dumps were piled directly on top of the landslip material until the lower open pit was completely filled in and therefore no longer recognizable in the terrain (**fig. 8f**).

However, after the mining subsidence, which thanks to combined evaluation and modeling of radiocarbon dates can be dated to after ca. 920 BC, the settlement structure in the immediate vicinity of the open pit changed. The old dumps at the southern and eastern edge of the buried open pit were leveled to make flat terraces and built up with dwellings and workshops. The precise dating of the mining subsidence should ideally make it possible to study the effects of the catastrophe on the operation, organizational structure, and provisioning of the Late Bronze Age mine, which can be reconstructed from the numerous preserved animal and plant remains (see Trebsche/Pucher 2013; Heiss et al. 2021). Investigations not only into the resilience of the miners, but also into the causes of the subsidence and the ultimate ending of copper mining in Prigglitz-Gasteil will therefore form the focus of research in the coming years. These investigations can rely on an excellently preserved archive of organic finds, which is well protected, but unfortunately also difficult to reach, at a depth of more than 20 m.

Acknowledgements

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Notes

1) Trebsche 2010; 2011; 2012; 2013; 2014a; 2014b; 2014c.

2) Archaeozoology: Trebsche/Pucher 2013; archaeometallurgy: Haubner et al. 2015; Haubner/Strobl/Trebsche 2017; 2019; Mödlinger/Trebsche 2020; 2021; Mödlinger/Trebsche/Sabatini 2021; archaeobotany: Heiss et al. 2021.

3) P. Trebsche, Fundberichte aus Österreich 52, 2013, 241-243 D1741-1750; 53, 2014, D2867-2877.

4) 20 sediment samples were also taken from the moist layers at depths of between 20.80-31.75 m and checked for pollen preservation. Unfortunately, the results were negative (kind communication Univ.-Prof. Dr. Klaus Oeggl, Institute of Botany, University of Innsbruck, dated 17.4.2018).

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Zusammenfassung / Summary / Résumé

Ein Bergschaden um 920 v. Chr. im spätbronzezeitlichen Kupferbergbau von Prigglitz-Gasteil (Niederösterreich)

Mit Hilfe von Kernbohrungen gelang es im Jahr 2017, Hinweise auf einen Kupfererz-Tagebau im Bereich der urnenfelderzeitlichen Bergbausiedlung von Prigglitz-Gasteil am Rand der Ostalpen zu finden. Der Tagebau erstreckte sich über mindestens 48 m in Nord-Süd-Richtung und erreichte eine Tiefe von mehr als 32 m unter der heutigen Geländeoberfläche. Die Kupfererzgrube am Fuß des Berges Gahns war bereits teilweise mit Haldenmaterial verfüllt, als eine Massenbewegung stattfand und eine mächtige Gleitscholle den Tagebau verschüttete. Dieses Ereignis fand um ca. 920 v. Chr. statt, wie die Auswertung einer Serie von Radiokarbondaten zeigt, die an Grubenhölzern und weiteren organischen Resten gemessen wurden. Nach dem Bergschaden wurde die Kupfergewinnung ohne erkennbare Unterbrechung weitergeführt, allerdings änderte sich die räumliche Struktur der Bergbausiedlung.

A Mining Subsidence Event around 920 BC in the Late Bronze Age Copper Mine of Prigglitz-Gasteil (Lower Austria)

With the help of core drilling, it was possible in 2017 to find evidence of an open-pit copper ore mine in the area of the Urnfield period mining settlement of Prigglitz-Gasteil at the edge of the Eastern Alps. The open pit extended for at least 48 m in a north-south direction and reached a depth of more than 32 m below the present ground surface. The copper ore mine, located at the foot of the Gahns mountain, was already partially filled with tailings when a massive subsidence event occurred and a mighty landslide buried the open pit. This event took place around 920 BC, as shown by the analysis of a series of radiocarbon dates measured on pit timbers and other organic remains. After the subsidence event, copper mining continued without apparent interruption, but the spatial structure of the mining settlement changed.

Un éboulement vers 920 av. J.-C. dans la mine de cuivre de l'âge du Bronze final de Prigglitz-Gasteil (Basse-Autriche)

Grâce à des carottages, il a été possible en 2017 de trouver des preuves de l'existence d'une mine de cuivre à ciel ouvert dans la zone de l'habitat minier de la période des Champs d'Urnes, à Prigglitz-Gasteil, au pied des Alpes orientales. La fosse ouverte s'étendait sur au moins 48 m dans le sens nord-sud et atteignait une profondeur de plus de 32 m sous la surface actuelle du sol. La mine de cuivre située au pied du mont Gahns était déjà partiellement remplie de résidus lorsqu'un glissement de terrain s'est produit et qu'un énorme éboulement a enseveli la mine à ciel ouvert. Cet événement a eu lieu vers 920 av. J.-C., comme le montre l'analyse d'une série de dates radiocarbone mesurées sur des boisages et d'autres restes organiques. Après le glissement de terrain, l'exploitation du cuivre s'est poursuivie sans interruption apparente, bien que la structure spatiale de l'établissement minier ait changé.

Schlüsselwörter / Keywords / Mots-clés

Niederösterreich / Urnenfelderzeit / Kupferbergbau / Abbautechnik / Absolutchronologie
Lower Austria / Urnfield period / copper mining / mining technology / absolute chronology
Basse-Autriche / Champs d'Urnes / exploitation du cuivre / technologie minière / chronologie absolue

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