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Late Bronze Age/Early Iron Age fahlore mining in the Lower Inn Valley (North Tyrol, Austria)

ABSTRACT: *Within the framework of the international DACH-project "Prehistoric copper production in the eastern and central Alps – technical, social and economic dynamics in space and time" (funded by the Austrian Science Fund FWF, I-1670-G19, the DFG and SNF, 2015 - 2018) traces of Late Bronze Age to Early Iron Age mining activities were systematically prospected and investigated in the fahlore mining district Schwaz-Brixlegg, North-Tyrol, Austria. The aim was to reconstruct the production chain for copper from fahlore and to demonstrate the spatial and chronological development of the prehistoric mining activities in this district. Archaeological excavations were carried out at different places below and above ground comprising a series of fire-set mines, areas with surface depressions (german: "Pingenfelder") and one smelting site. Besides the uncovering, documentation and interpretation of prehistoric structures and findings it was essential to obtain organic materials like wood, charcoal and animal bones for radiocarbon dating and – in the ideal case – timber and/or charcoal for dendrochronological analyses. These investigations could be realised at different spots distributed alongside the mining district of Schwaz-Brixlegg. Parallel to the excavations relevant sectors of the mines were mapped, mine plans were drawn and 3D-models were generated. In addition to the archaeological fieldwork, ore samples from the mining district were systematically collected for mineralogical and geochemical analyses with the aim to characterise the mineral assemblages for subsequent provenience studies. This paper reports on the mining sites investigated within the DACH-project as well as on first results from archaeometric analyses.*

KEYWORDS: COPPER MINING, LATE BRONZE AGE, EARLY IRON AGE, FAHLORE, FIRE-SETTING, CHAÎNE OPÉRATOIRE, DENDROCHRONOLOGY

Introduction

Within the framework of the trinational DACH-project "Prehistoric copper production in the eastern and central Alps – technical, social and economic dynamics in space and time" (funded by the Austrian Science Fund FWF, I-1670-G19, the DFG and the SNF, 2015-2018) traces of Late Bronze Age to Early Iron Age mining activities were systematically prospected and investigated in the fahlore mining area Schwaz-Brixlegg, North-Tyrol, Austria. The main aim and goals were to reconstruct the production chain for copper from fahlore and to demonstrate the spatial and chronological development of the prehistoric mining activities in this district. Archaeological excavations were carried out at different places below and above ground comprising a series of fire-set mines, areas with surface depressions (german: "Pingenfelder") and one smelting site. Besides the uncovering, documentation and interpretation of prehistoric structures it was essential to obtain organic materials like wood, charcoal and animal bones for radiocarbon dating and – in the ideal case – timber and/or charcoal for dendrochronological analyses. These investigations could be realised at different spots distributed alongside the mining area of Schwaz-Brixlegg (Fig. 1). Parallel to the excavations relevant sectors of the mines were mapped, mine plans were drawn and 3D-models were generated (Staudt et al., 2017a; 2018a; 2018c). In addition to the archaeological fieldwork, ore samples from the mining districts were systematically collected for mineralogical and geochemical analyses with the aim to characterise the mineral assemblages for subsequent provenience studies. In the fillings and dumps of fire-set mines bigger fragments of charcoal are frequent and can be used for accurate age determinations. However, the prehistoric mines are often superimposed by younger activities showing traces of iron tools (hammer and pick) or black powder blasting. In such cases the Bronze Age and/or Early Iron Age layers are often not visible anymore or have been removed to an outside dump. This paper reports on the mining sites investigated

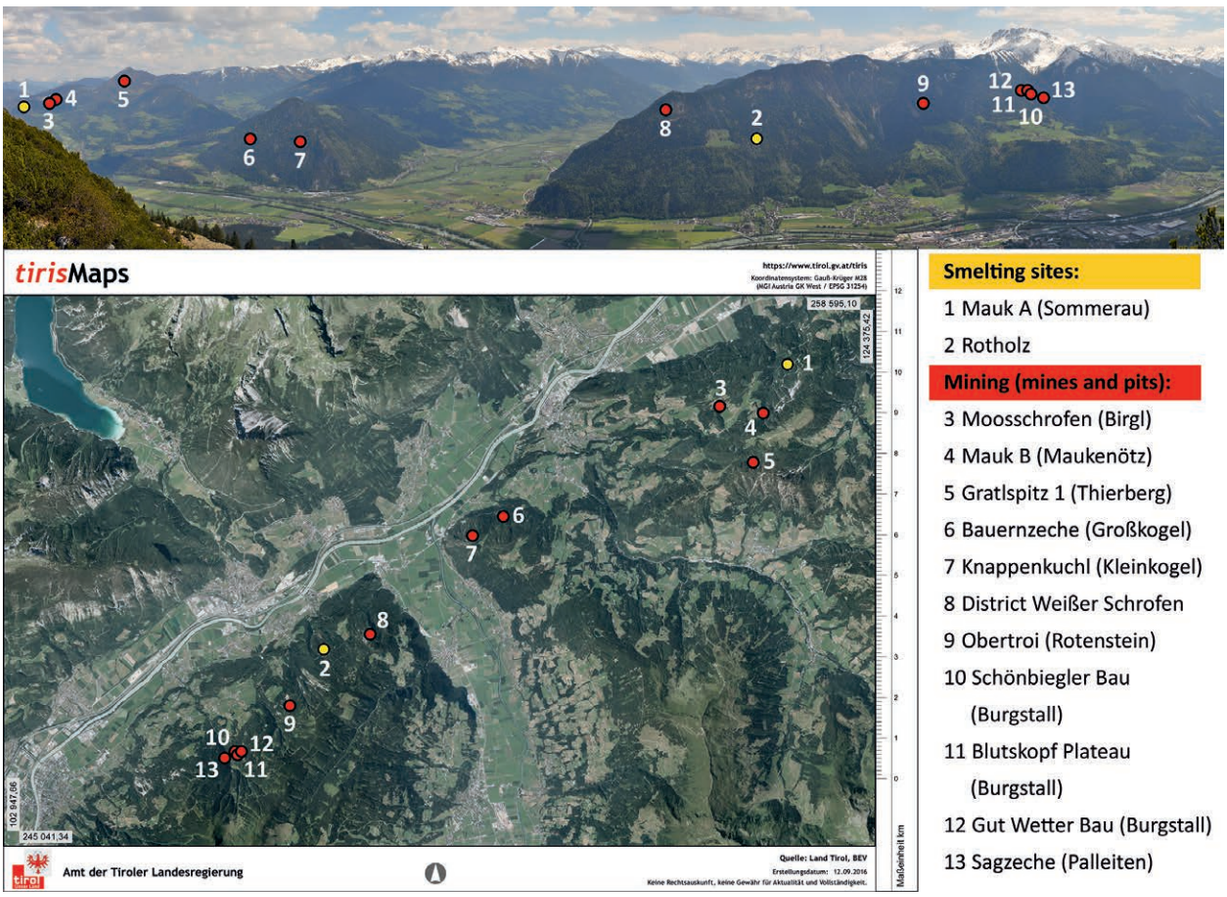

Fig. 1: The investigation spots of the DACH-project (2015-17) in the mining area Schwaz-Brixlegg (graphic: M. Staudt).

within the DACH-project as well as on first results from archaeometric analyses.

Evidence for prehistoric fahlore mining in the area of Schwaz-Brixlegg

The fahlore mining area of Schwaz-Brixlegg extends along the southern side of the central Lower Inn Valley and is well known for extensive mining in the late medieval/early modern period. In the fifteenth and sixteenth centuries AD cupriferous and argentiferous fahlores were extracted on a large scale in the so called "Schwazer Dolomit" (Wolfskron, 1897; 1898; 1899; Worms, 1904; Pirkl, 1961; Gstrein, 1978). The region became one of Europe's leading mining centres, as pictured in the "Schwazer Bergbuch" of the years 1554/56 (Bartels et al., 2006).

Joseph von Sperges (Sperges, 1765) and Joseph von Senger (Senger, 1806) considered that if there was any prehistoric or roman mining, these activities were concentrated only on iron ore. In the early 20th century Robert von Srbik assumed prehistoric copper mining activities in the mining area of Schwaz (Srbik, 1929). Because of Late Bronze Age finds in the vicinity of the mining district, Franz von Wieser (Wieser, 1904) and later Gerhard Kaltenhauser (Kaltenhauser, 1965) also supposed a connection with nearby mining activities.

A significant influence of North Tyrolean fahlore copper is proved for the Early Bronze Age (Krause, 2003; Möslein & Winghart, 2002; Martinek & Sydow, 2004; Höppner et al., 2005; Junk, 2003; Schubert, 2005; Krismer et al., 2013; Töchterle, 2015a). Corresponding early metallurgical activities could be documented along the Lower Inn Valley at hilltop settlements like Kiechlberg (Thaur; Töchterle, 2015b), Buchberg (Wiesing; Martinek & Sydow, 2004) and Mariahilfbergl (Brixlegg; Huijsmans and Krauß, 1998, 2015; Bartelheim et al., 2002) as well as in the cave site Tischofer Höhle (Kufstein; Mostler, 1969; Neuninger et al., 1970; Harb, 2002). Material analyses performed on Bronze Age metal artefacts (copper and bronze) show different geochemical characteristics. The results of these investigations are indicating the use of different copper ore occurrences in the east Alpine region and their time-dependent exploitation during the Bronze Age (Pernicka & Lutz, 2015). It could be demonstrated that after an early domination of "fahlore copper" in the Early Bronze Age this type of metal was replaced almost

completely since the late Early Bronze Age and during the Middle Bronze Age by “chalcopyrite copper” (“east Alpine copper”) especially from the Mitterberg and Kitzbühel/Jochberg areas (Stöllner, 2015a, 2015b; Tomedi & Töchterle, 2012; Koch Waldner & Klaunzer, 2015). The fahlore copper reappears only in the Late Bronze Age and is then used in parallel and mixed with the east Alpine copper type (Pernicka & Lutz, 2015).

Since the 1980s archaeological field research and subsequent investigations have been dealing with this second prehistoric fahlore mining boom from the Late Bronze Age to the Early Iron Age (Egg, 1981; Gstrein, 1981; 1988a; 2013; Rieser & Schrattenthaler, 1998/99, 2004; Goldenberg & Rieser, 2004; Palme et al., 2002; Heiss & Oeggl, 2008; Schibler et al., 2011; Goldenberg et al., 2012; Goldenberg, 2013, Goldenberg, 2015; Pichler et al., 2013; Tomedi et al., 2013; Staudt & Tomedi, 2015; Goldenberg et al., 2019). Late Bronze Age copper ore smelting activities in the Lower Inn Valley are so far known from two smelting sites and can also be detected indirectly by analysing slag tempered ceramics from settlements as well as from cemeteries (Sölder, 1987/88, 2015; Zemmer-Plank, 1990; Huijsmanns & Krauß, 1998; Harb, 2002; Reider, 2003; Töchterle et al., 2013; Töchterle, 2015b; Krismer & Staudt, 2012; Krismer et al., 2013; Tomedi et al., 2013; Krismer et al., 2015; Staudt & Tomedi, 2015; Goldenberg et. al, 2019). A significant increase of burials in the region during the Late Bronze Age was attributed to the rise of fahlore mining and metallurgy by Lothar Sperber (Sperber, 2004). Excavations and archaeometrical investigations between 2007 and 2012 within the international special research project SFB HiMAT (supported by the Austrian Science Fund FWF, F3106-G02) could demonstrate a first big picture of the „chaîne opératoire“ in connection with the copper production in the Lower Inn Valley (Goldenberg et al., 2012; Schibler et al., 2011). For the first time it was possible to present dendrochronological data from different spots of the fahlore mining district (Nicolussi et al., 2009, 2015; Nicolussi & Pichler, 2013; Pichler et al., 2012, 2013).

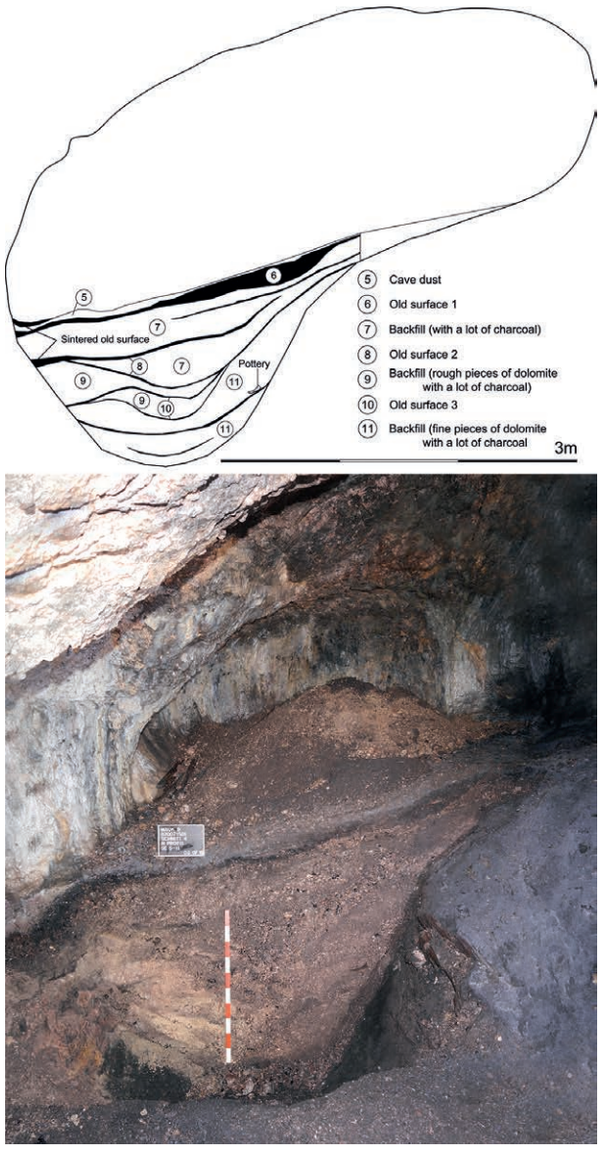

Fig. 2: Northern profile of section 4 in the mine Mauk B (graphic/photo: M. Staudt).

Archaeological investigations underground in fire-set fahlore mines (2015 – 2017)

Mauk B (district Maukenötz/Sommerau, Brixlegg)

The small fire-set mine “Mauk B” is situated in a ravine in the upper part of the Mauken valley, just above the base of a small torrent (Staudt et al., 2017a). An upper and a lower mine entrance are visible. The exploitation of fahlore in the dolomitic host rock (Schwazer Dolomit) left behind characteristic traces of fire-setting in the form of cupola shaped cavities. The mine shows a horizontal extension of 17 m, a maximum height of 3 m and a width up to around 5 m. The floor of the front part of the mine is covered with an undated mudslide of reddish sandstone which came inside with floodwater. At the backmost area the original prehistoric surface (Fig. 2, layer 6) is apparent underneath a distinct layer of soft and fluffy “cave dust”, which is about 1 to 2 cm thick. Beside older sections (1 and 2) from previous investigations by Gert Goldenberg (Goldenberg & Rieser, 2004) two new sections (3 and 4) could be researched. In the first instance radiocarbon analyses from the older excavation showed quite unsatisfying dating (Late Bronze Age / Iron Age) caused by the problem of the “Hallstatt plateau” for the ^{14}C-calibration curve (OZB 360, 2691 ± 38 BP, cal. BC 919 - 809; OZB 361, 2507 ± 33 BP, cal. BC 788 - 511; OZB 362 U, 2491 ± 52 BP, cal. BC 787 - 425; OZB 363 U, 2262 ± 47 BP, cal. BC 395 - 203); VERA 1322,

Fig. 3: The eastern (left) and western (right) fire-set mines at the Moosschrofen (photos: M. Staudt and D. Brandner).

2440 ± 35 BP, cal. BC 754 - 407; all values: 2 σ, 95,4 %; Goldenberg & Rieser, 2004; Goldenberg, 2014).

In section 3 the mining layers are just a few decimetres (max. 40 cm) thick and only a few charcoal fragments could be collected. In section 4 the base of the mine could be reached in a depth of around 1.30 m. In the filling (consisting of finely broken dolomite) a few layers including ancient working horizons could be documented (Fig. 2). Partly sintered dolomite fragments inside these horizons could indicate longer breaks between the mining activities. Most of the recovered charcoal pieces come from section 4. In the fire-set backfill a hammer stone fragment and a piece of domestic pottery could be found. Two ^{14}C-analyses of charcoal fragments from section 4 date around the final phase of the Late Bronze Age and the beginning of the Early Iron Age (dendro-sample maub-51: MAMS 25907, 2689 ± 26 BP, cal. BC 897 - 805; dendro-sample maub-27: MAMS 25906, 2651 ± 26 BP, cal. BC 891 - 792; all values 2 σ, 95,4 %).

Altogether 81 charcoal pieces were selected for dendrochronological and dendrological analyses. With one exception all pieces originate from section 4. The assemblage is clearly dominated by spruce (*Picea abies,* n = 79 pieces), only two pieces could be identified as fir (*Abies alba*). The longest tree-ring series established for a single piece of charcoal from the mine Mauk B has 76 rings, however, the median of all tree-ring series analysed is just 29 rings. Most series could be clustered into several groups. One of these groups, based on tree-ring series of 23 charcoals and covering 108 years, dates to 812 - 705 BC referring to regional chronologies. One charcoal of this calendar-dated group has a waney edge proving the cutting of the tree shortly after the onset of the vegetation period in the year 705 BC. Due to a possible further waney edge identified on another charcoal, felling activities took also place in autumn/winter 705/704 BC. Another group of 12 crossdating tree-ring series resulting in a mean series of 74 rings is dated on the base of the two radiocarbon results mentioned above. The end year (last ring) of this mean series dates cal. BC 818 - 724 (95,4 %, median: 745 BC) due to wiggle matching calibration by using OxCal 4.3 and IntCal13 calibration curve (Bronk Ramsey et al. 2001, Reimer et al. 2013). The single charcoal from section 3 crossdates with a sample from section 4. Therefore similar calendar dates for these two sections can be assumed. The dated charcoals prove that exploitation in the mine Mauk B took place in the 8th century BC with the last record for the year 705 BC.

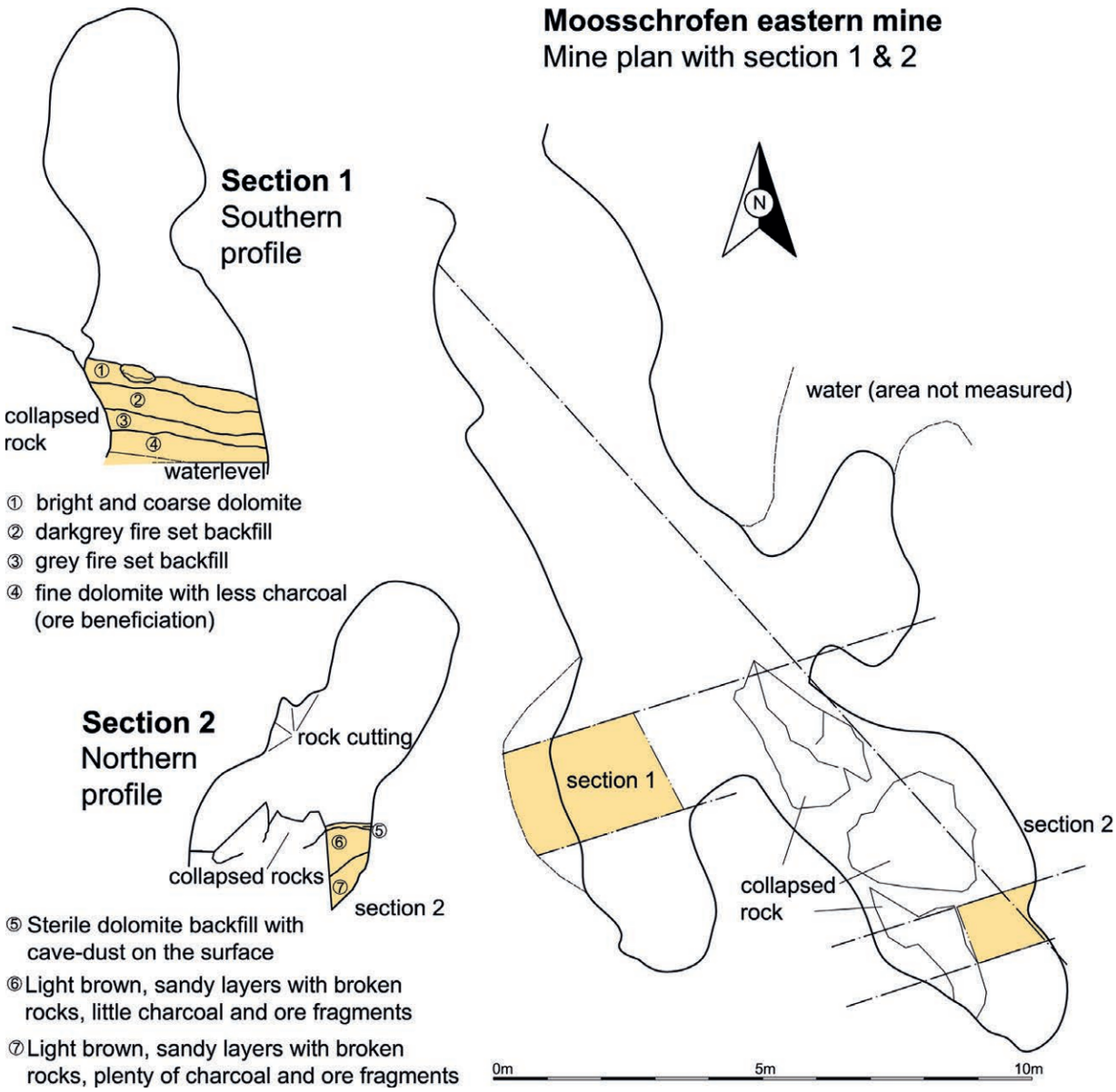

Fig. 4: The plan of the mine Moosschrofen (east) and cross sections of section 1 and 2 (graphic: M. Staudt).

Moosschrofen (district Zimmermoos, Brixlegg)

An ideal spot for mining archaeological investigations is located about 3 km east of Brixlegg. It is a 200 m long, 70 m wide and around 30 m high isolated rock called „Moosschrofen“, consisting of “Schwazer Dolomit”. A series of impressive dome-shaped cavities, representing the typical relicts of fire-setting, are visible from a distance in the vertical rock faces on the northwest side of the hill (Fig. 3). Even though some traces from younger work with hammer and pick as well as blast holes from black powder blasting are apparent, the main mining technique used on this site was fire-setting. In the 1990s Gert Goldenberg could prove a prehistoric exploitation of fahlore with radiocarbon analyses on charcoal samples (Goldenberg & Rieser, 2004). One sample from the eastern mining dump dates roughly into the Late Bronze Age/Early Iron Age (BETA 82923, 2700 ± 80 BP, cal. BC 1058 - 665, 2 σ, 95,4 %). Other charcoal pieces from the backfill inside the eastern mine are indicating a similar age (VERA 1324, 2710 ± 35 BP, cal. BC 918 - 806; VERA 1323, 2505 ± 35 BP, cal. BC 792 - 519; all values 2 σ, 95,4 %; Heiss & Oeggl, 2008).

Further charcoal samples could be taken within the DACH-project with the aim to generate more accurate dating by dendrochronological investigations (Staudt et al., 2017a). It was also scheduled to draw a mine plan as well as profiles to get a basis for the estimation of the amount of the exploited dolomite respectively ore.

Fig. 5: The northern profile of section 2 inside the eastern mine Moosschrofen (photo: M. Staudt).

The excavated fire-set dome situated in the eastern part of the Moosschrofen shows the biggest cubing with extensions up to 19 m and a maximum height of more than 8 m. In the back of the mine some big boulders of dolomite, which collapsed from the roof, are laying in and on the stowage (Fig. 4 and 5). It is not clear, if all these rocks came down during the mining activities or later on. In this mine two excavation trenches were traced out in the innermost parts (section 1: 12 m from the entrance and section 2: 17 m from the entrance, Fig. 4).

In section 1 four different layers could be distinguished and the floor level could not be reached because of upcoming water (at 1.80 m depth). Except for the topmost layer all other layers consist of finely crushed dolomite. In addition to a hammer stone fragment, some bigger pieces of charcoal could be picked up. The backfill-layers in this area are stratigraphic younger than the rock fall event.

In the small section 2 one of these big rocks lays on the surface of the topmost layer and is stratigraphically younger than the dump in this part of the mine. The layers in section 2 are much darker but as fine as in section 1 (Fig. 5). The sand-like material suggests that it could be the left over from ore processing work. Some fahlore fragments as well as pieces of charcoal could be collected for mineralogical/geochemical and dendrological/dendrochronological analyses.

Approximately 10 m eastwards of the excavation area some ceramic fragments from the Ha C period could be picked up “in situ” at a small fire-set cupola during former investigations by Goldenberg (Reider, 2003; Goldenberg, 2014; Goldenberg et al., 2019). This area belongs to the eastern mine Moosschrofen. More charcoal fragments originate from the dump underneath the big fire-set western cavern which is situated behind the modern cowshed. Due to erosion these samples were visible in a profile of the dump and it was possible to collect them without any excavation. Further a 3D-model of this tall mine (western mine) was rendered using photogrammetry (structure from motion = technique for estimating three-dimensional structures from two-dimensional image sequences).

Charcoals from both sections of the eastern part of the Moosschrofen mine have been analysed. The 57 selected pieces belong to the species spruce (n = 50) and fir (n = 7). All fir charcoals were collected in section 1. The length of the tree-ring series vary between 19 and 86 rings, the calculated median is 36.5. Crossdating of 37 charcoal series were successful and gives end years that range between 772 and 719 BC. However, most series end 742 BC or earlier, two end in the 730s BC and one ends with a possible waney edge in 718 BC. The three charcoals with the youngest end years originate from section 1, whereas the youngest end years from section 2 date into the 740s BC.

Gratlspitz (district Thierberg, Brixlegg)

The mountain Gratlspitz (1899 m a. s. l.) is situated between the tributary valleys Wildschönau and Alpbachtal and can be seen from a distance due to its exposed position. The Gratlspitz massif consists mainly of “Schwazer Dolomit” and fahlore mineralisations are frequent. The mining district is also known as “Thierberg” and fire-set mines can be recognised from the foot of the mountain up to the hilltop. This massif has been intensively exploited during the late medieval and modern times (Pirkl, 1961; Haditsch & Mostler, 1969; Mutschlechner, 1984; Gstrein, 1988a; Manninger, 2011). Near the hiking trail from the Holzalm to the summit some stone tools, pottery fragments and animal bones were found by Brigitte Rieser and Hanspeter Schrattenthaler (Schrattenthaler, 1994; Rieser & Schrattenthaler, 1998/99). Close to the summit a few pits and overgrown dumps can still be observed where prehistoric stone tools could be collected during field surveys done by the authors. All these findings prove prehistoric mining from the bottom to the top of the mountain.

Westwards of the Holzalm (a former miners hut, today a mountain guesthouse), along the northern foot

Fig. 6: A fire-set mine (red: Gratlspitz 1) at the north wall of the Gratlspitz (photos: M. Staudt and D. Brandner).

of the Gratlspitz massif, a series of mines showing clear marks from fire-setting are visible. Most of these prehistoric traces are overprinted by modern mining activities. The mine "Gratlspitz 1" is situated in the steep north face of the massif, where two side by side mining portals can be seen from a distance (Fig. 6). The mining entrance is accessible via a narrow path and with a gentle climb. From inside, this mine offers a good view to the Moosschrofen further down as well as of the Inn Valley. The mine is around 10 m deep and 9 m wide. During the excavation in the southern part of the innermost mine it was possible to reach the bottom of the mine which consists of hard dolomite rock (Staudt et al., 2017a). The backfill here is around 1.50 m thick and could be divided in four different working phases. The topmost layer derives from modern activities at a second window-like mine port (prospection only). Maybe this "window" was opened for better light conditions in the deeper part of the mine. Inside it is quite bright and working would have been possible without any artificial light (splints of wood, mining lamp). In the topmost layer of dolomite backfill some pottery fragments of early modern times, as well as a minor amount of prehistoric ceramic could be documented. It looks like the modern and prehistoric backfill has been mixed up. Beside the typical prehistoric fire-set traces, only a few tiny marks from iron-tools of more recent workings are visible on the wall.

Underneath this younger horizon two layers (3 and 4) consisting of fine dolomite sediment as well as bigger fragments of dolomite mixed with charcoal appeared. Most of the analysed charcoal, as well as some samples of fahlore, originate from these two older layers. At the western part of the section remains of a origin prehistoric

Fig. 7: A mainly fire-set mine (Gratlspitz 3) at the north wall of the Gratlspitz (photo: M. Scherer-Windisch).

layer including prehistoric pottery came to light. Additional to the archaeological excavations a 3D-Modell of the mine was created.

A first charcoal sample from this mine, collected by Gert Goldenberg, could be roughly dated into the Early

Fig. 8: Fire-set walls and mine entrances inside the "crater" of the Bauernzeche with the investigated "upper mine" (above right) and "lower mine" (below; photos: M. Staudt).

Iron Age: VERA 1320, 2540 ± 45 BP, cal. BC 805 - 538, 2 σ, 95,4 %; Heiss & Oeggl, 2008). Another sample from the recent investigations dates into the last stage of the Late Bronze Age (MAMS 25905, 2669 ± 26 BP, cal. BC 895 - 798, 2 σ, 95,4 %).

The dendrochronological analysed charcoals consist of two groups, one already collected in the 1990s by Gert Goldenberg (n = 10) and the second one collected during the recent excavations (n = 13). Even though selected material was analysed, the number of tree-rings ranges between 16 and 50 (median: 20) and only two tree-ring series with more than 30 rings could be constructed. The species of all charcoals analysed is spruce. Six charcoal series were averaged into a mean series with 56 rings that dates 808 to 753 BC. The ^{14}C-date (see above) established on the base of few rings of one of the dendro-dated charcoals backbones this dating: the expected date of the last ring of the mean series is between cal. BC 847 and 750 (95,4%; median cal. BC 774) due to radiocarbon calibration by using OxCal 4.3.

To the west of the above mentioned mine "Gratlspitz 1", two other small fire-set mines "Gratlspitz 2" and "Gratlspitz 3" could be briefly investigated. In both cases the backfill material was rougher and no bigger charcoal fragments were apparent. In these two mines traces from blasting as well as from work with iron tools are visible. Therefore it can be supposed, that the prehistoric stowage has been removed either during the Late Bronze Age / Iron Age or in the course of modern prospection activities. In the mine Gratlspitz 3 (Fig. 7) an iron knife from the 15th/16th century AD could be discovered in an excavated fireplace.

Bauernzeche (district Großkogel, Reith im Alpbachtal)

The mining area Kogel, situated on the eastside of the Ziller Valley, can be separated into two units: the Großkogel (Reither Kogel) and the Kleinkogel (Hinterkogel). Casually

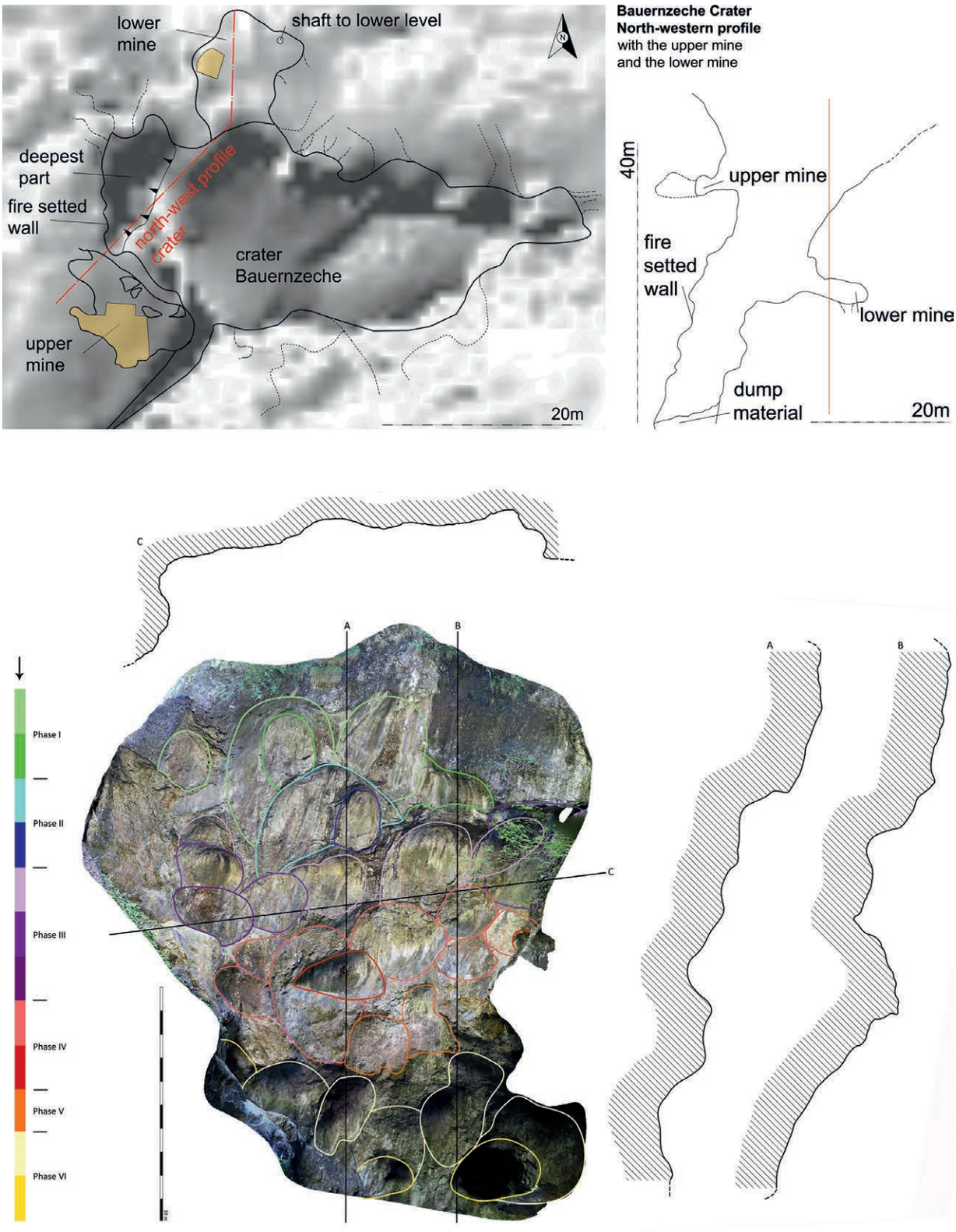

Fig. 9: The crater Bauernzeche with the position of the two excavated mines (top left) and the north-west profile of the crater (top right); 3D-model and profils of the wall underneath the excavated "upper mine" with different stages of fire-setting (bottom) (graphics: M. Staudt and M. Scherer-Windisch).

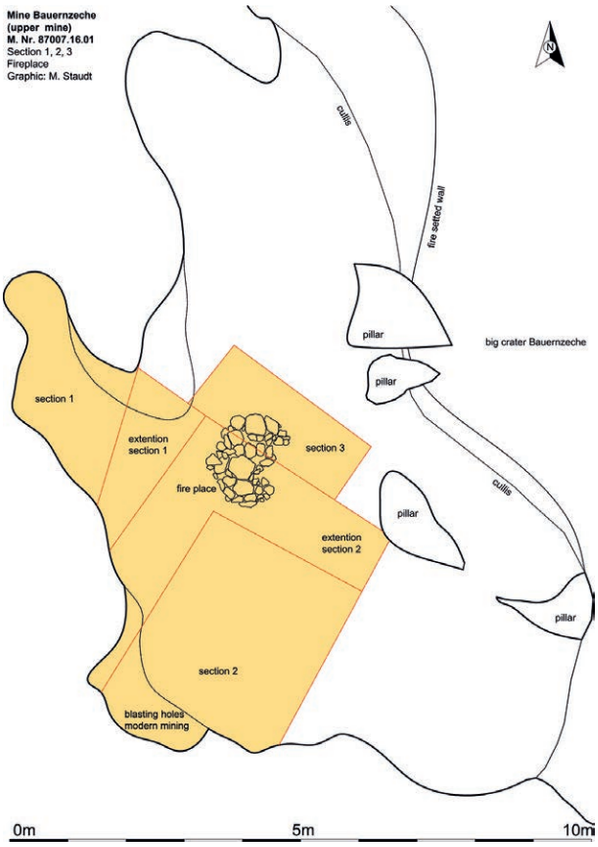

Fig. 10: Mine plan Bauernzeche "upper mine", with the fire place (graphic: M. Staudt).

the field name "Heidstein" is still in use (Mutschlechner, 1984) which can be translated to "stone of the heathens". The term "Heid…" or "Haid…" can be traced back to the descriptions of "old mining works" in the "Schwazer Bergbuch" of the 16th century AD (Bartels et al., 2006). In those days such surface-near and fire-set mines were generally interpreted as of pre-Christian age, originating from pagan or roman mining work. Along the northern slope of the Groß- and Kleinkogel Rieser and Schrattenthaler could prove prehistoric mining activities (Rieser & Schrattenthaler, 1998/99, 2002).

The so called "Bauernzeche" (Fig. 8) represents one of the most spectacular mining sites in the area of Schwaz-Brixlegg and shows very impressive fire-set walls, giving a nice picture of the enormous mining activities, which were carried out already in prehistoric times. This mining complex is situated at the northern hillside of the Großkogel which was exploited together with the Kleinkogel on a large scale in medieval and modern times (Isser von Gaudententhurn, 1888; Schmidegg, 1953; Pirkl, 1961; Gstrein, 1988a). The Bauernzeche is a big and deep hole with a cross-section dimension up to 50 m. The enormous size can be easily recognised on the LIDAR-based digital terrain model. On every wall traces of fire-setting as well as fire-set mining entrances are visible. It is not clear, if the whole complex is more a result of a huge collapsed mining system or of a large open cast mining. Most likely both aspects are to be considered. Beside the numerous and omnipresent relicts from prehistoric fire-setting, traces from medieval and modern day mining are also frequent. Within the frame of geological field surveys carried out by Herwig Pirkl, a "Bronze Age" fibula could be found (Gstrein, 2013) in the crater of the Bauernzeche (find not published).

On the western side of the crater a very impressive fire-set wall (higher than 30 m) is still well preserved. The wall shows an exceptional number of truncated fire-set cupolas which could be documented using photogrammetry (structure from motion, 3D-model, Fig. 9; Scherer-Windisch, 2017). By analysing the 3D-model and the system of overlapping of the fire-set cupolas it was possible to identify the progression of different stages of fire-setting, which shows a driving system from top to bottom. Some sintered backfill material, which is still visible on this wall, could be a sign for underground mining in origin.

Just above this fire-set wall, a small and typical prehistoric mine with some well-preserved pillars is located, the "Bauernzeche, upper mine" (Staudt et al., 2018c). This quite exposed mining spot (Fig. 8 and 11) is only accessible by climbing and was selected for detailed archaeological investigations. The steep and rocky track was secured with fixed ropes with the help of the Bergbau Aktiv Team (BAT) from Brixlegg. In front of the mine there is a narrow "balcony" left as a relic of the original mine. This shows clearly that in prehistoric times the mine was bigger and has meanwhile partly collapsed into the peripheral zone of the big crater of the Bauernzeche. The underground part of the mine is around 15 m long and 8 m wide/deep (Fig. 10). The maximum height of the mine is around 2.60 m (measured after excavation from top to ground). In the southwest corner traces of a few drilling holes are representing the remains of younger ore prospection activities. In the eastern part a former pillar was extracted. In the frame of previous investigations Goldenberg could collect small charcoal samples for two radiocarbon analyses (VERA 1608 and VERA 1609; Stöllner, 2009). These first dating attempts spread into the so called "Hallstatt plateau" of the calibration curve ("Iron Age") without a satisfying dating result.

Within the recent studies section 1 was set up in a tiny fire-set area in the western part (Fig. 10) of the mine. Underneath a 20 cm strong layer of natural collapsed dolomite (1) the typical "cave dust" (2) appeared. Below these fine strata, two layers of prehistoric backfill material, which could be separated by colour, became visible. Inside this material, a small amount of pottery, animal bones and hammer stone fragments were picked up. Together these two stowage layers (3a and 3b) are nearly 40 cm thick and overlay a cultural layer (4), which consists mainly of fine and homogeneous organic material, particularly charcoal with nearly no dolomite inside. This up to 15 cm thick stratum looks similar to what can normally be expected from an excavation at a settlement site and is very uncommon for an underground mining

Fig. 11: Bauernzeche "upper mine", with some leftover pillars for static purposes (photos: M. Staudt).

site. The stratigraphically oldest backfill in the mine is left underneath the cultural layer and consists of a thin layer of small pieces of dolomite in section 1 (layer 5).

In section 2, which was excavated eastwards of section 1, the same sequence of layers became apparent but without the lowest backfill layer (5). The cultural layer (4) was deposited directly on the bottom of the mine. After opening the part between section 1 and 2 with an enlargement to the north a fire place, carefully set with flat dolomite stones, could be excavated at the bottom of the mine and inside the cultural layer. This impressive two-phase hearth construction was covered with tiny charcoal and thick ash layers (Fig. 12), proving a long-lasting use of the fire-place. Obviously this part of the mine was used as a miners lodge/shelter for quite a while in prehistoric time. Later in time the mining activities started again and the cultural layer as well as the fire place was covered with backfill material (3a and b).

Inside the described cultural layer a huge amount of pottery, greenish animal bones and stone tools as well as a few antler and bone tools were collected. In total 2274 pieces (33.25 kg) of pottery could be inventoried (Zetzmann, 2019). In the corpus of findings there are big fragments of domestic vessels as well as fine and occasionally also painted ceramics. Two pottery fragments show repair marks (holes, Fig. 13). Further two antler tools with production marks (cutting) and signs of use came to light as well as a tapered thin bone tool (bodkin). The different antler tools were probably used for crushing nuts or to loosen the rock slabs after fire-setting. A grooved stone hammer was picked up on the surface of the youngest prehistoric layer (3a). Further hammer stone fragments could be found in the backfill stowage (3a and 3b), in the cultural layer (4) and in between the fire place. A sharpening stone comes out of the cultural layer and a bigger stone with tiny dimples out of the top most backfill material. This stone is a sign for ore beneficiation inside the mine. In general it is approved that stone tools found at the prehistoric mining sites were rather used for ore processing than for mining. This is obvious in the mining area Schwaz-Brixlegg where most of the hammer stones found come from ore processing sites. In

Fig. 12: The two-phase fire place at the bottom of the Bauernzeche "upper mine", with the cultural layer and the overlapping backfill layers (photos: M. Staudt).

connection with fire-setting as the main driving technique, the use of hammer stones is usually not really necessary for the rock extraction (depending on the rock material; Gätzschmann, 1846; Py & Ancel, 2006). Inside the prehistoric mines fragments of stone tools are therefore only occasionally found. The unusual high amount of hammer stone fragments together with the backfill material inside the investigated sector of the mine Bauernzeche indicates ore beneficiation works inside the mine.

The pottery fragments from this mine often show a horizontal strip with finger impressions. These bellied vessels with different diameters are typical ceramic finds also in other fire-set mines in the area Schwaz-Brixlegg. In many cases they show a slightly inwards curved edge. This kind of shape and adornment is representative for the domestic pottery of the Early Iron Age (Ha C, 8th/7th century BC, Fig. 13). The ceramic finds give a good overview of the Early Hallstatt period. Settlements of this period are very rare in North Tyrol and therefore the corresponding pottery is difficult to find. The same kind of pottery is known from the dendrochronological dated mines Mauk E (707 BC, Klaunzer et al., 2010), Mauk B (705 BC, see above) and Moosschrofen (719 BC, Reider, 2003; Goldenberg, 2014). Comparable pieces could also be picked up in the "Heidenzechen" at the Eiblschrofen (Rieser & Schrattenthaler, 1998/99; Rieser & Schrattenthaler, 2004) and in front of the entrance of the "Ivanuslauf" (district Burgstall, Gstrein, 1981). The bigger vessels found inside the upper mine Bauernzeche were probably used for cooking and storing food. Also a representative and numerous selections of bowls were found inside the upper mine of the Bauernzeche. One of them shows painting marks inside the vessel. This finer kind of pottery represents the dinnerware of the prehistoric miners (Fig. 13).

From the excavation inside the "Bauernzeche, upper mine", three radiocarbon dates could be obtained from animal bones found in the youngest backfill (MAMS 28725, 2520 ± 20 BP, cal. BC 788 - 549, 2 σ, 95,4 %), the oldest backfill underneath the cultural layer (MAMS 28726, 2470 ± 20 BP, cal. BC 763 - 492, 2 σ, 95,4 %) and in between the two phases of the fire place (MAMS 28727, 2479 ± 20 BP, cal. BC 766 - 524, 2 σ, 95,4 %). Because of the "Hallstatt-plateau" of the calibration curve the ^{14}C-data again spread into the Iron Age and cannot be dated exactly. The dendrochronologically analysed charcoals (n = 14) from this mine resulted in relatively short tree-ring series from 16 to 39 values (median 23). Only few series could be clustered and no dendro dates could be established till now. The investigated assemblage is dominated by fir pieces, i. e. 12 out of 14 charcoals belong to this species, and the two other charcoals are spruce. It seems that some of the end years date into the 7th century BC, but due to the small annual rings there are no concrete dating approaches.

Inside the crater, opposite the massive fire-set wall and 15 m deeper than the "upper mine" it was possible to investigate another small fire-set mine, the "Bauernzeche, lower mine" (Fig. 9). The work was done in the upper level of this underground mine which is linked by a shaft to a deeper part. The surface of the prehistoric mining backfill was almost preserved and in the frame of a small excavation two prehistoric pottery fragments and some bigger pieces of charcoal could be picked up out of the 0.90 cm thick filling. Additionally to the archeological excavations a 3D-model was constructed of the lower mine Bauernzeche.

The investigated charcoals from the "lower mine" allowed the establishment of dendro-dates. Here also mainly fir (29 pieces out of 39) could be identified and the other analysed charcoals are again spruce. The length of the tree-ring series established for these 39 charcoals range from 17 to 66 (median: 27). Fir as well as spruce series could be crossdated and consequently averaged

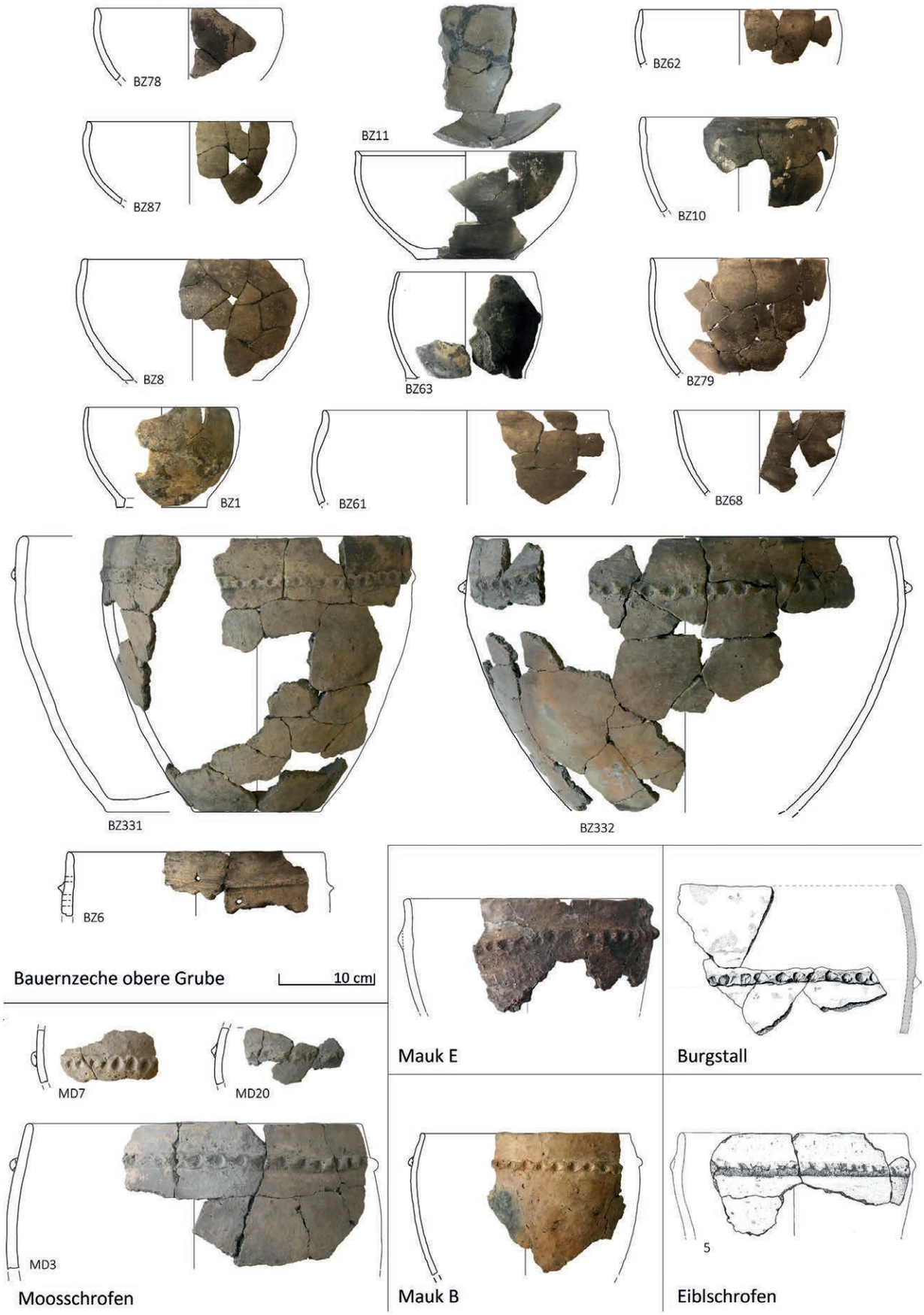

Fig. 13: Pottery from the Early Iron Age mines Bauernzeche, Moosschrofen, Mauk E, Ivanuslauf (Burgstall), Mauk B and Eiblschrofen (graphic: M. Staudt, B. Rieser and H. Schrattenthaler, P. Gstrein).

Fig. 14: The mine „Knappenkuchl“ with the upper (top left) and lower (bottom left) levels, which are linked with a shaft/chimney (right; photos: M. Staudt).

to an 82 values long mean series, which dates 853 to 772 BC. Most series, i. e. 15 out of 21, have their last ring within the last decade of the mean series. Moreover, waney edges could be identified on few samples. A fir charcoal prove logging in autumn/winter 777/76 BC, a spruce as well as a fir charcoal document also such activities in summer 772 BC and an additional fir sample display only a possible waney edge which suggests cutting in summer 772, too.

Knappenkuchl (district Kleinkogel, Reith im Alpbachtal)

In mining history the Kleinkogel is as famous as the Großkogel (Isser von Gaudententhurn, 1888; Schmidegg, 1953; Pirkl, 1961; Gstrein, 1988a). Alongside traces of medieval and modern day mining, traces of fire-setting can be seen from the bottom up to the hilltop. The so called presumable prehistoric mining complex “Wilde Kirche” at the Kleinkogel shows a similar dimension as the “Bauernzeche” and also shows traces of fire-setting (Mutschlechner, 1984). This open cast mine was already illustrated in the Schwazer Bergbuch (Bartels et al., 2006). Underneath the “Wilde Kirche” and estwards of the modern Johannstollen (Pirkl, 1961; mine nr. 20) a Certosa-fibula could be picked up during a field survey (Huijsmans & Krauß, 2015). This artefact made of bronze dates into the Late Hallstatt/Early Latène period (Ha D2-Lt A).

The mine “Knappenkuchl” is located on the northside of the district Kleinkogel in a steep trench approximately 750 m westwards of the Bauernzeche (district Großkogel), around 170 m below the summit (1068 m a. s. l.). Obviously the western fire-set mining part has collapsed a long time ago. A younger mining system, exploited mainly by hammer and pick as well as by black powder blasting, with remains of wooden trails from a so called “Spurnagelhunt” (buggy) is evident directly underneath the prehistoric mine. Inside one of the adits, parts of a wooden ore trough could be collected by the authors.

In the prehistoric two-storied mine, little marks from younger mining actions are apparent. The mine consists of two levels, which are linked together with a fire-set chimney/shaft (Fig. 14). In the less voluminous upper level, the only small amount of dolomite filling left behind is less suitable for archaeological investigations (Staudt et al., 2018c). The lower level in contrast could be partly excavated with good results. In front (north) of the mine, on a small plateau, more buried fire-set entrances are partly visible. This plateau was probably created during modern mining activities and used as a base of a miners hut. Even though there are no visible structures left, most likely a part of the southern dolomite wall has been flattened for the same reason.

The lower level of the fire-set mine with a length of 25 m, a height of 3.70 m and a depth of more than 20 m shows different entrances on the north- and east-side (Fig. 15). Because of the sloping backfill, which

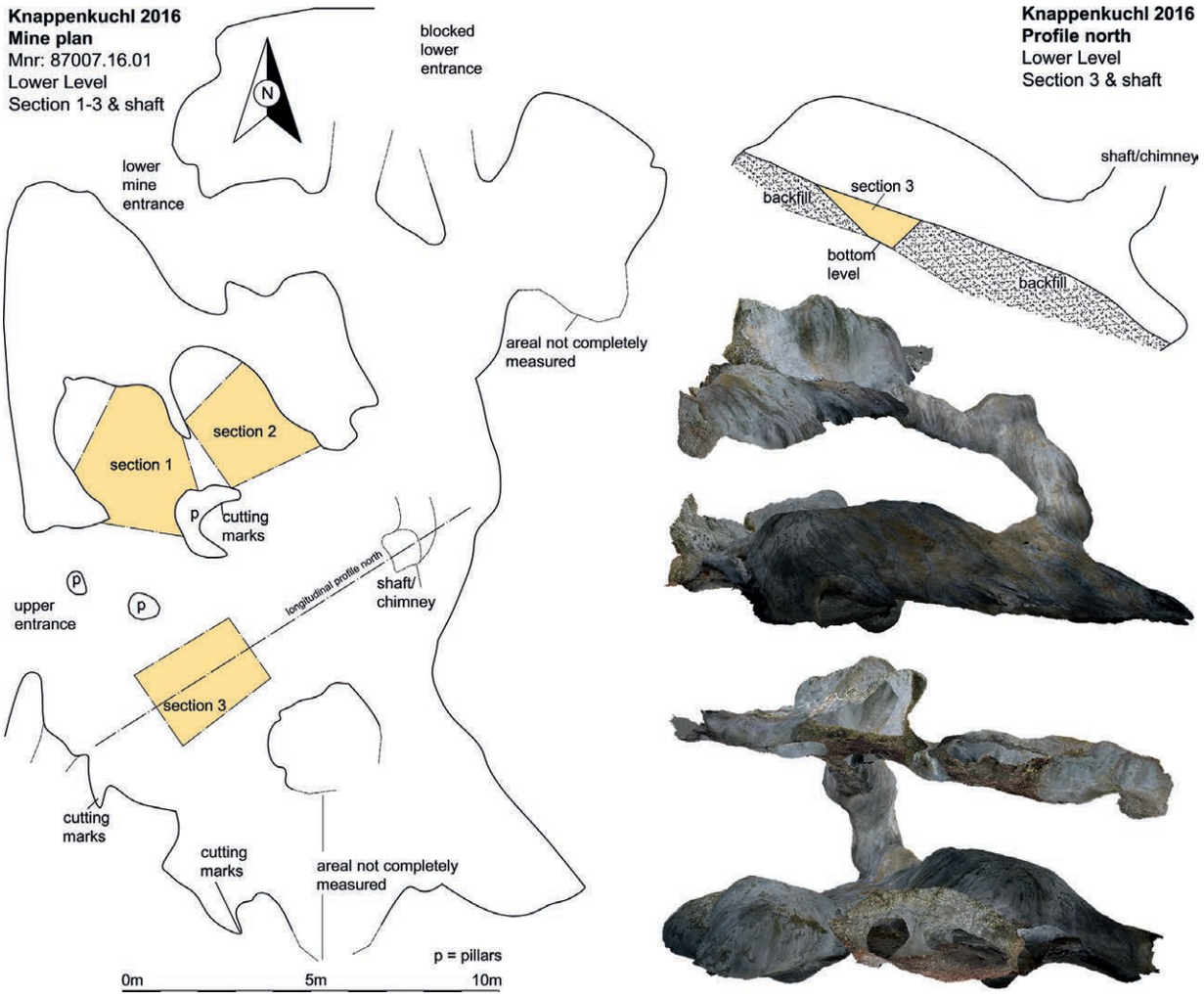

Fig. 15: Plan and longitudinal profile north of the lower level of the mine Knappenkuchl with the 3D-model (graphics: M. Staudt and D. Brandner).

covered the whole mine floor, it was only possible to measure the height in section 3 (see below). The areas on the east side could not completely be documented. There was too much backfill material and a shortage of investigation time, because of the arriving winter. At the peripheral zones in the western part some pillars are well preserved. In the southern part a collapsed zone and another blocked entrance or access to a further mining system is evident.

North and east of the highest entrance of the lower mining level, three sections could be traced out. Section 1 and 2 are situated between two fire-set cupolas and a pillar. In all sections the same sequence of prehistoric layers could be observed underneath grit dolomite pieces from younger mining periods. In this upper layer a fragment of a pipe bowl (17th/18th century AD) and some leather fragments, animal bones and remains of lighting sticks were picked up. In section 1 this stratum is up to 90 cm thick. The thickest prehistoric backfill material (1.10 m) was documented in section 3 (Fig. 15). In all the prehistoric layers charcoal pieces from fire-setting were collected for dendrochronological analyses. In section 2 and 3 prehistoric domestic pottery fragments were apparent and two fragments of hammer stones with mounting marks could be recovered. Where the fire-set cupola passes into the aeration chimney, some sintered dolomite debris is left on the wall. This may indicate, that the lower part of the mine was filled up once with stowage material, before this was removed later on for further mining activities or prospecting. Out of the chimney, a piece of sintered charcoal could be taken for radiocarbon analyses (MAMS 29941, 2966 ± 21, cal. BC 1261 - 1117, 2 σ, 95,4 %). One greenish bone fragment was picked up in the lower part of the top most prehistoric backfill material of section 3 for ^{14}C-analyses (MAMS 29940, 2908 ± 22, cal. BC 1193 - 1016, 2 σ, 95,4 %). A digital photogrammetric 3D-model (structure from motion) was created by Daniel Brandner out of the complete upper level, the linking chimney/shaft as well as the southern half of the lower level (Fig. 15).

Fig. 16: The southern prehistoric fire-set part of the mine Schönbiegler Bau with chimney (photos: M. Staudt).

Fig. 17: Northern profile of section 1 inside the southern part of the mine Schönbiegler Bau underneath the chimney (photo: M. Staudt).

Schönbiegler Bau (district Burgstall, Gallzein)

The mining district "Burgstall" lies to the south of Gallzein between the Bucherbach in the west and the Schlierbach in the east (Gstrein, 1986, 1990). Westwards of the Bucherbach, in the surroundings of the Kogelmoos, the famous legend of the "bull of Kogelmoos" was originated in 1409 (Gstrein, 1988b; Grundmann & Hanneberg, 1994). At the Blutskopf (district Burgstall) a lot of underground mines, pits and opencast mines are still visible. Within the frame of field surveys close to the hill top in front of the historic Ivanus mine, some fragments of prehistoric domestic pottery could be picked up by Peter Gstrein in the years 1963 and 1974 (Gstrein, 1978, 1981, 2015). This was the first documented pre-Christian ceramic find in the mining area Schwaz-Brixlegg. In the 1990s Rieser and Schrattenthaler could also prove prehistoric mining activities along the Blutskopf (Rieser & Schrattenthaler, 1998/99, 2002).

The mine "Schönbiegler Bau" is situated at the steep western hillside of the Blutskopf, above the Bucherbach. In the direct surroundings several small fire-set underground mines and opencasts with marks from fire-setting are visible. Again the coexistence of fire-setting techniques, cutting activities and blasting operations is apparent. In the 1990s Goldenberg could collect a tiny amount of charcoal samples from this mine which proved mining in the last stage of the Late Bronze Age (VERA-1319, 2680 ± 30 BP, cal. BC 897 - 802, 2 σ, 95,4 %; Heiss & Oeggl, 2008). In the frame of his dissertation Gstrein was able to draw a detailed plan of the whole underground mining system from late medieval to modern times (Gstrein, 1978).

The "Schönbiegler Bau" is devided into two west-east orientated mining systems (Staudt et al., 2018c). The southern part shows a big fire-set underground chamber with the extensions around 11 m x 7 m and a height of 7 m (Fig. 16). The whole floor is covered with dolomite backfill. In the east a younger dump, which comes from the adjacent modern mining area, is apparent. During the

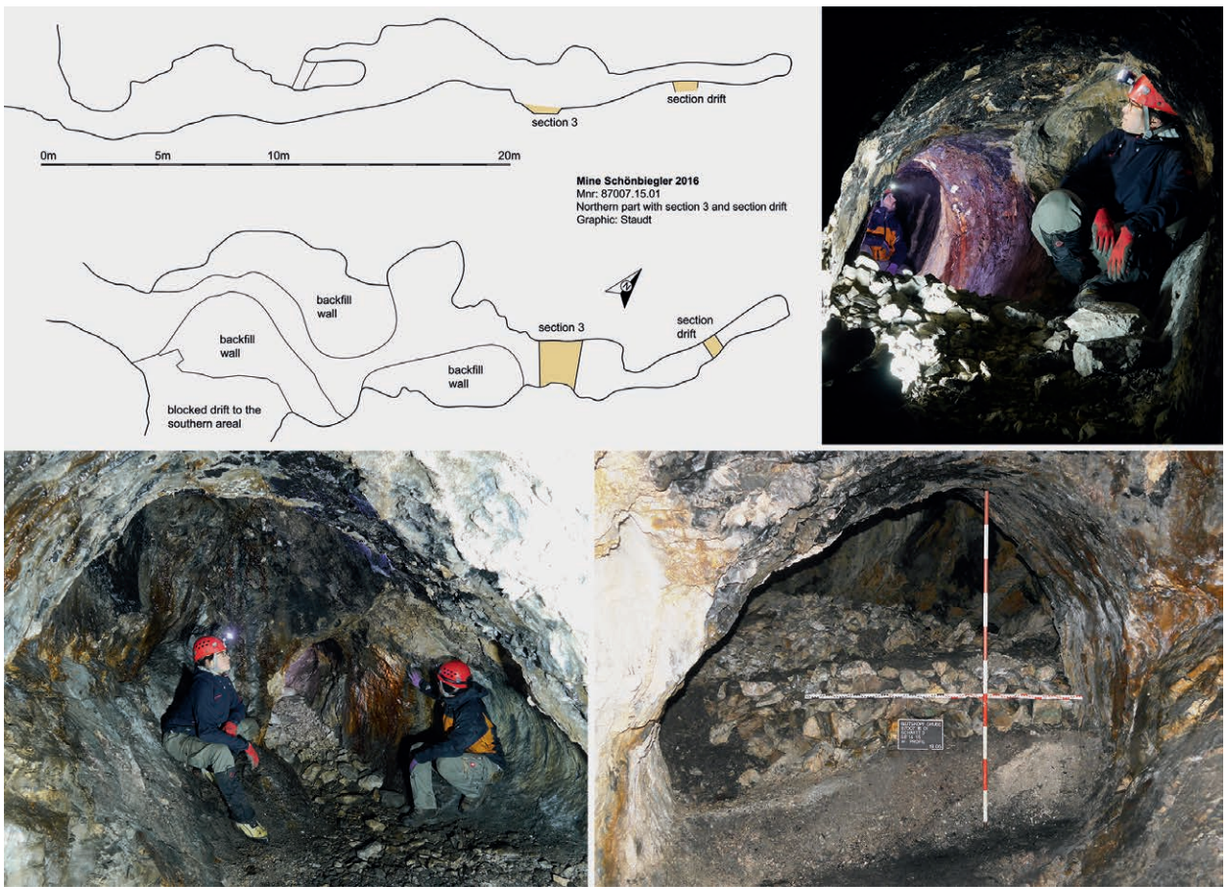

Fig. 18: Mine plan and "Seigerriss" (top left), western profile of section 3 (bottom right), the fire-set drift (top right) and the deepest prehistoric mining area (section 3, bottom left) inside the northern part of the mine Schönbiegler Bau (graphic/photos: M. Staudt).

excavation the ground level could not be reached and is assumed deeper. At the roof a small, 2.50 m long chimney up to the surface is visible. At the backside the modern mining gallery with a length of 45 m is adjoining. Section 1 was traced out in the southern fire-set mining system underneath the chimney (Fig. 17). The topmost layer included a few modern finds. Below, in a 10 cm to 50 cm thick dolomite deposit with finds from the 15th/16th century AD ceramic fragments of two miner lamps ("Schwazer Lampen") as well as fragments of domestic pottery came to light. Also here the prehistoric backfill material then becomes evident underneath the typical thin layer of "cave dust". This prehistoric dump could be distinguished into two layers, which include domestic pottery and a lot of bigger charcoal fragments. For technical and security reasons this excavation had to be stopped at 1.90 m depth and the ground level could not be reached. Radiocarbon analyses from charcoal samples out of this section show no exact dating (MAMS 29938, 2515 ± 20 BP, cal. BC 786 - 547, 2 σ, 95,4 %), due to the problem of the "Hallstatt-plateau" of the calibration curve.

The northern mining part was originally linked with the big chamber, but today the connection is collapsed. Entering this northern area is possible from the west through a collapsed open cast mine. In the northern part traces of fire-setting are visible up to the heading face, which is situated 35 m innermost in the east (Fig. 18). Although drifted by the fire-setting technique, the last 8 m look similar to medieval/modern drifts. Additional working traces from hammer and pick, as well as blasting holes, are discernible. A small excavation (section 3, Fig. 18) was realized inside the mine in front of this drift in a nice fire-set cupola 24 m southwards of the entrance. The fine structured backfill was up to 50 cm thick and could be separated in two layers of dolomite mixed with some charcoal fragments. The floor level shape is nearly flat. Radiocarbon analyses from section 3 show a more exact dating (MAMS 29939, 2639 ± 20, cal. BC 827 - 794, 2 σ, 95,4 %) than in the southern part of the mine.

Another section (section drift) was trenched out in the smaller drift in the nearly innermost fire-set part of the mine (Fig. 18). There the backfill on the floor was sintered and a few bigger charcoal fragments could be picked up for dendrochronological/radiocarbon analyses. No other datable artefacts could be collected during the excavations in the northern part of the mining system. The same shape of fire-set drift as in the deepest part of the investigated mine can also be observed in other mines in the area Schwaz-Brixlegg (Fig. 19). Inside a mine at the Kleinkogel (Reith i. A.) and another one at the district

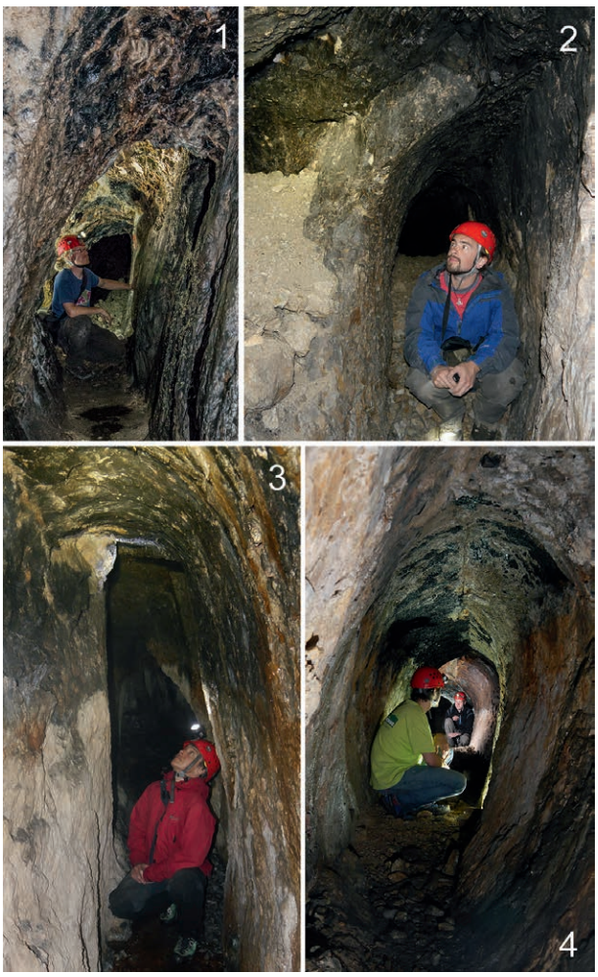

Fig. 19: Fire-set drifts from medieval/modern day mining activities: 1 - district Palleiten, 2 - district Weißer Schrofen, 3 - district Kleinkogel, 4 - district Hintersommerau (photos: M. Staudt and A. Schirmer).

Weißer Schrofen (Pirkl, 1961; mine nr. 502) the sequences of cutted drifts which merge to stratigraphic younger fire-set drifts show clearly medieval/modern activities. The illustrated pictures (Fig. 19, 1 and 4) of the fire set drifts Sagzeche (district Palleiten) and another one in the district Hintersommerau have not yet been dated. In the case of the "Schönbiegler Bau" it was possible to date this fire-set drift with radiocarbon analyses from a charcoal sample out of the sintered backfill. As it was expected, this deepest part of the northern mine was exploited in historic times and the fire-set drift dates into the 15th/16th century AD (MAMS 31599, 443 ± 30 BP, cal. AD 1415 - 1609, 2 σ, 95,4 %). A 3D-model (structure from motion) was rendered of this drift, as well as of the adjacent prehistoric fire-set copulas in the west.

The dendrochronologically analysed charcoals from the „Schönbiegler Bau" belong to two groups. Four samples were collected in the 1990s whereas 101 charcoals originate from the recent excavations. The material is dominated by spruce, only eight out of 105 charcoals have been identified as fir (*Abies alba*, 4 pieces) and larch (*Larix decidua*, 4 pieces). One of the larch pieces – together with three spruce pieces – belong to the group of late-medieval timber material that is not completely charred. Only short tree-ring series, i.e. 18 to 30 values long, could be established for these wood fragments. The length of the series of the other pieces vary between 9 and 61 rings (median: 20). In the end two mean series could be established on base of the prehistoric charcoals from this mine. The series of four charcoals could be cross-dated to a 59 years long mean series. Few rings of the innermost part of a charcoal were used for radiocarbon dating (MAMS 29939, see above) and the calibration dates the end year of the mean series to cal. BC 774 - 741 (95,4 %, median: 754 cal BC). A second mean series is based on 51 tree-ring series from charcoal of both sections 1 and 3. The mean series dates 768 to 703 BC (66 years), however, this calendar-dated series ends without a waney edge. For one of the tree-ring series included a prehistoric ^{14}C date is available (MAMS 29938, cal. BC 786 – 547, see above). The adjusted calibration of this ^{14}C result dates the last ring of the mean series to cal. BC 750 - 511 (95.4 %, median: cal. BC 601) which is in agreement with the dendro-date but highlights the limitation of radiocarbon dating in the Hallstatt period.

Gut Wetter Bau (district Burgstall, Gallzein)

The mine „Gut Wetter Bau" is situated near the surface and represents the uppermost part of the mining system called "Katzenstollen". The entrance is around 90 m to the south of the Ivanus mine on the top of the Gallzeiner Joch. Mining pits as well as traces of open cast mining characterise the surrounding landscape. The "Gut Wetter Bau" is accessible from the west through a sloping fire-set entrance. Inside traces of fire-setting are omnipresent (Fig. 20). On the eastside the mine is defined by a shear zone. The biggest dimension of the fire-set areal is around 15 m wide. The maximum height is up to 6 m. In the south the cavity is connected to a big mining system from the historic mining periods, which shows mining marks from hammer and pick, wedge pockets ("Keiltaschen") and blasting holes. This quite deep mine was documented by Gstrein in the 1970s (Gstrein, 1978).

During a prospection, one complete hammer stone and a fragment (with mounting marks) could be picked up on the backfill underneath the entrance, next to humous material slipped in from outside (Staudt et al., 2018c). Directly above these artefacts, some sintered dolomite with pieces of charcoal was left on the wall. The same kind of sintered material could be noticed on the opposite side at the big shear zone. It is assumed, that in prehistoric time backfill material covered the whole mine floor and was removed later on by subsequent mining activities. The radiocarbon sample from the sintered backfill dates into the Early Iron Age (MAMS 28724, 2528 ± 26 BP, cal. BC 788 - 579, 2 σ, 95,4 %). The fire-set part was documented

Fig. 20: The fire-set part of the mine "Gut Wetter Bau" (photos: M. Staudt).

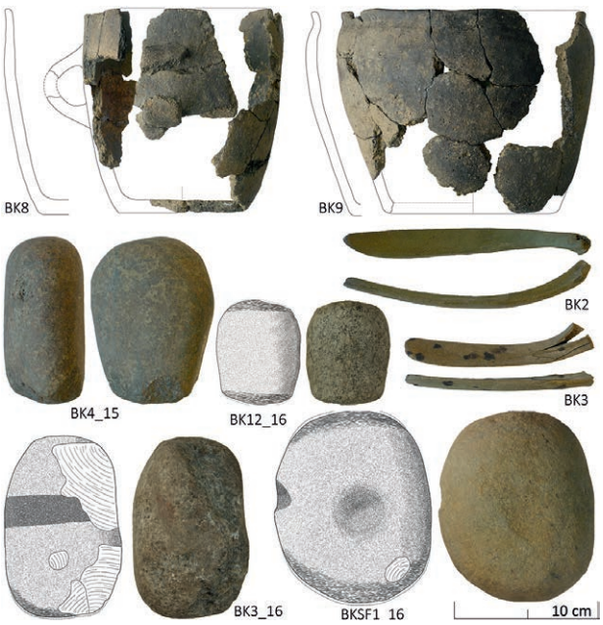

Fig. 21: Some Late Bronze Age findings from the Blutskopf plateau (stone tools, bone tools and pottery; graphic: M. Staudt and R. Lamprecht).

and a plan with cross-sections was established. So far, no archaeological excavation has been carried out, because there is not a lot of backfill left in the assumed prehistoric section.

Sagzeche (district Palleiten, Gallzein)

The Sagzeche is situated eastwards of Kogelmoos and next to the Bucherbach. This mine represents a medium-sized flat lying extraction area with around 200 m² and shows different Late Medieval/Early Modern Period driving techniques (Pirkl, 1961; Gstrein, 1978). At the roof of the mine some fire-set cupolas are still visible. Again a radiocarbon sample from sintered backfill was analysed and dates into the Late Bronze Age/Early Iron Age (MAMS 32531, 2613 ± 23 BP, cal. BC 816 – 780, 2 σ, 95,4 %). Also a trench with traces of fire-settings is apparent (Fig. 19, 1) but it looks more like the one at the Schönbiegler Bau (Fig. 18) which dates to the Late Medieval/Early Modern mining period.

Archaeological investigations above ground – mining pits "Pingenfelder" (2015 – 2017)

The Blutskopf plateau (district Burgstall, Gallzein)

Directly south-west to the entrance of the "Gut Wetter Bau" a few pits and traces from open cast mining are clearly visible (Fig. 22). This signs of mining can also be tracked alongside the hill top to the north east. In the frame of a field survey, domestic pottery fragments and artefacts for ore processing (hammer stone fragments and greenish animal rips with toolmarks), could be picked up in the year 2015 along a new forest track (Staudt, 2016; Staudt et al. 2017a). This track curls through the mining pits southeast of the open cast mines and passes the modern deflection station of a former ropeway for material transport (from the iron ore mines of the "Schwader Eisenstein" to the "Jenbacher Werke" on the bottom of the Inn Valley), where the foundation is still visible. After restoring the pottery finds, it appears that the pieces belong to two small pots of the Late Bronze Age (Fig. 21). One of them has a strap handle. Possibly the two vessels were originally stored next to each other and were only destroyed during the building of the forest track. Both pots are tempered with tiny slag fragments and prove the contact with nearby copper smelters (Staudt et al., 2017a).

Because of these prehistoric finds, which came out just underneath the forest floor, a small archaeological excavation was organized (Staudt et al., 2018c). Section 1 was situated on a small flat area between two pits and directly above the open cast mining area. Under the 10 cm to 20 cm thick forest humus, a mining/ore processing dump was visible. This max. 40 cm thick layer of broken dolomite (Fig. 22) contained a lot of prehistoric pottery, some fahlore, greenish animal bones and hammer stones as well as hammer stone fragments (Fig. 21). It was obvious,

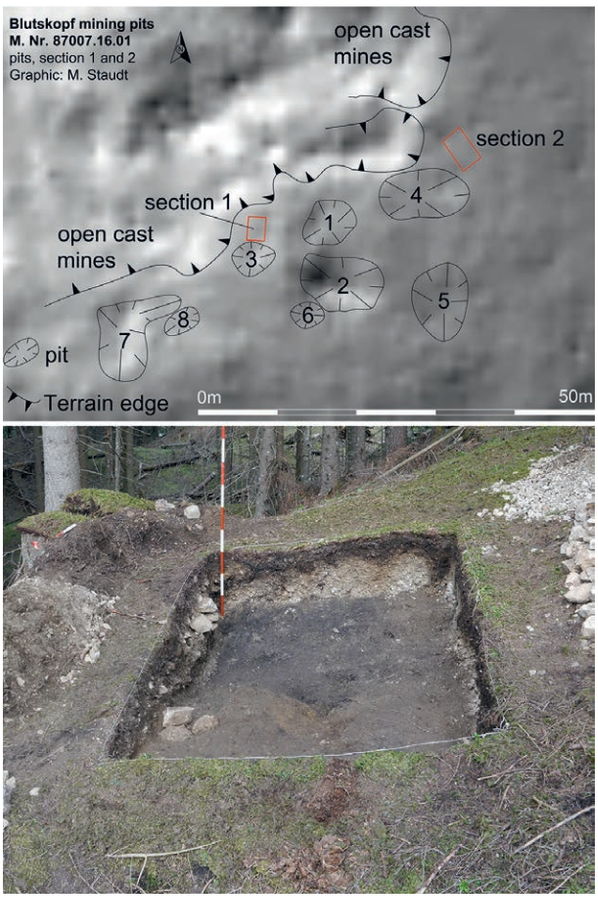

Fig. 22: The mining pits on top of the Blutskopf plateau (top). Section 1 with the prehistoric dump (bottom; photos: M. Staudt).

that the heap came from pit 1, which lies 4 m above on the east. In section 1 the dump was bordered with a "wall" of bigger dolomite stones to the southern pit (3) which is situated just next to the section. It is assumed that this construction was built to secure the mining activities in pit 3 and maybe the open cast mines too. This could indicate that mining was going on in pit 1 and 3 at the same time. A hammer stone with mounting marks was included in this construction. Underneath the dump a thin and dark cultural layer/working horizon, with finds and charcoal fragments, was visible on the natural ground.

By opening a small trench in section 1, it could be demonstrated, that the ore bearing dolomite at this place was originally covered by a very compressed glacial sediment. So the outcrop was not visible for the prehistoric miners. This indicates that the miners knew by experience and with a certain geological knowledge where to dig for the ore bearing dolomite.

Radiocarbon analysis was conducted on one animal rip which was used for ore processing and found in 2015 along the forest track. This find dates into the Late Bronze Age (MAMS 25911, 2743 ± 24 BP, cal. BC 968 - 826, 2 σ, 95,4 %). Two ^{14}C-analysed bones out of section 1, one from the dump and one from the working horizon, also date in the last stage of the Late Bronze Age (MAMS 28721, 2723 ± 19 BP, cal. BC 908 - 823, 2 σ, 95,4 %; MAMS 28722, 2709 ± 19 BP, cal. BC 900 - 815, 2 σ, 95,4 %). The greenish tinge of the bones is caused by the storage inside the cupriferous dump. By analysing such bones it was possible to identify the kind of ore contained in the dump (Rieder, 2014).

Section 2 was situated east of the boundary area of the mining pits. In this small investigation spot a lot of hammer stones and hammer stone fragments as well as pieces of fahlore with secondary minerals could be documented just 10 cm beneath the forest surface. These finds came out of a max. 10 cm thick cultural layer. In this horizon a small zone with reddish burned clay was visible at the western profile. This was probably a left over from a fire place without any stone edging. There was no evidence of mining activities in section 2. The large amount of hammer stones and hammer stone fragments as well as the pieces of ore suggest that this flat area was mainly used for the beneficiation of ore extracted from the nearby pits and open cast mines.

The pits on the plateau of the Blutskopf/Gallzeiner Joch are representing mining pits/shafts from the Late Bronze Age. At the neighbouring open cast mining area traces of fire-setting as well as collapsed fire-set mines are visible. The landscape was heavily remodelled presumably already in prehistoric times and the ore processing took place at the flat areas.

A hammer stone with mounting marks could be picked up at the eastern end of the Blutskopf plateau (Trebachwald). Remains of massive open cast mining occur in the direct surrounding of this find. It can be assumed that the local mining already started in prehistoric times and spreads over the whole Burgstall district (see also Rieser & Schrattenthaler, 1998/99, 2002).

Field surveys in Obertroi (district Rotenstein, Buch i. T.)

Within the frame of field surveys in the mining district Rotenstein to the south of Obertroi, a few prehistoric pottery fragments (some with slag temper), greenish animal bones and some hammer stones were picked up by the authors (Staudt et al., 2018c). These finds stretch along a north-south orientated mining pit field ("Pingenfeld"), which is situated north of the Geistgraben. The Schlierbach and Geistgraben separate the two mining districts Burgstall and Rotenstein. The pit field and the corresponding heaps look similar to the prehistoric ones from the top of the Gallzeiner Joch. The big pits are clearly visible in the digital elevation model and are presumably mostly from prehistoric times. Also some fire-set mines are visible, which are overprinted by younger mining activities (Hanneberg et al., 1997). Some of the large pits were filled up while building a forest road in the 1990s (Rieser & Schrattenthaler, 1998/99). Below and 200 m westwards of this pit field some dark cultural layers includ-

ing animal bones and prehistoric pottery fragments came to light underneath a historic mining dump. Radiocarbon analyses were done on an animal bone and date into the Late Bronze Age (MAMS 33503, 2746 ± 24 BP, cal. BC 968 – 828, 2 σ, 95,4 %).

Mining pits and ore processing in the district Weißer Schrofen (Strass im Zillertal)

The mining district "Weißer Schrofen" is situated to the east of the "Raffl" farm and north of the Larchkopf on the west side of the Ziller Valley. It was an important mining area in historic times and – like the districts Burgstall and Rotenstein – part of the bigger district "Ringenwechsel" (Sperges, 1765; Isser-Gaudententhurn, 1893; Schmidegg, 1951; Pirkl, 1961; Arlt et al., 1999). Due to the low stability of the local dolomite in this area nearly all surface near mines and mining entrances from medieval and modern times are collapsed (Gstrein, 1978). However there are still a few signs of fire-setting activities left in the area north, west and south of the "Schrofenmarterl" (Perger, 1995; Rieser & Schrattenthaler, 1998/99; 2002). In 2007 Rieser and Schrattenthaler discovered a huge amount of slags on a small plateau underneath the Larchkopf and in the immediate vicinity of some mining pits. Because of the slag finds together with finds of prehistoric pottery they supposed a Bronze Age smelting site, even though the slags looked like medieval blacksmith slags (Rieser & Schrattenthaler, 2007). During field surveys conducted by the authors the slags could be clearly identified as the leftover of a blacksmith and not of a prehistoric copper smelting site.

Because of a number of illicit excavation trenches which were visible in this area and a few left over prehistoric pottery fragments in the rummaged soil, an emergency excavation with financial support from the BDA (Bundesdenkmalamt) could be organized in summer 2016 (Staudt et al., 2018a).

Section 1 was situated at the lower, flat western part of the plateau just above a steep wall and underneath/northwest of the pit field (Fig. 23). In this section no structures became evident, but some artefacts from the 15th/16th century AD came to light including an iron mining pick, some stamped domestic pottery and a lot of stove tiles as well as some blacksmith slags. Therefore it was supposed that there was a former miners hut nearby on the north side of the plateau. The north-eastern part of the lower terrace consists partially of dump material and was filled up by hand, probably in the younger mining periods.

About 13 m to the east section 2 could be traced in one of the illegal excavation areas to verify the stratigraphy. Beneath the forest surface a 10 cm to 30 cm thick layer from the 15/16th century AD with stones from a hut foundation could be documented. By excavating these features a lot of slags were collected, which indicates the former position of the blacksmith hut. Directly underneath, an up to 1 m

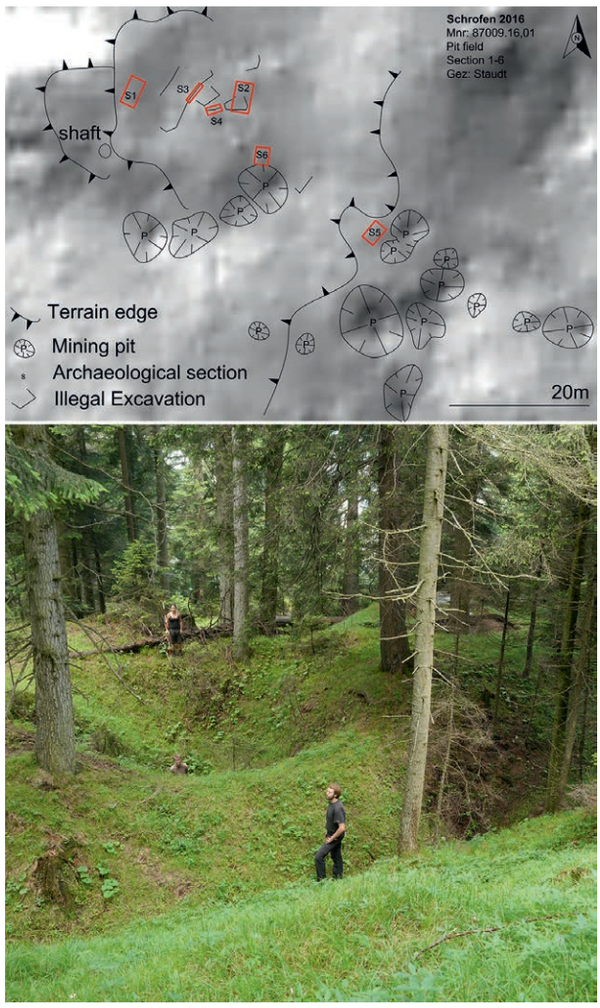

Fig. 23: Plan of the pit field Weißer Schrofen (top) and one of the biggest pits (bottom; graphic: M. Staudt).

thick prehistoric cultural layer/dump appeared (Fig. 24). This homogenous layer consists mainly of organic material (waste) which is mixed with ore beneficiation sand/crushed dolomite. This layer furnished a big amount of greenish animal bones, domestic pottery (Fig. 25, Eß, 2018), hammer stones (Fig. 24) and hammer stone fragments as well as small pieces of fahlore. The most spectacular find of this section was a fragment (Fig. 24) of a socketed pick (type Mitterberg; Mayer, 1977). The distribution area of this kind of mining tool is around the Mitterberg district. These mining picks were mainly used in softer schist material (Stöllner & Schwab, 2009; Thomas, 2018; Koch Waldner, 2017). Most likely it was not the favourite tool within the solid Schwazer dolomite. The main driving technique in the fahlore area Schwaz-Brixlegg was fire-setting. So far only four pieces are known from the mining districts of North Tyrol (Goldenberg et al., 2019).

One isolated piece of plate slag out of the illicit excavation may indicate the direct contact of the miners with the smelters from the nearby Late Bronze Age smelting

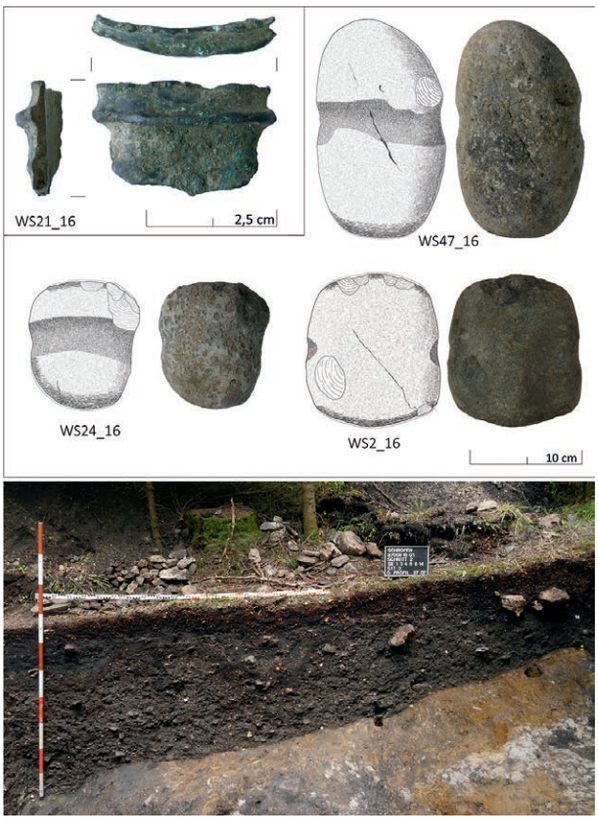

Fig. 24: Profile east of section 2 with the massive prehistoric layer (bottom left) which is rich in finds and miners tools (top, fragment of a bronze mining pick and hammer stones; graphics: M. Staudt and R. Lamprecht).

Fig. 25: Prehistoric pottery fragments (top) and the prehistoric layers which are sloping in the pit (bottom) in section 6 (photos: M. Staudt; graphics: M. Staudt and L. Eß).

site in Rotholz. The smelting site is situated around 1.2 km downwards to the west and is probably the place where the fahlore from the district "Weißer Schrofen" was smelted (Staudt et al., 2017b; Staudt et al., 2018b; see also article Staudt et al. for the smelting site Rotholz in this volume).

A few meters south-east of section 2 and directly north of a pit, section 6 was excavated. A flat layer with a height of 30 cm consisting of small pieces of dolomite with some iron fragments was deposited on an older humus, which has developed between the prehistoric and the modern mining phase. In the topmost prehistoric layer some ore beneficiation sand/crushed dolomite and a hammer stone/crushing stone deposit was apparent. Below, loose relocated soil and darker layers are falling down into the nearby mining pit (Fig. 25). That means that the growing layers slipped into the depression after the end of the prehistoric mining activities in this pit. Perhaps the side part of the pit was flattened with prehistoric material for a better worktop. This fact also shows, that the original cross section dimension of this pit was bigger than it is visible today. The pit was probably filled with soil material from the neighbouring pit. A classical mining dump was not visible and probably lies on the opposite side of the pit. It is not clear, if these pits are collapsed mining (hauling shaft) or ventilation shafts. Maybe they are just remains of open cast pits. It is conspicuous, that they are situated in a line. This could be a sign for a kind of "Duckelbau" as well. Therefore narrow shafts ("Duckeln") were sunk down to the deposit. Then the driving was continued circular along the shafts. The massive layers, dumps and the amount of prehistoric finds, suggest rather underground mining, than digging in open pits. Or maybe it is a mixture of both mining types. The prehistoric layers could be excavated to a depth of 1.40 m and contain hammer stones and hammer stone fragments, small pieces of fahlore, greenish animal bones and pottery fragments.

Section 5 was situated 16 m south east of section 6 on a clearly visible dump, directly west of the corresponding mining pit (Fig. 26). Underneath the forest humus, a 30 cm to 90 cm thick dolomite dump was apparent. In there, a few pieces of iron could be found. It was suggested, that this must be a heap of "modern" mining activities.

Below a more finely structured dump with hammer stone fragments came to light. This prehistoric heap is 1 m thick and lies on a 20 cm strong cultural layer, with some animal bones and domestic pottery fragments inside.

Fig. 26: Section 5 was traced out in a dump which belongs to a mining pit (top). Underneath the dump a prehistoric cultural layer is visible which is rich in finds (bottom; photos: M. Staudt).

Because of the aslope profiles of the section, only a very small area of this cultural layer could be investigated. The cultural layer consists of organic material mixed with fine ore beneficiation sand/crushed dolomite and looked similar to the prehistoric layer in sections 2 and 6. It looks like that around this pit field and on the plateau this prehistoric layer spreads in large scale and proves intensive prehistoric mining in the district Weißer Schrofen.

In total six animal bones were selected for radiocarbon analyses. The samples out of section 2 from the prehistoric layer show the following dates: MAMS 28731, 2720 ± 21 BP, cal. BC 906 - 819, 2 σ, 95,4 %; MAMS 28732, 2882 ± 20 BP, cal. BC 1125 - 996, 2 σ, 95,4 %. The ^{14}C-analyses from section 6 verify this prehistoric age: MAMS 28728, 2858 ± 20 PB, cal. BC 1110 - 940, 2 σ, 95,4 %; MAMS 28730, 2918 ± 21 BP, cal. BC 1207 - 1031, 2 σ, 95,4 %. One bone from the dump and one from the cultural layer out of section 5 also belong to the Late Bronze Age: MAMS 28729, 2778 ± 20 BP, cal. BC 996 - 848, 2 σ, 95,4 %; dump: MAMS 28733, 2794 ± 20 BP, cal. BC 975 - 912, 2 σ, 95,4 %.

The bone material from Schwaz-Brixlegg provides evidence for a remarkable change in the diet of mining communities in the Lower Inn Valley from the Late Bronze Age to the Iron Age, the transition from a pig to a cattle economy. The most important species (cattle, sheep/goat and pig) were delivered to the mining sites mostly as whole animals. In some cases, there is evidence for additional meat packages (especially ribs). According to the age and sex structures obtained from the bone material it seems that the miners consumed meat of high quality. The butchery marks noted on the bones from the Schwaz-Brixlegg sites point towards professional and systematic slaughter techniques, as it can be observed also on other prehistoric mining sites in the Eastern Alps (Saliari et. al, in press).

Conclusions

Within the DACH-project continuous prehistoric fahlore mining from the Late Bronze Age to the Early Iron Age (12th - 8th century BC, Fig. 27) could be demonstrated for the mining area of Schwaz-Brixlegg. A series of underground mines as well as pit fields above ground were investigated. Fire-setting was the main extraction method in the hard dolomitic host rock. Charcoal as leftover from fire-setting is abundant in the dumps and backfills of the mines. This material proved to be very suitable for accurate dating by dendrochronological analysis. The ^{14}C-dating method was also applied, animal bones being the preferred material for dating with the aim to avoid old wood effects.

The radiocarbon analyses performed on animal bones and charcoal fragments from belowground date from the 9th/8th century BC up to the 7th - 5th century BC. Often the datings are inaccurate and dissatisfying due to the unfavourable course of the ^{14}C-calibration curve corresponding to the first half of the Iron Age (“Hallstatt plateau”). Only the analysed samples from the mine Knappenkuchl prove underground mining activities already in the 12th/11th century BC. Better results could be obtained by dendrochronological analysis. So far all the dendrochronological dated mines in the mining area Schwaz-Brixlegg date into the second half of the 8th century BC, which represent the final stage of the fahlore mining activities in general. It has to be taken into account that usually the younger backfill materials were left inside the mines when they were abandoned and that therefore it is difficult to date the beginnings of the mining work. A hint for the latest mining activities could be slag tempered ceramics from the grave 626 at the prehistoric cemetery in Kundl (Lang, 1998). By watching the original pictures of the excavation in the 1970s it becomes clear that some of the graves have been covered with flat anvil/grinding stones.

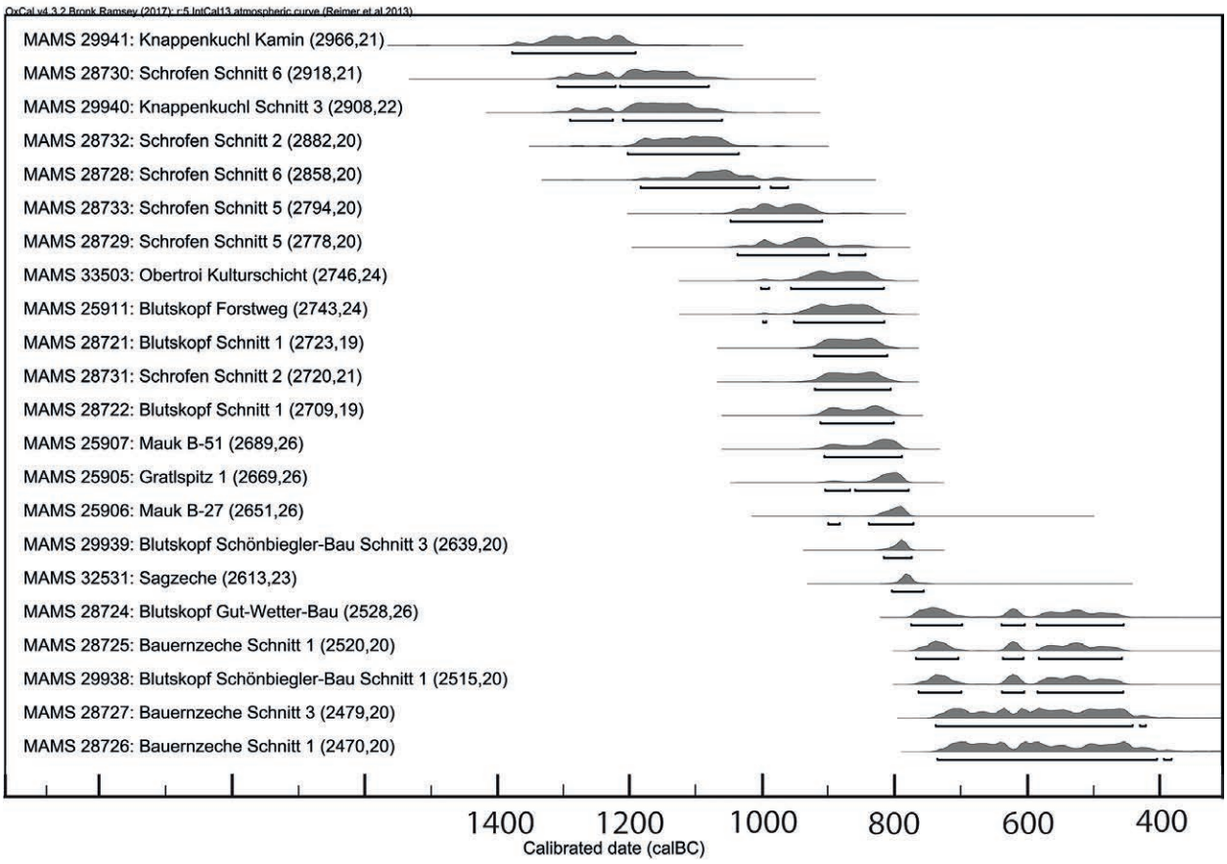

Fig. 27: Radiocarbon data from the investigated mining sites of the DACH-project 2015 – 2016 (graphics: OxCal v4.3.2.).

From the pit fields above ground only ^{14}C-dates are available for the moment. Though there is a clear tendency that these mining structures are older than the above mentioned mines. The Radiocarbon dates from the pit field "Weißer Schrofen" prove activities from the 12th to the 9th century BC. The dating results are overlapping with those from the nearby smelting site Rotholz (12th to 10th century BC). It can be assumed that both sites were active at the same time and that the ore from the "Weißer Schrofen" was smelted on the Rotholz smelting site. The pit field on the plateau of the "Blutskopf" dates on the basis of radiocarbon analyses into the 10th/9th century BC.

The present state of art suggests, that the second fahlore mining boom in the Lower Inn Valley lasted for about 500 years and ended in the Early Iron Age around 700 BC.

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