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Prehistoric mining in a small medieval mining district in Montafon, Vorarlberg (Austria)

ABSTRACT: *Intensive settlement and mining activities during the Medieval period as well as the early Modern Age are evidenced in Montafon (Vorarlberg, Austria). A number of prehistoric settlements and numerous archaeological single findings confirm that these inner alpine environments were already settled and managed during the Bronze and Iron ages in varying intensity. New multidisciplinary investigations on mining activities (archaeology, vegetation history, geochemistry) have brought new indications for Iron Age mining. In the period between 250 and 50 BC, the anthropogenic indicators rise in the pollen diagram. A causal relationship of the landscape with a Late Iron Age mining phase seems likely in view of the synchronous rise of copper values (to over 1,400 ppm) in the mire and in a waste heap in the immediate vicinity, which dates back to the 4th/3rd century BC.*

KEYWORDS: MONTAFON, IRON AGE, MINING ACTIVITY, VEGETATION HISTORY, GEOCHEMISTRY

Introduction

The Montafon valley lies in the South of the Austrian federal state of Vorarlberg, on the borderline between the Western and Eastern Alps (Fig. 1). Located in this mountainous landscape is a small mining district with many traces of a long and varied history. The oldest known documented mention of mining in Montafon stems from 1319. The naming of eight iron melting furnaces in the Urbarium of Churraetia from 843/844 already confirms that mining for iron ores occurred during Carolingian times in the region of the Verwall mountains between Bludenz, the Klostertal and the Ill valley (Scheibenstock, 1996, pp.9-11; Neuhauser, 2012, pp.9-21).

The Montafon was Vorarlberg's most significant mining district for over centuries' time. Intensive mining activities during the Medieval period as well as the early Modern Age are evidenced in Montafon between St. Anton and St. Gallenkirch in numerous places with diverse traces of mining operations. These sites are located at mountain heights of up to 2,500 m a.s.l., such as the mining galleries and waste heaps on the Alpe Spora above St. Gallenkirch, or by the Rona Alpe (Alpguss) and the Fresch Alpe in the inner Silbertal. A few smelting places are known as well, for example, in Ganzenahl near the municipality of Tschagguns or Schmelzhof in the Silbertal (Krause, 2013).

The most abundant traces of mining activities are found on both sides of the Kristberg, as well as in the land parcels Knappagruaba and Worms on the Bartholomäberg. There varied evidence of mining was found: mostly large and small waste heaps (*Halden*) with waste rock and collapsed mining galleries. Particular mention should also be made of the impressively beautiful churches in Bartholomäberg, the mountain chapel on the Kristberg with their altars dedicated to miners, and the Romanic crucifix in Bartholomäberg, all of which underscore the status of medieval mining and the resulting prosperity (Krause, 2015, pp.85-88).

Various single findings from Montafon and a large complex of iron artefacts dated to the Iron Age from Bludenz-Unterstein (cf. Leitner, 1976) gave Elmar Vonbank reason to suspect that the iron ore occurrence in Montafon might have been exploited and used already during the Iron Age (Vonbank, 1966, p.86). Until now, though, no evidence for Iron Age mining has been detected, presumably owing to the fact that broad parts of the landscape are seriously marked by intensive mining industry. Through the closely interconnected disciplines of mining archaeology, archaeobotany and soil studies as well as heavy-mineral examinations, the first evidence for mining activities during the later Iron Age has been achieved. The question as to mining in earlier times as far back as the Bronze Age could not be clarified hitherto,

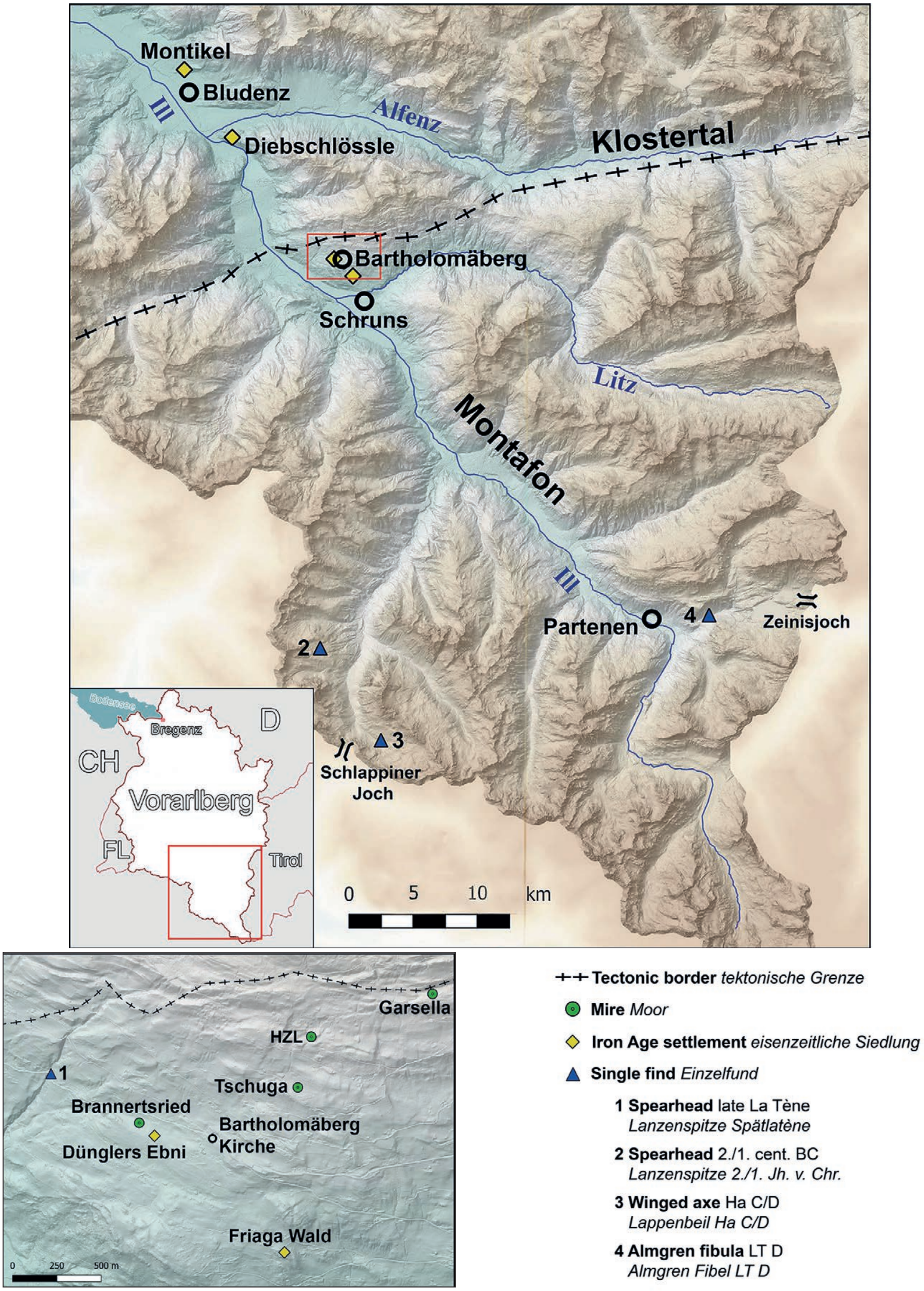


Fig. 1: Montafon is the southernmost valleyscape of Vorarlberg. The tectonic border between the Northern Limestone Alps and the Silvretta Crystalline Alps runs across the valley. Along this line are polymetallic deposits, which were probably exploited since the later Iron Age until recent times. One centre of this mining activity was the community of Bartholomäberg, located on the mountain of the same name (map: Montafonprojekt, map basis: Land Vorarlberg – data.vorarlberg.gv.at).

but this is being discussed based on numerous find complexes and radiocarbon ages.

Study area – Geographical setting of Montafon

Montafon is an almost 40-kilometre-long glaciated trough valley which is drained by the Ill River towards the Rhine River. The valley is enclosed within the alpine mountain ranges of the Verwall, Silvretta and Rätikon. Due to its inner alpine location, the climate of Montafon Valley is temperate with an intermediate position between sub-oceanic and sub-continental conditions. In Schruns, on the valley floor of the Montafon (689 m a.s.l.), the annual mean temperature is 7.4 °C and precipitation reaches 1,243 mm (Walter & Lieth, 1967; Werner, 2005). The present vegetation is dominated by sub-continental, interalpine spruce-fir forests with meadows and pastures in the subalpine region. The terraces in the southward-facing slopes of the Bartholomäberg have little woodland (mainly *Picea abies* (spruce) and *Abies alba* (fir)), while *Fagus sylvatica* (beech) is often admixed. On the valley floor at approximately 700 m a.s.l., grasslands as well as remnants of deciduous forest composed of *Fagus sylvatica* (beech), *Fraxinus excelsior* (ash), *Acer* (maple), *Tilia* (lime) and *Alnus* (alder) occur (Mayer, 1974; Waldegger, 2005). The actual pasture zone Allmein is situated at approximately 1,450 m a.s.l. The lower boundary (1,300-1,450 m a.s.l.) is characterized by remains of former mining activities, such as waste heaps, mining debris and pits. Today, this region is primarily used for meadows and pastures.

Geology and ore deposits of Montafon

The Montafon valley belongs almost entirely to the austroalpine nappe. The northern part is covered by the Northern Limestone Alps whereas the major part rank among the Silvretta. The ore deposits occur along this tectonic boundary (Fig. 1) of Mesozoic sediments and late Palaeozoic old crystalline (Heissel, et al., 1965). Aside from smaller deposits in the Silvretta mountains, four types of ore deposits are known from Montafon. First, disseminated copper ores in Permian ignimbrites, which also contain gold and molybdenum. Second, sedimentary baryte mineralisation associated with Permian volcanism, as well as, third, sedimentary copper mineralisation from the lower Triassic, which emerged through the processing of the disseminated copper ores (Angerer, et al., 1976, p.4; Tropper, et al., 2011, pp.27-29; Hofmann & Wolkersdorfer, 2013, pp.16-18).

Only the fourth type, young-alpidic silver-containing chalcopyrite-fahlore veins, achieved an economic significance in the past. The conditions of its formation must still be clarified precisely. Likely, in the course of the orogeny of the Alps, hydrothermal solutions along disturbances and surface borders formed ore veins, comprising chalcopyrite, silver-containing fahlore, pyrite, among others, sulfidic ores in association with mainly siderite, ankerite and quartz. The mineralisation is concentrated in the Phyllite-Gneiss-Zone, but also extends farther into the overlying sediment layers (among others, the Alpine Verrucano). In Montafon this zone of mineralisation (Fig. 1) reaches from Rellstal in the West to the Bartholomäberg as far as the ridge of the Kristberg in the East (Haditsch & Mostler, 1986, pp.282-288; Tropper, et al., 2011, pp.28-29). Thus, most of the mines were located within a 2 km wide belt southward of the tectonic border.

Archaeological sites and topography

The discoveries of single bronze and iron artefacts were already assessed as signs of human presence in prehistoric Montafon, even before the first settlement sites were revealed (Schwarz, 1949, pp.284; Vonbank, 1966, p.86). In addition to the bronze winged axe of the Hallstatt period, which was found on the Alp Vergalda (St. Gallenkirch), there are single Iron Age findings, including two Latène iron spearheads and a fibula of the type Almgrem 65c2 (Vonbank, 1966, pp.84-86; Krause, 2009b, pp.22; Demetz, 1999, p.223). One of the spearheads was found during construction of a service road to Fritzentobel (Bartholomäberg). The other two artefacts were discovered farther into the valley, each at the foot of a pass. On the Schafberg near Gargellen, close to the Schlappiner Joch leading into Prättigau in Graubünden, the aforementioned spearhead was retrieved during house construction. The remains of its wooden shaft could be dated to the 2nd/1st century BC. The late Latène fibula of the type Almgren 65c2 was found at the ascent of the Zeinisjoch, which leads to Tyrol.

The picture of settlement history in Montafon underwent a change in the 1990s. The first vegetation historical investigations indicated the presence of prehistoric settlement (Kostenzer, 1996), and were supported by later palynological studies (Oeggl, et al., 2005; Oeggl & Wahlmüller, 2009). The final evidence for human presence in prehistoric times was adduced by the discovery of a fortified settlement in Friaga Wald in 1999 (Krause, 2001, pp.43-47; Krause, 2009b, pp.28-34). Until now a total of five prehistoric settlement places are known in Montafon, whose beginnings lie in the later Early Bronze Age. With the exception of the site of Diebschlössle near Lorüns at the entrance to the Ill valley, all of the sites are located on the Bartholomäberg, which due to its favourable settlement parameters can be considered the nucleus of prehistoric settlement in Montafon. A settlement phase in the Iron Age could be confirmed for hitherto three places as well: Dünglers Ebni, Friaga Wald and Diebschlössle.

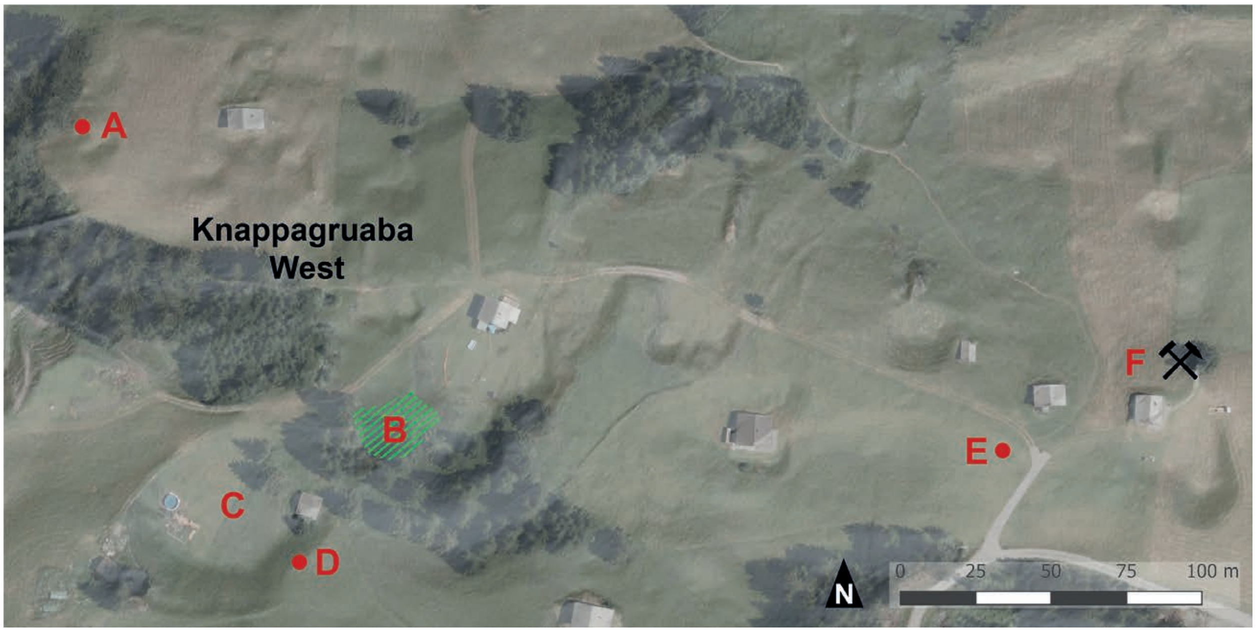


Fig. 2: Bartholomäberg, Knappagruaba. The field parcel Knappagruaba above Bartholomäberg. Numerous collapsed shaft openings and large-sized waste heaps are distinct in the underlaid elevation model. A Waste heap complex. B Mire 'Herbstzeitlose' (HZL). C Large waste heap. D Trial trenches from 2011 and 2012. E Settlement contexts. F Visitors mine 'St. Anna Stollen' (graphic: Montafonprojekt, data basis: Land Vorarlberg – data.vorarlberg.gv.at).

The Iron Age site of Dünglers Ebni is located on a flat surface on a mountain terrace southwest of the church in Bartholomäberg.[1] Dated house foundations and a large-sized stone pavement attest settlement there during the Hallstatt period. Indications of metallurgical processes are not present. All of the radiocarbon ages from the cultural layer fall into the Hallstatt plateau, and also the large quantity of local Illtal pottery cannot be localised more precisely within the Hallstatt period basing on the present state of research. The fragment of a handle of Taminser ceramic type, which was widespread in the Alpine Rhine valley, points to the later Hallstatt period.

The hillfort settlement in Friaga Wald is located in a topographically exposed place at a height of 940 m a.s.l., high above the Schruns basin. The stratigraphy of this site contains settlement phases of the Bronze and Iron Ages. Until now the Iron Age settlement has been dated to the transition from Hallstatt to Latène period. However, a renewed review of the findings did not confirm this date. Nonetheless, a completely restored vessel, belonging to the so-called Schneller ceramic type (Latène A-Latène C; Gurtner. 2004, p.106), two fragments of fibulae of the type Certosa VII (advanced Latène A; Teržan, 1976, pp.425-429), as well as the rim fragment of an early Latène Fritzen bowl[2], distributed in North Tyrol, attest a settlement in the Friaga Wald during the advanced early Latène period as well as in the middle and even into late Latène times. This is supported by a corresponding radiocarbon date to the 2nd/1st century BC.[3] Like at the site of Dünglers Ebni, no relics of metallurgical processing or production in Friaga Wald are known until now.

The inventory of Iron Age findings from Diebschlössle, located near Lorüns at the valley entrance (Wink, 2005, pp.47-49), together with early Latène Fritzener bowls and Schneller ceramic type (Krause, 2009b, Fig. 51, 1, 2, 6-8), corresponds with the spectrum of forms found in Friaga Wald. In addition, there are sherds of bowls with S-shaped profile, whose duration lasts until the middle Latène period. A few sherds derive from the Hallstatt time (Wink, 2005, pp.60-62).

The Montikel, the town hill of Bludenz, has three sites of findings: the Unterstein, Kleiner Exerzierplatz and the peak plateau. Between 1830 and 1935 more than 200 metal artefacts, mainly objects made of iron, were recovered at the foot of the hill. Most date to the later Latène period. The exact character of this particular site has not been clarified to this day; it might relate to findings originally from a place meant for burnt offerings and sacrifices, which eroded or slid downhill (Leitner, 1996, pp.36-41). Discovered on the Kleiner Exerzierplatz was a settlement layer with many disturbances within the later construction; the inventory consisted of Hallstatt to late Latène period findings (Leitner, 1996, pp.15-35).

New mining-archaeological investigations in Montafon

Since 2002 mining-archaeological investigations have been carried out in annual campaigns within the framework of the Montafon Project: first by the Free University in

Fig. 3: Bartholomäberg, Knappagruaba. Relicts of mining are comparably small-scaled in the western Knappagruaba, for which reason already at an early stage of work older find contexts were anticipated in this area. Near the forest (left in picture) the slope becomes very steep. At the transition of meadow to forest, trench 6 and 7 were laid out on a multiphased waste heap complex, in the late summer 2016 (photo: Montafonprojekt).

Berlin, and since 2006 by the Goethe University Frankfurt/Main, which brought forth a number of different find complexes dating from the high to the Late Middle Ages (Krause, 2009a; Krause, 2013). These undertakings also resulted in the discovery of different find complexes and in radiocarbon dating, which have enabled conclusions to be made about prehistoric activities that reach back into the Bronze Age. These could have been associated with a pasture economy as well as with mining activities. One focal point was investigations in the land parcels Knappagruaba (with the Herbstzeitlose mire) and Worms on the Bartholomäberg (Fig. 2).

Knappagruaba, north of the village centre of Bartholomäberg, lies at a height of ca. 1,330-1,350 m a.s.l. on a terrace with a slope to the South and within the traditional Maisäß zone. The lush meadows there are still used for pasturing today. The collapsed mining galleries with waste heaps in front are located in dense order and overgrown with grass. In the eastern part of the area are larger waste mounds and two accessible mines from the Middle Ages or the Early Modern Age. One has been restored as the sole mine open for visitors (Krause, 2015, pp.127). Located in the steeper western part of Knappagruaba are numerous waste heaps and structures, which indicate an older date in time (Fig. 3). Since 2015 systematic investigations have been conducted in this mountain landscape within the framework of an interdisciplinary project on mining archaeology, supported by the German Research Foundation.[4] Several preliminary investigations have formed the basis for the project. Initial indications of prehistoric activities in Knappagruaba were noted already during excavations in 2008 (Krause, 2009a, pp.530-531) and during archaeologically controlled dredging work in 2009: a pit containing prehistoric pottery.[5] Further indicators were gained through geomagnetic surveying carried out between 2009 and 2015. Systematic excavations in 2015 and 2016 yielded additional settlement find contexts, such as pit structures with a flat base, stone filled fire pits, and collapsed substructures built of stones. The pottery recovered in several places is clearly prehistoric. By means of charcoal samples the fire pits could be dated to the Middle Bronze Age (Tab. 2, samples 9, 10 and 12). Similar contexts of the same date already appeared in the settlement on Bodaweg. Through the analysis for heavy metals an association with metallurgy could be excluded. It seems that the pits are related to food production (Würfel, et al., 2010, pp.510-512). Furthermore, no indications of metallurgical activities were observed in the mining area in Knappagruaba.

Traces of mining confirming Iron Age mining on the Bartholomäberg were finally attested in Knappagrua-

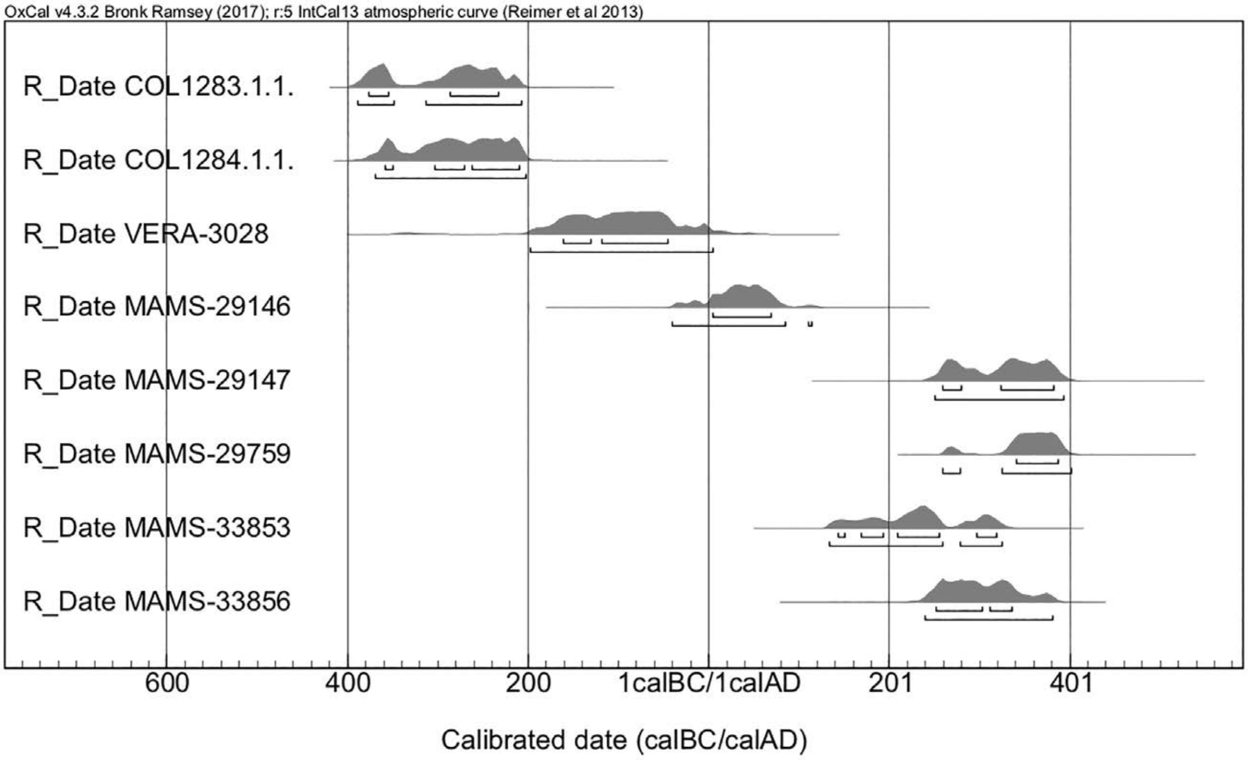


Fig. 4: Datings from Knappagruaba West as well as the Iron Age settlement layer in 'Friaga Wald'. Samples 1 and 2 derive from the large waste heap south of mire 'Herbstzeitlose' (HLZ) and attest the creation of the heap during the Iron Age. They overlap almost with the date for sample 3 from 'Friaga Wald'. Samples 4 to 8 are out of the High Medieval colluvium inside trenches 6 and 7 (graphic: Montafonprojekt).

Sample	Position	Laboratory number	14c-Age (BP)	1 Sigma	2 Sigma
1	Knappagruaba, great heap lowest fill	COL1283.1.1.	2245±24	cal BC 378 - 234	cal BC 389 - 208
2	Knappagruaba, great heap fossil soil below lowest fill	COL1284.1.1.	2219±24	cal BC 359 - 210	cal BC 370 - 203
3	Friaga Wald settlement, cultural layer	VERA-3028	2075±40	cal BC 161 - 46	cal BC 199 – AD 5
4	Knappagruaba, trench 6 infilling of mining shift	MAMS-29146	1963±27	cal AD 5 – 70	cal BC 41 – AD 115
5	Knappagruaba, trench 6 infilling of mining shift	MAMS-29147	1714±28	cal AD 260 – 383	cal AD 251 - 394
6	Knappagruaba, trench 6 feature 5 (colluvium)	MAMS-29759	1693±18	cal AD 341 – 387	cal AD 260 - 402
7	Knappagruaba, trench 7 feature 5 (colluvium)	MAMS-33853	1793±26	cal AD 145-319	cal AD 135-325
8	Knappagruaba, trench 6 feature 5 (colluvium)	MAMS-33856	1739±25	cal AD 253-336	cal AD 241-380

Tab. 1: Bartholomäberg, selected radiocarbon datings from the Knappagruaba and the Friaga Wald (table: Montafonprojekt).

ba-West, some 200 m away from the prehistoric settlement contexts. Numerous small-sized surface structures, small waste heaps and depressions from collapsed galleries are located there on the steep mountain slope. Two of the largest waste heaps in the area extend to the East and to the South. In the course of cutting a section through one of the waste heaps at least two fills of mining waste could be determined. Basing on radiocarbon ages, the upper, by far more massive fill consisting of phyllite-gneiss and mica slate could be dated to the Late Middle Ages; the lower deposit, by contrast, dates to the 4th/3rd century BC (Röpke, 2012b, p.274), thus to the Latène period (Fig. 4, Tab. 1).

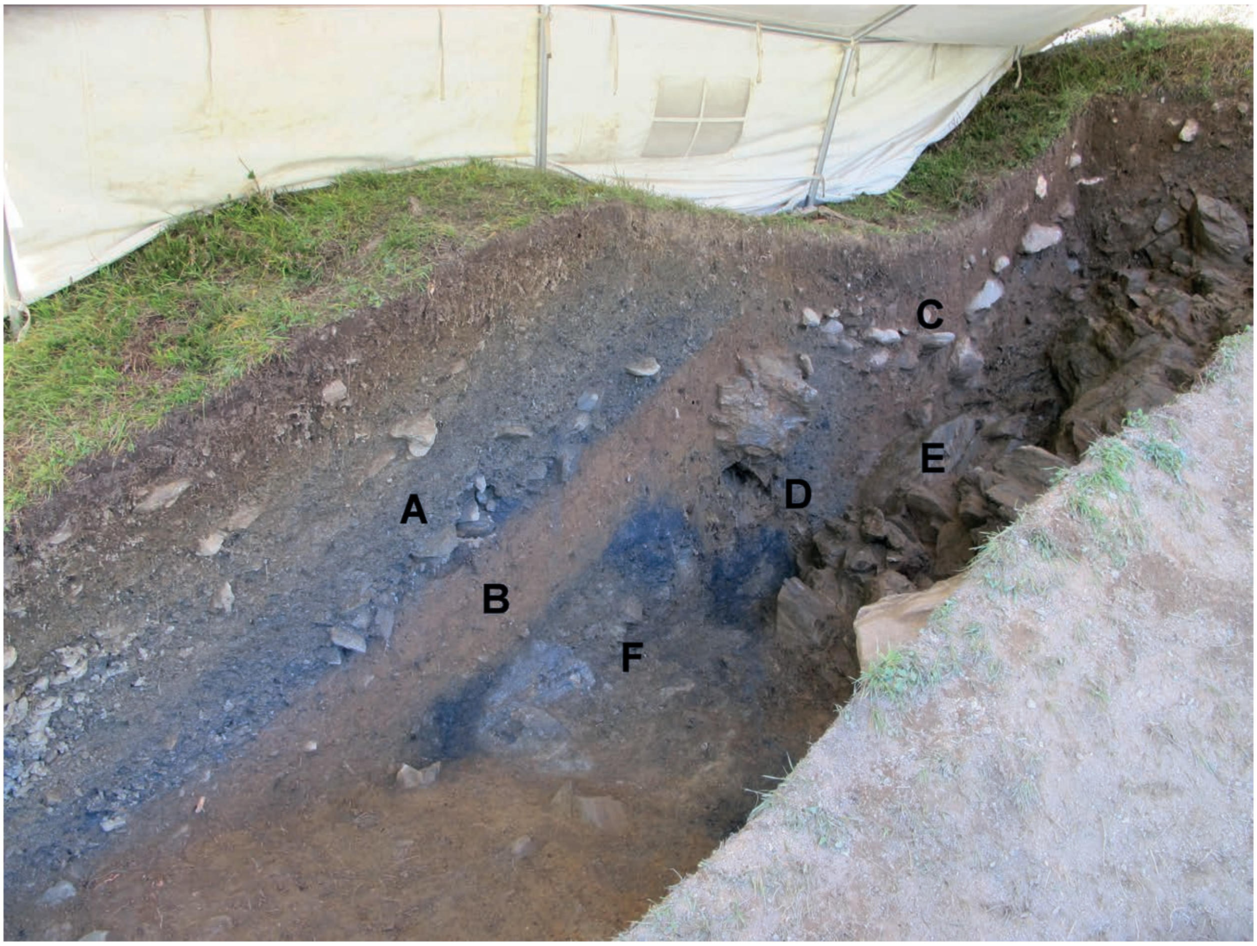


Fig. 5: Bartholomäberg, Knappagruaba, west profile of trench 6. A The layer of waste material dates from the 13th century AD. B The brown-reddish colluvium is from the High Medieval Period and contains older charcoals (Late Iron Age till 4th century AD). The backfilling C also contains charcoal from this age. Maybe the pitlike feature D belongs to another period of mining activity. The native rock E is decomposed in some parts F (photo: Montafonprojekt).

Further investigation on Late Iron Age mining was performed on a multi-phased, comparably small waste heap complex (Fig. 2, A), located on a steep slope with easy access to the ore veins (thin layer of organic litter). The complex contains traces of no less than two phases of mining activity (Fig. 5). The uppermost layer of waste material, mainly composed of mica slate, was piled up in the 13th century AD. It covered a reddish brown colluvium from the High Medieval Period. Five radiocarbon-dated charcoals are from the Late Iron Age to the late 4th century AD (Tab. 1, samples 4-6). Detectable under the colluvium are one or even more phases of mining activity (small heaps and pit features). Maybe this zone of Knappagruaba, not far from the Herbstzeitlose (HZL) mire, was part of the Iron Age mining area.

The question as to the presence of older mining activity that would possibly reach back to the Bronze Age still cannot be conclusively answered. In the course of various trial trenches and excavation in the mining zone on Bartholomäberg (Krause, 2009a; Würfel, et al., 2011, pp.127-134), several features were recovered that provided dates from the Bronze Age (Fig. 6, Tab. 2). They point to human presence and land-use practices at this elevation (1,300-1,450 m a.s.l.), which is far above the zone of the actual prehistoric settlements.

Palynological and geochemical investigations of a mire in the mining area of Knappagruaba

The environment of Knappagruaba has been completely altered by large and small mining waste dumps and numerous galleries; thus, tracing the location of possible prehistoric ore exploitation is difficult. One method of detection is provided by combining palynological analyses of pollen, microscopic and macroscopic charcoal, and geochemical parameters of peat cores from within the mining district. The opening of the landscape, the extraction of timber and fuelwood and the extension of settled

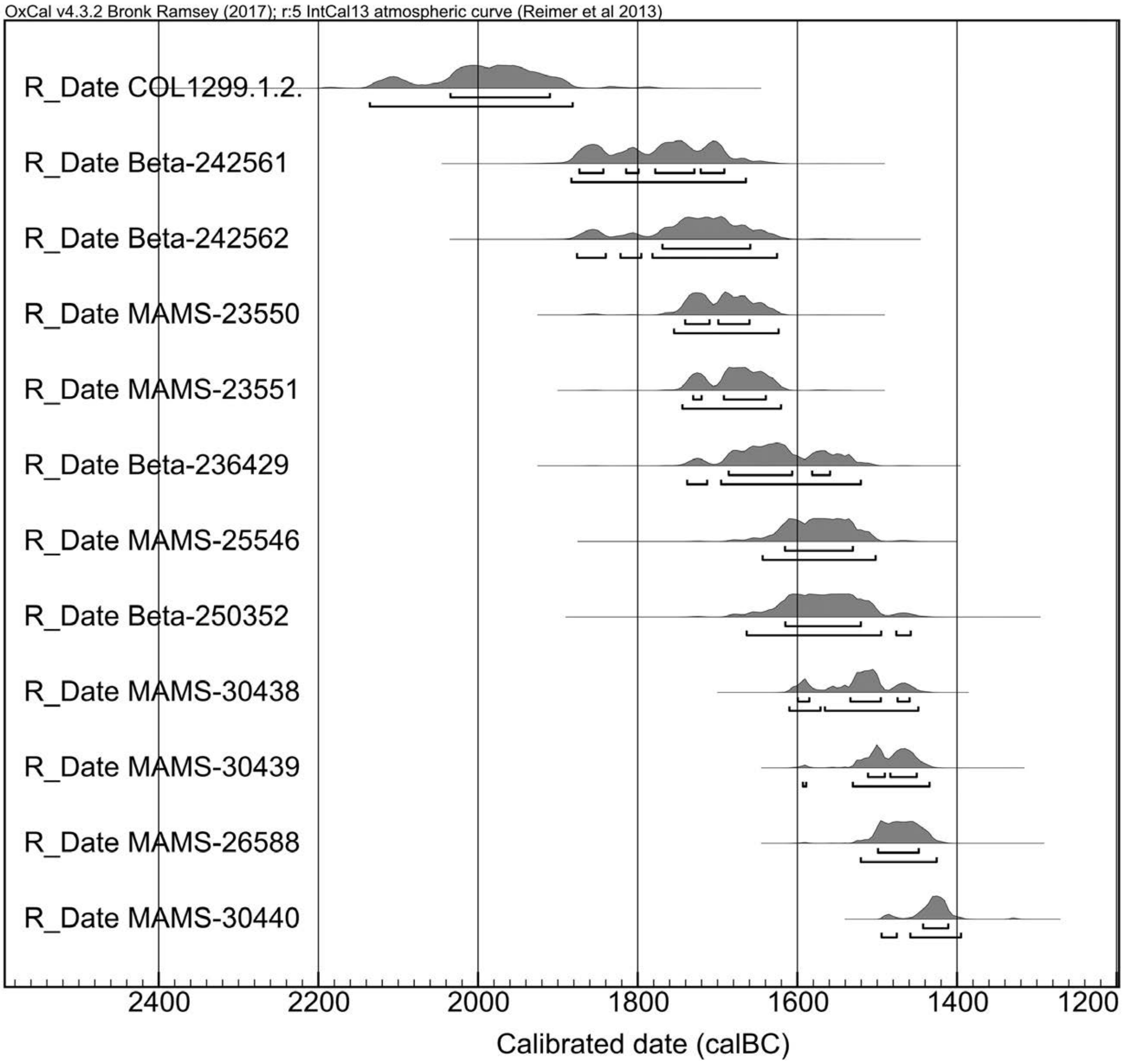


Fig. 6: Bronze Age datings from different find contexts within the mining zone of Bartholomäberg. In addition to well-defined settlement complexes (samples 9, 10 and 12 from fire pits), there are also finds without an exact context, like shallow pits or charcoal piles (samples 2 and 8) (graphic: Montafonprojekt).

areas are evident in pollen diagrams in the form of forest clearings and an increase of non-arboreal pollen (NAP). Fire activities are reflected in the abundance of micro- and macro-charcoals in the peat deposits. Furthermore, different methods applied in ore or metal processing caused the accumulation of heavy minerals, such as copper and lead during peat bog formation.

Ombrogenic bogs are not only excellent chronostratigraphic archives for pollen, but also for atmospheric depositions as by-products of metallurgical processes and procedures. The minerotrophic peats that are present in the Knappagruaba area are equally suitable for palynological studies, but their potential for geochemical analysis has been disputed, because influx and removal of elements by surface and groundwater can hardly be estimated. However, some investigations have re-evaluated the usefulness of mires for metal precipitation measurements (eg. Mighall, et al., 2009; Shotyk, et al., 2002; Breitenlechner, et al., 2010; Hansson, et al., 2015). The palynological and geochemical results presented here (section 6.1-3) can serve as an indicator for mining activities. Rather than reflecting the atmospheric pollution of minerotrophic peats with heavy minerals, they prove that higher concentrations are caused by contaminated slope water, which has long been circulating in Knappagruaba's mining galleries until today. In combination with pollen and charcoal analyses, evidence is presented for the effects of prehistoric mining in general and phases of increased mining activities in particular.

Sample	Position	Laboratory number	14c-Age (BP)	1 Sigma	2 Sigma
1	Roferweg Bergschmiede, underneath forge layer	COL 1299.1.2	3620±47	cal BC 2035 – 1911	cal BC 2136 - 1882
2	Knappagruaba Geländegraben, underneath old soil development	Beta-242561	3450±40	cal BC 1874 - 1692	cal BC 1884 - 1665
3	Knappagruaba Geländegraben, out of old soil development	Beta-242562	3420±40	cal BC 1770 - 1660	cal BC 1877 - 1626
4	Roferweg Bergschmiede, feature 102, shallow pit	MAMS-23550	3399±28	cal BC 1741 - 1661	cal BC 1755 - 1624
5	Roferweg Bergschmiede, feature 102, shallow pit	MAMS-23551	3383±27	cal BC 1731 - 1640	cal BC 1745 - 1621
6	Goritschang, within a sinkhole, close to mineshaft	Beta-236429	3340±40	cal BC 1687 - 1560	cal BC 1739 - 1521
7	Garsella West, drill core at a depth of 80 – 85 cm	MAMS-25546	3299±31	cal BC 1616 - 1531	cal BC 1644 - 1503
8	Knappagruaba Geländegraben, pit with fire debris	Beta-250352	3290±40	cal BC 1616 - 1521	cal BC 1664 - 1459
9	Knappagruaba trench 4, feature 14, fire pit	MAMS-30438	3247±24	cal BC 1600 - 1460	cal BC 1611 - 1449
10	Knappagruaba trench 4, feature 23, fire pit	MAMS-30439	3225±22	cal BC 1512 - 1451	cal BC 1594 - 1435
11	Knappagruaba trench 4, feature 10, concentration of charcoal	MAMS-26588	3206±25	cal BC 1500 - 1449	cal BC 1521 - 1426
12	Knappagruaba trench 4, feature 23, fire pit	MAMS-30440	3152±18	cal BC 1443 - 1412	cal BC 1495 - 1396

Tab. 2: Bartholomäberg, mining zone. Radiocarbon datings form the Bronze Age. (table: Montafonprojekt).

Fig. 7: Bartholomäberg, Knappagruaba. The small reed-covered mire 'Herbstzeitlose' (HZL). To the left and right are large mining waste heaps that probably date to the Late Middle Ages or early modern period (photo: Montafonprojekt).

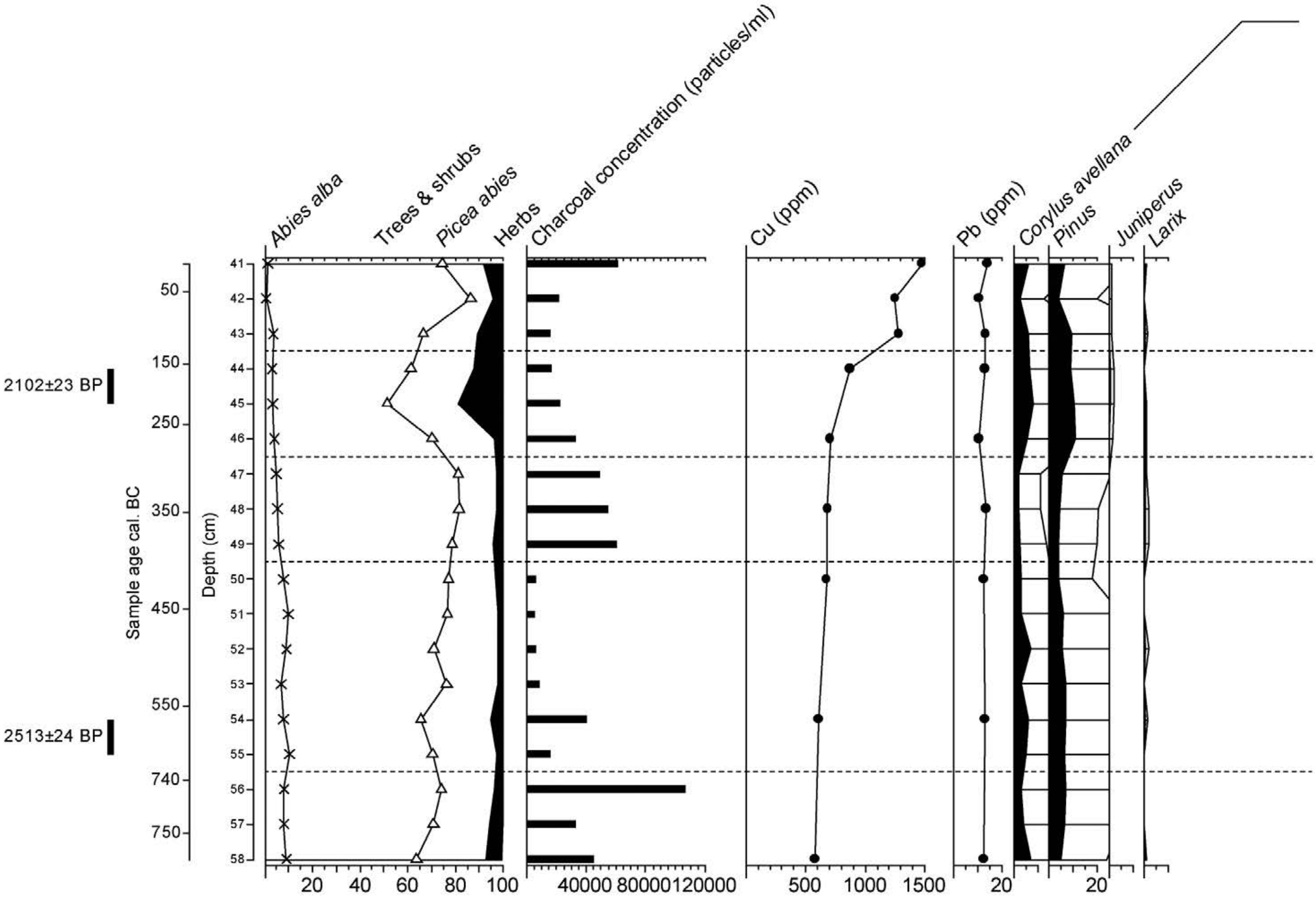


Fig. 8: Bartholomäberg, Knappagruaba. Pollen diagram of the mire 'Herbstzeitlose' (HZL) (graphic: Montafonprojekt).

The investigated mire at Bartholomäberg

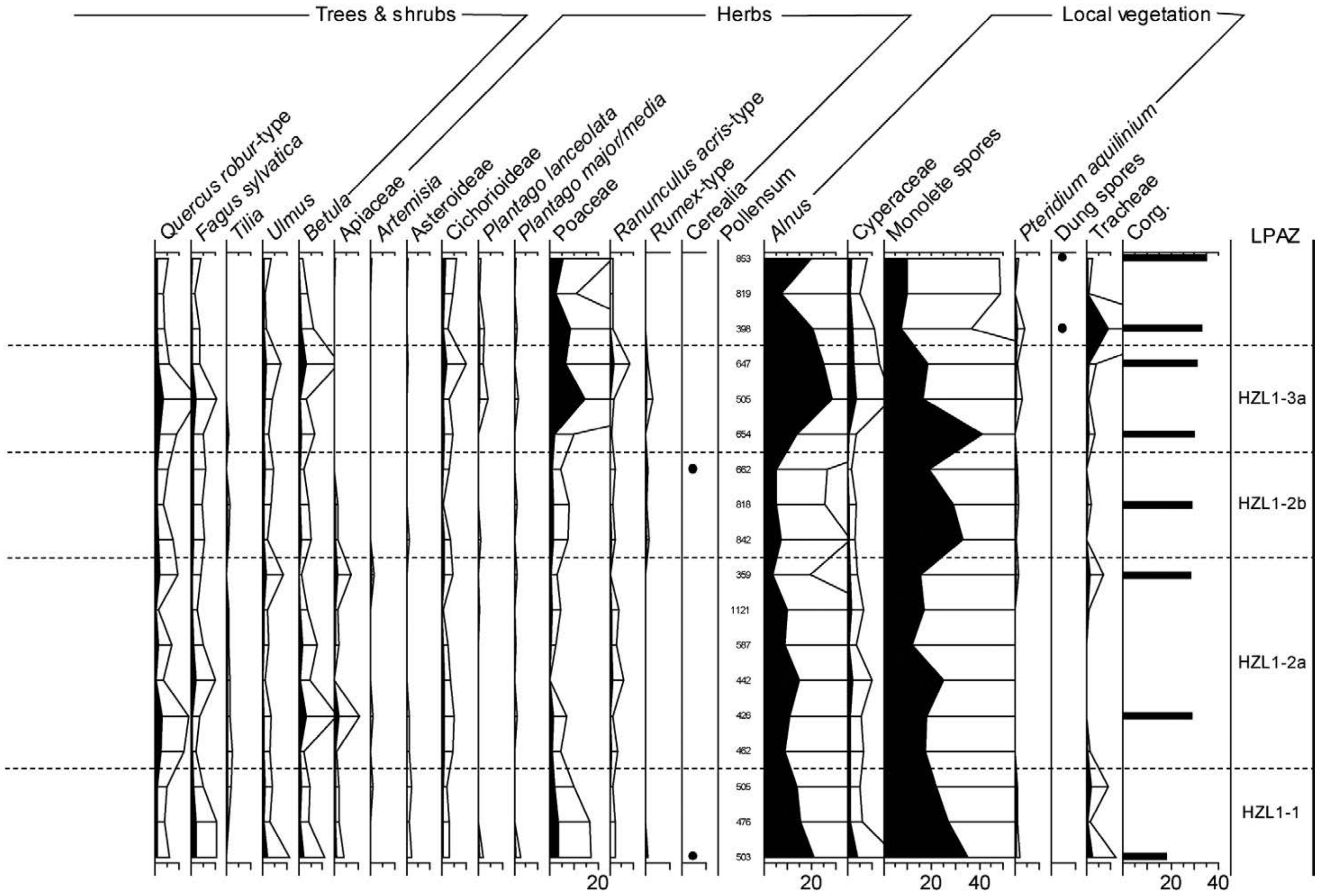
Today, the Knappagruaba mining area is largely deforested and used for grazing. Small forest patches that still exist consist of spruce (*Picea abies*) and fir (*Abies alba*), partly with beech (*Fagus sylvatica*). Wet depressions occasionally contain alders (*Alnus*). Above 1,400 m, spruce is accompanied by larch (*Larix*) and stone pine (*Pinus cembra)*. The small reed-covered mire Herbstzeitlose (HZL) is situated between mine dumps (Fig. 2, B, Fig. 7) at an altitude of 1,300 m a.s.l. and, thanks to its small size, especially suited for reconstructing the local vegetation.

With the help of an avalanche probe, two transect surveys were carried out to identify the thickest peats; subsequently, a core of 6 cm diameter and 109 cm length was retrieved with a gouge auger (coring 2) in the summer of 2015. Another core from the edge of the mire contains only 60 cm of peaty material (coring 1). The minerotrophic reed peats are underlain by sands. The PH value of all varies between 4.7 and 5.7. Samples were taken from the cores for further palynological and geochemical analysis.

Methods

The preparation of samples for palynological pollen analyses followed standardized methods of acetolysis and mounting of pollen grains in silicone oil (Moore, et al., 1991). For the calculation of pollen concentrations, *Lycopodium* tablets were added to each sample (after Stockmarr, 1971). Charred plant remains larger than 10 µm were counted and are shown as concentrations. Pollen grains were counted up to a regional pollen sum between 500 and 1,100, excluding local species like hydrophytes, hygrophytes or swamp forest species (alder).

The cores were sampled at intervals of 1 to 2 cm for geochemical analyses. Thanks to the key role of the elements copper and lead for the identification of prehistoric mining, only these two elements were measured. We decided against measuring scandium, a reference element used to normalize heavy mineral curves against their natural occurrence, due to the dominant role of aquatic rather than aeolian contamination in our area of study and the significantly higher metal values involved.



Continued from Fig. 8.

The samples were dried, homogenized and subsequently measured with the AAS (Atomic Absorption Spectrometer, model: Perkin-Elmer Pinnacle 900T).

AMS datings of peat samples were carried out at the Klaus-Tschira-Laboratory for Radiometric Dating Methods (Curt-Engelhorn-Centre Archaeometry, Heidelberg), and Beta Analytic (Miami, Florida). The results were calibrated with OxCal v4.2.4 (Bronk Ramsey and Lee, 2013); IntCal13 atmospheric curve (Reimer, et al., 2013). In this paper, only the analyses' results concerning the Iron Age are presented. Namely, peat growth stops at this point and does not continue until the Middle Ages; that part of the profile will be addressed in a future publication.

Results of analyses

The pollen diagram HZL 1 (Fig. 8, Tab. 3), can be divided into three zones (LPAZ). The beginning of pollen zone LPAZ HZL1-1 (800-600 cal. BC) is characterised by a dominance of spruce (*Picea*) (60%). Fir (*Abies*) reaches 10%. Hazel (*Corylus*), oak (*Quercus*), ash (*Fraxinus*), lime (*Tilia*), beech (*Fagus*) and elm (*Ulmus*) are constantly present. The NAP values lie between 4 and 7%. The appearance of *Rumex*, *Campanula*, Asteroideae and pollen grains of Cerealia, *Artemisia*, Chenopodiaceae and *Plantago lanceolata* suggests agropastoral activities in the wider surroundings of the mire. Alder (*Alnus*) used to grow on wet sites. Charcoal concentrations range between 3,300 and 10,600. Copper values range between 580 and 610 ppm, lead values between 12 and 13 ppm.

Pollen zone LPAZ HZL1-2 (600-300 cal. BC) contains two sub-zones. From 600 BC – Pollen zone LPAZ HZL1-2a – spruce dominates the pollen spectrum with up to 80%, while fir values decrease to below 5%. Minor NAP percentages and low charcoal concentrations point to a moderate degree of human impact in the vicinity of the mire. Copper has risen to 680 ppm, but lead values remain unchanged with 12-13 ppm. In pollen zone LPAZ HZL1-2b, charcoal concentrations increase significantly to 5,000-6,000. The values of Poaceae are slightly higher as well.

Pollen zone LPAZ HZL1-3 (250 BC-50 AD) can also be divided into two sub-zones. In Pollen zone LPAZ

LPAZ		Depth (cm)	Age cal. BC/AD	Charcoal concentration	Geochemistry (ppm)
HZL 1-1	Spruce/Fir Zone	58-55.5	800-600 BC	3300-10600	Cu 580-610 PB 12-13
HZL1-2a	Spruce Zone	55-49.5	600-350 BC	500-1500 (4000)	Cu 610-680 Pb 10-13
HZL 1-2b		49-46.5	350-250 BC	5000-6000	Cu 680-700 Pb 12-13
HZL 1-3a	Spruce/Pine/ NAP Zone	46-43.5	250-100 BC	1600-3300	Cu 700-870 Pb 10-13
HZL 1-3b		43-40.5	100 BC-50 AD	1500-6000	Cu 1250-1450 Pb 10-14

Tab. 3: Bartholomäberg, Knappagruaba. Pollen zones within the mire 'Herbstzeitlose' (HZL). (table: Montafonprojekt).

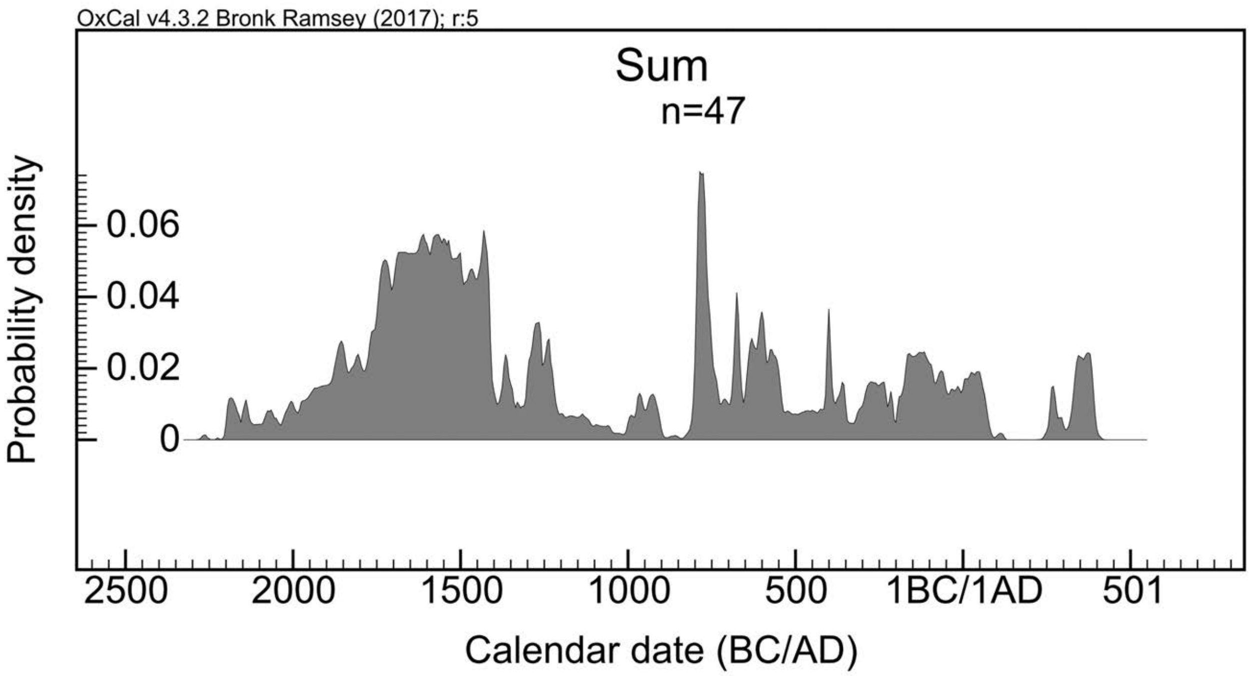


Fig. 9: Sum diagram of radiocarbon datings from Bartholomäberg, ranging from the Early Bronze Age to Late Antiquity. 25 datings are from settlement excavations, seven from mining situations, nine from finds without a closer context, and six datings from the mire profiles. They denote phases, that can be associated with episodes or developments in mining, for example, increased amounts of heavy minerals (graphic: Montafonprojekt).

HZL1-3a, spruce values drop to less than 50%. Fir values also decrease. Together with the rise of light-demanding hazels, pines and a closed curve of juniper (*Juniperus*), this documents an opening of the canopy. The curve of NAP rises to 19%, and Poaceae reaches a maximum of 15%. Other indicators of human and livestock presence (especially *Plantago lanceolata*) occur frequently. The alder, a wetland representative, shows increased values as well. Copper values have risen and now lie between 700 and 870 ppm; the values for lead are constant at 10-13 ppm. In pollen zone LPAZ HZL1-3b, the spruce curve rises again to over 80%. At the same time, abundant wooden vessels hint at the occurrence of spruce either on the mire or in its immediate environs. The NAP values have decreased, but their composition is mostly identical with the one of the zone below. Alder, however, decreases considerably. Charcoal concentrations lie between 1,500 and 6,000. Copper has risen to values of 1,250 to 1,450 ppm, while lead is steady at 10-14 ppm.

Iron Age activities in the mining district of Knappagruaba

The sub-alpine forest in Montafon had already been cleared to a large extent in the Early Bronze Age (Oeggl et al., 2005; Oeggl & Wahlmüller, 2009). This action has been well documented by settlement archaeology and

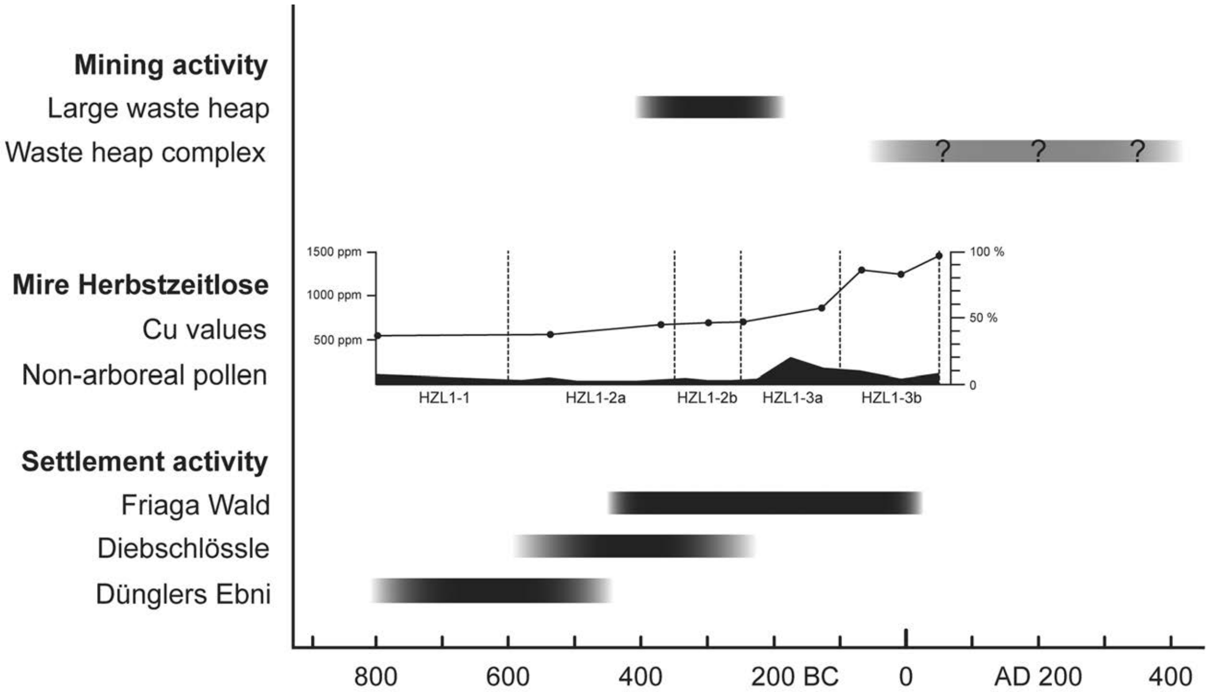


Fig. 10: Bartholomäberg. Settlement and mining activity compared to the geochemical and palynological results of the mire 'Herbstzeitlose' (HZL). The large waste heap is located in the immediate vicinity of the mire. As charcoal samples were dated, an old-wood effect cannot be ruled out. Radiocarbon dated samples out of a colluvium inside of the waste heap complex may be linked to mining activity. The rise of copper values and non-arboreal pollen is related to mining activity in the proximity of the mire at the same time as the settlement activity in the 'Friaga Wald' (graphic: Montafonprojekt).

data from the settlement zone on the Bartholomäberg. Human pressure on forests apparently increased during the Middle Bronze Age up to an elevation of about 2,000 m a.s.l (Wahlmüller, 2002). The high values of micro- and macro-charcoals in the pollen diagrams and the abundance of charcoals in the soils (Röpke, 2012a; 2012b) attest that fire played an important role in forest clearance. Spruce benefited from burning, while the more sensitive fir, a previously dominant component of sub-alpine forests, gradually disappeared in the course of the Bronze Age.

This development had already been completed when the Herbstzeitlose mire started to form at ca. 1000 BC in the central part, versus 900/800 BC at its margins. During this time, a spruce forest with low percentages of fir covered the Knappagruaba area. In the wider surroundings of the mire, land use practices were taking place, as indicated by findings of pollen of *Plantago lanceolata*, Chenopodiaceae and cereals. The settlement and grazing areas were probably located at some distance, because NAP and also coprophilous fungus spores are relatively few. The effects on the forests must therefore be rated as moderate. Data from the Tschuga mire confirm that human impact between 800 and 300 BC was distinctly less than during the Bronze Age (Schwarz & Oeggl, 2013). It seems that, unlike in the Bronze Age, land use was now largely restricted to areas below 1,200 m a.s.l. The high charcoal concentrations demonstrate, however, that burning was a part of land management practices, most likely in order to prevent bush encroachment and reforestation at a low grazing pressure. On the other hand, it could also have been the outcome of ore processing. This is suggested by the geochemical results from the respective peats. Particularly the copper values of 500-600 ppm are markedly high in relation to measurements from other mires. For instance, the Tschuga mire located approximately 100 m below, only reaches values of 50 ppm (Krause, 2015, p.103, Fig. 158). The latest measurements from the Garsella mire, ca. 100 m above, yielded copper values of merely 20 and 40 ppm. The peats from the centre of the Herbstzeitlose mire, which are about 200 years older, also reach copper values of ca. 230 ppm, thus indicating the lateral inflow of copper solutions already during the earliest phase. This may be interpreted as an effect of prospecting or initial processing which caused water contamination. Such practices intensified around 800 BC as revealed by the increased copper values. The influence on the surrounding vegetation was however spatially limited, for it is not reflected by any regional signal, apart from higher micro-charcoal concentrations. Nonetheless, they must have triggered erosion at Knappagruaba, since the peat profile from the centre contains minerogenic deposits from that period. This part of the sequence has copper values of merely 80-140 ppm, hence proving that copper is mainly bound to humic substances which is why the retention capacity of peats is decidedly higher (Würfel, et al., 2010).

Around 600 BC, anthropogenic influence was slightly reduced. The low NAP values and charcoal concentrations suggest that the vegetation around the mire was closed and land use in the wider area was minimal. Nonetheless, copper-bearing water was still seeping into the mire. This phase lasted until approximately 350 BC, when charcoal concentrations started to increase significantly without any obvious changes in NAP. These occur about 100 years later, with a distinct rise in NAP as well as heliophilous pioneer species like hazel, pine and juniper. The strong increase in Poaceae confirms the opening of the vegetation cover, which may also have been achieved by intentional burning. A similar development can be seen around 300 BC in the Tschuga mire, where crop production and pastoralism apparently intensified (Oeggl, et al., 2005; Schmidl, et al., 2005; Schwarz & Oeggl, 2013). For the Knappagruaba area, however, there is still no direct indication of agriculture or livestock raising. Coprophilous fungal spores only occur sporadically, and cereal pollen is completely absent. On the other hand, a local thinning and clearing of forests is clearly observable. A causal relationship with a Late Iron Age mining phase seems likely due to the synchronous rise of copper values (to over 1,400 ppm) and a waste heap in the immediate vicinity of the Herbstzeitlose mire, which dates back to the 4th/3rd century BC (Röpke, 2012b, p.274). As charcoal samples were dated, an old wood effect cannot be excluded.

Even the Tschuga mire, located 100 m above Knappagruaba, shows increased copper values in the Late Iron Age, although they amount to a maximum of only 100 ppm (Krause, 2015, p.103, Fig. 158). At that point, a hiatus is present in the diagram. The subsequent peats originate from the Middle Ages.

Discussion

Multidisciplinary investigations in Montafon have discovered prehistoric settlements and numerous single findings as far as the area of Bludenz, which confirm that these inner alpine environments were already settled and managed during the Bronze and Iron Ages in varying intensity (Fig. 9). Artefacts of the Iron Age attest the exchange and network with the Alpine Rhine valley as well as with neighbouring northern Tyrol. As described above (sections 2-5), new mining-archaeological investigations have achieved firm evidence for Iron Age mining on Bartholomäberg. Thereby, archaeological features and scientific data derive from a comparably small area in the mining district of Knappagruaba. There remains of outcropping hydrothermal ore veins are still visible in near-surface rock on the steep slopes, and mine drainage water flows out of the galleries and shaft openings even today. It can be assumed that there was an extensive occurrence of ores near the surface in prehistoric times. For example, when digging deep into the slope, ground water that is strongly contaminated with copper flows out. This content is confirmed by heavy metal analyses on peat profiles taken from the mire Herbstzeitlose (HZL), located in the midst of the waste heaps in this mining zone and in the sections of the Late Iron Age. It shows a strong rise in copper values, indicating mining activities. These find contexts were accompanied by distinct intrusions and changes in the vegetation. They also show an opening of the vegetation cover as the result of intensified land use in the surroundings. Subsequently accumulations of colluvia occurred in the mire (section 6.4).

The scientific data gained from geological, palynological and geochemical investigations were evaluated with specific reference to the different archaeological findings and contexts that were revealed. One waste heap of gangue represents the first mining archaeological context, which was covered by a large waste heap from the Late Middle Ages. It was discovered in the course of an excavation in 2012. It dates to the Late Iron Age and lies only a few metres down slope, below the Herbstzeitlose mire (Fig. 2). Thus, the data and find contexts could be set in immediate association with one another. Thereby the basic problem of the paucity of material from prehistoric mining became obvious: namely, traces of prehistoric mining are covered by extensive medieval and modern mining activities and can be recovered today only through specifically aimed prospection.

Nevertheless, the above-mentioned iron spearhead found in Fritzentobel in the settlement zone of Bartholomäberg might be indicative of Iron Age mining. Elmar Vonbank already interpreted the spot where the artefact was found in immediate proximity to the ocurrence of ore as an important indicator. The exposure of rock in the deep ravine (Tobel) would have enabled relatively easy access in terms of prospection and exploitation. However, archaeological evidence for mining has certainly been destroyed by erosion processes and subsequent mining in the area.

On the Bartholomäberg – and this applies to the entire inner Alpine settlement area in Montafon as well – until now neither in Bronze nor Iron Age settlements or in the mining zone have indications been found of metallurgical processes of preparing and smelting ores or the remains of copper or iron processing. This situation stands in strong contrast to the abundance of remains present in other mining districts, for example, in the Oberhalbstein in Graubünden or Mitterberg in Pongau, where there is a multiplicity of evidence for the chain of processing and production. An explanation for this difference might be that in Montafon in prehistoric times only the first beginnings of ore exploitation and its processing are present, and that possibly any further processing was not carried out at all in the ore and mining zone, but instead in another locality. The prepared and enriched ore had to be transported to these places. Two melting furnaces are known at least for the High and Late Middle Ages: the smelting furnace in Silbertal and in Tschagguns, which are located directly next to water courses. If we were to imply such a situation for prehistorical findings, then their preservation and discovery would be even more problematic and indeed coincidental.

These new results reinforce the suggestion that during the Late Iron Age small-scale mining for copper or iron was conducted in Montafon on the Bartholomäberg (Fig. 10). This has been affirmed consistently by radiocarbon datings for decisive mining contexts and the results of the vegetation history, soil studies and heavy-metal analyses. Moreover, this phase can be linked with archaeological settlement contexts on the Bartholomäberg. By continuing and intensifying mining archaeology investigations in this region, we have the opportunity to record in depth a comparably small mining district, in contrast to large mining districts in the Eastern Alps, and to use settlement contexts and data on the natural environment data in order to model its socioeconomic function.

Notes

1 This site was studied by Rudolf Klopfer for a master's thesis in 2014 at Goethe University in Frankfurt/Main. It is being prepared for publication.

2 The sherd bears a rare stamped decoration with a standing S (Lang, 1998, pp.170-173). Another sherd with comb-stamped decoration confirms relations to early Latène culture in Northern Tirol (Lang, 1998, p.173).

3 Concerned here is one charcoal sample from an Iron Age layer, trench 3, find complex 62 Vera-3028 2974 BP ±40 1σ 161-46 cal BC, 2σ 199 cal BC – 5 cal AD.

4 Since 2015 this project is supported by the German Research Foundation and titled: *Montanarchäologie im Montafon, Vorarlberg (*Österreich*) – Zur Archäologie und Geschichte eines Montanreviers in den Zentralalpen*.

5 Documentation was carried out by the *Archäologischer Dienst* company in Söll/Tirol, commissioned by the Austrian Federal Monuments Office. We express our gratitude for the provision of documentation and findings for scientific study.

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