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Dendrochronological dating of charcoal from high-altitude prehistoric copper mining and smelting sites in the Oberhalbstein Valley (Grisons, Switzerland)

ABSTRACT: *From 2013 to 2019, the prehistoric copper mining region of Oberhalbstein was in the focus of archaeological research carried out by the Department of Prehistoric Archaeology at the University of Zurich in cooperation with the Archaeological Service of the Canton of Grisons. The surveys and excavations of mining and smelting structures unexpectedly yielded numerous large, well-preserved charcoal fragments from conifers (Picea abies/Larix decidua, Pinus cembra, Pinus mugo/sylvestris). A total of 534 charcoal fragments and 7 wooden objects were retrieved from the 23 sites studied. Most of the sites are located between 1695 m and 2450 m a.s.l. The larger charcoal fragments bore up to 200 tree rings, and even fairly small fragments had a considerable number of rings. Dendrochronological analysis allowed us to construct two conifer chronologies that correlated with those from the central and eastern Alps and covered the period between the 12th and the 7th centuries BC. These made it possible to establish accurate calendar dates even for the period of the Hallstatt ^{14}C plateau, which often limits precise radiocarbon dating for that time period. The absolute chronological framework showed that, up to the present state of research, prehistoric copper mining and production in this part of the central Alps took place within two major events: one in the 11th century BC, the other in the 7th or 6th century BC.*

KEYWORDS: ANTHRACOLOGY, HIGH-ALTITUDE SITES, COPPER MINING, CHARCOAL PRODUCTION, LATE BRONZE AGE AND EARLY IRON AGE

Introduction

For some specific mining features in the Oberhalbstein region, Late Bronze Age and Early Iron Age evidence had already become available by the end of the 20th century in the form of radiocarbon dates (Wyss, 1993; Schaer, 2003). When prehistoric mining and smelting processes in the Oberhalbstein Valley became the focus of research again in 2013 (Della Casa et al., 2015; Turck et al., 2014), one of the key questions was their temporal and absolute chronological dimension. At mining and smelting sites, which are predominant within the research project presented here, processes took place which naturally require a lot of wood (fire setting, roasting, smelting). As a consequence, the sites yielded a large amount of charcoal. However, their size and dendrochronological potential greatly exceeded expectations and led to the first extensive dendrochronological analysis of charcoal in Switzerland.

Basically, dendrochronological analysis of charcoal is rarely carried out, because of both the nature of the material and its state of preservation: in many cases, charcoal from soils does not contain a sufficient number of tree rings for dendrochronological analysis due to fragmentation. High-altitude sites can be an exception as slow growing trees are more frequent here, provided that charcoal has survived – as was the case at the sites in the Oberhalbstein project (Fig. 1). In addition to climatic factors, a reason for this slow annual growth of trees may also lie in the high tree density of the exploited woodlands. As a result, even relatively small fragments can bear a large number of tree rings (e.g. Pichler et al., 2013; Pichler et al., 2011).

Radiocarbon analysis also yielded Hallstatt period dates for several sites in the Oberhalbstein project (Turck et al., in press; Turck et al., 2014, pp.223). For various methodological reasons, they were not very precise: dates scattered widely within the Hallstatt plateau (c. 750 to 400 BC) on the ^{14}C calibration curve hamper any attempts to achieve a more precise chronological resolution (e.g. Jacobsson et al., 2019). A further difficulty was that it was not known where on the tree trunk the annual rings of each radiocarbon-dated charcoal sample had originated from. In extreme cases, it is possible that several centuries lie between the heartwood rings that have been radiocarbon

Fig. 1: Sample no. 87854 with 161 tree rings, dated to the end year 685 BC, from the site at Marmorera, Gruba I. Less than 2 cm in length (photo: ADG).

dated and the outermost tree ring, which would provide the date for the event or archaeological feature that is actually being examined. This problem is known as the *old-wood effect* and has been extensively discussed since the late 1970s by researchers attempting to obtain absolute dates for archaeological timbers (Warner, 1990; Schiffer, 1986; most recently: Palincas, 2017). The *old-wood effect* has particularly serious consequences for charred wood from very old tree individuals, from which the majority of the dendrochronologically examined samples presented here originated. This obviously raised the question of whether waney edges were present, which is crucial to eliminating any potential for *old-wood effect*, how they could be firmly identified in charcoal in general and how well they were preserved in this particular case. Another set of questions to be explored were the wood species composition and the function and material value of the charcoal within the mining and copper production context: when it comes to mining and firing processes, the question always arises as to whether wood or (intentionally) charred wood was used (Hanning et al., 2015). From the point of view of dendrochronology, another goal was to establish the first confirmed reference chronology for the earlier stages of the Iron Age in the Grisons. The primary aim, however, was to establish as detailed a chronological framework as possible for the mining activities and copper production that took place in the valley and to reconstruct the *chaîne opératoire* (Turck, 2019; Reitmaier-Naef, 2019; Della Casa et al., 2015; Turck et al., 2014).

Material and methods

Out of approximately 80 archaeological sites in the Oberhalbstein Valley, 23 yielded charcoal fragments, some in significant numbers. In addition, seven fragments of wood, six of which could be identified as artefacts, had been preserved in waterlogged conditions (Reitmaier-Naef et al., in press). A total of 541 samples were dendrochronologically examined. The majority of samples were retrieved during excavations and surveys carried out between 2013 and 2019. As part of the project, other finds from mining contexts excavated earlier were also taken into account to determine their suitability for dendrochronological analysis (Reitmaier-Naef, 2018). The sites which yielded the samples that were suitable for dendrochronological examination were located at altitudes of between 1200 m and 2500 m a.s.l. (cf. Tab. 1). Three smelting sites were identified as the most important in terms of the amount and quality of dendrochronological samples: Gruba I (203 samples), Val Faller Plaz (96 samples) and Pareis I (52 samples). Two mines were also well represented: Cotschens and Avagna-Ochsenalp (Tab. 1) (published separately: Reitmaier-Naef et al., in press). With a total of 351 samples these five sites yielded just under two thirds of all samples examined as part of the project. The mining sites excluded (Cotschens, Avagna-Ochsenalp), they provided as much as 80% of all samples. All were stratified samples from large-scale excavations. Each charcoal sample with at least 25 annual rings was included in the analysis. Most charcoal fragments were extraordinarily well preserved, both in terms of their size – up to 5 cm in length – and in terms of their stability. The growth rings were very narrow (cf. Fig. 5e for mean values of tree ring widths) and some samples bore up to 200 tree rings. Most charcoal fragments from the Oberhalbstein Valley came from tree trunks.

Both their charred state and narrow growth rings posed a challenge: determination of the wood species was handicapped and it was difficult to identify possible examples of waney edges. The parameters for determination of the wood species and waney edges, therefore, had to be narrowly defined.

1) Features that are relevant for species determinations are more clearly visible in earlywood than in latewood cells, because the growth pattern in the former is less dense than in the latter. The narrow-ringed samples contain fewer earlywood cells, with some only bearing one earlywood and one latewood cell, so that because of charring the features relevant for wood species determination are often excellently preserved, but hardly visible.

Charring also makes sapwood impossible to recognise, either with the naked eye or under the microscope, and hampers the distinction between it and heartwood. In uncharred wood, it is possible to distinguish between *Larix decidua* and *Picea abies* by virtue of the fact that the sapwood in larch is distinctly lighter in colour than the heartwood, whereas in *Picea abies* the same distinction cannot be made. This distinguishing feature, however, does not occur when the wood is charred.

Previous wood anatomical studies on the microscopic distinction between *Larix decidua* and *Picea abies* were revealed to be impracticable (cf. Anagnost et al., 1994). Their identifying anatomical features overlap in that *Picea abies* is characterised by a rather continuous transition from early to latewood with bordered pits usually arranged

	context quality	altitude ma.s.l.	total number of samples	*Larix decidua/ Picea abies*	*Picea abies/ Larix decidua*	*Pinus cembra*	*Pinus mugo/ Pinus sylvestris*	species indet.	number of undated samples	number of dated samples	youngest end year	datings with waney edge
MINING SITES												
Marmorera, Cotschens	sondage (2017)	2275	19	10	7	1	1		16	3	1131 BC, 67 BC	
Marmorera, Gruba II, Pinge 1	excavation (2016-2018)	1849	15	9	6				15			
Marmorera, Gruba II, Pinge 3	excavation (2016-2018)	1849	13	13					11	2	1494 AD	
Marmorera, Vals	sondage (2014; 2016)	1748	7	3	2	2			6	1	745 BC	
Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	2487	72	12	60				46	26	1043 BC	certain, autumn/winter: 1061 BC
SMELTING SITES												
Bivio, Brüscheda I	survey (2014)	2047	1				1		1			
Bivio, Sur Eva I	survey (2017)	2015	2		1	1			2			
Cunter, Dafora	sondage (1974)	1185	9				9		9			
Marmorera, Alp Natons	excavation (2015)	1948	5	1	3	1			3	2	615 BC	
Marmorera, Gruba I	excavation (2013-2017)	1845	203	140	46	16	1		141	62	607 BC	certain, autumn/winter: 634 BC, uncertain: 607 BC, 614 BC
Marmorera, Gruba III	survey (2016)	1841	9	1	7			1	7	2	613 BC	uncertain: 613 BC
Marmorera, Pardeala	excavation (1952)	1635	1	1					1			
Marmorera, Pareis I	sondage (2014-2015; 2017)	1696	52	20	28	3		1	45	7	614 BC	
Marmorera, Scalotta I	sondage (2014)	1590	17	3	14				15	2	393 AD	
Mulegns, Val Faller Plaz	excavation (2013; 2016)	1764	96	52	24	20			83	13	621 BC	certain, autumn/winter: 642 BC, uncertain: 621 BC
Riom-Parsonz, Tigignas Sot II	survey (2006)	1491	2	1	1				1	1	636 BC	
Riom-Parsonz, Tigignas Sot III	survey (2006)	1477	4	2	2				2	2	636 BC	uncertain: 636 BC
Savognin, Parseiras II	survey (2015)	1387	1		1				1			
Tinizong-Rona, Mulegn	survey (1995)	1247	1		1				1			
CHARCOAL LAYER (INDET.)												
Bivio, Drauscha	survey (2017)	1912	1		1				1			
Marmorera, Survey (Tges Alva/Pareis)	survey (2014)	1705	1		1				1			
Marmorera, Survey (Pareis)	survey (2014)	1841	1		1				1			
Savognin, Parnoz	survey (1997)	1467	9	5	4				9			
TOTAL			**541**	**273**	**210**	**44**	**12**	**2**	**418**	**123**		

Tab. 1: Overview of the wood species and dendrochronological dates (graphic representation: ADG).

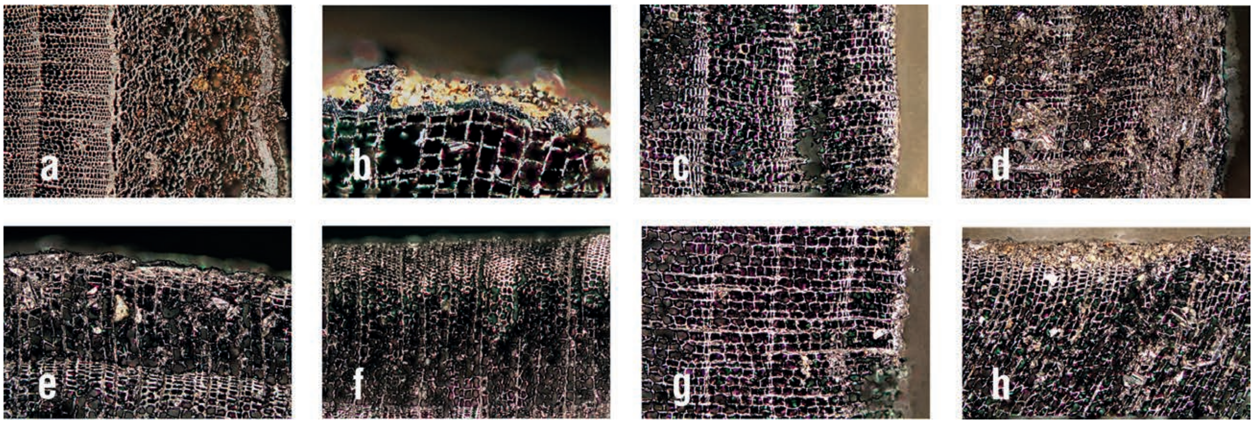

Fig. 2: Some examples of positively identified and/or uncertain waney edges. Width of the image sections: 5 X magnification: 1.7 mm, 10 X: 0.85 mm, 20 X: 0.425 mm (Photos and graphic W. H. Schoch/ADG). a) 87889; Pareis I; Picea abies/Larix decidua; undated; complete bark, autumn/winter waney edge, 5 X magnification. b) 87845; Gruba I; Picea abies/Larix decidua; 634 BC; remnants of bast; autumn/winter waney edge, 20 X magnification. c) 88838; Tigignas Sot III; Picea abies/Larix decidua; 636 BC; no remnants of bast, yet probably with a waney edge, with intact final growth ring cells over the whole tangential surface; classified as "with an uncertain waney", 10 X magnification. d) 88792, Pareis I; Larix decidua/Picea abies; undated; remnants of bast; autumn/winter waney edge, 10 X magnification. e) 88219; Val Faller Plaz; Larix decidua/Picea abies; undated; no remnants of bast, yet probably with waney edge; final growth ring intact over the whole tangential surface; classified as "with an uncertain waney", 10 X magnification. f) 88217; Val Faller Plaz; Larix decidua/Picea abies; undated; no remnants of bast; final growth ring fully developed and intact over the whole tangential surface; autumn/winter waney edge, 5 X magnification. g) 88169; Val Faller Plaz; Picea abies/Larix decidua; undated; classified as "with an uncertain waney", 10 X magnification. h) 88164; Val Faller Plaz; Picea abies/Larix decidua; undated; bast remnants; autumn/winter waney edge, 10 X magnification.

in a single row on the tracheid walls. *Larix decidua*, on the other hand, shows quite an abrupt transition from early to latewood and often has bordered pits in double rows (Schweingruber, 1990, pp.54, pp.56). For obvious reasons, this criterion is not applicable in wood with extremely narrow rings.

As a consequence, the identifications presented here include both names, whereby the name of the more likely species is mentioned first (e.g. *Larix decidua/Picea abies* and vice versa) (Tab. 1). The same applies to *Pinus sylvestris* or *Pinus mugo*. Anatomical differentiation between *Pinus cembra* and other conifers, on the other hand, was clear. Because of the predominance of *Larix decidua/Picea abies* and *Picea abies/Larix decidua* in the samples presented here, we built our dendrochronological mean curves across species, as long as the correlation matches were satisfactory. In this way, we ensured a sufficiently high replication of our mean curves.

2) In contrast to uncharred wood, the final year of growth, and thus the felling date of the tree, is not easily determined in charred wood samples. Any charcoal fragments suspected of containing a waney edge were examined in detail under a microscope magnified up to 50 times and those that did, in fact, include a waney edge, were photographed. Waney edges were positively identified where remains of bast fibres were definitely present or where the outermost cells were invariably fully developed and intact over the whole tangential surface. If the presence of a waney edge was only probable and there were no remnants of bast, it was described as "uncertain" (Fig. 2). Charcoal fragments often break along the boundaries between growth rings, particularly in earlywood cells, which are softer and slightly less stable than the denser latewood cells. In cursory evaluations, such breaks can easily be mistaken for waney edges. Moreover, the generally rather high degree of fragmentation in charcoal means that any potential waney edges must be detected on particularly small surfaces. Similarly, the maximum trunk diameter and the shape of the timber (e.g. split timber etc.) could not be reconstructed in the material presented here.

In an attempt to deal with a set of questions that present themselves regarding the advantages and/or disadvantages of the use of charcoal and wood in firing processes, we conducted an experiment to examine how wood behaves when it is charred. A recent fragment of larch wood (sample no. 85667; Grisons, Langwies-Medergen Wald, 1990 m a.s.l., dated to 2010, larch, 475 tree rings, pith, 36 sapwood rings, waney edge: spring) was divided into two identical pieces; one was then carbonised (Fig. 3).

At this stage of the project, the deposits which contained the charcoal fragments – in particular Gruba I and Val Faller Plaz – have not yet been attributed to any kind of archaeological sequence. This, however, is a prerequisite if also short series are to be included in the overall analysis. It is not yet clear, whether the samples from each site were retrieved from different archaeological features or how they related to each other from a relative chronological point of view. We therefore decided that a

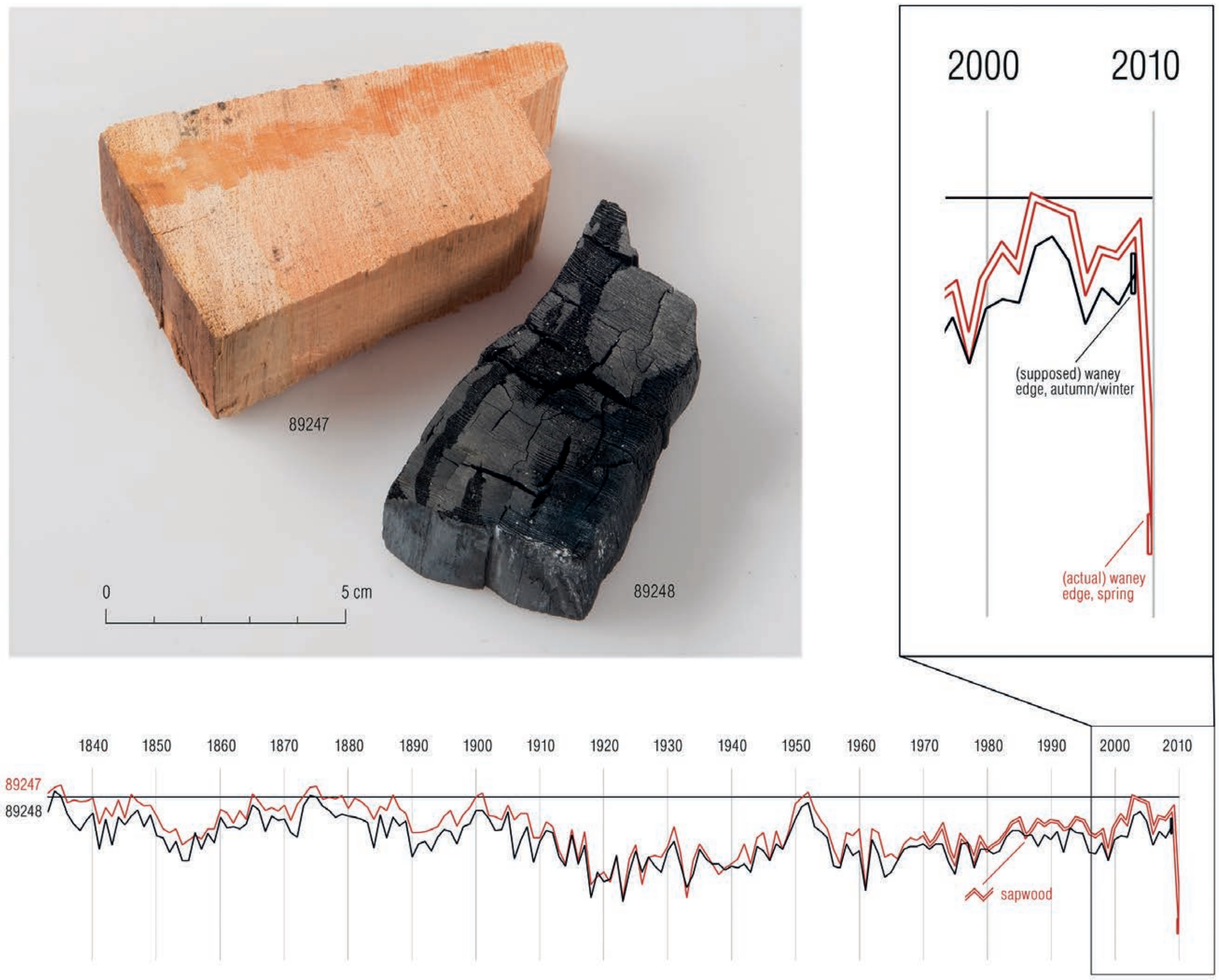

Fig. 3: Charcoal experiment. Recent alpine larch sample, charred and uncharred fragments and the correlation of both series. Values: Gleichläufigkeit 81.3, t-value after Hollstein 10.0 (graphic ADG).

sample must have at least 50 annual rings in order to be taken into account for sites not yet evaluated. Any potential dates from samples with 25 to 49 tree rings will have to be obtained and reviewed at a later date, once they have been firmly associated with one of the phases of use. In the case of Avagna-Ochsenalp and Cotschens, on the other hand, which have been conclusively studied and evaluated with regard to the relative chronological sequence, samples with less than 50 annual rings have already been taken into account and contextualized (Reitmaier-Naef et al., in press).

Our focus therefore was to establish a robust reference chronology, which would ideally be composed exclusively of long and well cross-correlated series. In view of the extraordinarily large number and good quality of the samples, the decision was made to use only the series from Gruba I, which had at least 50 tree rings. The aim of this first step in the analysis was to date the samples from Gruba I and then to date the remaining sites using Gruba I as a reference.

In constructing the Gruba reference mean curve we applied the leave-one-out principle: every series was first checked against the mean curve obtained from all other series. It was then divided into shorter segments for which alternative synchronous positions were checked in the neighbouring years. This allowed us to detect missing rings. Only if a series showed a t-value of at least 5 compared to the master chronology of all other series and only if there were no indications of missing rings, the series in question retained its place in the data set.

Two versions of the mean curve were constructed: one was calculated from the raw values, the other from the detrended series. For detrending prior to calculating the mean curve we used a *cubic smoothing spline* with an interval of 9 years (Cook & Peters, 1980) in order to remove medium and low frequency variability. The strength of the common signal that is contained in the resulting mean curve versions from Gruba I (MK 3940 and 5129) was evaluated using the mean correlation coefficient between all series and the *Expressed Population Signal* in 30-year segments (cf. Fig. 5, EPS: Briffa & Jones, 1990). These calculations were carried out in R (R Core Team 2017) using the DplR package (Bunn, 2008).

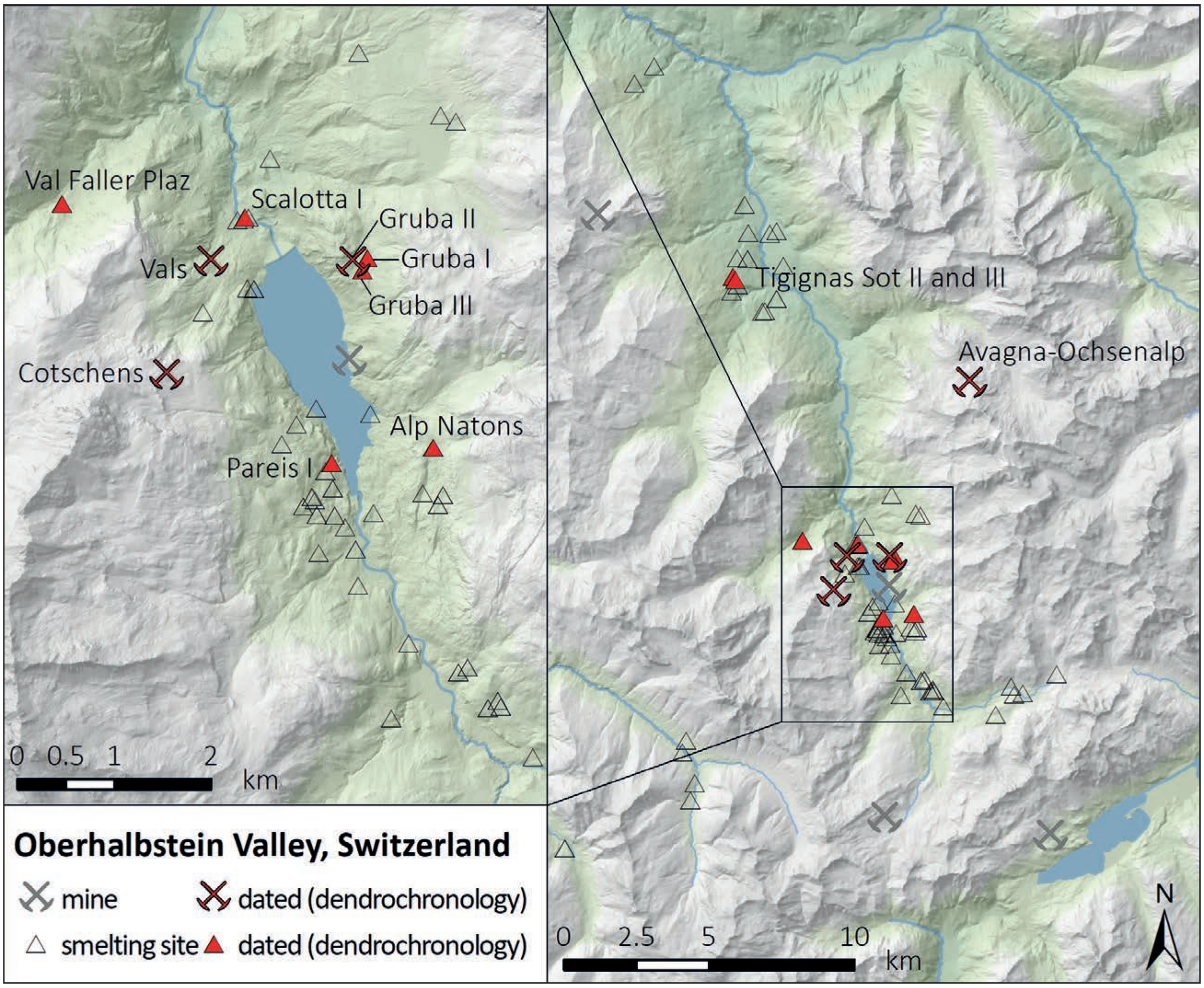

Fig. 4: Location of all sites with dendrochronologically dated samples (graphic L. Reitmaier-Naef).

Results

The vast majority of samples were identified as either *Larix decidua/Picea abies* (51%) or *Picea abies/Larix decidua* (39%), followed by *Pinus cembra* (8%) and a small number of *Pinus mugo/sylvestris* (2%) (Tab. 1). Overall 9 waney edges, autumn/winter in any case, were positively identified whilst a further 9 were labelled as "uncertain" (Fig. 2); a total of 8 samples including a waney edge were dendrochronologically dated (cf. Fig. 7).

Having compared both the dendrochronological series and the fragments themselves, the result of the experiment concerning carbonised wood was that after carbonisation the volume had been reduced by about half and the sample had lost some 75% of its original weight. The waney edges also exhibited differences (Fig. 3). While the last growth cells, which had formed in the spring of 2010, were present in the unburnt piece, they were no longer preserved in the other fragment: during carbonisation, the less robust earlywood cells, which represented the spring growth, had been burnt away completely. Without this background information, one would have assumed that the tree had been felled in the autumn or winter of 2009, simply because the denser and therefore more robust latewood cells had survived the fire, whilst the earlywood cells had not.

A total of 123 individual wood samples (23%) from 12 different sites – 4 mining and 8 smelting sites – were dated as part of the project (Tab. 1, cf. Tab. 2).

With two exceptions (Riom-Parsonz, Tigignas Sot II and III) all sites were located on the upper valley step, clustered around today's Marmorera water reservoir and were excavated as part of the Oberhalbstein project (Fig. 4). Unfortunately, charcoal samples from the associated surveys and from a number of excavations carried out in the 20th century did not yield any useful dendrochronological results.

The majority of samples date from the Hallstatt period. The dates were all obtained on the basis of mean curve MK 5129 consisting of 51 individual wood samples from Gruba I (Fig. 5a-b). It covers a period of 373 years between 980 BC and 607 BC.[1] The first 70 and final

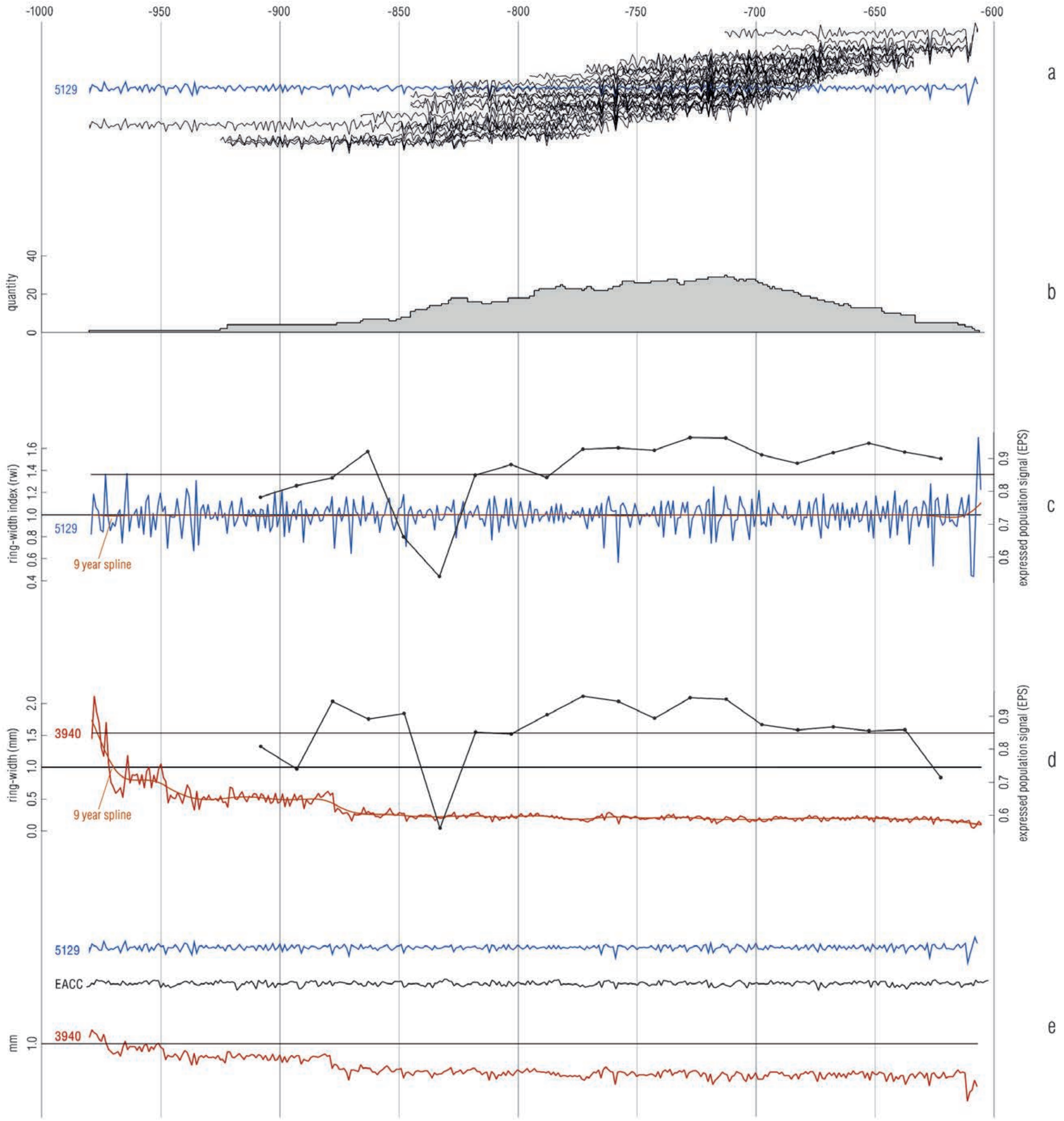

Fig. 5: Marmorera, Gruba I. Superimposed detrended series including the mean curve MK 5129 (graphic representation: ADG). Replication of the mean curves MK 3940 and MK 5129 (graphic representation: ADG). Expressed Population Signal (EPS), detrended series (graphic representation: N. Bleicher/ADG). Expressed Population Signal (EPS), raw data series (graphic representation: N. Bleicher/ADG). Cross-correlations of MK 5129 (Gleichläufigkeit 70.2%, t-value after Hollstein: 13.3) and MK 3940 (Gleichläufigkeit 69.7%, t-value after Hollstein: 13.9) with the Eastern Alpine Conifer Chronology (EACC; K. Nicolussi, University of Innsbruck) (graphic K. Nicolussi/ADG).

15 tree rings were excluded from the evaluation due to poor replication values. The chronology shows a solid *Expressed Population Signal (EPS)* of at least 0.85 for the period between c. 820 BC and 620 BC (Fig. 5c). The period between c. 910 BC and 820 BC was the only section of the mean curve that yielded inferior values. In comparison, the raw data series yielded slightly lower but still quite solid values (Fig. 5d).

Cross-correlation of the detrended mean curve MK 5129 with the *Eastern Alpine Conifer Chronology (EACC),* which goes back uninterrupted to the 8th millennium BC (Nicolussi et al., 2009), was very robust and statistically highly significant, even in the area evaluated by the EPS as non-confident (Fig. 5e). The period between 980 BC and 915 BC did exhibit some areas of *Gegenläufigkeit*. In MK 5129 this period is represented by only one series.

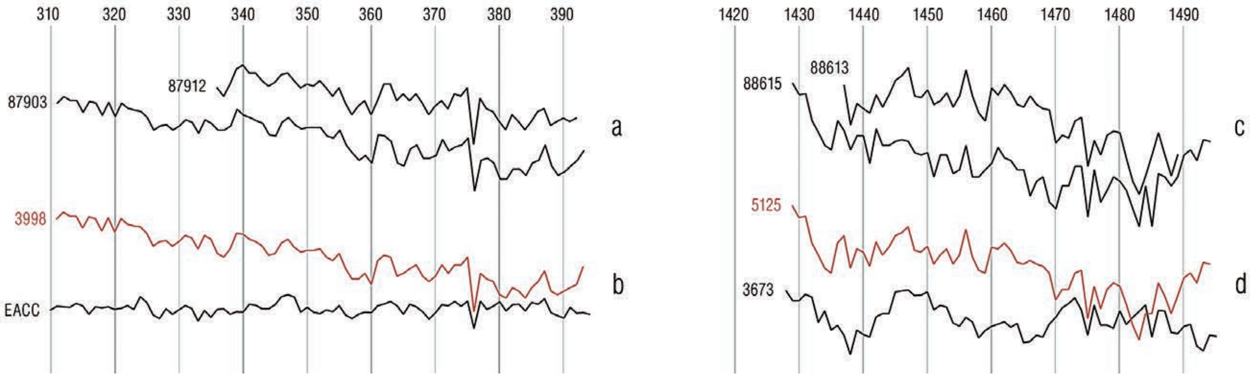

Fig. 6: Overlapping mean curves. Marmorera, Scalotta I. MK 3998 consists of series 87903 and 87912; Gleichläufigkeit 69.9%, t-value after Hollstein 10.0 (graphic representation: ADG). Marmorera, Scalotta I. MK 3998 cross-correlated with the Eastern Alpine Conifer Chronology (K. Nicolussi, University of Innsbruck); Gleichläufigkeit 70.7%, t-value after Hollstein 7.7 (graphic representation: K. Nicolussi/ ADG). Marmorera, Gruba II, Pinge 3. MK 5125 consists of series 88613 and 88615; Gleichläufigkeit 76.9%, t-value after Hollstein 5.4 (graphic representation: ADG). Marmorera, Gruba II, Pinge 3. MK 5125 cross-correlated with mean curve MK 3673 from S-chanf, house no. 25; Gleichläufigkeit 66.2%, t-value after Hollstein 5.1 (graphic ADG).

As expected, the detrended mean curve yielded a higher *Gleichläufigkeit* – though only marginally – and a lower t-value when compared to the raw data series MK 3940 (Fig. 5e).

A further 11 samples from Gruba I as well as a number of samples from other sites were subsequently dated by means of MK 5129 from Gruba I. In order to enhance the quality of these dates, rather rigid parameters were set, with the lowest t-value after Hollstein being 5 and the minimum number of tree rings being 50: the samples came from the sites Val Faller Plaz (13 samples), Pareis I (7 samples), Gruba III (2 samples), Alp Natons (2 samples), Vals (1 sample) and Tigignas Sot II and III (2 samples). With the exception of the two latter sites, which were located at an altitude of 1400 m a.s.l., all samples dating from the Hallstatt period were found at altitudes of between c. 1695 m and 2000 m a.s.l.

All seven waney edges from the Hallstatt period sites were dated to between 642 BC and 607 BC, though the earliest end year date was calculated as 855 BC (cf. Fig. 7). In the case of Gruba I, which yielded three samples with a waney edge, these represented the most recent, the fifth most recent and the eighth most recent of a total of 62 end year dates.

Besides the Hallstatt period, other periods were also represented at various sites: Scalotta I yielded one Late Antique end year date (AD 393)[2] and Gruba II, Pinge 3 one late medieval end year date (AD 1494) (Fig. 6). Prehistoric phases of these two sites are also evidenced by radiocarbon dated charcoal unsuitable for dendrochronological analyses (Turck et al., in press). It was not possible to ascertain the number of tree rings that were missing between the outermost rings and the waney edges.

The results obtained by dendrochronological analysis from the material from the mining sites at Cotschens and Avagna-Ochsenalp are shown here for the sake of completeness but have already been published and contextualised elsewhere (cf. Tab. 2) (Reitmaier-Naef et al., in press).

Discussion

The dates obtained have shown that charcoal as a material can provide important results but is also associated with certain difficulties due to its nature. Because it was not possible to ascertain the degree of fragmentation, it was also not clear whether the wood species distribution was representative of the original number of individuals and in how far it mirrored the species composition of the surrounding woodland in the period concerned. The wood charring experiment further revealed that potential spring/summer waney edges were perhaps not available because the soft earlywood did not survive the charring process, as was the case, at least, in the experiment we conducted. Determinations and interpretations of seasonal dates of charcoal samples must therefore be treated with some degree of circumspection.

A total of 90 samples were retrieved from the sites of Gruba I, Val Faller Plaz, Gruba III, Alp Natons, Pareis I, Tigignas Sot II and III and Vals (Fig. 7), which, thanks to the extremely robust mean curve (MK 5129) from Gruba I, could be dated. Apart from Tigignas Sot II and III (and Cotschens and Avagna-Ochsenalp; Reitmaier-Naef et al., in press), all sites were located at altitudes of between 1695 m and 2000 m a.s.l.; because of the similarly high altitudes, the samples can be expected to cross-correlate well, both within and beyond the site boundaries.

Although seven waney edges is a very small number, they were distributed throughout almost all sites and yielded strikingly similar dates of between 642 BC and 607 BC, thus covering only the final 35 years of a

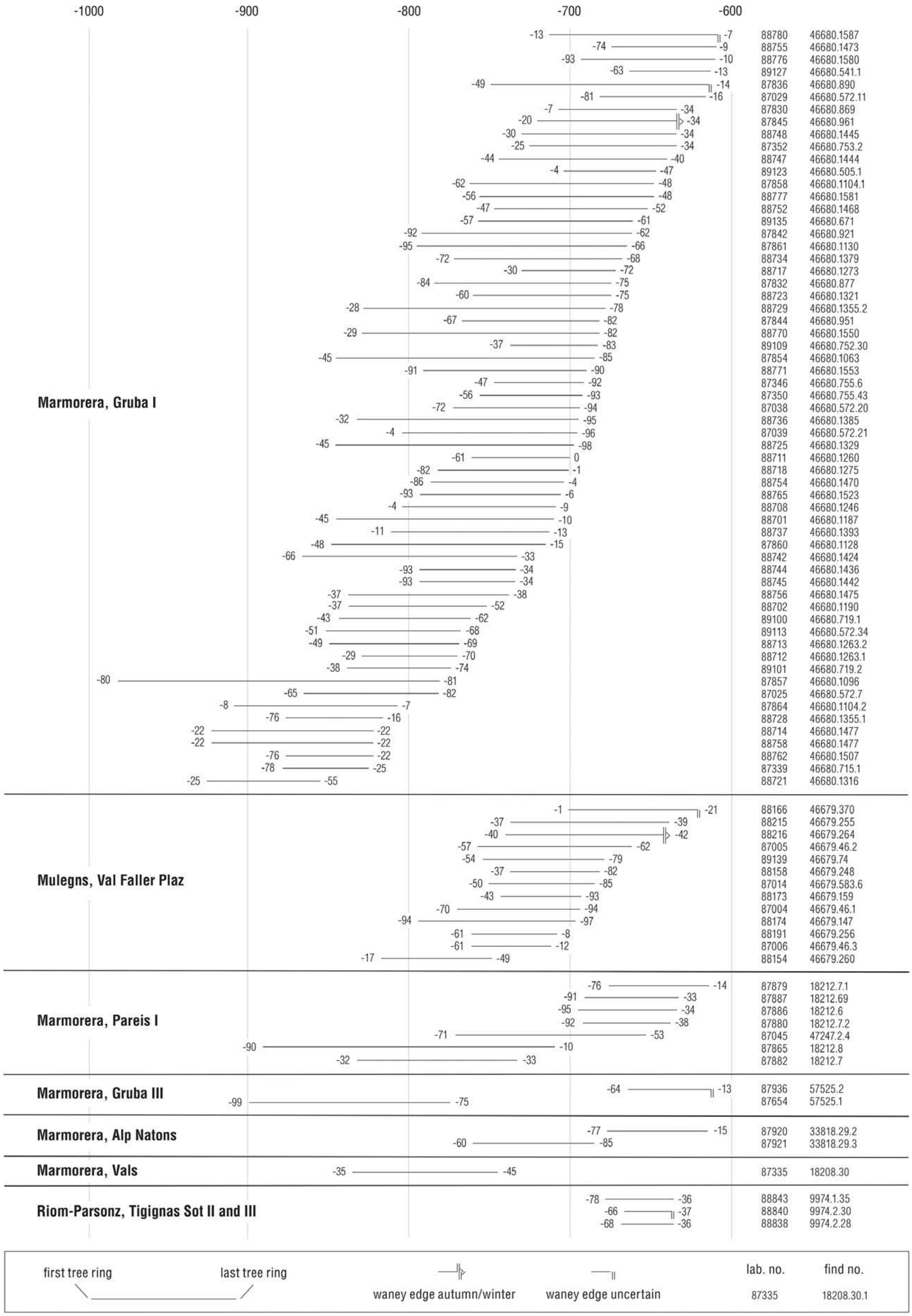

Fig. 7: Bar chart of all samples dating from the Hallstatt period (graphic ADG).

373 year-long mean curve. In the case of Gruba I, which yielded 62 dates in total, the ones with a waney edge were amongst the eight most recent end year dates.

It is as yet unclear whether these end year dates belonged to one or more phases of Gruba I (Turck, 2019). Only if there was a single short phase at Gruba I, all data could be interpreted together, including the end year dates with a waney edge. If that was the case, the entire data set of the series without a waney edge would show how large the range of end year dates can be, thus quantifying the *old-wood effect*. Even if these dates only indicated a *terminus post quem* for the final smelting activity, one might still assume, with the most recent end year being 607 BC, that the local activities took place around the end of the 7th and the first half of the 6th centuries BC.

So far, the data from the other sites with waney edges, i.e. Val Faller Plaz, Gruba III and Tigignas Sot II and III, do not allow such statements, as the number of dated samples is not sufficient. However, based on the most recent end year dates from these sites (Gruba I: 607 BC, Val Faller Plaz: 621 BC, Gruba III: 613 BC, Pareis I: 614 BC), all of which were located quite close to one another and were closely related with regard to their mining contexts, we can postulate a close chronological correlation or perhaps even contemporaneity between them. In case these sites turn out to be multi-phased, at least some of these phases might be synchronous, especially their final phases of use. It is possible, or perhaps even probable, that this also applies to the mining site at Vals, which yielded very little dendrochronologically datable charcoal and only one end year date of 745 BC. We cannot say for certain, but we could be dealing with the *old-wood effect* in this particular case. Tigignas Sot II and III (636 BC) were located at some distance from the other Hallstatt-period sites, which means that the connection to the other sites was based mainly on contextual similarities rather than geographical proximity.

Conclusion

Due to the large number and high quality of samples, dendrochronological analysis has become one of the cornerstones of the project over the past seven years.

Based on the current state of dendrochronological research, we would assume that the Hallstatt period copper mining and production at the sites investigated took place within a short period of time in the late 7th century BC (and/or at the beginning of the 6th century BC). However, this hypothesis rests on only few waney edges and the fact that no younger rings were found. The stratigraphical position has up to now not been taken into account. If the stratigraphical position of some samples should contradict our hypothesis, a critical reappraisal of either the *old wood-effect* or the stratigraphical consistency might become necessary, as taphonomical effects such as bioturbation might also affect the stratigraphical position of charcoal fragments.

We argue that the *old-wood effect* can be minimised by analysing a large number of samples, as shown by the project presented here. The more samples are provided by a site and analysed dendrochronologically, the more restricted the variation of the most recent end year dates becomes – even if there is a lack of dates with a waney edge. Chronologically speaking, it is the sum of all available samples that yields the best possible results.

Gruba I yielded 62 dendrodates (3 with a waney edge; 203 samples in total), Val Faller Plaz provided 13 dendrodates (2 with a waney edge; 96 samples in total). This poor yield is due to the fact that samples with fewer than 50 tree rings have not yet been analysed as part of the project (Gruba I: 56, Val Faller Plaz: 46). Once the relative chronological sequence of the features has been examined and the archaeological context can be used as additional information in the dating process, it will be possible to examine a few more series of samples with less than 50 rings, which may allow us to date the sites with greater precision.

Acknowledgements

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lab. no.	find no.	site	context quality	date	dating quality	waney edge	tree rings	ER no.	site no.	material	wood species	notes	^{14}C and *wiggle-matchings*
MINING SITES													
88581	67457.22.1	Marmorera, Cotschens	sondage (2017)	-67	b		88	67457	1890	wood	*Picea abies/ Larix decidua*	trough; pith	ETH-84250 (tree rings 82-84): 2076±17 BP
88593	18203.1109.3	Marmorera, Cotschens	sondage (2017)	-1137	b		50	18203	1890	charcoal	*Larix decidua/ Picea abies*		*wiggle-matching* with lab. no. 88596; ETH-86920 (tree rings 6-16; values 6-16 of mean curve 5095): 3054±22 BP
88596	18203.1109.6	Marmorera, Cotschens	sondage (2017)	-1131	b		43	18203	1890	charcoal	*Larix decidua/ Picea abies*		*wiggle-matching* with lab. no. 88593; ETH-84251 (tree rings 33-43; values 6-16 of mean curve 5095): 3073±17 BP
88613	56371.303.1	Marmorera, Grubaç II, Pinge 3	excavation (2016-2018)	1489	a		53	56371	1854	charcoal	*Larix decidua/ Picea abies*		
88615	56371.303.3	Marmorera, Gruba II, Pinge 3	excavation (2016-2018)	1494	a		66	56371	1854	charcoal	*Larix decidua/ Picea abies*		
87335	18208.30	Marmorera, Vals	sondage (2014; 2016)	-745	a		91	18208	1885	charcoal	*Larix decidua/ Picea abies*		ETH-58638 (tree rings 1-10): 2660±27 BP; ETH-58639 (tree rings 81-90): 2481±26 BP
87897	18203.1049	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1112	b		68	18203	3911	charcoal	*Picea abies/ Larix decidua*		ETH-86921 (tree rings 57-68): 2973±21 BP
88633	67459.2.5	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1058	a		52	67459	3911	charcoal	*Larix decidua/ Picea abies*		
88635	67459.2.7	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1061	a		36	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88637	67459.2.9	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1067	a		57	67459	3911	charcoal	*Larix decidua/ Picea abies*		
88639	67459.2.11	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1069	a		38	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88644	67459.2.16	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1059	a		61	67459	3911	charcoal	*Larix decidua/ Picea abies*		
88647	67459.2.19	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1079	a		24	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88648	67459.2.20	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1065	a		40	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88653	67459.2.25	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1061	a	autumn/ winter	52	67459	3911	charcoal	*Picea abies/ Larix decidua*	bast remnants	
88655	67459.2.27	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1079	a		25	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88656	67459.2.28	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1078	a		36	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88658	67459.5.1	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1062	a		46	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88659	67459.5.2	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1063	a		44	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88662	67459.5.5	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1075	a		43	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88668	67459.5.11	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1076	a		37	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88671	67459.6.1	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1063	a		59	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88674	67459.6.4	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1081	a		38	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88675	67459.6.5	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1071	a		38	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88676	67459.6.6	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1111	a		76	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88678	67459.6.8	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1105	a		50	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88684	67459.8.2	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1078	a		42	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88687	67459.8.5	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1061	a		47	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88689	67459.9.1	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1061	a		56	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88691	67459.9.3	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1083	a		79	67459	3911	charcoal	*Picea abies/ Larix decidua*		
88692	67459.9.4	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1043	a		63	67459	3911	charcoal	*Larix decidua/ Picea abies*		
88695	67459.9.7	Tinizong-Rona, Avagna-Ochsenalp	sondage (2015; 2017)	-1071	a		32	67459	3911	charcoal	*Picea abies/ Larix decidua*		

lab. no.	find no.	site	context quality	date	dating quality	waney edge	tree rings	ER no.	site no.	material	wood species	notes	^{14}C and *wiggle-matchings*
		SMELTING SITES											
87921	33818.29.3	Marmorera, Alp Natons	excavation (2015)	-685	a		76	33818	1870	charcoal	*Picea abies/ Larix decidua*		
87920	33818.29.2	Marmorera, Alp Natons	excavation (2015)	-615	a		63	33818	1870	charcoal	*Picea abies/ Larix decidua*		
87025	46680.572.7	Marmorera, Gruba I	excavation (2013-2017)	-782	a		84	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87029	46680.572.11	Marmorera, Gruba I	excavation (2013-2017)	-616	a		66	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87038	46680.572.20	Marmorera, Gruba I	excavation (2013-2017)	-694	a		79	46680	1852	charcoal	*Pinus cembra*		
87039	46680.572.21	Marmorera, Gruba I	excavation (2013-2017)	-696	a		109	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87045	47247.2.4	Marmorera, Gruba I	excavation (2013-2017)	-653	a		119	47247	1860	charcoal	*Picea abies/ Larix decidua*		
87339	46680.715.1	Marmorera, Gruba I	excavation (2013-2017)	-825	a		54	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87346	46680.755.6	Marmorera, Gruba I	excavation (2013-2017)	-692	a		56	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87350	46680.755.43	Marmorera, Gruba I	excavation (2013-2017)	-693	a		64	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87352	46680.753.2	Marmorera, Gruba I	excavation (2013-2017)	-634	a		92	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87830	46680.869	Marmorera, Gruba I	excavation (2013-2017)	-634	a		74	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87832	46680.877	Marmorera, Gruba I	excavation (2013-2017)	-675	a		110	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87836	46680.890	Marmorera, Gruba I	excavation (2013-2017)	-614	a	uncertain	136	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87842	46680.921	Marmorera, Gruba I	excavation (2013-2017)	-662	a		131	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87844	46680.951	Marmorera, Gruba I	excavation (2013-2017)	-682	a		86	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87845	46680.961	Marmorera, Gruba I	excavation (2013-2017)	-634	a	autumn/ winter	87	46680	1852	charcoal	*Picea abies/ Larix decidua*	bast remnants	
87854	46680.1063	Marmorera, Gruba I	excavation (2013-2017)	-685	a		161	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87857	46680.1096	Marmorera, Gruba I	excavation (2013-2017)	-781	a		200	46680	1852	charcoal	*Picea abies/ Larix decidua*		ETH-69841: 2907±13 BP
87858	46680.1104.1	Marmorera, Gruba I	excavation (2013-2017)	-648	a		115	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87860	46680.1128	Marmorera, Gruba I	excavation (2013-2017)	-715	a		134	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87861	46680.1130	Marmorera, Gruba I	excavation (2013-2017)	-666	a		130	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87864	46680.1104.2	Marmorera, Gruba I	excavation (2013-2017)	-807	a		102	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87867	46680.1096	Marmorera, Gruba I	excavation (2013-2017)	-841	a		140	46680	1852	charcoal	*Picea abies/ Larix decidua*		
87882	18212.7	Marmorera, Gruba I	excavation (2013-2017)	-733	a		100	18212	1860	charcoal	*Larix decidua/ Picea abies*		
88701	46680.1187	Marmorera, Gruba I	excavation (2013-2017)	-710	a		136	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88702	46680.1190	Marmorera, Gruba I	excavation (2013-2017)	-752	a		86	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88708	46680.1246	Marmorera, Gruba I	excavation (2013-2017)	-709	a		96	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88711	46680.1260	Marmorera, Gruba I	excavation (2013-2017)	-700	a		62	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88712	46680.1263.1	Marmorera, Gruba I	excavation (2013-2017)	-770	a		60	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88713	46680.1263.2	Marmorera, Gruba I	excavation (2013-2017)	-769	a		81	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88714	46680.1477	Marmorera, Gruba I	excavation (2013-2017)	-822	a		101	46680	1852	charcoal	*Larix decidua/ Picea abies*		

lab. no.	find no.	site	context quality	date	dating quality	waney edge	tree rings	ER no.	site no.	material	wood species	notes	^{14}C and *wiggle-matchings*
		SMELTING SITES											
88717	46680.1273	Marmorera, Gruba I	excavation (2013-2017)	-672	a		59	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88718	46680.1275	Marmorera, Gruba I	excavation (2013-2017)	-701	a		82	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88721	46680.1316	Marmorera, Gruba I	excavation (2013-2017)	-855	a		71	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88723	46680.1321	Marmorera, Gruba I	excavation (2013-2017)	-675	a		86	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88725	46680.1329	Marmorera, Gruba I	excavation (2013-2017)	-698	a		148	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88728	46680.1355.1	Marmorera, Gruba I	excavation (2013-2017)	-816	a		61	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88729	46680.1355.2	Marmorera, Gruba I	excavation (2013-2017)	-678	a		151	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88734	46680.1379	Marmorera, Gruba I	excavation (2013-2017)	-668	a		105	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88736	46680.1385	Marmorera, Gruba I	excavation (2013-2017)	-695	a		138	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88737	46680.1393	Marmorera, Gruba I	excavation (2013-2017)	-713	a		99	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88742	46680.1424	Marmorera, Gruba I	excavation (2013-2017)	-733	a		134	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88744	46680.1436	Marmorera, Gruba I	excavation (2013-2017)	-734	a		60	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88745	46680.1442	Marmorera, Gruba I	excavation (2013-2017)	-734	a		60	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88747	46680.1444	Marmorera, Gruba I	excavation (2013-2017)	-640	a		105	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88748	46680.1445	Marmorera, Gruba I	excavation (2013-2017)	-634	a		97	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88752	46680.1468	Marmorera, Gruba I	excavation (2013-2017)	-652	a		96	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88754	46680.1470	Marmorera, Gruba I	excavation (2013-2017)	-704	a		83	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88755	46680.1473	Marmorera, Gruba I	excavation (2013-2017)	-609	a		66	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88756	46680.1475	Marmorera, Gruba I	excavation (2013-2017)	-738	a		100	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88758	46680.1477	Marmorera, Gruba I	excavation (2013-2017)	-822	a		101	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88762	46680.1507	Marmorera, Gruba I	excavation (2013-2017)	-822	a		55	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88765	46680.1523	Marmorera, Gruba I	excavation (2013-2017)	-706	a		88	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88770	46680.1550	Marmorera, Gruba I	excavation (2013-2017)	-682	a		148	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88771	46680.1553	Marmorera, Gruba I	excavation (2013-2017)	-690	a		102	46680	1852	charcoal	*Larix decidua/ Picea abies*		
88776	46680.1580	Marmorera, Gruba I	excavation (2013-2017)	-610	a		84	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88777	46680.1581	Marmorera, Gruba I	excavation (2013-2017)	-648	a		109	46680	1852	charcoal	*Picea abies/ Larix decidua*		
88780	46680.1587	Marmorera, Gruba I	excavation (2013-2017)	-607	a	uncertain	107	46680	1852	charcoal	*Picea abies/ Larix decidua*		
89100	46680.719.1	Marmorera, Gruba I	excavation (2013-2017)	-762	a		82	46680	1852	charcoal	*Larix decidua/ Picea abies*		
89101	46680.719.2	Marmorera, Gruba I	excavation (2013-2017)	-774	a		65	46680	1852	charcoal	*Pinus cembra*		
89109	46680.752.30	Marmorera, Gruba I	excavation (2013-2017)	-683	a		55	46680	1852	charcoal	*Larix decidua/ Picea abies*		
89113	46680.572.34	Marmorera, Gruba I	excavation (2013-2017)	-768	a		84	46680	1852	charcoal	*Picea abies/ Larix decidua*		
89123	46680.505.1	Marmorera, Gruba I	excavation (2013-2017)	-647	a		58	46680	1852	charcoal	*Picea abies/ Larix decidua*		

lab. no.	find no.	site	context quality	date	dating quality	waney edge	tree rings	ER no.	site no.	material	wood species	notes	^{14}C and *wiggle-matchings*
		SMELTING SITES											
89127	46680.541.1	Marmorera, Gruba I	excavation (2013-2017)	-613	a		51	46680	1852	charcoal	*Picea abies/ Larix decidua*		
89135	46680.671	Marmorera, Gruba I	excavation (2013-2017)	-661	a		97	46680	1852	charcoal	*Larix decidua/ Picea abies*		
87654	57525.1	Marmorera, Gruba III	survey (2016)	-775	a		125	57525	56328	charcoal	indet.	sample missing	
87936	57525.2	Marmorera, Gruba III	survey (2016)	-613	a	uncertain	52	57525	56328	charcoal	*Picea abies/ Larix decidua*		ETH-69844: 2499±15 BP
87865	18212.8	Marmorera, Pareis I	sondage (2014-15; 2017)	-710	a		181	18212	1860	wood	*Larix decidua/ Picea abies*	toolmarks	
87879	18212.7.1	Marmorera, Pareis I	sondage (2014-15; 2017)	-614	a		63	18212	1860	charcoal	*Picea abies/ Larix decidua*		
87880	18212.7.2	Marmorera, Pareis I	sondage (2014-15; 2017)	-638	a		55	18212	1860	charcoal	*Picea abies/ Larix decidua*		
87886	18212.6	Marmorera, Pareis I	sondage (2014-15; 2017)	-634	a		62	18212	1860	charcoal	*Picea abies/ Larix decidua*		
87887	18212.69	Marmorera, Pareis I	sondage (2014-15; 2017)	-633	a		59	18212	1860	charcoal	*Larix decidua/ Picea abies*		
87903	18191.25.1	Marmorera, Scalotta I	sondage (2014)	393	a		83	18191	1842	charcoal	*Picea abies/ Larix decidua*		ETH-85520 (tree rings 1-10): 1775±24 BP; ETH-75698 (tree rings 70-80): 1780±22 BP
87912	18191.25.15	Marmorera, Scalotta I	sondage (2014)	392	a		57	18191	1842	charcoal	*Picea abies/ Larix decidua*		
87004	46679.46.1	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-694	a		77	46679	2120	charcoal	*Larix decidua/ Picea abies*		
87005	46679.46.2	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-662	a		96	46679	2120	charcoal	*Larix decidua/ Picea abies*		
87006	46679.46.3	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-712	a		50	46679	2120	charcoal	*Larix decidua/ Picea abies*		
87014	46679.583.6	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-685	a		66	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88154	46679.260	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-749	a		69	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88158	46679.248	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-682	a		56	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88166	46679.370	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-621	a	uncertain	81	46679	2120	charcoal	*Picea abies/ Larix decidua*	bast remnants	
88173	46679.159	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-693	a		51	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88174	46679.147	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-697	a		98	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88191	46679.256	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-708	a		54	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88215	46679.255	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-639	a		99	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88216	46679.264	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-642	a	autumn/ winter	99	46679	2120	charcoal	*Larix decidua/ Picea abies*		
89139	46679.74	Mulegns, Val Faller Plaz	excavation (2013; 2016)	-679	a		76	46679	2120	charcoal	*Larix decidua/ Picea abies*		
88843	9974.1.35	Riom-Parsonz, Tigignas Sot II	survey (2006)	-636	b		43	9974	56325	charcoal	*Picea abies/ Larix decidua*		ETH-86922 (tree rings 31-43): 2528±22 BP
88838	9974.2.28	Riom-Parsonz, Tigignas Sot III	survey (2006)	-636	b	uncertain	33	9974	64189	charcoal	*Picea abies/ Larix decidua*		
88840	9974.2.30	Riom-Parsonz, Tigignas Sot III	survey (2006)	-637	b		30	9974	64189	charcoal	*Larix decidua/ Picea abies*		ETH-86923 (tree rings 21-30): 2477±21 BP

Tab. 2: All dated samples from the Oberhalbstein Valley project (graphic ADG).

Notes

1 This article uses the historical time scale, where the year "0" does not exist.

2 Due to insufficient correlation values with local references, *wiggle-matching* samples were taken from sample no. 87903. They resulted in a 2 sigma range of 295-325 cal. AD (plus 3 annual rings) for the more recent tree rings (for raw data cf. Tab. 2). Only then did Kurt Nicolussi check the dendrochronological analysis and achieve a dating on the EACC reference to the end year 393 – which meant that the deviation from the 2 sigma range was several decades. Contamination in the radiocarbon laboratory could be ruled out as a possible cause. Similar deviations for the 4th century AD have recently been observed elsewhere, which suggests that the cause may lie in the course of the calibration curve itself. Cf. Friedrich et al., 2019.

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