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Prehistoric copper pyrotechnology in the south-eastern Swiss Alps : an overview on previous and current research

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Introduction

Since 2013 new archaeological studies undertaken by the Dept. of Prehistoric Archaeology at the University of Zurich have revisited previous research carried out since the 1970s in the Oberhalbstein region (Canton Grisons, Switzerland). The aim is to add an important area to the existing information regarding the production and use of Alpine copper during the Bronze and Iron Ages. South-eastern Switzerland is a key area because the existing information on prehistoric copper mining is still rather limited compared to Austria and northern Italy where corresponding projects have been ongoing for several decades. Hardly any traces of prehistoric mining and smelting structures have been recorded in detail, and prominent hypotheses – such as those regarding the origins of Early Bronze Age finished products discovered at the cemetery in Singen (D), or numerous bronze artefacts dating from the 2nd and 1st millennia BC from the Swiss Plateau and from central and southern Alpine areas - still remain unconfirmed.

The state of research in south-eastern Switzerland

The Oberhalbstein Valley was already an important north-south link in prehistoric times. Human activity and its impact on the vegetation is attested to in the neighbouring valleys from as far back as the Stone Age (Gobet *et al.* 2004). Most of the settlements discovered in the Oberhalbstein itself date from the Bronze Age and are located in the region around present-day Savognin (Nauli 1977 ; Wyss 1977 ; 1982 ; Rageth 1986). These sites appear to have been occupied all year round. They are located at elevations of between 1200 (Savognin-Padnal) and 1400 masl (Salouf-Motta Vallac) ; the slag heaps are situated at 1150 (Salouf-Gneida), at 1600 (Stierva) and up to just above 2000 masl (Bivio-Tgesa, Brüscheda) depending on the valley step they are found on ; the (undated) gallery at Cotschens is even located as high as 2300 masl. One would generally assume that most of the work on higher elevations was carried out during the summer months with some tasks being performed in the settlements over longer spells or even all year round.

South-eastern Switzerland as an historical and prehistoric mining region has been discussed on several occasions (e.g. Annaheim 1986 ; Brun 1988 ; Schreiber 2004). Yet only a few systematic investigations have been conducted to date in the Oberhalbstein (for a short summary see Krause 2011). Up to the 1980s the remains of some 40 prehistoric sites (fig. 1) were interpreted as iron smelting sites (Zindel 1977). It was not until 1984 that a re-evaluation of the slags led researchers to conclude that local chalcopyrite ores had been processed in order to produce copper (Geiger 1984 ; 1988). From an archaeological point of view, extractive metallurgy in the area is mainly attested to by numerous slag heaps (Brun 1988 ; Schaer 2003). The most recent, albeit still preliminary studies on archaeological slag deposits (Wyss 1993 ; Schaer 2003) and scientific slag analyses (Fasnacht 1999) were carried out in the 1990s. The state of research was last summarised more than ten years ago (Schaer 2003 ; Fasnacht 2004 ; Wyss 2004). One slag heap, excavated in the 1970s by the Deutsches Bergbau-Museum Bochum and dated to the latter stages of the Bronze Age, was recently published by Leandra Naef (2013).

European context

Mining research in the Alpine region has a continuous decades-old tradition, mainly in Austria (most recently : HiMAT research project ; generally : Goldenberg *et al.* 2012 ; Lower Inn Valley : Grutsch and Martinek 2012 ; Töchterle *et al.* 2012 ; Goldenberg 2013 ; Styria : Kraus *et al.* 2011 ; Mitterberg: Stöllner *et al.* 2012) and in the Trentino-Alto Adige (Metten 2003 ; Cierny *et al.* 2004a ; Cierny *et al.* 2004b ; Hohlmann

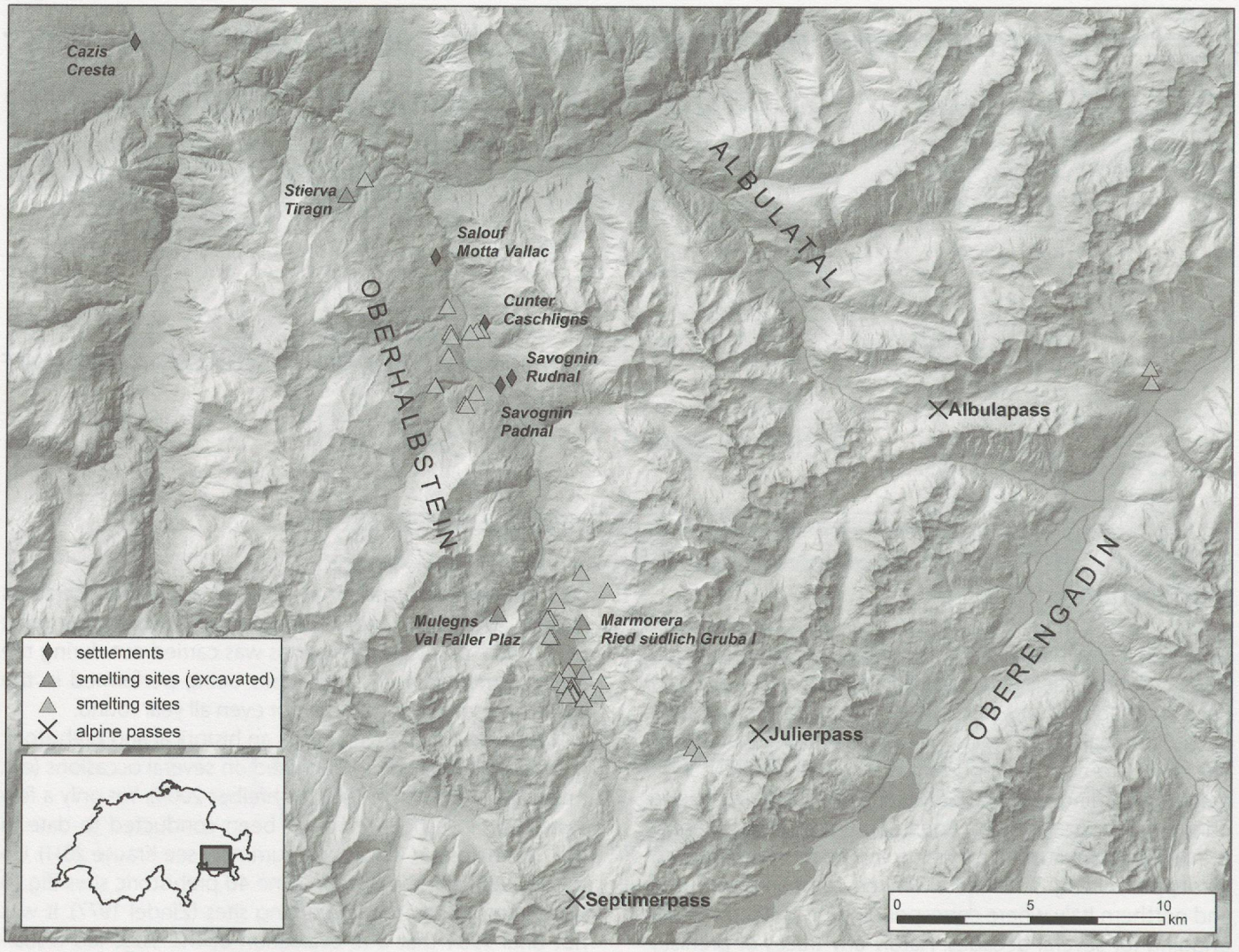


Fig. 1. Slag heaps and settlements in the Oberhalbstein GR (L. Naef ADG/UZH).

et al. 2004 ; Cierny 2008). Significant progress has been made in the exploration and investigation of mining archaeological features on one hand (pits, galleries, extraction sites; ore processing sites; smelting sites) and in the analysis of ores, slag and metal products and study of smelting technologies on the other. The main task consists of the exploration of the technological link between copper deposits, slags and finished products. Knowledge such as this is indispensable when it comes to understanding technological developments, i.e. the exploitation of different ores throughout the course of the Bronze and Iron Ages. This in turn will form the basis upon which the distribution systems of finished products and the associated systems of communication and exchange can be identified. The Oberhalbstein Valley had an important key position within a European context, albeit for the time being by acting as a «missing link» in the central Alps because of the comparatively limited state of knowledge. The origins of numerous Bronze Age finished products from areas both north and south of the valley (Lake Constance, Swiss Plateau, southern Alpine region) have not yet been linked conclusively with any of the known deposits (e.g. Christoforidis *et al.* 1988 ; Krause 1988 ; Rychner and Kläntschi 1995 ; Rychner 2004).

Moreover, the debate on the social and cultural developments in the form of structural inequality, which came into being in the Late Neolithic (Cevey *et al.* 2006 ; Turck 2010) and intensified in the Early Bronze Age, is dominated by unanswered questions with regard to the origins and exchange of copper-based artefacts and, more generally, the access to copper (deposits). Examples of this are the Early Bronze Age flanged axes from Salez (SG) and the bronze artefacts from the wider area around Singen/Hegau (D) (Krause 1988 ; 2003 ; 2011 ; Kienlin 2006a; 2006b ; Kienlin and Stöllner 2009).

The Oberhalbstein (Canton Grisons) production area

Thanks to numerous known slag sites (fig. 1) the Oberhalbstein Valley can justifiably be called a «production area». Besides slag the sites regularly yielded significant amounts

of charcoal and fragments of technical ceramics (i.e. tuyère fragments). All the finds can be associated with copper smelting.

The smelting sites are situated in a settlement landscape that has only partially been studied and evaluated. Copper processing within settlement contexts is attested to by the following finds : Savognin-Padnal has yielded numerous finds associated with metalworking (summarised by Rageth 1986; see below) ; a copper matte fragment was recovered from Savognin-Rudnal (Wyss 1993) ; the finds from Cunter-Caschlings included two winged axes, a knife, a mould for a winged axe and a grooved hammerstone (Nauli 1977) ; from Salouf-Motta Vallac several bronze artefacts including daggers, pins, wires, rings, etc. as well as plate slag fragments were published (Wyss 1977 ; 1982) ; the settlement of Cazis-Cresta in the Hinterrhein Valley immediately to the north also yielded grooved hammerstones, a stone slab with a mortar, remnants of metal cake, slags as well as casting moulds (Wyss 1993 ; 2002) and can perhaps be associated with the processing of raw materials from the Oberhalbstein area.

Radiocarbon dates of settlement finds and slag dumps are few, yet they confirm the existence of unspecified mining and smelting activities from the late Middle Bronze Age to the latter stages of the Iron Age (Wyss 1993 ; Schaer 2003 ; Naef 2013). Most of the known slag heaps as well as the few potentially prehistoric mining sites such as «Vals» (Brun 1988) and «Cotschens» (Brun 1988 ; Schaer 2003) have not yet yielded any datable evidence. The slag heap at Stierva can tentatively be dated to the period between the 11th and 9th centuries BC (Naef 2013) and, based on radiocarbon dates, the site of «Plaz» in the Val Faller falls into the Hallstatt plateau, thus dating from considerably later (most recently Naef 2013).

On the basis the archaeological finds and a series of radiocarbon dates the settlements in the Oberhalbstein Valley can be associated with the Early to Late Bronze Age (Nauli 1977 ; Wyss 1977 ; 1982 ; Rageth 1986). No settlement remains clearly dating from the Iron Age have so far been found in the region. Therefore, the link between copper processing in the settlements and local ore smelting has not yet been satisfactorily established.

There is, however, a clear basis upon which to successfully carry out mining archaeological investigations with the aim of reconstructing the metallurgical chaîne opératoire and its relationship to the settlements.

Local ores

Local ores mainly consist of chalcopyrites with partially elevated nickel contents, so-called «Kupferkies» ($CuFeS_2$). Three subgroups can be distinguished (Dietrich 1972 ; Nievergelt 2001). They are related to the ophiolithic rock series (i.e. serpentinites) and have passed through a different petrogenesis compared to the main ore types of, for instance, the Mitterberg or Schwaz/Brixlegg districts in Austria (see Grutsch and Martinek 2012). This leads us to conclude that it should be possible to clearly distinguish between the Oberhalbstein ores and those from other regions when combining trace element analyses and lead isotope patterns. Some of the smaller deposits in the Oberhalbstein area are located particularly close to the surface. Several mining structures in chalcopyrite deposits near prehistoric smelting sites are known from the Gruba area (near Alp Flix) and from the region of Cotschens and Lake Marmorera, as well as from lower parts of the valley such as the Tinzener Ochsenalp (Dietrich 1972 ; Brun 1988 ; Schaer 2003). These offer a promising setting for a comprehensive study on mining and smelting.

We may assume that the near-surface copper ore deposits mentioned were, indeed, exploited. Activities such as these are, however, difficult to prove. Promising sites, e.g. «Gruba» were destroyed in the early modern period by large-scale mining operations (Brun 1988). The galleries in «Vals» and «Cotschens» west and north-west of the Marmorera water reservoir, on the other hand, became accessible once again in the summer of 2013. We plan to carry out systematic investigations from 2014 onwards.

Slag heaps

The slags from the known slag heaps in the Oberhalbstein area have been roughly categorised by the archaeologist Andrea Schaer (Schaer 2003). Based on surface finds, she defined her slag types according to morphological criteria (colour, composition, inclusions, blistering), but initially without carrying out any systematic mineralogical analyses. Different ranges of types could be identified for each site and area of the valley (lower valley step : Tiefencastel to Savognin ; upper valley step : Marmorera reservoir, Mulegns to Bivio). The reasons for these differences, which may have been caused by the raw material, the smelting techniques used or even the chronological differences between the sites, remain as yet undetermined. A more detailed study of the situation using extensive analyses (geochemical, mineralogical) is pending.

Settlements

Local settlements played a key role in the context of Alpine copper mining and processing (fig. 1). The only settlement that has so far yielded preliminary results of slag and copper analyses is Savognin-Padnal (Rageth 1986 ; Fasnacht 1991 ; 1999 ; Kruse 2010). While the finds (slag, casting drips, crucibles, moulds) clearly attest to the processing of copper, which was eventually cast into finished products, certain important indicators such as raw copper or casting cakes are absent. Moreover, the analyses show that, besides a number of slags that are certainly consistent with the chalcopyritic ores of the Oberhalbstein region, other types of copper such as a type commonly processed on the Swiss Plateau, and non-local copper from ores of the fahlerz type were also processed. No data are available from the other settlements.

It is imperative that the appropriate analyses be carried out in the near future.

While it is possible to prove a link between the settlement at Padnal and the smelting sites based on the slag found within the settlement, the connection between the local copper production and the bronze artefacts produced in the settlement - given the data currently available - cannot yet been established.

In search of the «*chaîne opératoire*»

When attempting to reconstruct a complete metallurgical *chaîne opératoire*, the following components are required : evidence of mining and ore extraction, ore processing sites (e.g. washing plants), smelting sites with roast beds, smelting furnaces and slag heaps, and finally metalworking sites used for casting and smithing (moulds, crucibles and waste including casting drips, half-finished objects and perhaps even finished copper or bronze products).

So far, throughout the entire Oberhalbstein Valley there is a lack of firmly dated ore extraction sites and also of processing sites or roast beds, which are regularly found in the mining regions of the southern and eastern Alps (Goldenberg *et al.* 2012 ; Goldenberg 2013 ; Cierny 2008). Therefore, the archaeological record in the different mining landscapes is highly diverse. Despite the proximity of ores, smelting sites and settlements, it is not currently possible to reconstruct a complete chaîne opératoire in the Oberhalbstein. This remains one of the key research questions to be tackled by the planned research projects.

Slags and furnaces : the initial results of the current research

In collaboration with the Archaeological Service of Canton Grisons, the Department of Prehistoric Archaeology at the University of Zurich has been carrying out systematic investigations in the Oberhalbstein Valley since 2013 with the aim of studying mining and metal processing in the area. The project is being supported by colleagues from the Institute of Archaeologies at the University of Innsbruck and from the Deutsches Bergbau-Museum Bochum, who have been actively studying prehistoric mining in the eastern Alps for several years.

During the first fieldwork phase in the summer of 2013 two promising sites were investigated by means of test excavations. One of the sites, Marmorera «Ried south of Gruba I» will briefly be described here:

Thanks to a slag heap which is visible on the surface, the smelting site has been known for several decades. Some fragments of slag were gathered up in the past and chemically analysed (Geiger 1988 ; Fasnacht 1999). No firm indication pointing to the date of the feature has yet been unearthed. A stone protrudes from the ground a few metres from the slag heap. Probably due to the impact of heat the stone bears red discolouration and chipping. Researchers have always been of the opinion that it could potentially be the remains of a smelting furnace. Just before the excavation was due to commence, Gert Goldenberg from the Institute of Archaeologies at the University of Innsbruck carried out a geomagnetic survey of the area, which clearly showed up the slag heap as an anomaly, whilst the potential furnace was not visible in the magnetic readings.

In order to identify the size and thickness of the slag heap and to recover slags as well as charcoal from inside the feature, which could provide absolute dates, two trenches were dug ; one measured 3 x 1.5 m and was located in the eastern area of the slag heap while the other measured 2 x 1.5 m and was located on the southern edge of the anomaly (figs. 2 and 3). The slag heap consisted of several layers of plate slag in various states of fragmentation and of slag cakes, with a compact layer of charcoal forming the bottom of the feature. The maximum thickness of the slag heap was 60 cm. Some of the charcoal fragments of Swiss pine and larch wood bore a sufficient number of growth rings to warrant dendrochronological dating. Moreover, several fragments of tuyères were also found.

Another test trench measuring 2.5 x 2 m at a distance of more than 3 metres from the slag heap revealed the first prehistoric smelting furnace to be found in the Oberhalbstein area (figs. 4 and 5). The stone mentioned above could be identified as the back wall of the furnace which had been dug vertically into the ground. The side walls of the

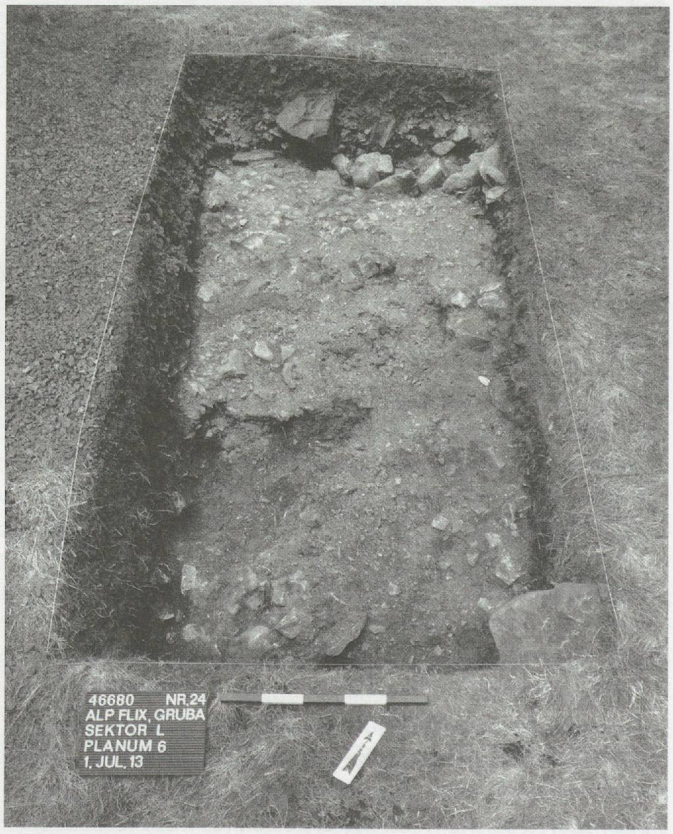


Fig. 2. Slag heap «Ried südlich Gruba I» (Marmorera GR), overview (photo UZH).

Fig. 3. Slag heap layers, section (photo UZH).

Fig. 4. Furnace «Ried südlich Gruba I» (Marmorera GR), overview (photo UZH).

furnace consisted of two or three extant layers of stone built up against the stone slab at right angles. The front of the furnace had probably been destroyed immediately after its final use. The kiln was dug into a pit measuring 50-60 cm in depth. A number of slag fragments, flakes of charcoal and some burnt stones were found inside the furnace. No clearly vitrified or slagged objects have yet been found. A grey matter with small flecks of charcoal and slag was worked into the gap between the side and back walls suggesting that it was intended either to seal or to repair the furnace.

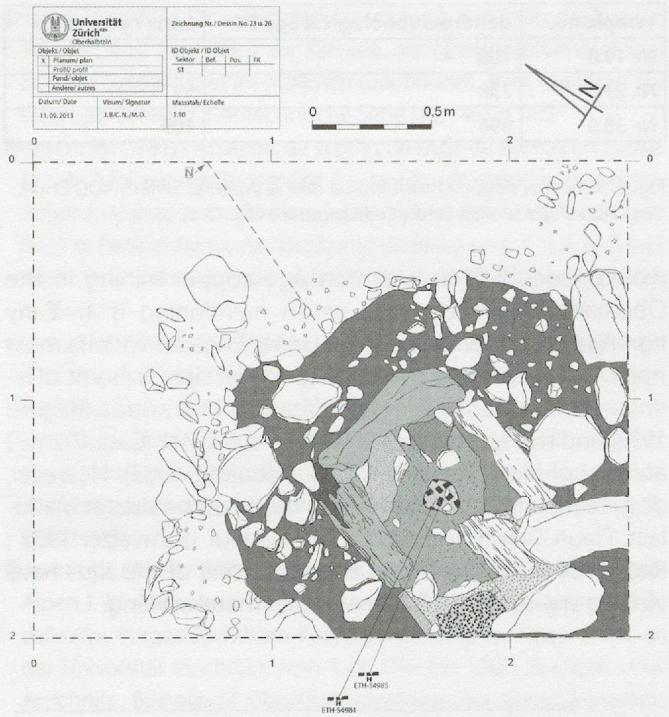


Fig. 5. Furnace «Ried südlich Gruba I», charcoal for AMS dating (J. Bucher UZH).

Several small clusters of tuyère fragments were found in the pit around the furnace and just below the topsoil.

Dendrochronological dating of three charcoal fragments from inside the slag heap date its formation to the first half of the 7th century BC (fig. 6). Unfortunately, it was not possible to carry out dendrochronological analyses on the charcoal fragments from inside the furnace due to their poor state of preservation. Radiocarbon dating of two small charcoal fragments from the furnace resulted in a date which was some 100-200 years earlier (fig. 7). In view of the Hallstatt plateau and the associated analytical pitfalls as well as a potential "old wood" problem inherent in the wood used, we may still assume that the furnace and slag heap were probably relatively contemporaneous despite these chronological discrepancies.

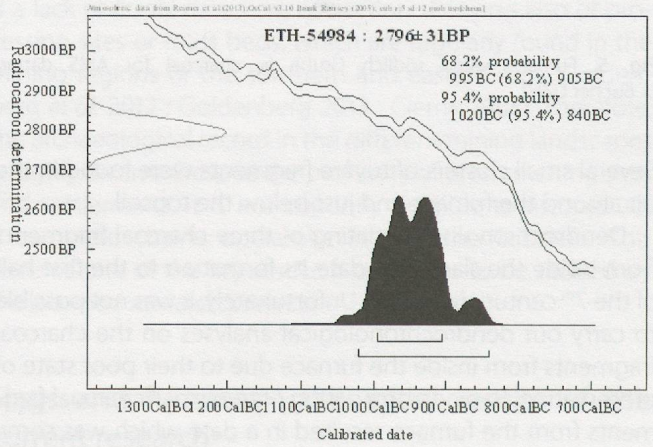
In the case of the Iron Age smelting sites there is a remarkable lack of contemporary settlements in the Oberhalbstein region. Whether this was due to the reduction of the settlement sizes noticeable from the Late Bronze Age onwards (Primas 2009), to the relocation of the settlements or perhaps to the preservation conditions remains entirely unknown.

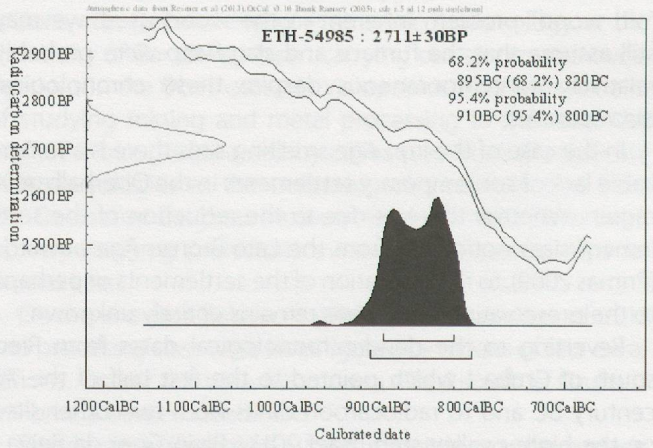
Reverting to the dendrochronological dates from Ried south of Gruba I which pointed to the first half of the 7th century BC and to radiocarbon dates from two other sites on the higher valley step (Naef 2013 : Bivio-Guet da Beiva : Mulegns-Val Faller, Plaz), we may draw comparisons with Early Iron Age sites to the north and south of the Oberhalbstein Valley. They include the cemetery at Tamins (Conradin 1978 ; Schmid-Sikimić 2002) which was first used in the 7th century BC. Schmid-Sikimić (2002) equated its earliest phase of use (phase Tamins I) with the latter stages of Ha C, which

sample no.	dendrochronological age BC	Larix / year rings
Nr. 19.0	700	47
Nr. 23.0	738	53
Nr. 38.0	696	109

Fig. 6. Results of dendrochronological dating (Mathias Seifert, ADG Chur) : slag heap «Ried südlich Gruba I» (Marmorera GR).

would, indeed, fit in with Iron Age copper mining in the Oberhalbstein region. Also worth mentioning is an Early Iron Age settlement area in the Lower Engadin with its most notable sites being a potential sacrificial site for burnt offerings at Scuol Russonch, used from Ha D onwards (Rageth 1998) and the settlements at Ardez-Suotchastè (Caduff 2007) and Scuol-Munt Baselgia (Staufer-Isenring 1983). However, despite their relative proximity to the smelting sites at Madulain, Plaun Grand and Alp Es-cha Dadour (Schweizer 1982 ; Rageth 2005) in the Upper Engadin, none of the sites have yielded any evidence for smelting or metalworking.





ETH	sample code	material	^{14}C age	1σ BP	δC13 ±1σ ‰	Mg C	C/N
ETH-54984	46680_51_612	charcoal	2796	31	-24,3	0,99	346,69
ETH-54985	46680_51_634	charcoal	2711	30	-24,6	1,00	477,69

Fig. 7. Results of AMS 14C analysis (ETH Zurich): furnace «Ried südlich Gruba I» (Marmorera GR).

Strategies and perspectives

While not yet studied in detail, the evidence for mining and copper processing in the Oberhalbstein area bears great potential and several questions may be answered by exploring it more closely. These questions may be summarised as follows :

- The basis upon which absolute and relative dates can be derived for the sites – both the settlements and smelting sites – is still insufficient. It will be necessary to establish further absolute dates and to analyse the archaeological material from the Bronze Age sites in greater detail.
- Based on mineralogical and geochemical analyses of the slags from the smelting sites and settlements, it is planned to carry out a regional distribution analysis (composition/dating), thus assessing the technological and archaeological position of copper exploitation in the Oberhalbstein Valley within the region and beyond.
- Moreover, further comprehensive ore analyses must be carried out in order to clarify the details of the chaîne opératoire of local ore extraction and smelting.
- Besides the known slag heaps and the furnace in Ried south of Gruba I, we hope to localise additional features of the *chaîne opératoire* by mounting further excavations ; there is still a lack, for instance, of processing sites and roast beds.
- The chronological framework of metal extraction in the valley must also be seen in the context of the chaîne opératoire and the socio-archaeological research questions : what is the connection between the Bronze Age smelting sites and settlements ? How must we interpret the Iron Age copper mining in the valley ? It will be indispensable to extend the mining archaeological research to encompass Iron Age sites and features.

All these questions can only be investigated by carrying out comprehensive fieldwork. In the coming years we plan to undertake targeted surveys and geomagnetic prospection, to dig test trenches and to mount excavations at various promising sites. The close collaboration with mining archaeologists, metallurgists, mineralogists and geoscientists will be continued and intensified. Both valley steps in the Oberhalbstein will be systematically investigated in order to unearth ores, smelting and processing sites as well as settlement activity. It is conceivable that the study area will be extended in the near future to include the region around Avers and the Upper Engadin, which, besides the already known slag finds from Madulain, have yielded numerous new reports of finds in recent years.

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