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PALAEOENVIRONMENTAL RECONSTRUCTION IN THE MINING TOWN OF FREIBERG (LKR. MITTELSACHSEN) IN SAXONY, FROM THE 12TH CENTURY ONWARDS

The town of Freiberg (Lkr. Mittelsachsen) in Saxony is a key site for the history of settlement and mining technology in Medieval Europe. From the first discovery of silver ore in the second half of the 12th century to the mid-20th century, the mining district of Freiberg (*Freiberger Zentralrevier*) was one of the most productive sources of silver in Europe (Wagenbreth/Wächtler 1988; Schwabenicky 2003; 2009). A rural village (*Christiansdorf*) was founded in this southern lower range of the *Erzgebirge* (Ore Mountains), probably near the Münzbach river, around 1156-1162 fostered by the colonisation policy in the margraviate of Meißen. Relying on written sources (Hoffmann/Richter 2012), the discovery of the first silver around 1168 and, subsequently, the granting of mining and city privileges led to a rapid growth of the settlement, beginning with the area for miners (*Sächsstadt/civitas Saxorum*), followed by the formation of separate quarters around the Nikolai church and around the castle of the margrave (*Burglehn*), and an expansion in the upper part of the city area (*Oberstadt*) by the end of the 12th century (Richter 2013). Since then, intensive mining and building activities have changed the area dramatically in many ways, including extensive levelling with landfill and mining waste or the canalisation of the Münzbach river. Additionally, the need for timber and the cultivation of food crops must have had a strong impact on the nearby environment.
Especially since 1990, research on historical buildings together with archaeological excavations have produced a broad and diverse dataset that includes sediment cores, dendrochronological analyses, macrobotanical spectra, geochemical analyses and archaeological data. By combining this dataset with multi-proxy analyses of two additional sediment cores from the buried central alluvial plain of the Münzbach valley we are able to reconstruct the palaeoenvironmental changes since the first settlement phase.

METHODS AND MATERIAL

Topography and sampling sites

Demarcated by a city wall built before 1233, the settlement area of Freiberg is situated on a ridge east of the former river Saubach or Goldbach (the later pond system *Kreuzteiche*) and on both sites of the Münzbach valley, a tributary of the *Freiberger Mulde* (**fig. 1**). Still visible as a canalised course on maps from 1837, the Münzbach river today is running through a pipe underground and the valley within the city boundaries has mostly been levelled with landfill (**fig. 2**). It is assumed that the initial rural settlement preceding the city was founded along the western bank of the Münzbach river in the mid-12th century and that the intersection between the river valley and one of the main ore veins (*Hauptstolln Stehender*) may have been the starting point for mining activities at the latest in 1168 contemporary with the development of the miner's district (*Sächsstadt/civitas Saxorum*) on the eastern bank of the Münzbach valley (Wagenbreth 1970; Wagenbreth/Wächtler 1988). Archaeological evidence reveals that during the late 12th century the settle-

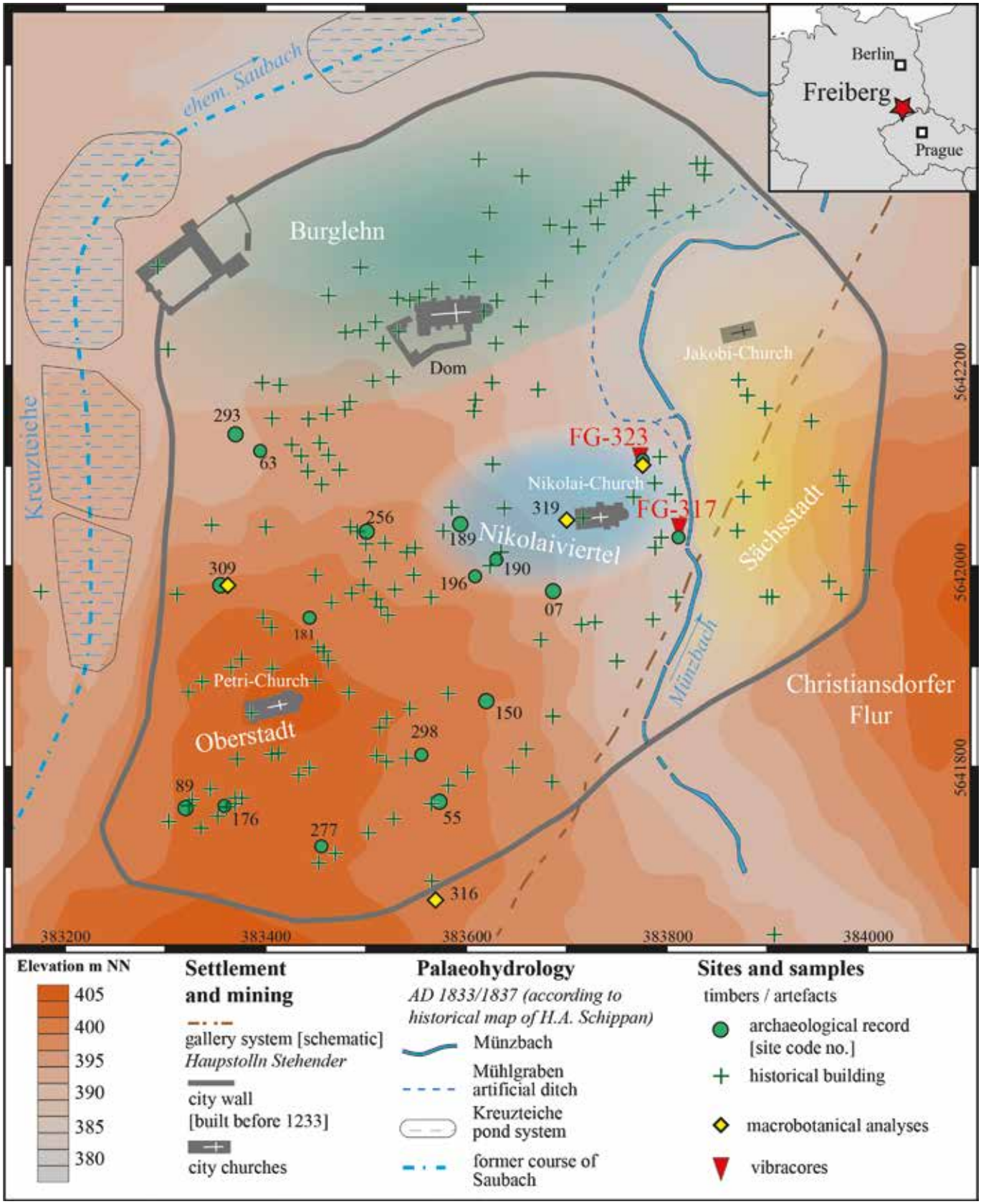

Fig. 1 Topographical map of Freiberg (Lkr. Mittelsachsen) with palaeohydrological features and the location of samples and sites included in this study. – (Illustration J. F. Tolksdorf).

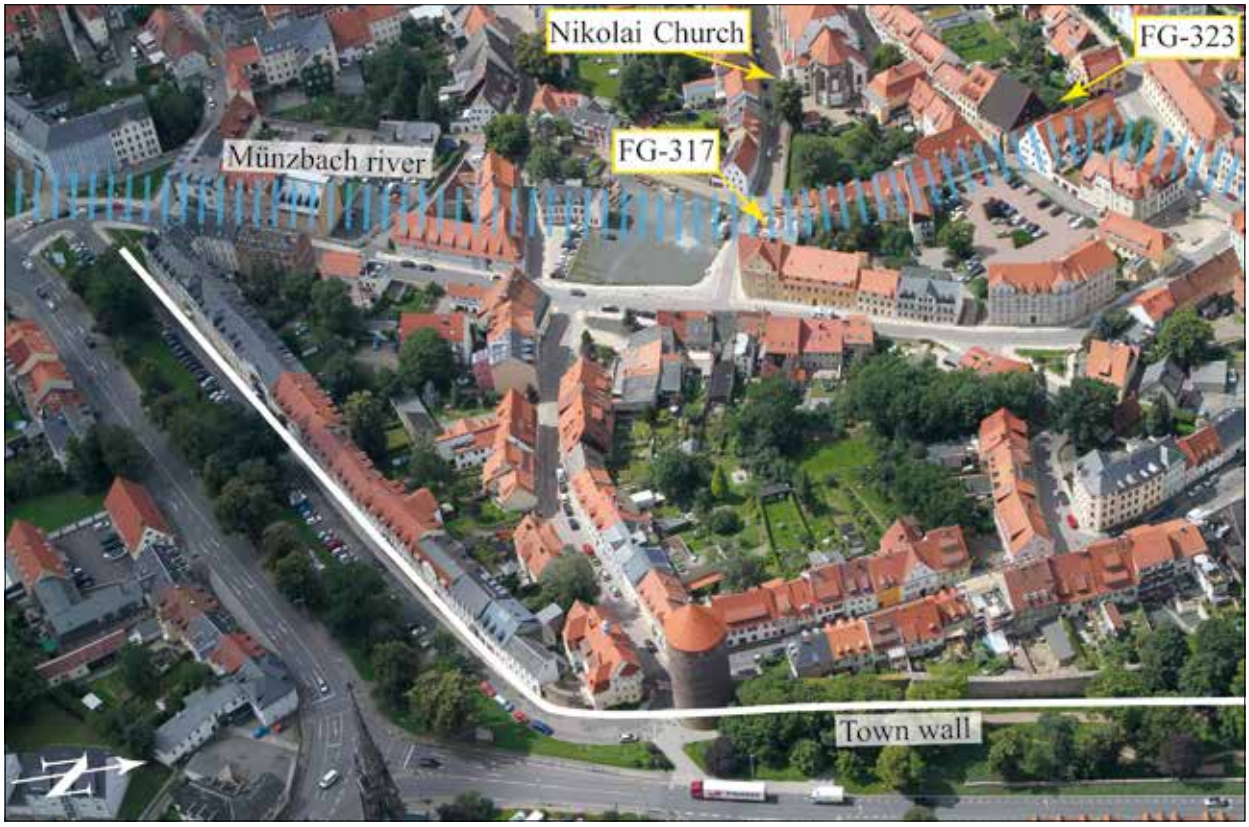

Fig. 2 Freiberg (Lkr. Mittelsachsen). Aerial view on the levelled and channelled Münzbach valley. – (Photo R. Heynowski, Landesamt für Archäologie Sachsen; illustration J. F. Tolksdorf).

ment had developed rapidly on the western bank of the Münzbach valley around the Nikolai church on the eastern slope, near the castle in the north and on the mountain ridge in the southwest (Hoffmann/Richter 2012).

The sediment cores used for sedimentological, geochemical and palynological samples have been taken on the western side of the Münzbach valley within the excavation sites FG-317 and FG-323 in the former alluvial plain of the Münzbach area. They are supplemented by six macrobotanical spectra from four different excavations (**fig. 3**). Two cesspits and a burnt refuse layer have been unearthed in the western part of the city at site FG-309 (Schubert/Bertuch 2016). More material was provided by the refill of a cesspit from site FG-323 in the western part of the city and by the refill of a ditch at site FG-316 immediately outside the southern city wall. A compact refuse layer was sampled below the pavement of a market square (*Buttermarkt*) beside the Nikolai church (FG-319). Material for dendrochronological analysis is provided by archaeological sites with waterlogged timbers and historical buildings that cover the whole city area.

Dendrochronological and macrobotanical analyses

A total of 963 dated tree-ring sequences were collected. Besides a few analyses being provided by the dendrochronological laboratory at the Universität Hohenheim, most dates were obtained from B. Heußner (Berlin) and are based on a correlation with the local standard curves. While the majority of 854 samples

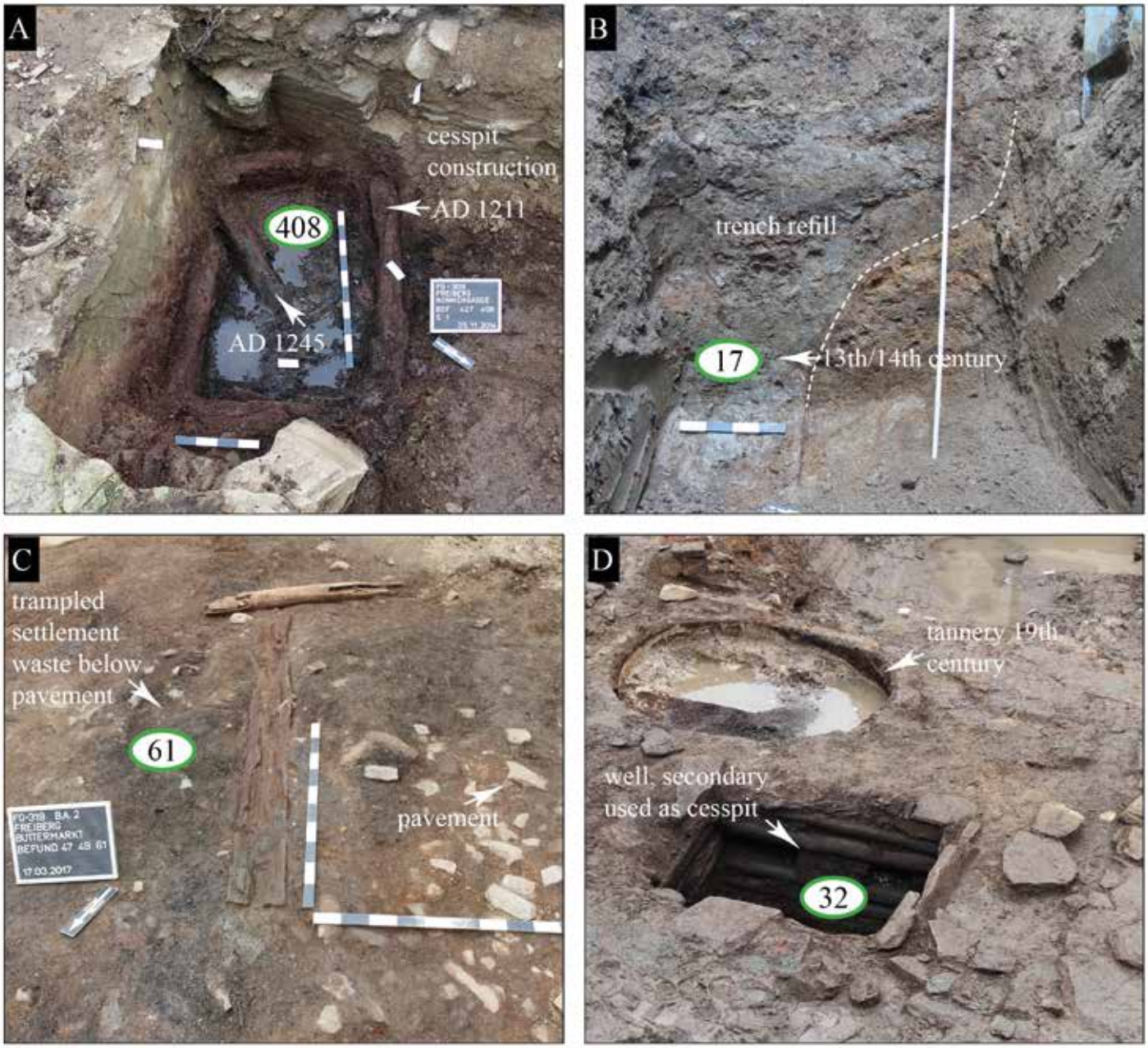

Fig. 3 Freiberg (Lkr. Mittelsachsen). Archaeological features sampled for botanical analyses: **A** FG-309, feature 408, cesspit. – **B** FG-316, feature 17, refill of ditch, 4.5 m below surface. – **C** FG-319, feature 61, compacted settlement waste below market pavement. – **D** FG-323, feature 32, cesspit. – (Illustration J. F. Tolksdorf; A-B photos M. Schubert; C photo S. Matson; D photo A. Kaltofen).

derives from historical buildings and consequently postdates the last devastating city fires in 1471 and 1484, a total of 109 timbers from archaeological sites cover the time as far back as the 11th century. The excavation areas FG-317 and FG-323 yielded wooden structures and allowed for dendrochronological analyses (Th. Westphal, Curt-Engelhorn-Zentrum Archäometrie gGmbH, Mannheim) thereby providing additional chronological information to be cross-checked with the vibracores by means of their stratigraphical position (**tab. 1**).

Six larger macrobotanical spectra from different time periods have been analysed in recent years. The excavation FG-309 in the western part of the city uncovered the infill of two cesspits (FG-309, feature 408

lab no.	archaeological context	species	first tree-ring (AD)	last tree-ring (AD)	comment
MAD-542	FG-317, feature 42, bottom of a barrel in secondary use as cesspit	*Abies alba*	1452	1509	no waney edge
MAD-543	FG-317, feature 42, stave from a barrel in secondary use as cesspit	*Abies alba*	1492	1531	no waney edge
MAD-544	FG-317, feature 42, stave from a barrel in secondary use as cesspit	*Abies alba*	1495	1528	no waney edge
MAD-545	FG-317, feature 42, stave from a barrel in secondary use as cesspit	*Abies alba*	1483	1528	no waney edge
MAD-659	FG-317, features 81/82, stave from a tub with remains of slacked lime	*Abies alba*	1424	1482	no waney edge
MAD-660	FG-317, feature 81, stave from a tub with remains of slacked lime	*Abies alba*	1419	1478	no waney edge
MAD-661	FG-317, feature 82, stave from a tub with remains of slacked lime	*Abies alba*	1434	1475	no waney edge
MAD-662	FG-317, feature 81, stave from a tub with remains of slacked lime	*Abies alba*	1422	1456	no waney edge
MAD-984	FG-323, feature 53, stave from a tub used for tannery	*Abies alba*	1563	1639	no waney edge

Tab. 1 Freiberg (Lkr. Mittelsachsen). Results of the dendrochronological analyses from sites FG-317 and FG-323.

[fig. 3A] and feature 559) and a layer of burnt material (FG-309, feature 546, sample 72) dating to the 13th/14th century. The cesspit feature 408 was constructed after 1211 from *Fagus sylvatica* and timbers found in the infill sediments indicate a refill after 1245 (Schubert/Bertuch 2016). The cesspit feature 559 is younger and could be dated to the mid-13th century based on stratigraphy and artefacts. The excavation FG-316 in the southern part of Freiberg revealed a trench-structure 3.9-4.5 m below the modern surface that had been refilled completely during the 13th/14th century (fig. 3B). FG-316, sample 17 was taken from the lowermost part of this feature from silty material deposited while the trench had been in use probably as sewage ditch. Material sampled at FG-319, feature 61 was retrieved from a compact layer beyond the pavement of a market square (fig. 3C). The abundance of pieces of leather, wood and small artefacts indicates that this layer consists of compressed settlement waste and can be dated to the 14th/15th century by means of archaeology. The youngest sample FG-323, sample 32 was recovered from a cesspit used during the 17th century (fig. 3D).

All macrobotanical samples have been extracted by flotation and subsequent wet sieving at mesh widths of 2, 1, 0.5 and 0.25 mm. The organic remains were determined according to literature (Cappers/Bekker/Jans 2012) and the reference collection of the Goethe-Universität Frankfurt am Main. The ascription of the taxa to phytosociological units follows the system of E. Oberdorfer (2001).

Palynological analyses

About 1 cm³ sediment was sampled from different stratigraphical units visible in the vibracores (FG-317: 6 samples from core 3; FG-323: 4 samples from core 1). The sample preparation followed common acetolysis procedure (Berglund/Ralska-Jasiewiczowa 1986; Moore/Webb/Collinson 1991) and the identification of palynomorphs based on the standard references (B eug 2004) with a minimum of 500 palynomorphs for each sample. As several samples showed abundant pieces of micro-charcoal, these were only recorded semi-quantitatively. The pollen sum was calculated based on the number of terrestrial taxa, thus excluding local wetland plants like Cyperaceae, *Alnus*, *Sphagnum* spores, *Caltha*, *Equisetum* and *Alisma*.

lab no.	site, core and depth below surface	material	^{14}C [BP]	C (calibrated; IntCal13, 1) [cal BC]	^{14}C (calibrated; IntCal13, 2σ) [cal BC]	d^{13}C (AMS) [‰]	comment
MAMS-28255	FG-317, core 3, 440-450 cm	charcoal particle indet.	900 ± 23	1048-1180	1042-1206	–29.9	for biostratigraphical reasons older than MAMS-29943 Bayesian model: 1047-1088 (1σ); 1036-1139 (2σ)
MAMS-30189	FG-317, core 3, 245-255 cm	charcoal particle indet.	937 ± 22	1039-1151	1032-1154	–29.3	very likely redeposited older material
MAMS-29943	FG-323, core 1, 370-380 cm	charcoal particle indet.	957 ± 19	1028-1147	1023-1153	–31.1	for biostratigraphical reasons younger than MAMS-29943 Bayesian model: 1090-1150 (1σ); 1076-1156 (2σ)

Tab. 2 Freiberg (Lkr. Mittelsachsen). Results of the ^{14}C analyses from sites FG-317 and FG-323.

The transport of pollen in fluvial environments is complex and their sedimentation in alluvial layers is mainly linked to periodic or episodic events (Brown/Carpenter/Walling 2007; 2008) with a fluvial transport of pollen being one of the most important vectors for pollen deposition from a wider catchment (Xu et al. 2012). These uncertainties regarding the catchment size, the chronological resolution, a possible overestimation of local vegetation elements, the effects of selective human impact on the species composition as well as the possible reworking of older material make landscape reconstruction models from alluvial sediment much more challenging compared to peatlands or lake sediments. In spite of these drawbacks, we decided to run several REVEALS models (Sugita 2007) as very broad estimates for the past vegetation composition. Based on a Lagrangian stochastic model implemented in the R package DISQOVER (Theuerkauf et al. 2016), the included parameters of sedimentation in a lake environment with different diameters (100 m, 500 m, 2000 m) and standard pollen production estimates and fall speeds (Soepboer/Sugita/Lotter 2010) were used.

Geochemical and sedimentological analyses

Sediment samples for geochemical analyses were taken from six different positions in FG-317, core 3 and four different positions in FG-323, core 1. Following the homogenization and high-pressure microwave acid hydrolysis of the samples, the contents of the elements Pb, Zn, Sn, Cu, As and Cd were measured by ICP-OES (A. Guhl, Technische Universität Bergakademie Freiberg). The calculation of the average value and standard error is based on six repeated measurements per sample. To resolve the complex stratigraphy of FG-317, core 3, the content of organic material was estimated by the loss-on-ignition (LOI, 550/2h) and the grain size fractions were measured on selected residuals using laser diffraction (A. Körle, HU Berlin).

^{14}C analyses

A total of three samples were analysed by the Curt-Engelhorn-Zentrum Mannheim for ^{14}C dating, applying the IntCal13 dataset (Reimer et al. 2013) for age calibration (**tab. 2**). In respect of the evident biostratigraphical relation of the basal units in FG-317 and FG-323, the Bayesian model implemented in the software package OxCal was applied to further refine the chronological relationship between both sediment units (Bronk Ramsey 2009).

RESULTS

Site FG-317, core 3

The sequence recorded in FG-317, core 3 (fig. 4) shows alternating layers of sandy material and fine-grained sediment with subfossil wood and a layer of high organic content at the base from 3.7 to 5.2 m indicating a sedimentation environment in a fluvial/alluvial context, possibly an oxbow. A ^{14}C age of pieces of charcoal from this sequence dates the start of sedimentation from 1042-1206 cal AD onwards (tab. 2). The lowermost palynological sample P1 (–4.55 m) reveals a spectrum dominated by arboreal pollen with a very high proportion of *Abies* (silver fir) but no cereal pollen or taxa related to human impact. Compared to this, pollen sample P2 (–4.30 m) shows a distinct drop in the share of arboreal pollen, a dramatic decline of *Abies* and a rise of *Picea* (spruce). Human activity is indicated by the presence of *Secale cereal* (rye), *Centaurea cyanus* (cornflower) and *Polygonum aviculare* (common knotgrass) together with a drastic rise of charcoal particles and an egg of *Ascaris*, an intestinal parasite on humans and pigs (Brinkkemper/van Haaster 2012). The uppermost sample P3 (–3.97 m) from this sediment unit shows a continuation in terms of the *Abies* decline and rising percentages of *Picea*, but contained single pollen grains of *Linum* (flax), *Cannabis/Humulus*-type and *Calluna vulgaris* (heather). Geochemical results show very low contents of Pb, Zn, Sn, Cu, As and Cd in the lowermost sample Ch-60 (–5.05 m) and rising contents of Pb, Zn and Cd in the samples Ch-40 and Ch-57 followed by their decline in Ch-39 (–3.97 m). This fluvial/alluvial sediment unit is covered by 1.1 m of loamy material with angular gneiss fragments that either derive from the slope as colluvial material or result from landfill activities.

On top of this, a small layer of peat is followed by a fine-grained material with high organic content and subfossil pieces of wood indicating a second phase of sedimentation in an alluvial environment. A charcoal particle from this sediment unit yielded an age of 1032-1154 cal AD (IntCal 13, 2σ). The pollen samples P4 (–2.68 m), P5 (–2.5 m) and P6 (–2.24 m) reveal a phase of declining arboreal pollen and a rise of *Secale cereale* in spectrum P5 that is followed by a recovery of the percentages of *Picea* and a decline in *Secale cereale* in the uppermost sample P6. Remarkable is the presence of a single pollen grain of *Fagopyrum* (buckwheat) in sample P4. Geochemical contents in this sediment unit are marked by a distinct rise of Zn and As contents from sample Ch-58 (–2.7 m) compared to sample Ch-59 (–2.5 m) from the peat layer.

The uppermost 215 cm of the stratigraphy are landfill layers with typical settlement debris, charcoal, and burnt brick fragments as well as ceramics dating to the 13th/14th century. Several younger archaeological features sunken into the top of this stratigraphy have been documented including two tubs (dendrochronologically dated to after 1483 and 1476) with remnants of slaked lime and a small barrel used as cesspit (dendrochronologically dated to after 1531).

Site FG-323, core 1

Covering the weathered local gneiss bedrock, a compact layer of alluvial deposits was recorded at a depth of 3.05-3.8 m (fig. 5). The pollen samples P7 (–3.75 m) to P9 (–3.35 m) show a trend with declining shares of arboreal pollen and a rise in *Secale cereale* percentages. The geochemical analyses show an increase of Pb- and As-concentrations from the lower to the upper part of this alluvial sequence while concentrations of Cu, Sn and Cd remain on stable levels. Numerous eggs of *Trichura trichiuris* are present throughout the whole sequence and indicate the input of human faeces (Florenzano et al. 2012). It is covered by a unit of fluvial sand up to a depth of –2.05 m that include layers of alluvial sediments and subfossil wood fragments.

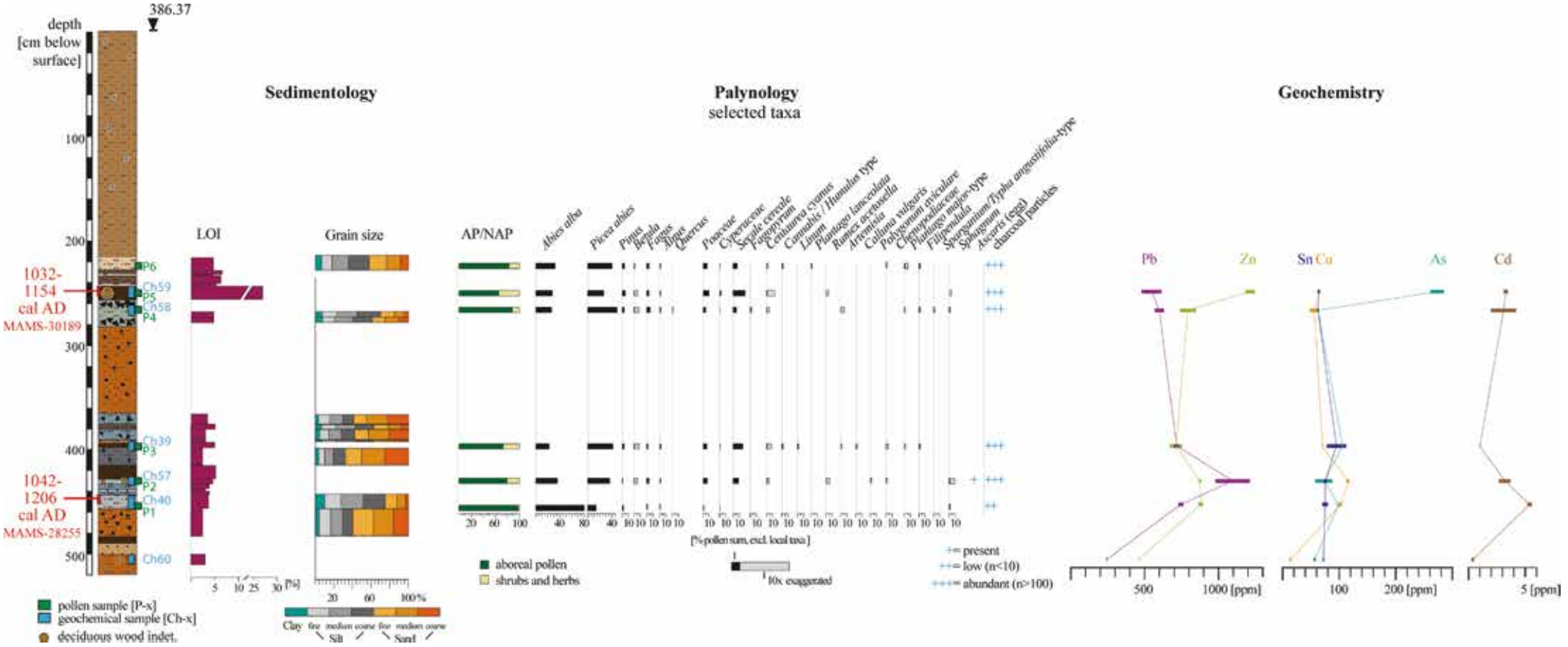

Fig. 4 Freiberg (Lkr. Mittelsachsen). Sedimentological, palynological and geochemical results from FG-317, core 3. – (Illustration J. F. Tolksdorf).

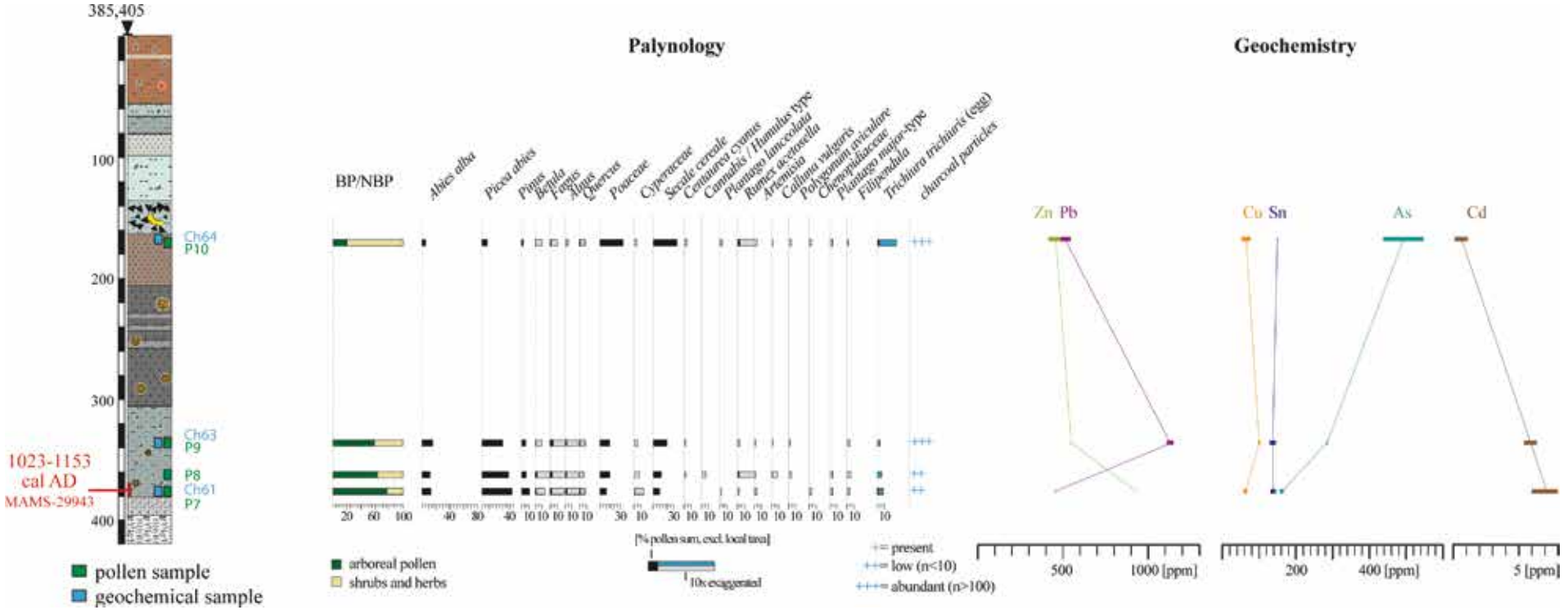

Fig. 5 Freiberg (Lkr. Mittelsachsen). Sedimentological, palynological and geochemical results from FG-323, core 1. – (Illustration J. F. Tolksdorf).

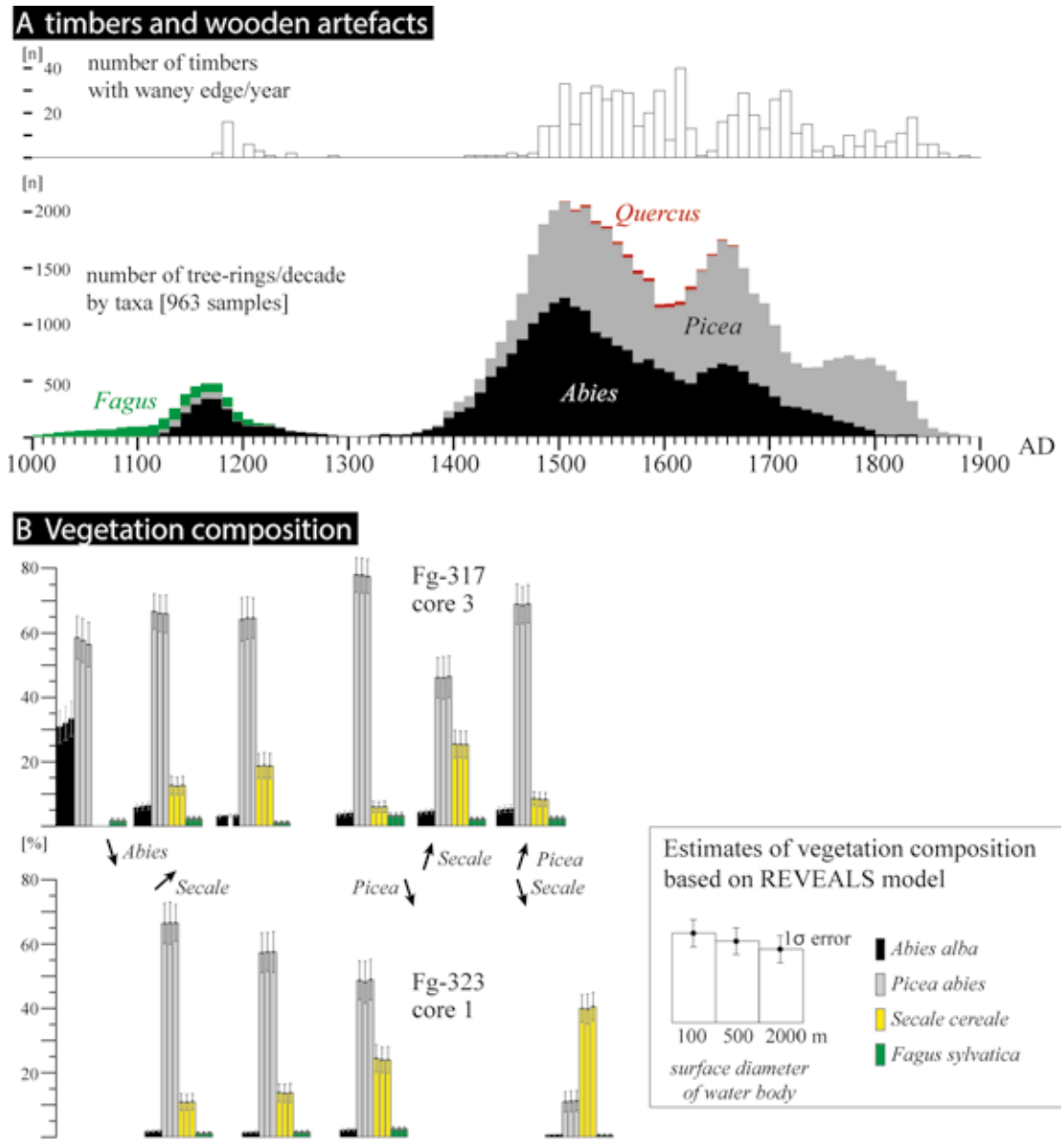

Fig. 6 Freiberg (Lkr. Mittelsachsen): **A** comparison of species used for timbering. – **B** vegetation cover in the area as reconstructed by REVEALS model. – (Illustration J. F. Tolksdorf).

Also of fluvial genesis is the fine to medium-grained sand on the top, where the pollen spectrum reveals the maximum of deforestation, and the high shares in *Secale cereale* and *Centaurea cyanus* indicate strong impact by crop farming. While the content of Pb diminishes and other elements are on a stable level, the concentration of As rises significantly in this stratigraphical unit. It is succeeded by a compact levelling layer of gneiss from 1.35-1.65 m that contained a ceramic fragment ascribed to the 13th/14th century. From a depth of 1.35-0.55 m we see at least three layers of silty loam typical for overbank deposits and rich in charcoal particles and a sandy layer that may indicate landfill or levelling. The uppermost 55 cm of the sequence are marked by a dense packing of settlement debris and burnt brick fragments. Archaeological features such as a tub used for tannery built after 1639 (**tab. 1**) and a cesspit from the late 17th century were uncovered in this uppermost layer of settlement debris.

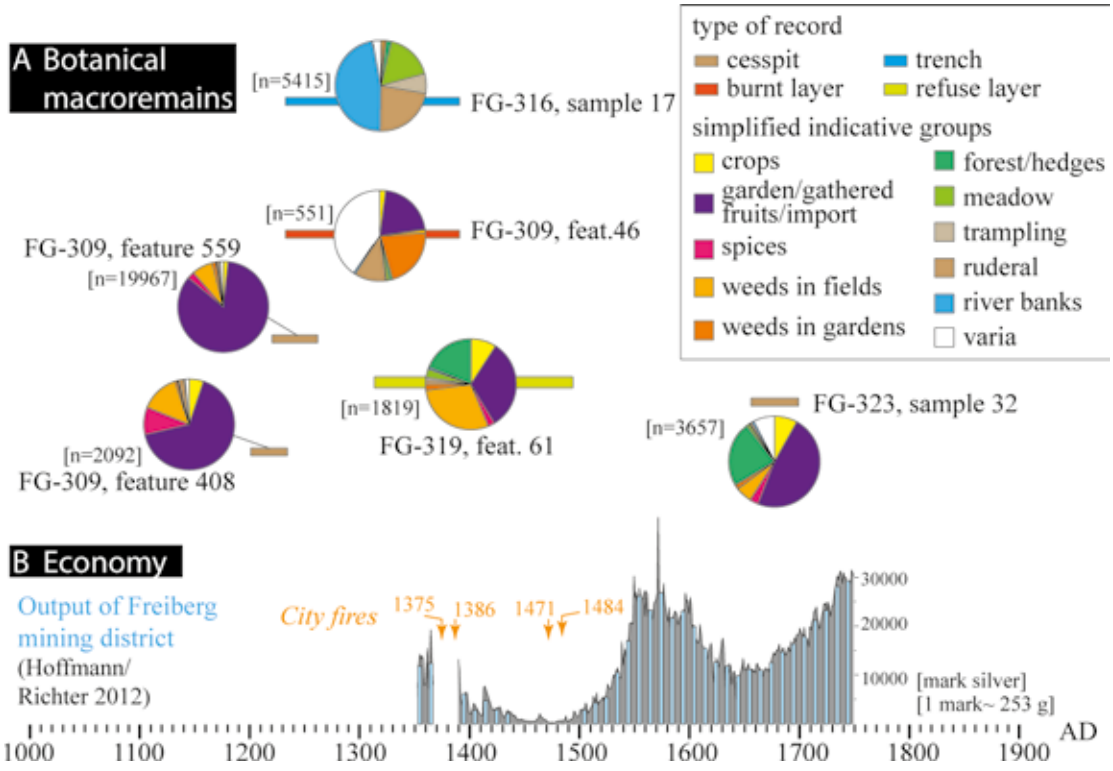

Fig. 7 Freiberg (Lkr. Mittelsachsen): **A** botanical spectra from archaeological features. – **B** silver output from historical sources as proxy for mining intensity and economic development. – (Illustration J. F. Tolksdorf).

Species used for timbering

The dataset reveals a strong hiatus between the earliest timbers in the late 12th/early 13th century and the onset of a younger building phase since around 1480 (fig. 6A). While the samples of the former derive mainly from archaeological contexts such as cesspits or streets, the latter represent the rebuilding of the city after the last devastating fire in 1484. *Abies* and *Picea* are the prevailing species used for building activities with *Abies* being dominant in the 12th/13th century and *Picea* becoming equally common from the late 15th century onwards. While *Fagus* is present in the oldest construction, it is completely absent from the younger buildings, where instead *Quercus* (oak) makes up a very small proportion of the timber used for building.

Macrobotanical spectra

The composition of the taxa present in the different samples depends largely on the type of geoarchaeological record (fig. 7A). Dominant in samples from cesspit and compacted refuse layers, both representing domestic waste, are crops (*Secale cereal* [rye], *Panicum miliaceum* [millet], *Hordeum vulgare* [barley], *Avena sativa* [oat]) and edible garden plants (*Cucumis sativus* [cucumber], *Brassica nigra* [black mustard], *Beta vulgari* [beet]) or gathered fruits and berries (*Fragaria vesca* [wild strawberry], *Prunus spinosa* [blackthorn], *Vaccinium myrtillus* [bilberry], *Rubus idaeus* [raspberry], *Sambucus nigra* [elderberry]). These plants are less abundant in the sample from the burnt refuse layer and nearly absent in the sample from the ditch refill.

The latter contained mostly plants representing the local flora in and around the ditch, consisting of ruderals growing in dry and wet places. These spectra complement the indicators for crop farming which are visible in the pollen record with plants from gardens or imports. Exotic fruits and spices, such as fig (*Ficus carica*) and black pepper (*Piper nigrum*) plus the discovery of a singular glume of rice (*Oryza sativa*) (Schubert/Herbig 2017) from FG-309 prove that long-distance trade was already established in the early 13th century.

DISCUSSION

Settlement and land-use history

Based on the Bayesian model of the biostratigraphically related ^{14}C ages, the onset of human impact can be dated to the mid-12th century. This transition is marked by a significant decline of *Abies* and the presence of Cerealia, indicating forest clearances in the Münzbach catchment and crop farming (**fig. 6B**). It is in very good accordance with the archaeological evidence from the nearby site of Warnsdorf (17 km northeastern; Lkr. Sächsische Schweiz-Osterzgebirge), where, in the context of a contemporaneous short-lived rural colonisation village, a dense layer of wooden chips and felled trees were excavated. Remains of a wooden well indicate that this short-lived village at Warnsdorf was founded around 1162/1163 (Spehr 2002). The less pronounced decline of *Picea* compared to *Abies* may be explained by the prevalence of the former in wetland environments while the latter prevailed on dry sites that were preferred for agricultural use and timber exploitation. This is supported by the dominance of *Fagus* and *Abies* in the oldest wooden constructions (**fig. 6A**). Although episodic heavy flooding events and changes in organic material and grain sizes can have impacts on the content of heavy metals in alluvial sequences (Knittel/Klemm/Greif 2005; Klemm et al. 2015), the disproportional rise of lead compared to other heavy metals probably mirrors a trend of intensifying metallurgical processes in the catchment area during the 12th/13th century.

Using REVEALS models aims to transform the pollen percentages to the vegetation composition and thereby enables a more realistic landscape reconstruction. However, these models are dependant on assumption such as the sizes of deposition surfaces and pollen production rates of the taxa. We are aware that every single parameter used in the model could have a yet unknown effect (Abraham/Oušková/Kuneš 2014) but comparing the results from the calculations with different surface sizes gives a rather stable range of estimates. This model shows a decline of *Picea* and a maximum of *Secale cereale* during a later phase of vegetation development (FG-317, samples P4-P5 and FG-323, samples P9-P10). The ^{14}C age from the layer of sample P5 is obviously too old for its stratigraphic position and may be explained by a reworked older material. Therefore, the chronological position for the uppermost part of the sequence FG-317 remains tentative. Based on the covering archaeological layer, the burnt material has probably been deposited sometime before 1400. The biostratigraphical implication of a single *Fagopyrum* pollen grain in sample P4 is problematic because it remained a singular find (de Klerk/Couwenberg/Joosten 2015) and because generally our knowledge on the regional cultivation of this species is comparatively sparse (Körber-Grohne 1988; Jankovská 2011; Badura et al. 2015). In Freiberg, the first evidence for the cultivation of *Fagopyrum* derives from seven charred grains in the spectrum FG-319 from the 14th/15th century, whereas it is common in younger spectra like cesspit FG-309 (late 17th century), as well as a contemporary cesspit in Dresden DD-178 (Wegener/Herbig 2011/2012). In spite of the large amount of analysed material, it could not be detected in any sample from site FG-309 or 316. These upper samples in both sequences corroborate an ongoing intensification of rural productivity and woodland clearances. Especially the vegetation cover modelled from

spectrum FG-323, sample P10 indicates that the nearby landscape must have been dominated by arable land. This is in good accordance with the high share of crops and field weeds revealed in the macrobotanical spectrum FG-319. Altogether, the proof of intensive local agriculture indicates that at least parts of the demand for cereals were met by local production. In contrast, botanical spectra from the Přísečnice/Preßnitz area (okr. Chomutov/CZ) in the upper part of the *Erzgebirge* (Kočar et al. 2014) or Jihlava/Iglau (okr. Jihlava/CZ) in the Bohemian-Moravian Highlands (Hrubý et al. 2014, 250-253) indicate that these mining settlements were more dependant on crops produced in the foreland.

The strong contribution of fruits cultivated in gardens or gathered from the forests to the nutrition is evident from the late 12th century onwards and complements the crop cultivation visible in the pollen record. The presence of exotic species like fig (*Ficus carica*) and rice (*Oryza sativa*) from the Mediterranean or black pepper (*Piper nigrum*) is comparable to records from Hanseatic towns in Northern Europe and proves that Freiberg was integrated into the network of long-distance imports (Wiethold 1995; 2007; Alsleben 2007).

Remarkable is the transition from the pollen spectrum P5 to P6 with a phase of reforestation by *Picea* and declining shares of crops. Based on its stratigraphical position, this phase might be related to an economic decline of Freiberg during the 14th century which has been reconstructed by a nadir of silver output (**fig. 7B**; Hoffmann/Richter 2012) and may have been accelerated by city fires in the late 14th and 15th century. Although both a supra-regional decline in population as well as a crisis in the mining economy have been discussed from the late 14th century onwards, possible cause and effect models of demography and economy are still lacking from a low chronological resolution and spatial density of data (Kenzler 2011; Bartels/Klappauf 2012). A change in the spatial distribution or intensity of metallurgical activities (e. g. roasting of ores) in later times may also be indicated by the rising As-concentrations observed in the upper part of both cores, although an attribution to a specific process remains tentative.

The importance of the Münzbach area for the assessment of how the disposal of settlement waste has been managed since the 12th century is highlighted by the discovery of intestinal parasites in floodplain sediments that were deposited as a result of human-induced increased soil erosion in the wider catchment. Archaeological evidence of an open ditch at FG-316 as well as the historical record of complex subterranean channels (*Anzüchte*) downhill to the Münzbach in the late 13th century indicate strong efforts to manage water drainage and waste disposal within the growing city. Based on the sediment record, it is likely that landfill was put deliberately into the Münzbach valley to prevent periodic flooding and to improve the usability of the floodplain area within the city, until finally the river had been completely transformed in modern times, running through pipes underground for the whole city area.

CONCLUSION

The multi-proxy reconstruction illustrates that the fast economic development of Freiberg is associated with a strong decline of the forest, affecting especially taxa like *Abies alba*, and intensive farming in the catchment area. Overbank sediments in the Münzbach valley indicate increased soil erosion since the 12th century and record rising pollution levels, especially by lead derived from metallurgical activities, but also from settlement waste. Since the 13th century, the nutrition of the population was supplemented by a broad spectrum of garden species as well as exotic imports. However, palynological results indicate that the increasing deforestation and land-use intensification did not occur continuously, but probably included phases of diminishing intensity, probably during the late 14th century. Layers of the landfill may indicate efforts to claim the floodplain of the Münzbach valley for expanding settlement activities.

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Zusammenfassung / Summary / Résumé

Rekonstruktion der landschaftsgeschichtlichen Entwicklung ab dem 12. Jahrhundert in der Bergstadt Freiberg in Sachsen (Lkr. Mittelsachsen)

Die Bergstadt Freiberg ist eine bedeutende Fundstelle, die es ermöglicht, die Siedlungs- und Landnutzungsgeschichte im Zusammenhang mit dem ersten Bergbauboom Sachsens im 12. Jahrhundert nachzuvollziehen. Durch das Zusammenführen des umfangreichen Datenbestandes dendrochronologischer Analysen, botanischer Makroreste und die palynologischen, sedimentologischen und geochemischen Ergebnisse aus zwei Rammkernsondagen im zentral in der Stadt gelegenen Münzbachtal kann man Trends der Landschafts- und Landnutzungsgeschichte ab dem 12. Jahrhundert nachzeichnen. Unsere Resultate belegen, dass sich der Siedlungsbeginn in der Mitte des 12. Jahrhunderts durch eine starke Entwaldung und Bodenerosion im Umfeld abzeichnet. Dieses geht mit steigenden Schwermetallgehalten und Verschmutzungszeigern in den Auensedimenten einher. Trotz des allgemeinen Trends einer zunehmend intensiveren Landnutzung zeigen sich auch Schwankungen im Anteil der entwaldeten Flächen, die mit ökonomischen Krisenerscheinungen des späten 14./15. Jahrhunderts zusammenhängen könnten. Die Aufschüttungen und Planierungen des Münzbachtales belegen die Bemühungen, Siedlungsfläche in diesem zentralen Stadtbereich zu schaffen und die Ableitung von Abwässern zu verbessern.

Palaeoenvironmental Reconstruction in the Mining Town of Freiberg (Lkr. Mittelsachsen) in Saxony, from the 12th Century Onwards

The city of Freiberg is a key site for understanding the dynamics of the settlement history during the mining boom in Saxony during the 12th century. Combining the extensive data sets from dendrochronological assemblages with macrobotanical spectra and including the palynological, geochemical and sedimentological results from two sediment cores in the Münzbach valley within the town, we reconstruct trends in land-use intensity and economy from the mid-12th century onwards. Our results indicate strong human impact by deforestation and subsequent soil erosion in this area during the establishment of the town in the mid-12th century. This was accompanied by rising pollution with heavy metals and waste in the overbank deposits. Despite the general trend of intensification, fluctuations in the share of deforested land become apparent and may be linked to economic crisis during the late 14th/15th century. Layers of landfill in the Münzbach valley could indicate efforts to reclaim this floodplain area within the town and may reveal attempts to improve the settlement's sewage.

Reconstitution du développement de l'histoire du paysage à partir du 12e siècle dans la ville minière de Freiberg en Saxe (Lkr. Mittelsachsen)

La ville minière de Freiberg est un site important qui permet de retracer l'histoire de la colonisation et de l'utilisation des terres en relation avec le premier boom minier de la Saxe au 12e siècle. En combinant la vaste base de données d'analyses dendrochronologiques, de macrorestes et de résultats palynologiques, sédimentologiques et géochimiques de deux sondages dans la vallée du Münzbach, situés au centre de la ville, les tendances de l'histoire du paysage et de l'utilisation du sol peuvent être retracées à partir du 12e siècle. Nos résultats montrent que la colonisation a commencé au milieu du 12e siècle en raison de la déforestation et de l'érosion du sol dans la région environnante. Ceci s'accompagne d'une augmentation de la teneur en métaux lourds et d'indicateurs de contamination dans les sédiments extérieurs. Malgré la tendance générale à une utilisation de plus en plus intensive des terres, il y a aussi des fluctuations dans la proportion de zones déboisées qui pourraient être liées à des crises économiques à la fin du 14e/15e siècle. Les remblais et le nivellement de la vallée du Münzbach prouvent les efforts pour créer des zones de peuplement dans cette zone urbaine centrale et pour améliorer le drainage des eaux usées. Traduction: L. Bernard

Schlagwörter / Keywords / Mots clés

Sachsen / Mittelalter / Silberbergbau / Paläoökologie / Pollenanalyse / Ernährung / Abwasser
Saxony / Medieval period / silver mining / palaeoecology / pollen analysis / diet / sewage
Saxe / Moyen Âge / exploitation des mines d'argent / paléoécologie / palynologie / nutrition / eau résiduelle

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