

Multi-proxy investigation of a unique Bronze Age deposit of broomcorn millet and human remains at a bog site in Bohemia, Czech Republic

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ABSTRACT

The deposition of broomcorn millet plants (*Panicum miliaceum*), found in the wetland of the Zahájí site in the Czech Republic, belongs to the oldest millet findings in Central Europe. Its appearance in a newly formed shallow lake in a small brook valley located in the populated lowland area was accompanied by a curious finding of a human fingernail (both dated ca. 1400–1300 BC); their joint presence in the same layer does not appear accidental. Although a wealth of contextual information has been gleaned from multi-proxy investigations (such as sediment lithostratigraphy, geo and water chemistry, pollen, plant macrofossils, aquatic invertebrae and organic residua analyses, and aDNA of millet and the fingernail), archaeological interpretation of the find is highly challenging having no known analogies in the European/wider context so far. We present some possible scenarios of what might have happened, including certain forms of ritual behaviour or reverence for millet, a crop that has only recently spread in central Europe around the mid-2nd millennium BC following its rapid westward migration from southeastern Asia.

1. Introduction

The large assemblage of waterlogged broomcorn millet (*Panicum miliaceum* L.) caryopses discovered 4.5 m below the current surface in the minerotrophic bog at Zahájí (central Bohemia, Czech Republic) was first encountered nearly twenty years ago during palaeoecological research. It is among the oldest-dated millet finds in central Europe (Filipović et al., 2020; Supplementary Information Fig. S1). During the 2021 coring revision, waterlogged stems and roots emerged alongside broomcorn millet caryopses, together with a human fingernail (further referred to as ‘nail’) situated from the same stratigraphic layer in one of the boreholes. Radiocarbon dating of the fingernail and broomcorn millet macrofossils confirmed an almost identical age at ca. 1400–1300 BC.

Broomcorn millet appeared in Europe after its spread from East Asia. It quickly became a staple crop in many regions. As such, it has recently received close attention from many scholars (e.g. Filipović et al., 2020; Stevens et al., 2021; Dal Corso et al., 2022 with further references; Huang et al., 2023). Its first appearance is known from present-day China in ca. early mid-6th millennium BC (Filipović et al., 2020) and it dispersed westward via central Asia in the 3rd millennium BC and then to Europe and Africa in the 2nd millennium BC (Dal Corso et al., 2022).

Finds of human remains in various types of bog – so-called bog bodies (both mummies and skeletal remains) – are among the best known and most enigmatic finds from European prehistory, often those associated with cults, rituals and mystery. There are currently 266 known sites and more than 1000 bog mummies (or their parts), almost exclusively situated in northwestern and north-central Europe and the

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eastern Baltic (van Beek et al., 2022). The southern limit of such findings lies in Lower Saxony, although there are extensive bogs further south in Germany.

Our finding is the first known deposition of broomcorn millet in a bog, as well as the first known co-occurrence of cereals and human remains in such a context. Furthermore, the recovered human remains are over 500 km away from the closest known bog bodies within this time window (phase 4 according to van Beek et al., 2022) in Lower Saxony (Fig. 1).

In this paper, we address three main research questions. The first concerns the environment of the site at the time the broomcorn millet and human remains were deposited. Currently, the site is a bog filling a narrow, deeply incised valley with a sediment sequence reaching up to 8.2 m (it spans the last 9000 years; Pokorný et al., 2015). However, it remains unclear what the site looked like at the time of the deposition; the millet could have been deposited either in the firmer peat material or, for example, in the shallow water body (bog lake), covering deeper bog sediments.

Next, we ask whether the entire body, rather than just a small fragment, was originally deposited in the bog. This question is key to interpreting the find within its archaeological context.

Finally, we question the possibility that the fingernail and broomcorn millet find are meaningfully connected, for example, in the sense of sacrifice or offering, in line with interpretations commonly associated with bog finds.

2. Study site

2.1. Environmental background

The Zahájí site is situated in a lowland area of the lower Ohře River in northern Bohemia, Czech Republic (50°22'44"N, 14°07'04"E, 200 m a. s.l.), ca. 40 km NW of the city of Prague (Fig. 1). The present climate is relatively warm, dry, and continental (mean annual temperature 8.3 °C, annual precipitation 496 mm) as a result of its low elevation (190 m a. s. l.) and its position in an orographic rain shadow of the Krušné hory (Ore Mountains).

The site lies in the source area of Podbradecký potok (Podbradecký Brook), a tributary of the Ohře River, which is sharply incised into the bedrock forming a canyon-like valley; at the site of the findings, the valley is today only some 60–80 m wide at its base and up to 35 m deep (Figs. 2–4). The bedrock is formed of Cretaceous sandstones with layers of calcareous claystones and marls covered by loess on the surrounding vast plateaus. The valley of the Podbradecký potok is fed by several springs which discharge from the slopes of the canyon or as artesian springs from the bottom of the valley. The discharged water is strongly enriched with iron and sulphur (Pokorný et al., 2015; Herrmann and Kůrková, 2016).

At present, the study site is covered by sparse swamp forest (dominated by *Alnus glutinosa* and *Fraxinus excelsior*), sedges and reeds. We use the term ‘bog’ here in its broader meaning, assuming that the presence or otherwise of trees varied in the past (as evidenced by palaeobotanical data; Pokorný et al., 2015, and in this paper).

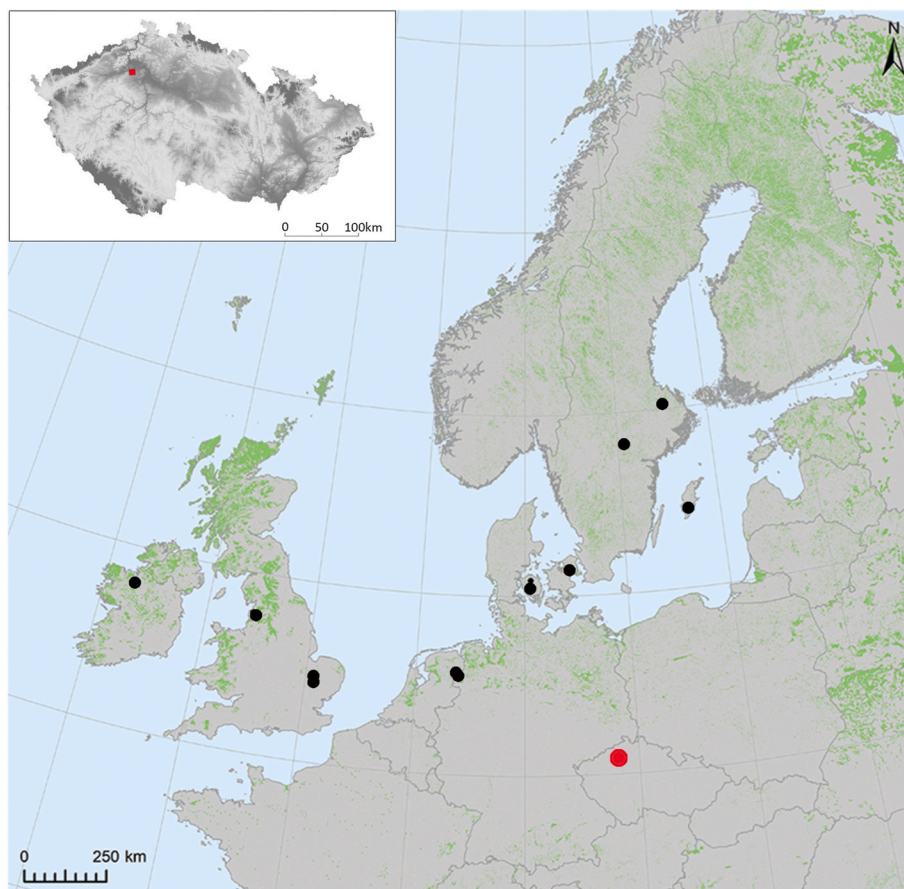


Fig. 1. Distribution of sites (black dots) with human remains from the period 1600–1000 BC in European wetlands (after van Beek et al., 2022; modified. With permission of the authors). Red dot = Zahájí site. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

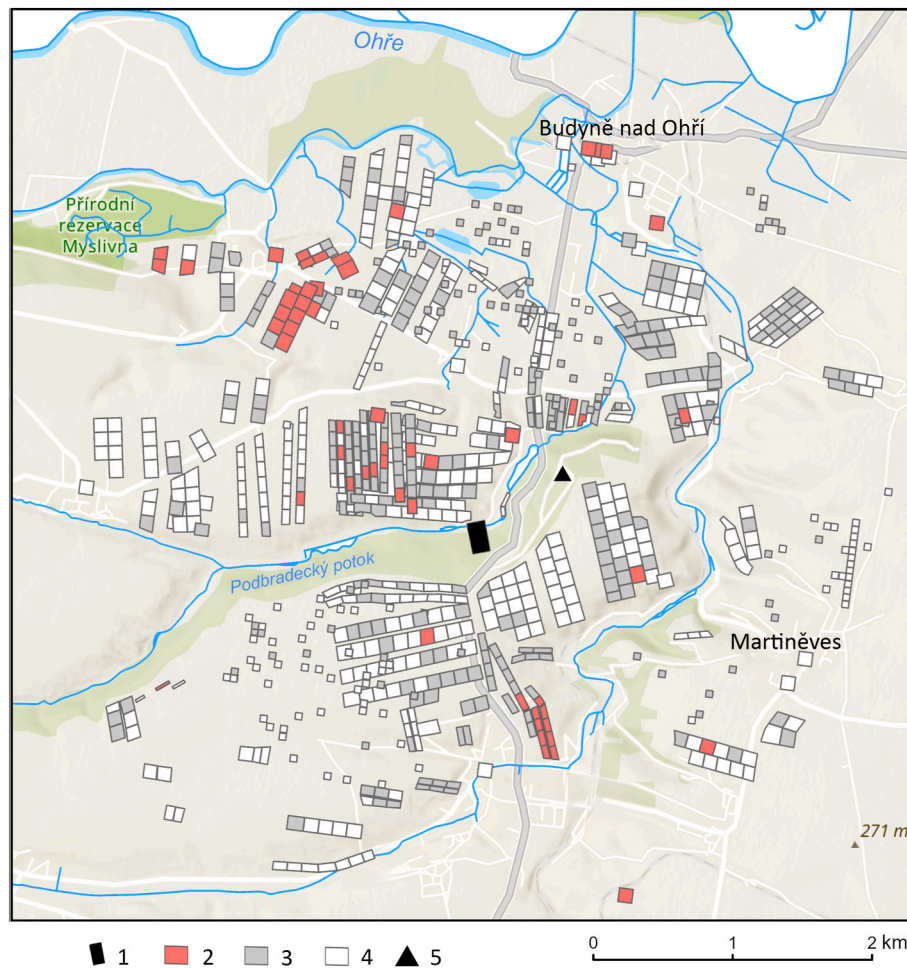


Fig. 2. Detailed map of the location of the Zahájí site. 1. Area described in detail in Fig. 5; 2. Surface survey polygons with the Bronze Age findings; 3. Surface survey polygons with prehistoric findings (which can also include the Bronze Age findings); 4. Empty surface survey polygons; 5. Burial area, probably from the Bronze Age.



Fig. 3. Aerial photo of the valley of the Podbradecký potok with the location of the investigated Zahájí site (arrow). Photo: P. Pokorný.

2.2. Archaeological background

The Middle Bronze Age (MBA), which encompasses our findings from the Zahájí site, was a period of extensive changes over a large area of Europe that resulted in a relatively unified archaeological manifestation coherent in both the artefactual and ideological spheres. This is



Fig. 4. Current appearance of the Zahájí site from above. Photo: J. Mařík.

evident, for example, in the similar funerary ritual of building barrows, such as in the Tumulus culture (ca. 1600–1250 BC), and present in the territory of what is now Bohemia (Jiráň (ed.), 2013).

Compared to the preceding Únětice culture of the Early Bronze Age and the following Urnfield culture of the Late Bronze Age, settlement density and habitation stability are lower (Dreslerová and Demján, 2019). The effect of reduced archaeological visibility in this period – from which (seemingly) only a small number of settlements have survived and been investigated – cannot, however, be ruled out (Jiráň (ed.), 2013).

Nevertheless, this is not the case in the vicinity of the Zahájí site, where fertile soils perfectly suited to agriculture allowed for a long-term, continuous, and relatively steady settlement pattern, beginning in the Early Bronze Age, and continuing well into the Iron Age. Several significant concentrations of settlement sites situated north (0.5 km) and south (1.5 km) of our study site are of comparable age with the bog findings (Dreslerová and Demján, 2019). A possible burial area lies on the opposite valley ridge, where several burial mounds are preserved (Fig. 2). Arable agriculture and animal husbandry seem to have been the main subsistence strategy in the MBA. *Triticum monococcum*, *T. dicocum*, *Hordeum vulgare* and legumes were cultivated, complemented with *Panicum miliaceum*, which arrived in central Europe in this period (Dreslerová and Kočár, 2013).

3. Methods and results

The following methods were used to answer questions posed in the introductory chapter, and, in particular, to comprehend the environmental conditions that existed at the site when the discoveries were deposited: lithostratigraphy, geochemistry, and micromorphology, palynology, plant macroremains analysis, radiocarbon (^{14}C) dating,

ancient DNA (aDNA) of plants and a human residue, analysis of past and modern aquatic fauna, and analysis of organic residues. Detailed descriptions of the methodology are appended in Supporting Information (further referred as to SI); here we mostly present the results.

3.1. Subsurface morphology of the study site, sediment coring, and radiocarbon dating

3.1.1. Details on methodology are provided in SI: S1

The Zahájí site was surveyed in 2004, 2021, and 2022. The position of the boreholes is shown in Fig. 5, and a description of the relevant analyses is provided in Table 1. In 2022, the valley floor was surveyed using electrical resistivity tomography (ERT) and hand-operated corers (coring chamber diameter of 2.5 cm) in a transect across the valley. A total of 21 boreholes were documented, and significant lithological horizons were sampled for environmental analyses.

Based on drilling and ERT profiling, the valley floor has an irregular surface; it slopes gently towards the NW. The organic deposits reach a maximum thickness of 8.6 m in the central part of the valley, where a channel-like structure parallel to the valley axis was identified. This represents the former stream channel, which folded towards the NW

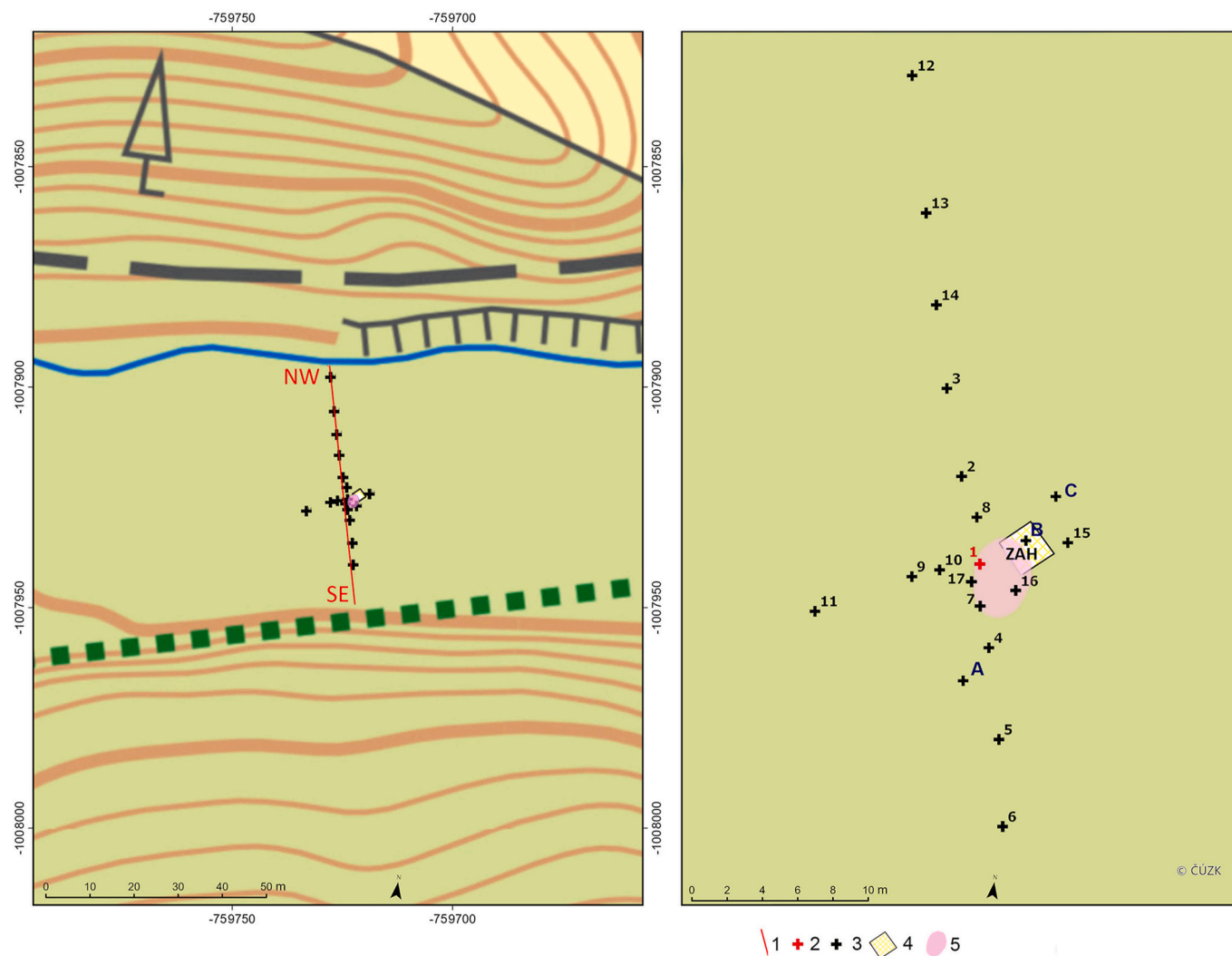


Fig. 5. Plan of the Zahájí site. Left: position of the lithostratigraphical cross-section (black crosses) and the ERT profile (red line; see Fig. 6). Right: detail of the Podbradecký potok valley floor showing coring and sampling sites. Red cross – position of the nail finding; black crosses – cores ZA 2–17 for lithostratigraphical and morphological analyses and for survey on millet macroremains (see Table 1); yellow square – original pit from 1999; purple ellipse – assumed area of millet spread; ZAH – position of the profiles ZAH 2004, ZAH 2015, ZAH A–C (see Table 1); A – organic-rich surface sediment sample; B – sample for water chemistry; C – Fe-rich surface sediment sample. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1

Zahájí. Overview of documentation points (cores) from Fig. 5.

| year | code | Depth | Analyses |
|------|----------|--------------------------------------|---|
| 1999 | ZAH 2004 | pit 2m + core 5.7 | plant macroremains, pollen, 14C |
| 2008 | ZAH 2015 | 8.6 m | pollen, 14C |
| 2021 | ZAH A | 5 m (analyses between 4th and 5th m) | broomcorn millet extraction, 14C, organic residual analysis |
| 2021 | ZAH B | 5 m (analyses between 4th and 5th m) | broomcorn millet extraction, plant macroremains, pollen, aquatic invertebrate remains |
| 2021 | ZAH C | 5 m (analyses between 4th and 5th m) | broomcorn millet extraction, plant macroremains, 14C, geochemistry, micromorphology |
| 2021 | ZA 2-17 | 5 m | broomcorn millet, litostratigraphy |
| 2021 | ZA 1 | 5 m | broomcorn millet, fingernail, 14C |
| 2021 | A | 0.2–1 m | surface sample for water chemistry and zoological analysis from the hand dug pit |
| 2021 | B | 0–0.02 m | Fe-rich surface sediment sample for zoological analysis |
| 2021 | C | 0–0.02 m | organic rich surface sediment sample for zoological analysis |

wall of the canyon during the Holocene.

AMS radiocarbon (^{14}C) dating of 37 organic samples was performed in ^{14}C laboratories in Poznań (Poz), Erlangen (Erl), and Prague (CRL) (Table 2, Table 3). The OxCal 4.4 calibration programme was used to determine sample ages along with the IntCal20 calibration curve for Northern Hemisphere terrestrial samples (Bronk Ramsey et al., 2000; Reimer et al., 2020).

3.2. Sediment lithostratigraphy, geochemistry, and micromorphology

3.2.1. Details on methodology and the data are provided in SI: S1

Three major lithological horizons (LH_1, LH_2, LH_3) can be distinguished in the laterally heterogeneous sedimentary record of the bog (Fig. 6).

LH_1 (ca. 1100 BC to recent) is composed of brown to black woody peat with variable clay and sand admixtures which form irregular layers up to several centimetres thick. Sediments are dominated by silicates (SiO_2 , TiO_2 , Na_2O , K_2O), which make up about 80 % of dry sediment content. The organic carbon content is relatively low, ranging between 7 % and 23 %. The maximum sulphur content measured is around 10 %.

LH_2 (ca. 1600–1100 BC) consists of a light grey clay and locally fine-

Table 2

Zahájí. Radiocarbon dates from multiple cores. Calibrated in OxCal 4.4 software using IntCal20 (Bronk Ramsey et al., 2000; Reimer et al., 2020).

| lab code | cm | BP | ± | BC from | BC to | % | material | profile |
|-------------|---------|------|-----|---------|--------|------|--|---------|
| Erl-3007 | 97–99 | 665 | 38 | AD1276 | AD1396 | 95.4 | <i>Alnus</i> wood (twigs) | ZAH2004 |
| Erl-3008 | 184–186 | 1005 | 39 | AD979 | AD1159 | 95.4 | Wood (twigs) | ZAH2004 |
| Erl-3012 | 297–299 | 2830 | 44 | 1123 | 843 | 95.4 | Aboveground parts of cf. <i>Molinia</i> | ZAH2004 |
| CRL22_0056 | 423–425 | 3389 | 24 | 1744 | 1618 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0057 | 427–429 | 3270 | 22 | 1613 | 1463 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0058 | 431–433 | 3231 | 20 | 1532 | 1442 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0059 | 435–437 | 3310 | 27 | 1629 | 1506 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0060 | 439–441 | 3104 | 19 | 1429 | 1297 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0061 | 443–445 | 3297 | 22 | 1615 | 1510 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0062 | 447–449 | 3181 | 21 | 1500 | 1419 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0063 | 451–453 | 3237 | 25 | 1500 | 1419 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0064 | 457–459 | 3399 | 26 | 1862 | 1617 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0065 | 461–463 | 3818 | 32 | 2451 | 2142 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| CRL22_0067r | 469–471 | 3840 | 133 | 2836 | 1901 | 95.4 | collection of terrestrial plant macroremains | ZAHA-C |
| Erl-3013 | 497–499 | 4134 | 50 | 2879 | 2576 | 95.4 | Aboveground parts of cf. <i>Molinia</i> | ZAH2004 |
| Erl-3011 | 554–555 | 4788 | 49 | 3649 | 3380 | 95.4 | Aboveground parts of cf. <i>Molinia</i> and wood (twigs) | ZAH2004 |
| Poz-51054 | 647–649 | 6180 | 40 | 5286 | 5003 | 95.4 | <i>Betula</i> seeds and mosses | ZAH2015 |
| Poz-51055 | 669–671 | 7130 | 40 | 6071 | 5914 | 95.4 | bark and charcoal | ZAH2015 |
| Poz-51057 | 783–785 | 8340 | 50 | 7531 | 7192 | 95.4 | <i>Betula</i> seeds | ZAH2015 |
| Poz-51058 | 825–827 | 8360 | 50 | 7574 | 7195 | 95.4 | <i>Betula</i> - bark from a trunk | ZAH2015 |

Table 3

Zahájí. Radiocarbon dates from millet grains and the human nail (ZAH A–C and ZA1 cores). Calibrated in OxCal 4.4 software using IntCal20 (Bronk Ramsey et al., 2000; Reimer et al., 2020). R_combine = combination of all measurements of millet.

| lab code | material | BP | ± | BC from | BC to | % |
|-------------|-------------------------|------|----|---------|-------|------|
| CRL 20_215 | broomcorn millet grain | 3136 | 18 | 1491 | 1316 | 95.4 |
| CRL 20_216 | broomcorn millet grain | 3096 | 18 | 1423 | 1295 | 95.4 |
| CRL 20_309 | broomcorn millet grain | 3098 | 23 | 1426 | 1291 | 95.4 |
| ETH-107373 | broomcorn millet grain | 3103 | 23 | 1430 | 1292 | 95.4 |
| UA3216 | broomcorn millet grain | 3122 | 30 | 1493 | 1293 | 95.4 |
| Poz-29572 | millet grain | 3140 | 40 | 1502 | 1296 | 95.4 |
| R_combine | broomcorn millet grains | 3113 | 10 | 1428 | 1311 | 95.4 |
| CRL 20_308A | nail | 3045 | 44 | 1419 | 1197 | 95.4 |
| CRL 20_308B | nail | 3096 | 24 | 1425 | 1287 | 95.4 |

grained sandy clays alternating with mossy layers. Fe_2O_3 and Al_2O_3 contents reach extremely high values of 40–60 %, accompanied by enormously elevated sulphur concentrations (up to 14 %). This horizon contains very abundant iron and alum (potassium-aluminium sulphate) concretions several centimetres across, which formed in response to the geochemical conditions of the environment. According to the results of an XRD analysis, the concretions are formed of goethite ($\alpha\text{-Fe}_3\text{O(OH)}$) and basaluminite (syn. felsöbányaite; $\text{Al}_4(\text{SO}_4)(\text{OH})10\cdot4\text{H}_2\text{O}$). At the base of sequence LH_2, the alum, coupled with the high iron concentrations, forms a mechanically resistant encrustation (for a more detailed description of the base of LH_2, where the broomcorn millet layer and the fingernail were discovered, see Fig. 6).

LH_3 (ca. 7300–1600 BC) is characterized by a dark brown to black mushy peat, interspersed with frequent layers of red to yellow-red clay 5–25 cm thick, alternating with layers of sand and gravel and numerous Fe/Al concretions. The abundance mineral clasts increase towards the base culminating in denser accumulations near the bottom. Like LH_2, Fe_2O_3 and Al_2O_3 contents are high (up to 72 % and 21 % respectively), but the sulphur content is low (3–4 %) and the organic carbon content is relatively high (~15–20 %).

The basal part of LH_2, represented by the cores ZAH B and ZAH C,

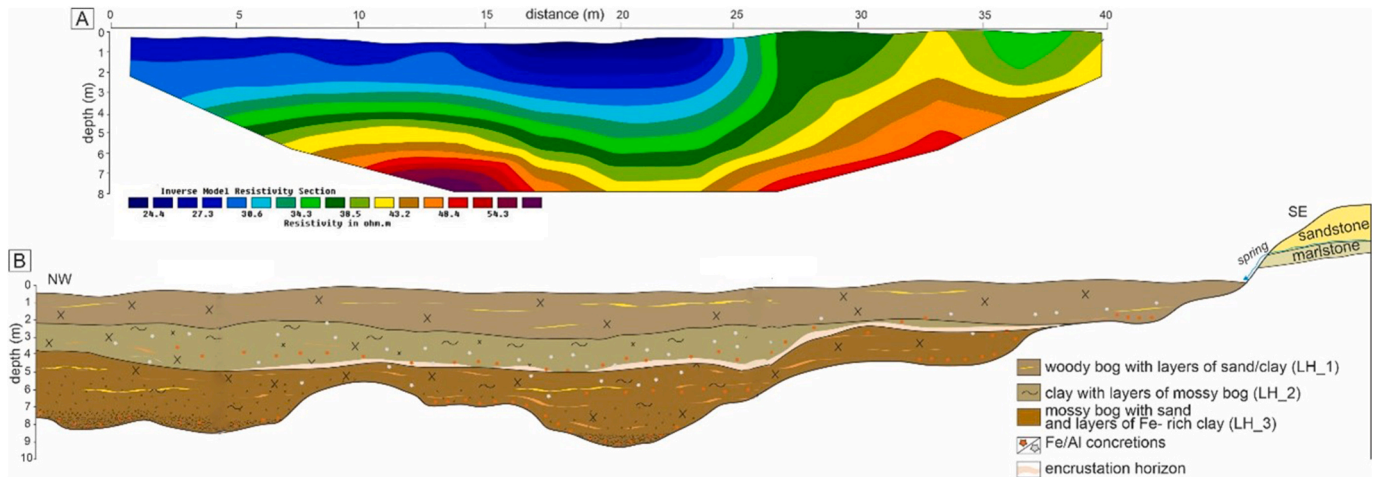


Fig. 6. Zahájí. (A) Results of electrical resistivity tomography; (B) Stratigraphical cross-section of the valley of the Podbradecký potok.

was analysed for bulk chemical composition and micromorphology, which confirmed the unusual sediment chemistry, including the presence of goethite and basaluminite. These two minerals typically precipitate under oxic, low-pH conditions (see SI, S1).

3.3. Palaeobotanical analyses and reconstruction of the vegetation cover

3.3.1. Details of methodology are provided in SI: S2

The first fieldwork at the Zahájí site started 20 years ago with a pollen profile from 2004 (here, ZAH, 2004). In 2008, a second profile

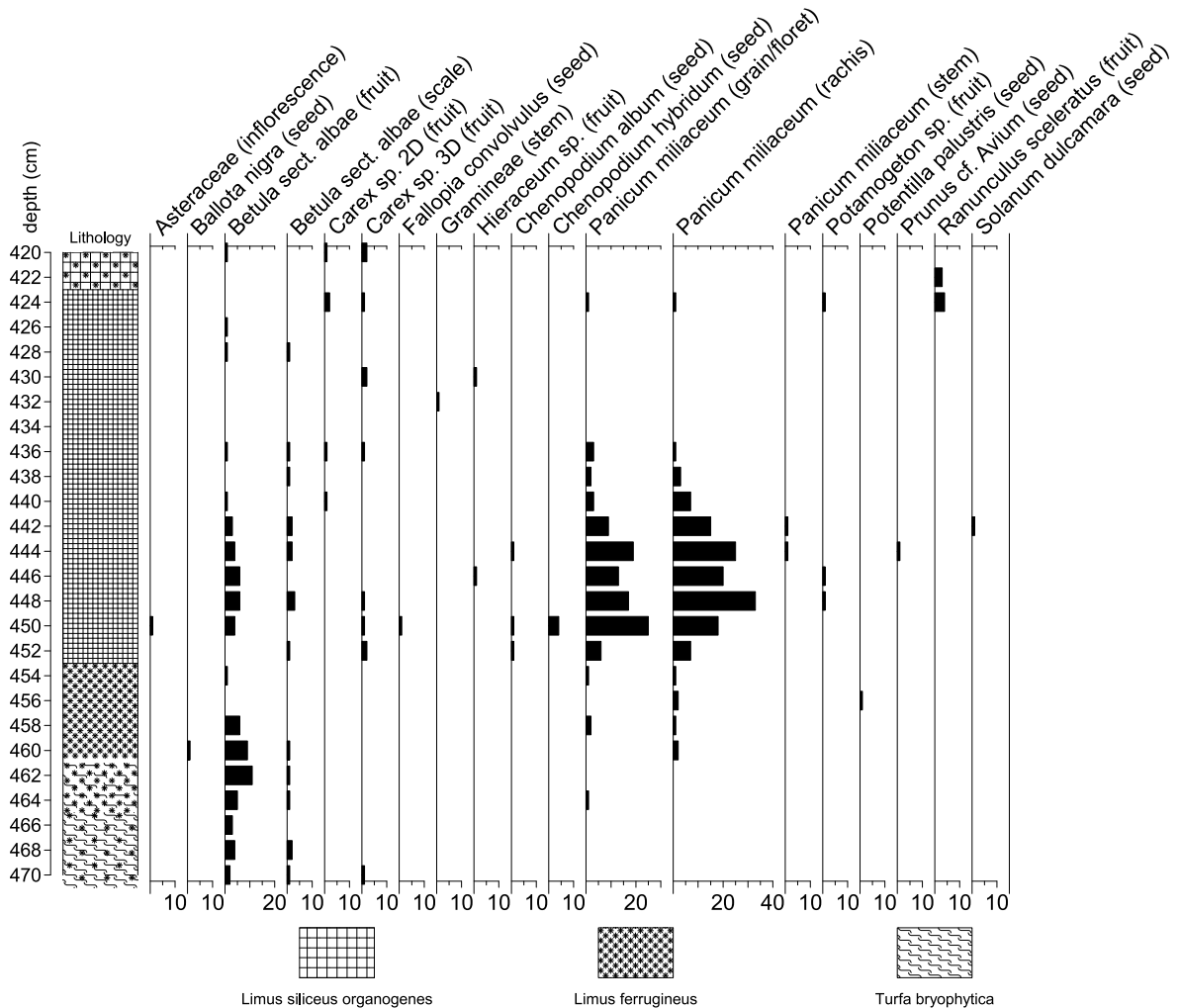


Fig. 7. Zahájí site. Diagram showing plant macrofossil stratigraphy obtained for the ZAH B and ZAH C cores. The X-axis scales show absolute numbers of finds in 25 cm³ of sediment.

(here, ZAH2015) was drilled from the bottom of a pit originally hand dug in 2004, and which reached a depth of 2.0 m. Reference cores ZAH A–C and ZH 1–17 from 2021 were drilled to a depth of 5.0 m by a piston corer (coring chamber diameter of 5.0 cm and length of 1.0 m). ZAH A–C were drilled immediately adjacent to the two original profiles, also from the bottom of the hand-dug pit. An additional drilling was carried out in the immediate vicinity of ZAH A–C to recover enough broomcorn millet for the analysis (Fig. 5). To provide enough material, two parallel cores, ZAH B and ZAH C, were wet-sieved and analysed for plant macrofossils. Both cores were correlated visually according to prominent lithological horizons.

The preservation of certain organic remains is excellent across the entire bog because of the acidic conditions and the high content of basaluminite, a compound that can prevent the biological degradation of organic materials (Pokorný et al., 2010). The unusual chemical composition also accounts for the fact that the deposit is exceptionally thick and demonstrably without any stratigraphic hiatuses, providing a fossil record that is unique for the otherwise dry lowlands of central Europe (Pokorný et al., 2015).

The plant macrofossil diagram (Fig. 7) clearly shows the position of broomcorn millet (*Panicum miliaceum*) remains within the investigated core section. They occur in association with local vegetation: the remains of birches (*Betula* sect. *albae*), sedges (*Carex*), and, importantly, *Potamogeton*, all of which provide evidence of a local aquatic environment, most likely, given the combination of taxa detected, a small pool of shallow water.

The pollen diagram (Fig. 8) is in full agreement with these findings (see *Potamogeton*, Cyperaceae, and *Hordeum*-type – the pollen taxon that includes pollen grains of both *Hordeum* and *Panicum*). In the vegetation signal captured by pollen analysis, evidence of cereal cultivation is exceptionally strong across the whole section. Even *Secale cereale* (rye), then presumably only a cereal weed, rather than an intentionally

cultivated crop (Behre, 1992), is present in large quantities. Grazing was also important in the same period, as evidenced by the persistent presence of *Plantago lanceolata* and *Rumex acetosa*-type pollen. The composition of forest stands is not subject to significant change in this short period.

3.4. Analysis of past and modern aquatic fauna

3.4.1. Details on methodology are provided in SI: S3

Some 26 sediment samples from the ZAH B core were taken in 2.0 cm steps from the depth interval 419–471 cm for analysis of the subfossil remains of aquatic invertebrates (insects, cladocerans, and bryozoans).

This 52 cm long section around the broomcorn millet layer revealed two distinct faunal biozones (Fig. 9). The older biozone (471–451 cm) is characterized by rare findings of aquatic invertebrate remains. Within this biozone, chironomid head capsule (HC) concentrations are lower than 6 HCs per 1 cm³; concentrations of other insect groups are lower than 3 individuals per 1 cm³; and concentrations cladoceran remains are lower than 10 per sample. The taxonomic composition indicates the presence of a very shallow and likely ephemeral pond (or several small ponds) at the bottom of the Podbradecký potok valley. Specifically, the environment of the very shallow lentic water body is indicated by the presence of inhabitants of lentic waters such as chironomids of the genus *Chironomus* and the cladoceran species *Chydorus sphaericus*. Other taxa, namely of the chironomid genera *Gymnometriocnemus* – *Bryophaenocladus*, *Limnophyes*, and *Pseudorthocladus* are known from spring-fed streams, wet soil and shallow ponds (or the splash zones of bigger lakes), and are often associated with mosses (see high concentrations of moss in this biozone (Fig. 7)). The presence of ceratopogonid HCs (Diptera: Ceratopogonidae) and *Sialis* mandibles (order Megaloptera) is common in both lentic and lotic waters. An isolated finding of a sciarid HC (Diptera: Sciaridae) indicates a wet soil environment.

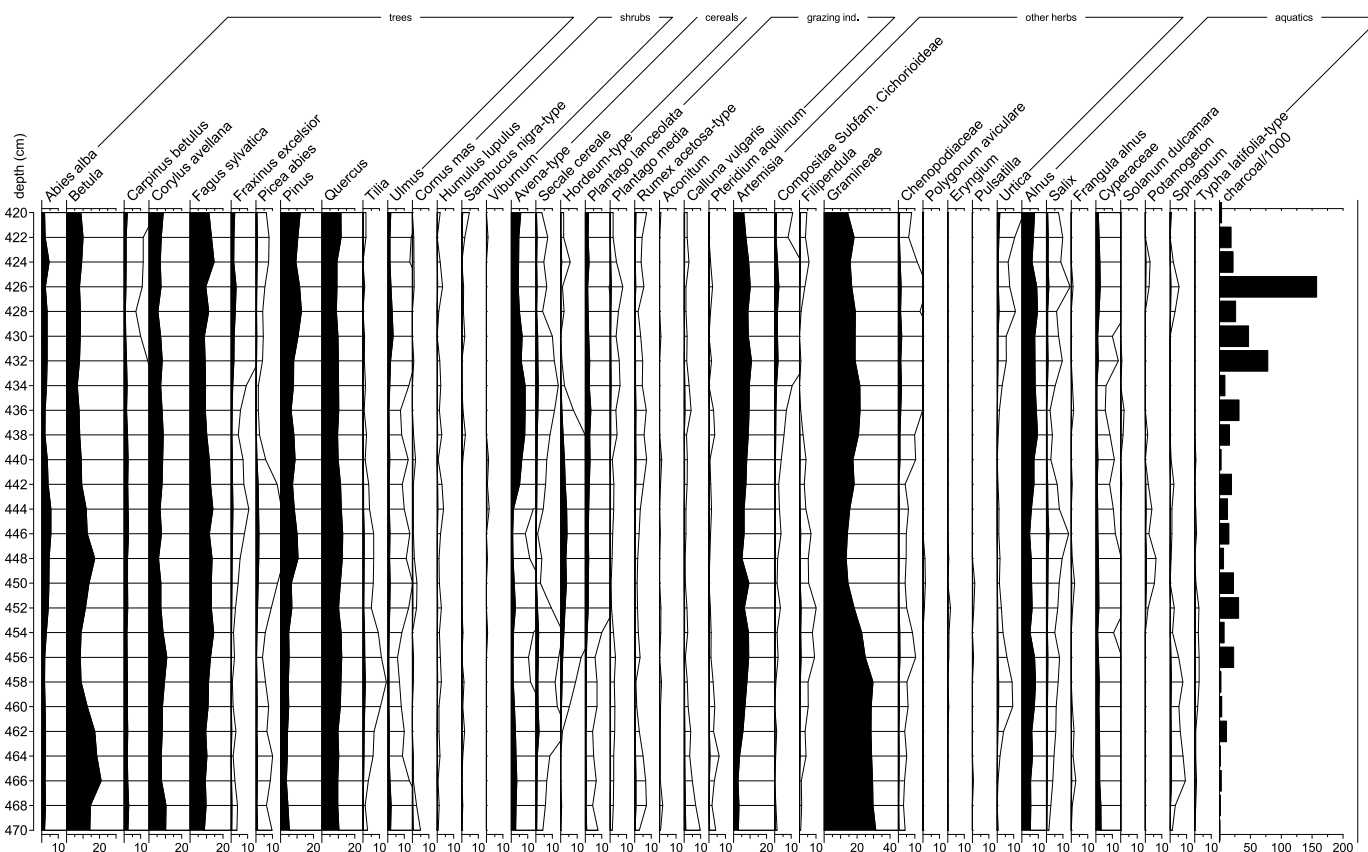


Fig. 8. Zahájí site. Diagram showing pollen percentages for the ZAH B core.

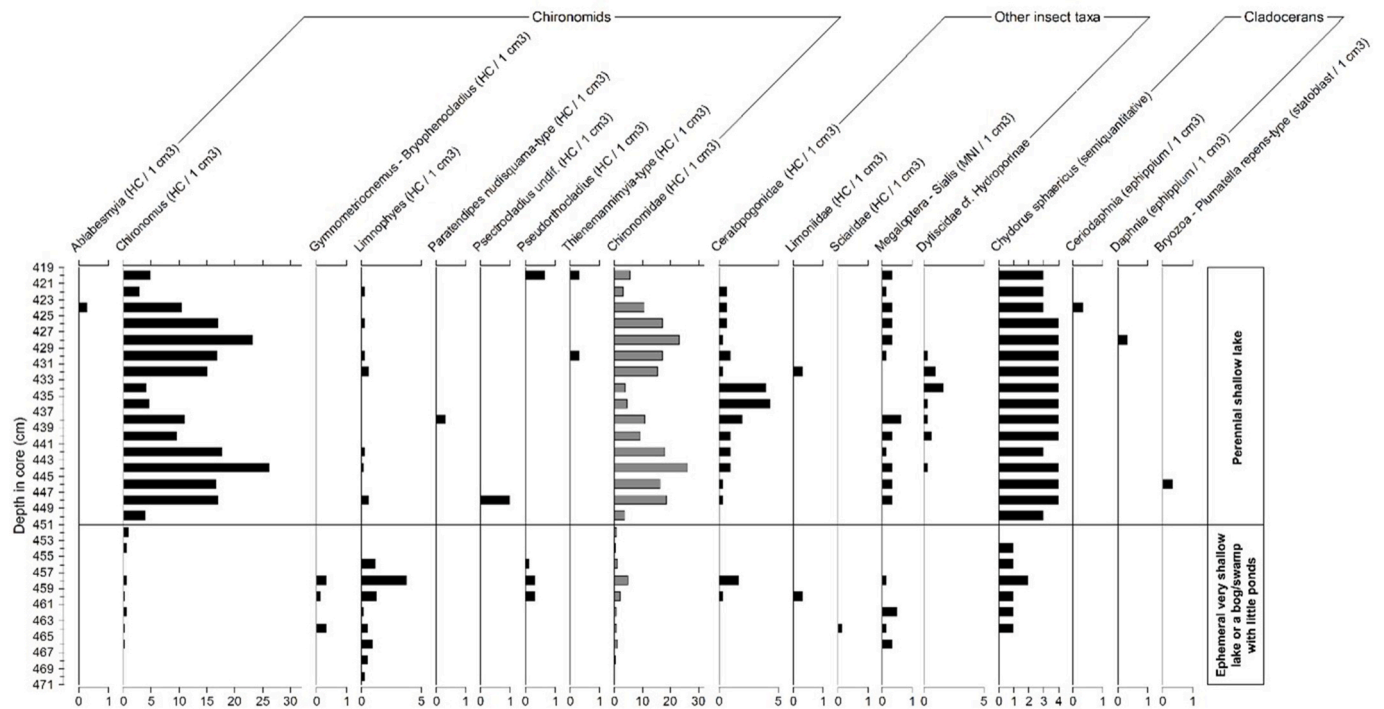


Fig. 9. Zahájí site. Diagram showing aquatic invertebrate stratigraphy for the ZAH B core. Two types of wetland environment (on the left) were distinguished based on the ecology of the fossil assemblages. *Chydorus sphaericus* concentrations are shown using a semi-quantitative scale (0 = absence; 1 = from 1 to 9 individuals per sample; 2 = from 10 to 100 individuals per sample; 3 = from 100 to 999 per sample; 4 = ≥ 1000 per sample). HC – head capsule; MNI – minimum number of individuals.

The younger biozone (451–419 cm) was distinguished according to the abundant subfossil remains of lake taxa, indicating an increase in water level and the existence of a perennial shallow water body. The biozone was not, however, rich in (morpho)species: a total of just 6 chironomid taxa, 4 non-chironomid insect taxa, 3 cladoceran taxa, and 1 bryozoan taxa. The most numerous remains belong to the cladoceran *Chydorus sphaericus* and reach high abundances up to thousands of individuals per 3 cm³. Other cladocerans (genera *Ceriodaphnia* and *Daphnia*) are represented only by single findings of resting eggs (ephippia). The most numerous chironomid HCs (abundances up to 27 HC per 1 cm³ of sediment) represent the genus *Chironomus*, a taxon usually associated with soft sediments from various types of lake. Other chironomids, namely *Ablabesmyia*, *Limnophyes*, *Paratendipes nudisquamis*-type, *Psectrocladius*, *Pseudorthocladus*, and *Thienemannimyia*-type, were found in low abundances (<1 HC per 1 cm³) and represent the fauna of small streams and/or the littoral zone of lakes. Of the non-chironomid finds, larval remains of diving beetles (family Dytiscidae) are worth mentioning as most species are lentic. Overall, the invertebrate assemblages with low species richness and the dominance of *Chydorus sphaericus* and *Chironomus* are unusual and clearly indicate extreme conditions.

We also analysed modern sediment and water samples at the Zahájí site to compare its current state with its state in the MBA. These reference samples were collected up to 10 m from the ZAH coring site, i.e., outside the channel of the current brook (Fig. 4; Table 1). The waterlogged surface with very slow running water in the middle of the brook valley is patchy, with two distinct sediment types: one with a striking red colour (assumed to reflect high iron content), and the other with a dark colour and a high organic content. The iron content in the first sediment sample was measured by a portable X-ray fluorescent (XRF) spectrometer (Vanta, Olympus). The proportion of iron in the sample after drying was 38.5 %.

Zoological analysis of the two modern sediment samples from the waterlogged surface of the current bog revealed the absence of

invertebrate fauna in the Fe-rich sample and the presence of invertebrate fauna of running waters and wet soils (mainly chironomids of the sub-family Orthoclaadiinae) without any lake taxa in the organically rich sample. Analyses of a water sample from the hand-dug pit (naturally flooded for 14 months) revealed low pH of 5.97, relatively high conductivity (K_{25}) of 865 $\mu\text{S}/\text{cm}$, and the absence of any cladoceran species, including *C. sphaericus*. This absence likely reflects the very low water residence time of the pit rather than extreme water chemistry. Under more favourable conditions, the pit would soon be colonized by cladocerans (Juračka et al., 2016).

In addition, a reference surface (0.0–1.0 cm) sediment sample and water samples for pH, conductivity, and planktonic fauna were taken in 2022 from the nearby Kamencové jezero (=Kamencové Lake, 50.472° N, 13.425° E; Fig. S2), a strongly acidic post-mining lake with uniquely high concentrations of dissociated potassium alum (Hrdinka, 2012). The sediment sample from Kamencové jezero was dominated by chironomids of the genus *Chironomus*. The pH and conductivity (K_{25}) values in the water samples were 3.4 and 1016 $\mu\text{S}/\text{cm}$ respectively. No cladoceran species were observed at this site either.

3.5. Analysis of the human fingernail

A human nail was discovered with the broomcorn millet remains in the ZA1 core. After picking it out from the core, the maximum measured width of the nail was 12.0 mm (at the fracture point), the maximum length was 8.2 mm, and the thickness at the edge was ca. 0.5–1.0 mm. Subsequently, the nail began to shrink as a result of drying. Parts of the nail (the edge and the underside) were damaged by the corer (Fig. 10).

Judging by its morphological features, the nail is likely to be from the thumb or big toe. On the inner side of the nail plate, fine longitudinal grooves are evident as a remnant of attachment to the nail bed, and it also appears that three layers of the human nail plate can be distinguished (namely the dorsal, intermediate, and ventral nail plate; Kobayashi et al., 1999). Slight vertical grooves are evident on the outer

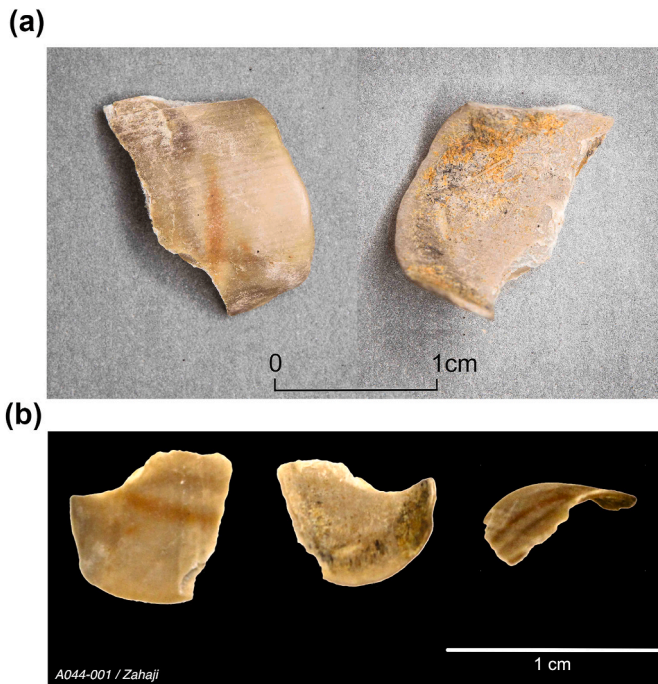


Fig. 10. A – Photo of the human nail shortly after it shrank as a result of drying out; B – A044_report, SciLifeLab Ancient DNA, Evolutionary Biology Centre, Norbyvägen 18C, Uppsala 752 36, Sweden.

surface. Mild vertical grooves often appear on the nails of older adults, probably due to a slowing of cell turnover. The translucent texture of the plate is probably suppressed by the tanning process, although its colour falls far short of the colouring seen on the nails of Old Croghan Man (Giles, 2020, p. 258).

The nail seems to be manicured on the distal edge, just as, for example, in the case of St. Bees Man and Lindow Man (Brothwell, 1986, p. 39). Its surface was smooth and bore only small scratches, which were hardly visible and might have been made after it was deposited in the wetland environment; there are also no signs of the damage from manual work that can be found, for example, in the nails of the Greenland mummies (Hansen et al., 1991, p. 80, Fig. 64). Here, numerous transverse cuts in the thumbnails were probably made by a knife.

3.5.1. Details of methodology for aDNA analyses are provided in SI: S4

Unfortunately, although DNA data were generated from the sample, the amount that matched human DNA was extremely low, like the blank controls. The interpretation is that no human aDNA was preserved in the specimen (Magnus Lundgren, Ancient DNA project A0 44). This is no surprise given the high acidity of the water in the bog (Fischer, 2012, p. 111; see chapter 4. Discussion). Until now, DNA has only been recovered from preserved teeth and bones, as in the case of Vittrup Man, deposited in a Danish bog between 3300 and 3100 BC (Fischer et al., 2024).

3.6. Analyses of broomcorn millet

3.6.1. Details of aDNA analysis are provided in SI: S5

A layer of waterlogged broomcorn millet grains, rachis, stalks (Fig. 11) and roots was detected at a depth of 4.35 m–4.50 m in ZAH2004, ZAH2009, ZAH A–C, ZA1, ZA7, and ZA16. This implies that the broomcorn millet was dispersed over an area of at least 6 m² (Fig. 4). The original thickness of the broomcorn millet layer is difficult to determine because of the action of taphonomic processes, but the plants appear to have been deposited into the pond as a single event and formed a layer a few centimetres thick at most (see Fig. 12).



Fig. 11. Collection of plant macroremains from depth 444 cm, ZAH B and ZAH C cores. The sample is clearly dominated by *Panicum miliaceum*, including one stem. Photo: P. Pokorný.

We attempted to recover preserved aDNA from two broomcorn millet grain samples (Z1 and Z2) recovered at a depth of 444 cm from the ZAH B and ZAH C cores.

The mapDamage plots for sample Z1 showed profiles consistent with damaged modern DNA rather than authentic ancient DNA. Sample Z2 showed nucleotide misincorporation patterns consistent with some authentic ancient DNA of low quality, as well as damaged modern DNA.

These results indicated that, as with the human fingernail, very little endogenous DNA was preserved in the Zahájí broomcorn millet. Although some studies have reported successful extraction and sequencing of endogenous DNA from waterlogged plant material, the majority of these have been from lignified tissues such as grape pips and subfossil wood remains (Schworer et al., 2022).

3.7. Analysis of organic residues

3.7.1. Details on methodology are provided in SI: S6

Several grams of the ZAH A sediment were scanned for organic residues to provide information regarding whether any other part of the human body might still be preserved in the bog.

Neither the total lipid extracts (TLEs) nor the neutral and acidic fractions of the TLEs revealed any signs of biomarkers which could be directly related either to adipocere formation or decomposing adipose tissue. The total lipid extracts and acidic fractions contained mainly free fatty acids, dominated by long even fatty acids C_{18:0}–C_{28:0}, together with ω-hydroxyfatty acids (e.g. 16-hydroxypalmitic acid). Neutral fractions dominated, with free fatty alcohols (C₁₈–C₂₈), long odd linear n-alkanes (C₂₇, C₃₁), long dicarboxylic acids, phytol and plant derived steroids – stigmasterol, β-sitosterol, campesterol, and 5β-stigmastanol, a degradative product of stigmasterol and sitosterol (Evershed and Connolly, 1994) (Fig. S3).

4. Discussion

4.1. Environmental context of the findings

A lentic water body appeared at the Zahájí bog shortly before the broomcorn millet/nail deposition around 1500–1400 BC. Such an environment does not currently occur at the study site. In view of the discovery of fine sediments rich in the remains of aquatic fauna, and the shape of the valley, this water body was between 1.0 m and 4.5 m deep, at most ca. 30 m wide, but of unknown length. The character of the deeply incised narrow valley and the lack of finds such as structural elements of the wooden platform, pottery, other edible plants, and also

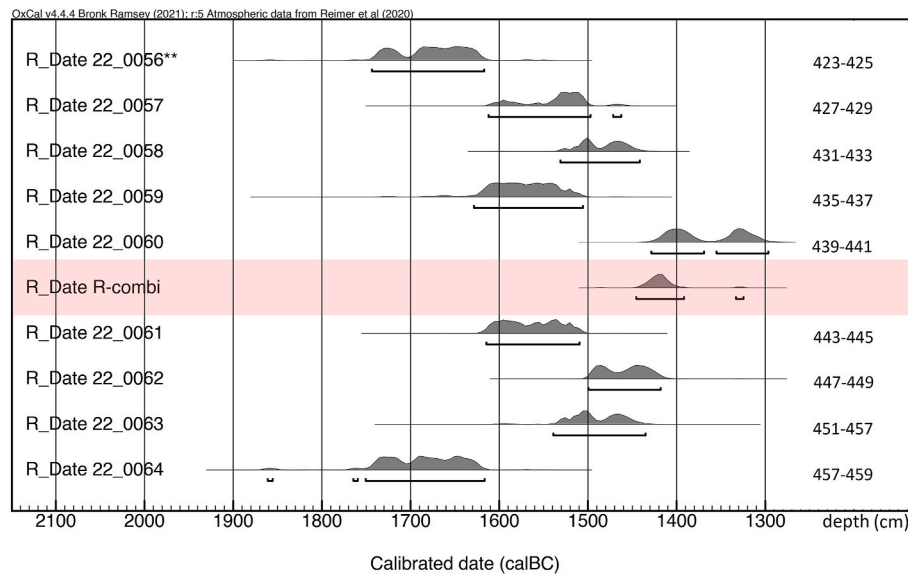


Fig. 12. Detail of the dating of the layers above and below the layer with millet (ZAH A). Depth intervals (in cm) for dated samples are shown on the right.

water quality (the water was probably not drinkable – see below) does not support the idea that the site may have been some kind of a pile dwelling, such as, e.g., Alvastra in Sweden (Göransson, 2014), Swiss lake shore sites (e.g. Menotti, 2001), or Scottish and Irish crannogs (Henderson and Sands, 2012).

The very low species richness of the aquatic invertebrate remains found in its sediments can be explained by the extreme chemistry of the lake water resulting from the geological bedrock in the catchment and the related presence of dissociated basaluminite. The two most abundant aquatic invertebrate taxa, the cladoceran *C. sphaericus* and the chironomids of the genus *Chironomus*, are known to be early colonizers of lakes after significant environmental change, especially under low pH conditions (e.g. Hrdinka et al., 2013; Stuchlík et al., 2017). Viable populations of some *Chironomus* species and *C. sphaericus* were observed even at water pH values of 2 and 3, respectively (Deneke, 2000; Takagi et al., 2005). These two dominant taxa were not found in the modern samples from Zahájí, which indicates that a different type of ecosystem was present at the study site in the Middle Bronze Age. Their high concentrations in sediments around the broomcorn millet layer suggest the existence of a perennial acidic water body. Water pH values were low, but likely higher than the current pH of Kamencové jezero (so probably in the range pH 4.0–5.0), where no cladocerans live, not even the hardy *Chydorus sphaericus*. This interpretation is further supported by the evidence on authigenic precipitation of basaluminite, a mineral associated with pH values between 3.5 and 5.5 (España, 2008). The low pH had a positive effect on the preservation of various remains (e.g. the unique preservation of filamentous algae; Fig. S5) but had a negative effect on the preservation of aDNA or adipocere formation (Ubelaker and Zarenko, 2011; Lerchi et al., 2022; Schworer et al., 2022).

Recognizing that at the time of the deposition of the findings the valley floor of the Podbradecký potok was not only a bog but at least partially a shallow water body alters the interpretation of the broomcorn millet/nail discovery, but not significantly. Deposits of artefacts in bogs were first found during peat digging or cutting as early as the 18th and 19th centuries in southern Sweden and a substantial number of them appeared during the first half of the 20th century (Larsson, 2006). At that time, there were naturally no detailed investigations of original deposition conditions; we assume that when bodies or objects were deposited in the bogs, their surface was muddy or, such as in Zahájí, covered by shallow water bodies.

4.2. Bodies and artefacts in bogs

Human remains in bogs are usually found in northwestern and northern central Europe and the eastern Baltic region. Van Beek et al. (2022) divided their occurrences into six phases, among which there are marked differences. For example, traces of violent death are most frequent in phase 2 (5200–2800 BC) and phase 6 (AD 1100–1900); on the contrary, phase 4 (1600–1000 BC), to which our finding belongs, has only one example of violent death from what is overall the smallest set of 12 findings (9 skeletal remains and 3 mummies: 4 males, 4 females, and 4 undifferentiated).

Bog bodies are usually considered social outcasts or ‘witches’ (Lund, 2002; cited in Randsborg, 2015) or those who had suffered unusual deaths (Ravn, 2010). Randsborg (2015, 8) considers bog bodies to be legal hostages killed in anger over broken treaty arrangements, and in accordance with the wording of such mutual agreements.

In Indo-European mythology, wetlands were associated with the gods of the underworld and the ghosts of the dead (Modzelewski, 2006), and as auspicious sites for contacting the spiritual world. Artefacts deposited in these wetland areas are often interpreted as ritual deposits that represent offerings to gods or spirits. The most common type of ritual deposits are everyday objects such as ceramic vessels, bones, and wooden artefacts (Mortensen et al., 2020). In addition to artefacts, food products are frequently found within the bogs. The most abundant of these is so-called bog butter, which was deposited in bogs in various types of containers from the Early Bronze Age until the 1800s; there was also a rich tradition of using butter in fertility ceremonies (Giles, 2020). For butter, cheese and meat, bogs eventually served as a larder.

So far, however, no find is known of either the deposition of dispersed cereal grains or bundles of whole plants except the Zahájí case.

4.3. Was the entire human deposited at Zahájí?

We suppose that complete broomcorn millet plants were thrown into the water body, but a lack of information prevents us from determining whether a complete human body also occurred there. If so, the corer might have torn the nail from the remainder of the finger/thumb tissue. The rest of the body may still be in the present-day bog, perhaps in the form of soft tissue, skin, and hair, as no bones would have survived in such an acidic environment. However, because of the depth of the discoveries and the nature of the waterlogged sediments, we do not yet have the means to conduct a comprehensive archaeological

investigation on the site.

The existence of the nail only could be, for example, a result of its having been separated from the rest of the finger tissue and drifted away through post-depositional processes, as observed in the case of the Lindow Man, where significant lateral displacement of the nails within the peat took place as a result of some later process after some degree of decomposition of the body (Brothwell, 1986, pp. 87–88).

Another possibility is that the nail is simply a fragment of a body that was spread over a broader area (catchment) of the lake, as at Kvarntorp, Högtorpsmossen, where numerous parts of a body were found within an area 50 m across (Fredengren, 2011).

There are many other ways in which a nail can be separated from the body prior to death: it can be torn from its bed because of torture or after some injury; it could come from an amputated finger/toe (McCauley and Collard, 2024); it could be accidentally cut off during some form of physical labour, such as harvesting.

The presence of biomarkers originating from adipocere or decomposed human tissues were not detected in either the analysed total lipid extracts or the perspective fractions. Based on the identified compounds, the lipids probably originated from the decomposition of plant tissues (leaves, roots) and plant lipid polymers such as cutin and suberin (Riederer et al., 1993; Simpson et al., 1999; Bull et al., 2009). Because of their hydrophobicity, non-polar lipids of decomposing tissues are not usually prone to leaching or to dissemination further into the surrounding environment (Evershed and Connolly, 1994). Lipids released into the soil through adipocere formation can be found in the surrounding soil over a long timescale (Fiedler et al., 2009; Sousa Queirós et al., 2023). On the other hand, key factors in adipocere formation are usually a mildly alkaline pH and a warm, moist, anaerobic environment (Ubelaker and Zarenko, 2011; Lerchi et al., 2022). An acidic, anaerobic and nutrient-poor environment, typical of many bogs, would have favoured the preservation of soft tissue such as skin, hair, or nails (Sanden and Mellor, 1996; Nielsen et al., 2020). However, lipids other than from peat would probably be absent, as was shown in a peat sample immediately adjacent to the Lindow Man bog body in the study by Evershed and Connolly (1994).

Although we cannot rule out the possibility that the nail was the sole body component present, we believe it is improbable that only a single nail would be recovered in a borehole 6 cm in diameter without the presence of other body parts in the sediment.

4.4. An attempt at interpreting the findings

In interpreting the findings, we must reiterate that there are no known analogues to the given situation. Based on a detailed study of the literature, we have selected two examples that illustrate situations in which similar findings could enter the aquatic environment. The first is based on the few ethnographic sources of information on grain treatment related to the harvest customs of the European peasantry, which persisted until the late modern period; the second example is an idea that springs from the nature of the Zahájí site itself.

4.4.1. Harvest related custom?

While human remains are discovered in bogs relatively frequently, the broomcorn millet finding is the first of its kind to be described so it cannot be compared to any other known record. It was undoubtedly a staple crop in later prehistoric agriculture in Europe, but, like other cereals, there is no trace of its use in rituals, nor any mention of such customs in ethnographic literature. This does not apply in India. Here, millets have a rich cultural history and are used in various functions such as wedding ceremonies, crop harvesting celebrations, offerings to traditional Gods, worship rituals, and death commemorations (Ankita and Seth, 2025). However, the application of these behaviours to European prehistory is questionable.

Radiocarbon dating of the broomcorn millet remains (ca. 1428–1311 BC) places the site in a group of the four oldest dates from Bohemia and

among the oldest dates from central Europe (Filipović et al., 2020; Fig. S1). At Bohemian sites, the oldest broomcorn millet finds come from contexts that differ from the broader archaeology of central Europe: one from a wetland (this study), two from abris in a remote sandstone rocky area (Šída and Pokorný, 2020) and one from the heavily fortified Velim site, which is known for the large number of human sacrifices in ditches and is usually classified as a cult site (Harding et al., 2007). Only one find comes from an ordinary settlement pit. This assessment may, however, be swayed by the fact that macroremains from settlements of archaeologically known age are not commonly radiocarbon-dated in Czechia.

Because of the discovery of entire ears with mature grains, stems and roots, we assume that the deposition in the water body occurred in summer or early autumn, during harvest. This was an event that many ceremonies, customs and festivals have been associated with since ancient times. Many of them were recorded by ethnographers in the second half of the 19th century and the first half of the 20th (e.g. Mannhardt, 1875, 1884, cited by Stránská, 1932–33). In the geographical area of central and eastern Europe, the ethnographer D. Stránská (1932–33) collected a large amount of material, drawing on, among other things, extensive Slavic literature. The harvest customs she describes are mostly associated with the last sheaf of grain, which received special treatment. This was usually ceremonially reaped, tied (sometimes in the shape of a figure), brought to the householder's dwelling, and ceremonially stored or displayed in a place of honour. In *The Golden Bough* (1895; here the later edition of 1994), James Frazer described a quite different type of custom associated with the last harvest. Here, a figure known as the 'spirit of the crop' plays an important role. The so-called corn-spirit must be killed at the end of the harvest to be reborn the following year. The customs associated with the end of the corn-spirit may be based on the story of a mythological figure named Lityerses, an illegitimate son of Midas, a mythical king of Phrygia (12th–7th century BC). Lityerses reaped the corn. When a stranger happened to enter the cornfield or pass by it, Lityerses gave him plenty to eat and drink, then took him to the cornfields on the banks of the river and compelled him to reap along with him. Finally, he wrapped the stranger in a sheaf, cut off his head with a sickle, and carried away his body, swathed in the cornstalks. There are some grounds for supposing that in these stories of Lityerses we have the description of a Phrygian harvest custom in accordance with which certain persons, especially strangers passing the harvest field, were regularly regarded as embodiments of the corn-spirit, and as such were seized by the reapers, wrapped in sheaves, and beheaded, their bodies, bound up in the corn-stalks, being afterwards thrown into water as a rain-charm (Fraser, 1894, p. 337). According to Fraser, in many European countries and in numerous regional forms, the idea of the corn-spirit has persisted into modern times. The corn-spirit was usually considered to be the man or woman who harvested the last of the crop from the field. Alternatively, it was the thresher who gave the final stroke, or the person who untied the last sheaf on the threshing-floor. This person was wrapped in the sheaf, shamed, sometimes beaten, doused with water, thrown into a dunghill and finally into a brook (it should be noted that this was done without decapitation or other killing). Thus, the person whose remains were preserved at Zahájí could represent the corn-spirit and was thrown as such into the water together with the broomcorn millet plants or even wrapped into a sheaf of broomcorn millet.

Although this idea may seem far-fetched, other cases exist in which the same cultural customs have been passed down for centuries, if not millennia. Modzelewski (2006) demonstrates a principle of 'long memory' when he describes the correspondence between the ritual killing of criminals and their deposition in marshes as described in Tacitus' *Germania* and the barbaric customs recorded at the beginning of the 11th century AD.

The Czech historian Dušan Třeštík (2003) goes deeper into the past, describing identical elements in the New Year festivals of the pagan Slavs of Rügen in the 12th century AD and the ancient Greeks of Sparta.

According to Treštlík, the same rituals in remote parts of an Old World reflect their common cultural Indo-European foundation, and the rituals' origins would have been traced back at least to the Bronze Age.

Current linguistic theories regarding the time when the Indo-European proto-language was dispersed take us still further into the past, to the period between about 4500 and 2500 BC (Olander, 2019, p. 24). The westward migrations of descendants of the Proto-Indo-Europeans from their probable homeland on the Pontic-Caspian steppe (Mallory, 1989; Anthony, 2007) meant the expansion not only of the language but also of various cultural practices, including religious rituals such as offerings to the gods and the use of sacred spaces for ceremonies. Such theories could explain the similarity between customs in areas as distant as central Europe and ancient Phrygia some three thousand years ago.

4.4.2. "Prehistoric spa?"

The newly formed water body/lake might have attracted the attention of the Middle Bronze Age people because of its unusual water and lake-bottom colours (green, green-blue, brown, orange, or red), which are common in lakes with low pH and increased conductivity (saltiness) (Hrdinka, 2012; Hrdinka et al., 2013; Fig. S2). The water was extremely acidic and not suitable for drinking by either humans or livestock, but its properties might have been interesting otherwise. Because of elevated concentrations of dissociated basaluminite, it cannot be ruled out that the local water had therapeutic effects on skin diseases and rheumatism. Its chemical composition was similar to the water in Kamencové jezero near Chomutov in northwestern Bohemia (Fig. S3), where experiments with commercial bathing took place as early as the 19th century (Gabrielová and Lederle, 1997, and references therein), and was therefore intentionally used for this purpose.

The possibility that the water at Zahájí was used for some therapeutic purpose (disinfection of wounds, skin ailments, etc.) cannot, therefore, be ruled out. However, we could not identify any examples of similar spa practices prior to the 19th century.

5. Conclusions

At the Zahájí site, we found a phase of local bog development represented by a shallow body of water that formed in ca. 15th/14th century BC. Presumably relatively shortly after this event, a layer containing broomcorn millet macrofossils (over an area of at least 6 m²) and a human fingernail was deposited on the site. The first discovery of the prehistoric human remains in a bog environment in central Europe and the only known finding of whole cereal plants (broomcorn millet) deposited in the same environment are potentially highly significant, even though they (for now) do not have any archaeological or ethnographic parallels. Moreover, this environment was strongly acidic because of local mineral springs and might have attracted people because of its unusual nature. The extreme chemical conditions on the one hand caused the preservation of many organic remains, but on the other hand were unfavourable for the preservation of aDNA or biomarkers of decomposing human tissue.

The finding of a possible ritual treatment of broomcorn millet shortly after its introduction to the crop assemblage of the Middle Bronze Age make Zahájí a site of some significance and may help to address the question of why this crop swiftly became a staple in many European Bronze Age communities and to explore and explain the role it played in past societies. Specifically, we believe that reverence for this plant might have contributed to its rapid distribution throughout Bronze Age Europe.

Our research was limited by the difficulties in accessing the layer containing millet, which is located 4.5 m below the current bog surface and water table. The Zahájí site therefore deserves more extensive research in the future to clarify the reasons for the deposition of millet and the possible presence of a bog body with soft tissues.

CRedit authorship contribution statement

Dagmar Dreslerová: Writing – original draft, Visualization, Supervision, Investigation, Funding acquisition, Conceptualization. **Daniel Vondrák:** Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Jan Hošek:** Visualization, Validation, Supervision, Funding acquisition, Formal analysis, Data curation. **Veronika Brychová:** Validation, Methodology, Investigation, Funding acquisition, Data curation, Writing – review & editing. **Harriet Hunt:** Writing – review & editing, Methodology, Funding acquisition, Data curation. **Petr Pokorný:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Data curation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Plant ancient DNA analysis was carried out in the Department of Archaeology, University of Cambridge, UK, and the DNA Sequencing Facility, Department of Biochemistry, Cambridge, UK. We are grateful to Rosalyn Christian, Jo Osborne, and Shilo Dickens for their assistance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.quaint.2025.109898>.

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