

RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Stone grooved hammers from the Šumperk region in North Moravia and their possible association with metallurgical activity in the Late Bronze Age

Kamenné mlaty se žlábkem ze Šumperska a jejich možná souvislost s metalurgickou činností v pozdní době bronzové

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Stone grooved hammers from the Late Bronze Age represent a residual phenomenon in the use of such implements and are primarily associated with the extraction of metal ores. The present study discusses the discovery of two stone grooved hammers at the sites of Dubicko – Za Kostelem and Police-Polanka. These artefacts were subjected to use-wear, petrographic, 3D, and SEM/EDX analyses. The combination of these methods was employed to evaluate the overall degree of wear, determine the provenance of the stone raw material, and test the hypothesis that these tools were used during a specific stage of metallurgical activity. For comparison with the examined tools, additional stone grooved hammers from the Czech Republic, broadly dated to the period of 1300–800 BC, were also analysed.

stone grooved hammers – use-wear analysis – petrographic analysis – 3D analysis – SEM/EDX analysis

Kamenné mlaty se žlábkem z pozdní doby bronzové představují doznívající fenomén využívání těchto nástrojů a jsou spojeny zejména s těžbou kovových rud. Předkládaná studie pojednává o nálezů mlatů se žlábkem na lokalitách Dubicko – Za Kostelem a Police-Polanka. U těchto artefaktů byla realizována traseologická, petrografická, 3D a SEM/EDX analýza. Kombinace těchto analýz byla zvolena pro zjištění celkové míry opotřebení, provenience kamenné suroviny a potvrzení či vyvrácení hypotézy, že tyto nástroje byly součástí určité fáze metalurgické činnosti. Pro srovnání se zkoumanými nástroji byly analyzovány další mlaty se žlábkem datované do širšího období 1300–800 př. n. l. a nalezené v České republice.

kamenné mlaty se žlábkem – traseologická analýza – petrografická analýza – 3D analýza – SEM/EDX analýza

Introduction

Grooved stone hammers occur in Bohemia and Moravia from the Late Eneolithic to the Late Bronze Age (Procházka 1908, 120–129; Jiráň 2008, 49–50; Augustýnová 2016, 69–70; Kamarád 2023a, 40–43). These artefacts represent a substantive issue in Czech and international archaeological research, particularly because their recurrent presence at mining sites has encouraged their interpretation as tools linked to the extraction of diverse raw materials, most notably salt and metal ores. The densest clusters of these objects have been identified at Aibunar (Bulgaria), Rudna Glava (Serbia), Copa Hill (Wales), Mitterberg (Austria), and Špania Dolina – Piesky (Slovakia) (Craddock 1995, 74; Goldenberg 2013, 102–103; Lamprecht et al. 2022, 147–149). Also worthy of mention is the site of Duzdaği (Azerbaijan), where the use of grooved stone hammers in salt extraction has been documented (Hamon 2016, 510–526). For this reason, these tools are regarded as secondary evidence indirectly attesting to metallurgical activity and the skill of specialised craftsmen.

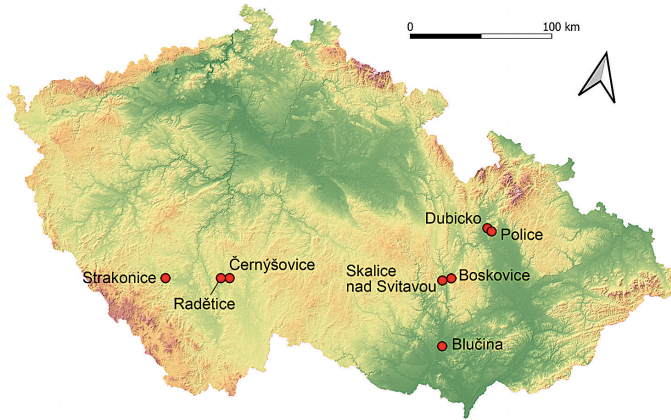


Fig. 1. Stone grooved hammers from the BD1–HaB3 period in Bohemia and Moravia.

However, establishing a possible link between the grooved hammers from Bohemia and Moravia and metallurgical activities remains problematic, as no metallogenic zone with confirmed Bronze Age metal extraction has yet been identified in the Czech Republic. Alternative hypotheses have been proposed, suggesting that these artefacts may have served other purposes in regions lacking specific metal ores. These include their potential use in the primary processing of certain types of stone raw materials, in warfare, in the crushing of plant or animal matter, or for driving wooden posts, as well as in other types of heavy-duty work requiring a robust implement (Tihelka 1966, 692–693; Turek – Daněček 2000, 251–252; Adams 2002, 173–174; Tajer 2014, 163; Fedyniaka – Giering 2016, 78–84).

The warfare hypothesis has so far received little attention in either Czech or international archaeology, as stone hammers are predominantly associated with mining activities. Detailed evidence showing grooved stone hammers primarily as weapons is still lacking (Adams 2002, 174–175; Kamarád et al. 2024, 51).

The hypothesis involving the processing of stone raw material appears particularly plausible for the 19 stone grooved hammers from the Prostějov district in central Moravia, all manufactured from locally available Culmian greywacke. On this basis, it has been suggested that these hammers may have been employed either in extracting Culmian greywacke or fine-grained conglomerates from nearby outcrops, or in breaking boulders within the stone fields around Velký Kosř. Culmian greywacke is the dominant rock used for making grain grinders and flat stone bases along the entire eastern edge of the Drahaný Highlands and Velký Kosř. Some artefacts obtained from surface collections at Bronze Age sites on Velký Kosř are characterised by their large size, high-quality Culmian raw material, and fine workmanship. These observations suggest that, in certain cases, the stone raw material may have been procured or worked using grooved stone hammers (Kamarád et al. 2024, 61–62).

The hypothesis concerning the processing of plant or animal materials was explored by Fedyniak and Giering (2016, 77–84), who analysed nine grooved stone hammers from the province of Alberta, Canada. Starch grain and lipid analyses of their surfaces revealed a variety of starches and lipids characteristic of specific plants and animals. Consequently, the primary function of all the examined grooved hammers was interpreted as tools employed during crushing or processing of plant and animal materials.

The assumption that grooved hammers may have been used for driving wooden posts or for various types of heavy work was proposed by *Adams (2002)* in her monograph *Ground Stone Analysis: A Technological Approach*. This hypothesis was tested and evaluated through use-wear analysis and experimental replication on grooved hammers from North America. A similar interpretation within the Czech context was proposed by *Tihelka (1966, 693)*, but it has not been corroborated by any analytical study of the local assemblage.

This study aims to determine the degree of wear and the provenance of stone raw materials from the Šumperk region in North Moravia by combining use-wear, petrographic, 3D, and SEM/EDX analyses, and to test the aforementioned hypotheses, with particular emphasis on potential links to metallurgical activities. For comparative purposes, additional stone grooved hammers from the Czech Republic, broadly dated to 1300–800 BC, were also analysed.

Materials

In the Šumperk region, grooved stone hammers were discovered at the sites of Dubicko – Za Kostelem and Police-Polanka (*Fig. 1*). Located approximately four kilometres apart, both sites have been known since the 1920s due to surface finds documented by local amateur archaeologists (*Brachtl 1993; Faltýnek 2008*). In the following decades, these sites continued to attract the attention of local amateur researchers, who conducted small-scale excavations and later also metal-detecting surveys (*Skutil 1931; Goš 1967*).

Between 2010 and 2017, a series of rescue archaeological excavations were carried out in Dubicko – Za Kostelem prompted by the construction of a new residential district, including a new road and associated utilities (*Halama 2013; 2015; Vránová 2015; Tomešová 2018*). Several hundred Late Bronze Age sunken features, mostly settlement structures, were excavated. An especially noteworthy discovery concerned artefacts associated with metallurgical activity, specifically one ceramic mould for casting, two nozzles, and 23 metal ingots (*Fig. 2; Halama 2013, 75–76; 2016, 25; Tomešová 2020, 80–93*). A stone grooved hammer from Dubicko – Za Kostelem (*Fig. 3: 1*) was found in a circular pit embedded in feature no. 549. Ceramic fragments, daub, two pieces of graphite, and other stone artefacts of uncertain function were also recovered from the pit (*Tomešová 2018, 15, 23*).

Regarding research at Police-Polanka, this site first attracted attention in the 1920s and 1930s from amateur researchers (*Červinka 1941, 125–138*). The first test excavations were conducted by J. Horký in 1950–1951, when a Neolithic settlement and a burial ground of the Lusatian culture were discovered. The most recent discovery, made in 2015, is a hoard from the site of Malá Polanka, dated to the HaB1–HaB3 phase of the Late Bronze Age. The assemblage consists of five torcs with a unidirectionally twisted body and smooth terminals, flattened by hammering and subsequently rolled into loops. The hoard also included a two-part Spindlersfeld-type fibula of the Křenůvka-Domaníža style with engraved and hammered decoration, which can be dated to the HaB1 phase (*Říhovský 1993, 44–45; Halama 2015, 53–58*). The dating of the stone grooved hammer from Police-Polanka (*Fig. 3: 2*) remains uncertain, as it originates from an old museum collection and lacks proper contextualisation. Its assignment to the Late Bronze Age is based on the evidence of a burial ground and the hoard dated to HaB1–HaB3.



Fig. 2. Photographic documentation of selected artefacts associated with possible metallurgical activity in Dubicko. 1–2 – ceramic nozzles; 3 – ceramic mould for casting; 4–22 – metal ingots (photo by author).

Stone grooved hammers from the BD1–HaB3 period in Bohemia and Moravia

For the comparison of the results of non-destructive scientific analyses, three grooved stone hammers from South Bohemia dated to the BD1–HaA2 period and five artefacts from Moravia (Fig. 1), which can be assigned to HaB1–HaB3, were studied (Militký 1988; Michálek 2002, 63; Dostál – Štřof 2001, 25–36; Salaš 2005, 295; Chvojka 2009, 109; Jarůšková – Štřof 2014, 166–168).

Apart from the artefacts from the sites of Dubicko and Police-Polanka, grooved stone hammers from the Late Bronze Age in Moravia are primarily concentrated in the southern part of the region. For example, a grooved stone hammer from the site of Boskovice – Masarykovo náměstí was found in a storage pit together with ceramic fragments and animal bones. At the same time, it is worth noting a possible connection with the site of Boskovice-Lipníky, located less than 3 kilometres away, where four bronze hoards were uncovered. Three of these have been interpreted as deposits from a metallurgist's workshop, based on the presence of a hammer and a large number of ingots (Dostál – Štřof 2001, 29–30; Jarůšková – Štřof 2014, 166–168).

An interesting case is represented by a stone grooved hammer from the Blučina-Cezavy site, which formed part of a hoard dated to the Velatice phase of the Middle Danube Urnfield culture, covering the BD–HaA period. Discovered in 1944, this hoard contained not only a stone grooved hammer but also four fragments of a sickle handle, a fragment of a needle with a flat head, a fragment of a spearhead, two bent chisels, 2.05 kilograms of ingots, and ceramic fragments (Salaš 2005, 295).

From South Bohemia, artefacts recovered from the flatland settlements in Černýšovice (Tab. 1: 2; Fig. 3: 4), Radětice-Soví (Tab. 1: 5; Fig. 3: 5), and Strakonice (Tab. 1: 6; Fig. 3: 6) can be attributed to the BD1–HaA2 period. The find contexts of all three stone grooved hammers show similar characteristics. The artefacts from Černýšovice (Tab. 1: 2;

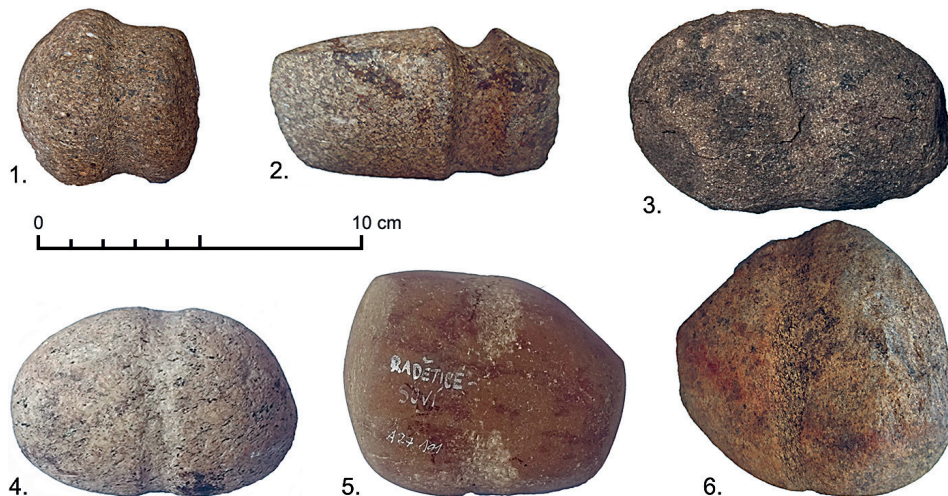


Fig. 3. Photographic documentation of stone grooved hammers from the BD1–HaB3 period. 1 – Dubicko – Za Kostelem; 2 – Police-Polanka; 3 – Boskovice – Masarykovo náměstí; 4 – Černýšovice; 5 – Radětice-Soví; 6 – Strakonice (photo by author).

Fig. 3: 4) and Strakonice (*Tab. 1: 6; Fig. 3: 6*) were discovered in settlement pits, while the tool from Radětice-Soví (*Tab. 1: 5; Fig. 3: 5*) was recovered during surface survey. In all three cases, the associated artefacts consisted only of ceramic sherds, and no evidence for a possible connection with metallurgical activity has been demonstrated (*Militký 1988, 163–164; Michálek 2002, 56, 63; Beneš – Chvojka 2008, 13; Augustýnová 2016, 69–70*).

Applied non-destructive scientific analyses

A combination of non-destructive scientific analyses (petrographic, use-wear, SEM/EDX, and 3D analysis) was applied to stone grooved hammers from Dubicko – Za Kostelem and Police-Polanka. The analyses aimed to determine the probable function of the investigated artefacts. For a comparison of the obtained data, several selected grooved hammers from the Czech Republic dating to the BD1–HaB3 period were analysed.

The petrographic analysis was conducted in collaboration with Peter Gadas from the Institute of Geological Sciences, Masaryk University, Brno. Its aim was to determine the lithological composition of the investigated artefacts and, where possible, to establish the provenance of the raw material. The analysis was performed using a Nikon SMZ18 stereomicroscope, with a maximum magnification of 100×, in bright field with single polarisation and oblique illumination.

The use-wear analysis was conducted at the Laboratory of Optical Microscopy, Institute of Archaeology and Museology, Masaryk University, Brno. An Olympus BX51-M optical microscope was employed in reflected light mode, bright field without polarisation, at a magnification of 200×. The analysis focused on identifying the overall wear patterns on the working surfaces, including the detection of possible metallic microresidues. For comparison of the observed wear traces, published use-wear studies of stone grooved

Site name	Inventory number	Preservation	Context	Chronology	Length (cm)	Width (cm)	Weight (kg)	Storage location	Reference
Boskovice – Masarykovo náměstí	A 20252	Complete	Sstorage pit	HaB1–HaB3	13.2	5.5	0.9	Boskovice Region Museum	<i>Dostál – Štřof 2001, 29–30; Jarůšková – Štřof 2014, 166–168</i>
Černýšovice	A 26 546	Complete	Settlement feature	BD1–HaA2	10.7	4.8	0.9	Bechyně Town Museum	<i>Beneš – Chvojka 2008, 13</i>
Dubicko – Za Kostelem	A 87 325	Complete	Settlement feature	HaB1–HaB3	4.8	3.5	0.2	Šumperk History Museum	<i>Tomešová 2018, 15, 23</i>
Police-Polanka	A 1054	Complete	Unknown	HaB1–HaB3	9.7	2.5	0.4	Šumperk History Museum	X
Radčice-Soví	27. 101	Complete	Surface survey	BD1–HaA2	10.3	7.5	0.9	Museum of South Bohemia in České Budějovice	<i>Augustýnová 2016, 69–70</i>
Strakonice	A 2314	Complete	Settlement feature	BD1–HaA2	10.5	2.8	0.7	Middle Otava River Region Museum in Strakonice	<i>Michálek 2002, 56, 63</i>

Tab. 1. Overview of stone grooved hammers from the BD1–HaB3 period in Bohemia and Moravia.

Site name	Inventory number	Petrography analysis	Use-wear analysis	3D analysis	SEM/EDX analysis
Boskovice – Masarykovo náměstí	A 20252	Friable sandstone to arkosic sandstone	Probably primary function in processing harder materials Microresidues	Work traces, such as notches and bruising penetrating deeper into the stone structure on both working surfaces	X
Černýšovice	A 26 546	X	Probably primary function in processing harder materials Microresidues	X	X
Dubicko – Za Kostelem	A 87 325	Orthogneiss	Probably primary function in processing harder materials Microresidues Mitterberg-type binding	Work traces, such as notches and bruising penetrating deeper into the stone structure on both working surfaces Mitterberg-type binding	Barite, zircon, allanite, ilmenite, and muscovite–minerals Isolated microresidues of lead and zinc combined with sulphur
Police-Polanka	A 1054	Gabbro	Probably primary function as an axe and a crusher Microresidues Mitterberg-type binding	Front working surface: slight irregularities implying relatively gentle use Rear working surface: battering and crushing of hard materials	Microresidues and abrasions of pure tin
Radčice-Soví	27. 101	Quartz	X	X	X
Strakonice	A 2314	Orthogneiss	X	X	X

Tab. 2: Overview of the results of non-destructive scientific analyses of stone grooved hammers from the BD1–HaB3 period in Bohemia and Moravia.

hammers from the Grotta della Monaca site were employed (*Larocca – Breglia 2016*, 301–311; *Caricola et al. 2020*, 263–283). An additional aim was to determine the type of tether used in the groove area. This line of inquiry was supported by the creation of photogrammetric 3D models of the stone grooved hammers, which served to reconstruct overall wear patterns and handling techniques. The models were created using the software programs Reality Capture and Cloud Compare (*Remondino – El-Hakim 2006*, 269–291; *Hanke et al. 2008*, 190–191).

The SEM/EDX analysis was conducted in collaboration with Peter Gadas using a JEOL scanning electron microscope at the Institute of Geological Sciences, Masaryk University, Brno. The principle of operation of a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray (EDX) analyser involves examining materials by directing a beam of electrons in a vacuum onto the surface of a sample. When the electrons interact with the sample surface, various types of radiation are produced. This radiation is detected and different types of images generated from it provide information about the analysed sample. The most common image is obtained from secondary electrons (SE), which provide data on surface morphology. Backscattered electrons are also measured using a BSE (backscattered electron imaging) detector, yielding phase-contrast images that allow the determination of surface topography. SEM systems are equipped with EDX analysers, which operate by processing X-rays generated when a stream of high-energy electrons strikes a solid material, thereby identifying the chemical composition of the sample (*Girão et al. 2017*, 153–168).

The working surfaces of the stone grooved hammers from Dubicko and Police were analysed to detect and perform a spectral characterisation of possible metallic residues adhered to the artefact surfaces (*Girão et al. 2017*, 153–168; *Ježek 2020*, 318–328).

Results of the applied non-destructive scientific analyses

Petrographic analysis

The analysis revealed that the stone grooved hammer from the Dubicko – Za Kostelem site (*Tab. 2: 3*) is made of orthogneiss containing quartz, feldspar, muscovite, and accessory ilmenite. The artefact from Police-Polanka is composed of gabbro (*Tab. 2: 4*) characterised by basic plagioclase and altered remnants of amphiboles.

The provenance of the rock used for both artefacts can be linked to the Hrubý Jeseník Mountains, specifically to the Jesenice Massif and the Keprnice Dome, particularly in the vicinity of Keprník, Vrbno pod Pradědem, and Bělá pod Pradědem (*Řehoř 1988*; *Koverdynský 1993*, 31–40; *Cháb et al. 2008*, 17–26). Gneiss and orthogneiss complexes, representing metamorphosed granitoid igneous rocks of Cadomian age, are commonly found in these areas and were extensively metamorphosed during the Hercynian orogeny. The Keprnice Dome is also characterised by the occurrence of basic rock intrusions, representing remnants of original gabbros, dolerites, and basalts. These rocks were transformed during Hercynian metamorphism into amphibolites, composed predominantly of amphiboles and recrystallised basic plagioclase (*Žáček – Pin 1999*, 57–82; *Přichystal 2009*, 27).

The petrographic analysis was also applied to stone grooved hammers from the BD1–HaA2 period. The first example is a stone artefact from Strakonice (South Bohemia region), which was made of orthogneiss of local provenance (*Tab. 2: 6*). The orthogneiss of this region is mainly metamorphic granitoids of the Moldanubian and is characterised by the

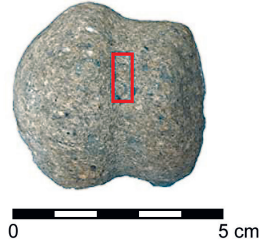
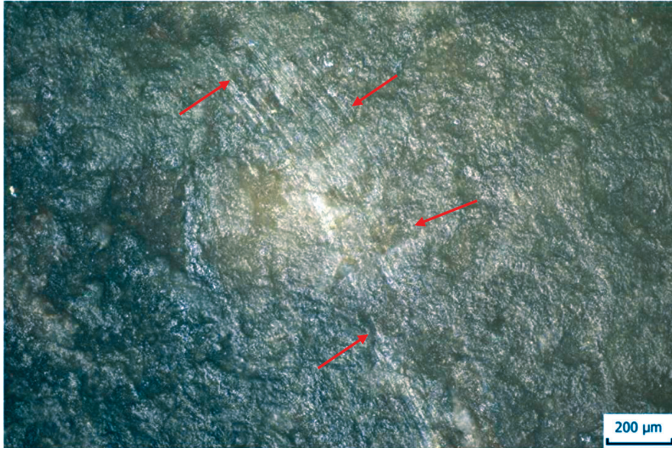


Fig. 4. Microtraces of Mitterberg-type binding on a stone grooved hammer from Dubicko (photo by author).

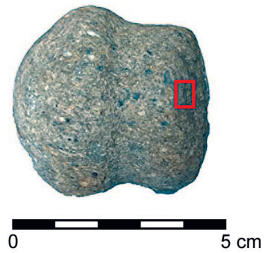
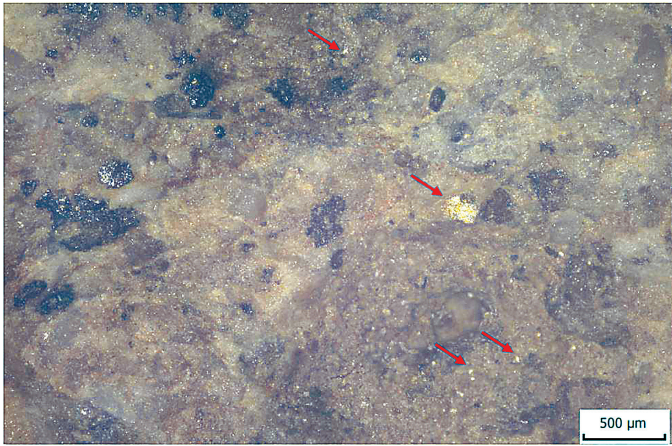


Fig. 5. Possible microresidues of unknown nature on the rear working surface of a stone grooved hammer from Dubicko (photo by author).



Fig. 6. Micro traces of Mitterberg-type binding on a stone grooved hammer from Police (photo by author).

presence of quartz, potassium feldspar and biotite. These rocks are commonly found in the Strakonice vicinity and their use for the production of tools can be considered as a consequence of their availability (*Chlupáč et al. 2002*, 32–39). An analogous example is the stone grooved hammer from Radětice-Soví (South Bohemia), which was made of quartz, also of local origin (*Tab. 2: 5*). In the vicinity of Radětice, quartz is abundant, especially in the form of vein fillings and lenticular accumulations in Moldanubian paragneiss and migmatites. Their occurrence is associated with hydrothermal processes and regional metamorphism (*Chlupáč et al. 2002*, 32–39). Both cases thus document the use of locally available rock raw materials, which, owing to their mineralogical composition and mechanical properties, were well suited for the production of striking tools. The artefact from Boskovice – Masarykovo náměstí (South Moravia) can be attributed to the Permo-Carboniferous formations of the Boskovice Furrow. This artefact is composed of a psammitic sedimentary rock, ranging from friable sandstone to arkosic sandstone (*Tab. 2: 1*). It contains ochre-coloured feldspar, chloritised biotite, a fine-grained siliceous matrix with an admixture of limonite, and quartz clasts. A petrographic analysis has not yet been carried out for the other stone hammers from the BD1–HaB3 period.

Use-wear analysis

During the examination of the front and rear working surfaces of the Dubicko stone grooved hammer, significant surface disturbances were observed, likely resulting from crushing, which may indicate a primary function in processing harder materials (*Tab. 2: 3*). The character of these micro traces on both working surfaces is very similar and displays a uniform pattern, suggesting that both surfaces were used for work. Analysis of the groove revealed micro traces of polishing and of binding with a rope made from a distinctly fibrous plant material (*Fig. 4*), which is characteristic of ‘Mitterberg-type’ binding (*O’Brien 1994*, 146; *Goldenberg 2013*, 102–103; *Thomas 2018*, 355; *Lamprecht et al. 2022*, 149). At the same time, small microresidues were observed on the rear working surface (*Fig. 5*), which can be interpreted either as mineral microresidues commonly present in any stone raw material (e.g. zircon, barite, chloritised biotite) or as metal microresidues, which would indicate a hypothetical primary function of the stone grooved hammers in the extraction or processing of metal raw materials. Consequently, it was necessary to proceed with SEM/EDX analysis in order to determine the elemental composition of these microresidues (*Girão et al. 2017*, 153–168).

Examination of the working surfaces of the Police stone grooved hammer revealed micro traces consistent with practical use. The two surfaces exhibit distinct wear characteristics. The front working surface, whose morphology is distinctly axe-like, displays slight irregularities that imply relatively gentle use, corroborated by the presence of grinding and polishing traces. In contrast, the rear working surface shows evidence of battering and crushing of hard materials, indicating the intensive use of this artefact. Considering the wear patterns on both surfaces (*Tab. 2: 4*), it can be inferred that this artefact could have been used as an axe due to maintenance of its edge, and, based on the wear observed on the rear surface, also functioned as a crusher (*Hamon 2016*, 514–516; *Lamprecht et al. 2022*, 148–155). Microscopic analysis of the groove, similar to the Dubicko artefact, revealed traces of Mitterberg-type binding (*Fig. 6*). Microresidues of unknown origin were identified on both working surfaces (*Fig. 7*) and were subsequently analysed by SEM/EDX.

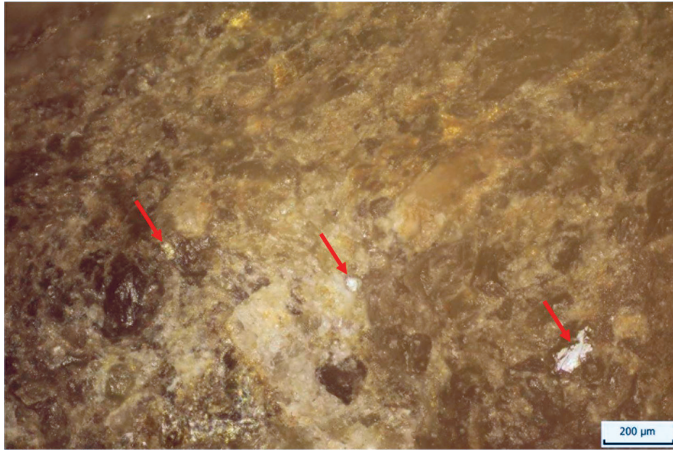


Fig. 7. Possible microresidues of an unknown nature on the front working surface of a stone grooved hammer from Police (photo by author).

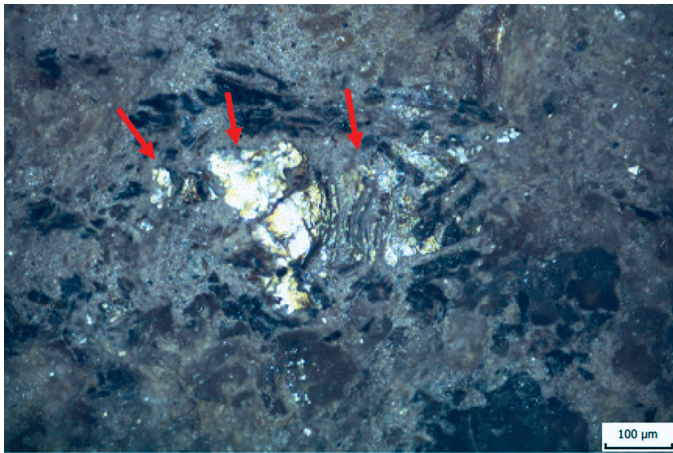


Fig. 8. Possible microresidues of an unknown nature on the rear working surface of a stone grooved hammer from Černýšovice (photo by author).

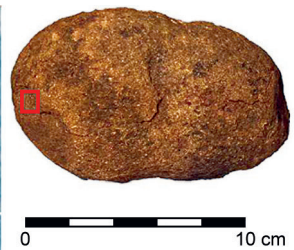
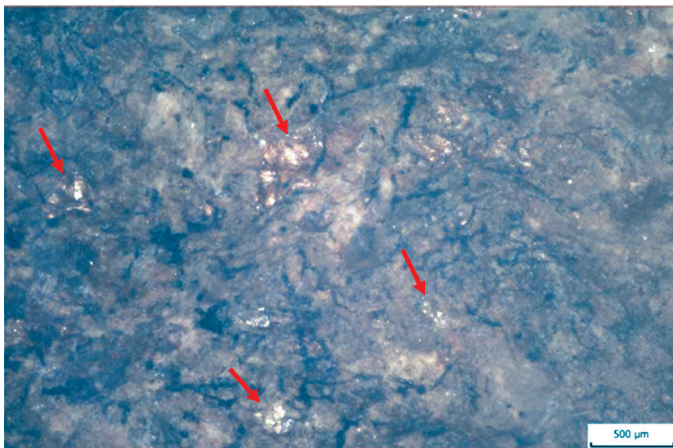


Fig. 9. Possible microresidues of an unknown nature on the front working surface of a stone grooved hammer from Boskovic (photo by author).

For comparative purposes, other stone grooved hammers from the BD1–HaB3 period were subjected to use-wear analysis, specifically artefacts from Černýšovice (*Fig. 8*) and Boskovice (*Fig. 9*). Microscopic analysis revealed that both artefacts exhibit a similar pattern of wear (battering, surface deformation), differing only in the degree of irregularity (*Tab. 2: 1, 2*). This irregularity is more pronounced in the Boskovice artefact, which displays a greater number of micro traces affecting the stone's structure than the grooved hammers from Černýšovice. In both cases, the micro traces indicate a consistent working direction, as also observed in the Dubicko artefact. Microresidues (*Tab. 2: 1, 2*) were identified on the working surfaces of both artefacts, as well as on the Dubicko and Police tools, which may suggest their use in metallurgical activities (*Fig. 8; Fig. 9*). The type of binding of Boskovice and Černýšovice tools could not be reliably determined due to the clearly disturbed condition of the groove surfaces.

3D analysis

In the case of the stone grooved hammer from Dubicko (*Tab. 2: 3*), the analysis revealed an overall rough and irregular surface, with no traces of polishing across the entire artefact (*Fig. 10*). These surface features complicate the determination of the precise degree of wear, as they may have been caused by natural weathering of the rock. Despite these limitations, work traces, such as notches and bruising penetrating deeper into the stone structure, can be detected and are clearly visible on both working surfaces (*Fig. 10: 1, 3*). Within the groove, distinct regular negatives are present (*Fig. 10: 2*), confirming the use of Mitterberg-type tying. A similar pattern of wear can be observed on the stone grooved hammer from Boskovice (*Tab. 2: 1*), where the character of the work traces is also obscured by weathering of the rock. As a result, no traces of polishing or detailed processing of the stone tool have been preserved. A notable difference is seen in the groove itself: the groove on the Boskovice artefact is superficial and does not penetrate the rock structure as deeply as on the Dubicko artefact, making it impossible to detect potential traces of tying through use-wear analysis or 3D modelling.

The 3D model of the stone grooved hammer from Police (*Fig. 11*) shows differences compared to the Dubicko artefact, particularly in the presence of polishing traces, rounding, and a reduced occurrence of surface bruising and notches on the sides and upper surface of the artefact (*Fig. 11: 2*). On both working surfaces (*Fig. 11: 1, 3*), the observations from the use-wear analysis were confirmed (*Tab. 2: 4*). Due to the more pronounced wear traces on the rear working surface (*Fig. 11: 3*), the predominant working direction can be determined there. This rear surface exhibits abundant micro traces of bruising, which caused minor deformation in this part of the tool. The model of the front working surface (*Fig. 11: 1*) indicates functional use that led to its irregularity. The pattern of wear suggests probable use for chopping.

SEM/EDX analysis

Measurements of both working surfaces on the examined stone grooved hammers yielded different results, providing some interpretative starting points. The analysis of the stone grooved hammer from Dubicko revealed small microresidues, identified as barite, zircon, allanite, ilmenite, and muscovite—minerals that naturally occur in the stone raw material.

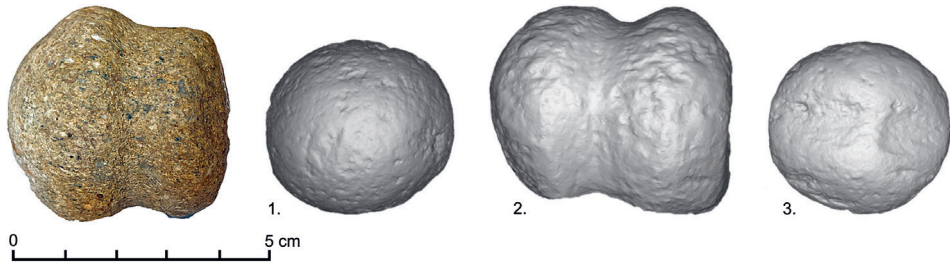


Fig. 10. Detailed views of the 3D model of the stone grooved hammer from Dubicko: 1 – front, 2 – side, 3 – back (photo by author).

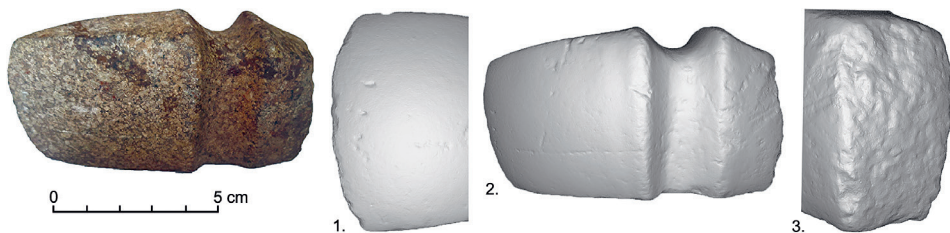


Fig. 11. Detailed views of the 3D model of the stone grooved hammer from Police: 1 – front, 2 – side, 3 – back (photo by author).

Additionally, isolated microresidues of lead and zinc combined with sulphur were detected, which may indicate the presence of lead and zinc sulphides typically found in ores (*Tab. 2: 3*). Due to the low level of residues of these microresidues, it is not possible to definitively determine a primary function of the stone grooved hammer for processing a specific metal raw material; contamination is a more likely explanation.

Microresidues and abrasions of pure tin (*Tab. 2: 4*) were discovered on the working surfaces of the stone grooved hammer from Police (*Fig. 12*). When interpreting these results, it is, however, essential to acknowledge the limitations of SEM/EDX analysis. While the method can confirm the presence of specific chemical elements, it cannot determine the processes by which they were deposited on the artefact's surface. Caution is further warranted because the post-excavation handling history of the object is unknown; consequently, the abrasions and tin microresidues observed on the stone tool may have been introduced secondarily. At the same time, according to the available results from examinations of other stone tools using the same analysis, such as touchstones (*Ježek 2020, 325–342*), it can be concluded that microresidues or metal abrasions may be preserved on stone artefacts and can indicate that they were used in working with metal raw materials.

Discussion and interpretation

Following the findings presented above, it can be stated that the results of the examination of stone grooved hammers must be approached with considerable caution. It is essential to take into account all available information from non-destructive scientific analyses,

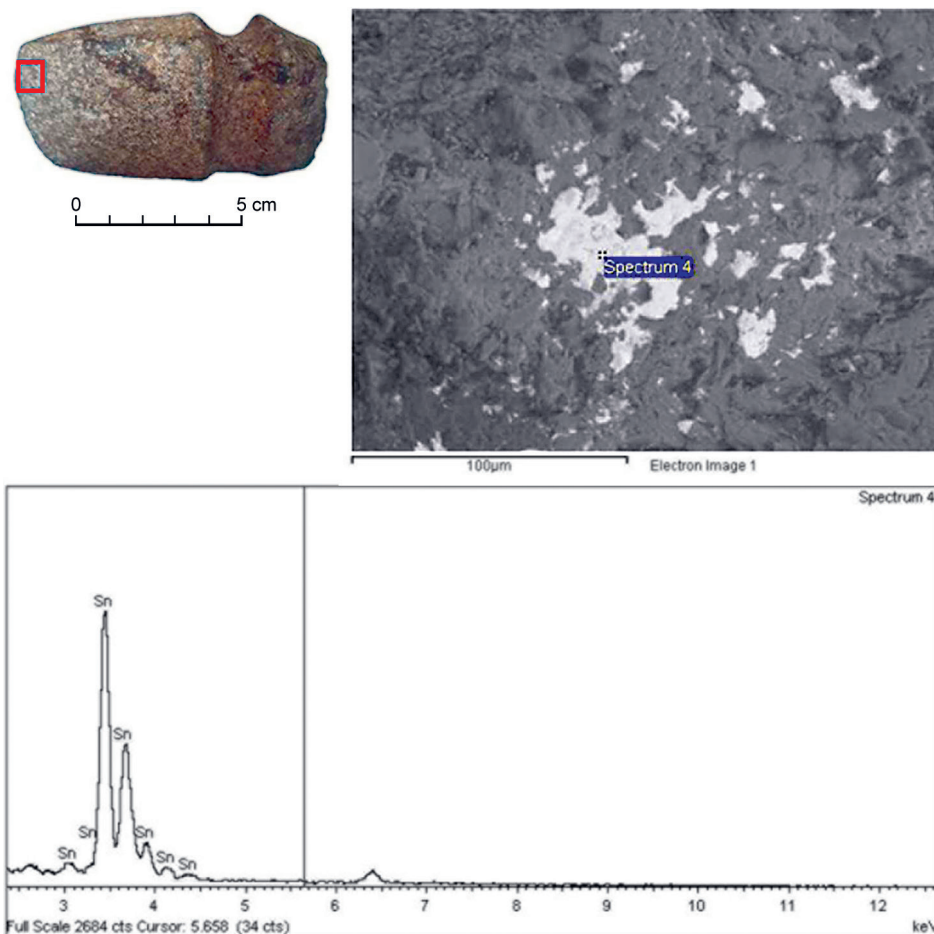


Fig. 12. Highlighted area of tin abrasion on the front working surface of the stone grooved hammer from Police (photo by author).

including their limitations. None of the methods used can determine with certainty the primary function of these stone tools, but when all findings are considered together, including the contexts of their discovery, they can at least indicate the probable primary function of the examined artefacts.

The hypothesis that stone grooved hammers were used in metallurgical activities must be supported by additional evidence confirming this specific activity in Dubicko and its surroundings. The Dubicko – Za Kostelem site is particularly interesting, as it has yielded finds that support the hypothesis of local processing of metal raw materials. The largest body of evidence for metallurgy is provided by the discovery of 23 bronze and copper ingots (*Fig. 2: 4–22*). These objects were recovered during a detector survey from the upper topsoil layer in various parts of the site, with no other accompanying finds. The exception is sunken feature 670, where several ceramic fragments, four ingots, chipped stone tools, and atypical pieces of daub were also discovered (*Halama 2013, 105–106; 2016, 25*).

Documented cases also include two nozzles recovered from the investigated site (*Fig. 2: 1, 2*). The first nozzle (*Fig. 2: 1*) was discovered in a storage pit with a pear-shaped profile in feature 615. Additional finds included ceramic fragments, pieces of daub, animal bones, and stones. A similar find was made in feature 655, which contained another nozzle (*Fig. 2: 2*), along with ceramic fragments, daub with impressions, and animal bones (*Tomešová 2020, 40–41, 71–72, 80*). Analogies to these nozzles from the HaB1–HaB3 period have been documented in Moravia at the sites of Kněždub–Šumárník and Skalice nad Svitavou – Nivy (*Dohnal 1988, 19, 43; Jarůšková – Štrof 2014, 128, 166–178*).

The final evidence of possible metallurgical activity in Dubicko is a fragment of a ceramic casting mould (*Fig. 2: 3*) measuring 4.8 centimetres in length and 2.4 centimetres in width. However, it is not possible to determine with certainty what object was cast in this mould. This artefact was discovered in a storage pit in feature 638, which had a regular, shallow, bowl-shaped profile. Ceramic fragments of the Lusatian Urnfield culture, a fragment of a ceramic figurine, daub with indeterminate impressions, parts of grain grinders, a stone smoother, and worked stone tools were also found there (*Tomešová 2020, 61, 91*). The frequency of casting mould finds from the BD1–HaB3 period in Bohemia and Moravia is considerably higher than that of nozzles. In Bohemia, examples include several mould fragments from the settlement sites of Svržno and Úholičky (*Blažek et al. 1998, 177, 188*). In Moravia, a hypothetical metallurgical microregion can be assigned to the HaB1–HaB3 phase within the Boskovice Furrow, where both direct and indirect evidence of metallurgy has been identified at all recorded settlements (e.g. Boskovice, Bořitov, Skalice nad Svitavou, Jevíčko, Šebetov, etc.). The richest assemblage indicative of metallurgical activity comes from the site of Skalice nad Svitavou – Nivy, where three moulds, one nozzle, one crucible, one stone grooved hammer, and remnants of raw pyrite ore were discovered (*Stuchlík 1993, 320; Jarůšková – Štrof 2014, 128, 166–178*).

Feature 549 at the Dubicko – Za Kostelem site, in which a grooved hammer was found, also yielded two split pieces of graphite (*Tomešová 2018, 15, 23*), which could hypothetically have been processed using this particular tool. The multifunctional character of stone grooved hammers may correspond to this finding. For instance, the discovery of 19 stone grooved hammers dating to the Early Bronze Age in the Prostějov region in central Moravia, an area distant from outcrops of metal ores, demonstrates that these tools were not exclusively used for ore processing. This opens the more general possibility that they were primarily employed for the extraction of stone raw materials. This hypothesis is supported by petrographic analyses, which indicate that most stone grooved hammers are made from Culmian greywacke. It is thus plausible that grooved hammers from the Šumperk region could have been used to extract Culmian greywacke or fine-grained conglomerates, either directly from rock outcrops or for breaking boulders in stony fields. Culmian greywacke is the predominant rock used for producing grain grinders or flat stone pads along the eastern edge of the Drahaný Highlands and Velký Kosřf. Therefore, in some cases, the raw material could have been obtained or processed using stone grooved hammers (*Kamarád et al. 2024, 62*). For these reasons, it can be concluded that stone grooved hammers may also have been employed in other production activities requiring the use of a durable and high-quality working implement (*Kamarád et al. 2024, 49–67*).

This hypothesis is also supported by reliefs from the Old Kingdom period in Egypt (2740–2198 BC), which document that similar, smaller stone grooved hammers mounted in a wooden handle were used to carve statues and work stone. These reliefs are most

prominently found in the mastaba of the vizier Ceya in Saqqara, who lived during the reign of the 5th dynasty (*Hassaan 2016*, 223–233). Based on the results of the use-wear and 3D analyses of the working surfaces of the stone grooved hammer from Dubicko, it can be determined that it was primarily used for processing harder materials, which could include metal or stone. An overall analogy to the aforementioned micro traces, including the wear of working surfaces, can be found in stone grooved hammers used for copper mining in Tyrol, in the mining microregion of Schwaz-Brixlegg (*Lamprecht et al. 2022*, 147–149). Furthermore, reference can be made to the results of the use-wear analysis of 25 stone grooved hammers from the site of Grotta della Monaca (Italy), which were used for copper extraction (*Larocca – Breglia 2016*, 301–311; *Caricola et al. 2020*, 263–283). The results of this analysis show a strong similarity to the wear traces observed on the grooved working surfaces from Dubicko and Police. The wear on these working surfaces mainly consists of micro traces (deformation, incisions, battering) that are characteristic of functional tools and were caused by rough handling (*Caricola et al. 2020*, 272–281). An interesting parallel to the stone grooved hammer from Police can be seen in the occurrence of similar artefacts in Grotta della Monaca Cave, which display identical micro traces of smoothing, polishing, and the deliberate accentuation of edges near the groove (*Larocca – Breglia 2016*, 302–307).

In connection with these findings, it should be noted that the SEM/EDX analysis did not confirm the presence of microresidues of copper, tin, gold, or silver, which would have allowed a direct association of the artefact with metallurgy. Although the detected microresidues of lead and zinc, in combination with sulphur, may suggest the presence of lead and zinc sulphides, which are part of ores, this hypothesis is unlikely without the detection of copper, tin, gold, or silver. A more plausible explanation, considering the analogy with stone grooved hammers from the Prostějov region (*Kamarád et al. 2024*, 62) and the discovery of graphite in the same context, is that the stone grooved hammer from Dubicko may have been used for the processing of stone raw material or graphite.

The circumstances of the discovery of the stone grooved hammer from Police are unknown. Since the time span of the use of stone grooved hammers in Bohemia and Moravia ranges from the Late Eneolithic to the Late Bronze Age, precise dating is impossible without other associated finds (*Halama 2015*, 53–58). Use-wear and 3D analyses revealed substantial differences in wear on the working surfaces. The front surface shows slight irregularity, which suggests more careful handling and is also confirmed by traces of grinding and polishing. In contrast, the rear working surface exhibits a different character of microwear, with evidence of battering and crushing, indicating intensive use for processing hard materials such as stone or metal. Based on these observations, it can be assumed that the prevailing working direction was on the rear surface. SEM/EDX analysis detected microresidues of pure tin on both working surfaces (*Fig. 12*). These findings could suggest a possible connection between the use of this tool and the processing of tin raw material. However, it is necessary to interpret these results critically and to recognise the limitations of SEM/EDX analysis, which while confirming the presence of certain metallic microresidues, cannot rule out that they were introduced to the surface of the stone tool during conservation or subsequent handling in museums. The findings of metal microresidues on the working surfaces of stone grooved hammers from the Czech Republic are not uncommon. For example, a stone grooved hammer discovered in Pekárna Cave had microresidues of pure gold on its front working surface (*Kamarád 2023b*, 21–22). Another example includes the stone grooved hammers from the Znojmo-Rotunda and Suchohrdly sites, where copper microresidues were identified on the working surfaces (*Kamarád 2023a*, 43).

Thanks to the use-wear and 3D analysis (*Tab. 2*) of the examined grooved stone hammers, together with additional analogous artefacts from the sites of Černýšovice and Boskovice – Masarykovo náměstí, it was possible to observe microresidues on their working surfaces, which may indicate their use in metallurgy. Due to the larger size of these stone hammers, however, SEM/EDX analysis could not be performed. Furthermore, the working surfaces of the hammers showed micro traces indicating a consistent working direction, which is the same observation as for the hammer from Dubicko. Overall, based on the aforementioned non-destructive scientific analyses, the primary function of these artefacts can be interpretively assessed in the same way as for the hammers from Dubicko – Za Kostelem and Police-Polanka.

Conclusion

Based on the results of non-destructive scientific analyses, it can be concluded that metallurgical activity most likely took place in Dubicko and its surroundings during the Late Bronze Age. This hypothesis is supported by the discovery of one ceramic mould for casting, two nozzles, and 23 metal ingots at the Dubicko – Za Kostelem site. The connection of these finds, which indicate metallurgical activity, with the grooved stone hammer from Dubicko – Za Kostelem is, however, highly debatable, because SEM/EDX analysis did not reveal any copper or tin microresidues on its working surfaces.

The use of grooved stone hammers in metallurgical activity in Dubicko, however, may be indicated by the artefact from Police-Polanka, which was found less than 4 kilometres from Dubicko and whose working surfaces contained microresidues of pure tin. Nevertheless, determining a connection with the possible use of this tool to work with tin raw material is highly questionable, because it encounters the limits of SEM/EDX analysis and the unknown circumstances of the find. Furthermore, it is necessary to consider the broader chronological range of the use of stone grooved hammers in Bohemia and Moravia, where these artefacts are documented from the Late Eneolithic to the Late Bronze Age. Due to this wide chronological range, the stone grooved hammer from Police cannot be safely connected directly with metallurgical activity in Dubicko and its surroundings during the HaB1–HaB3 period.

The same applies to other examined grooved hammers from the BD1–HaB3 period from other sites in the Czech Republic, which also could not be directly linked to metallurgical activity. Taking into account other finds of grooved hammers across Europe, we can argue that, despite a nearly identical appearance, the use of these tools was highly variable, context- and region-dependent. However, analysis of use-wear micro traces indicates that these were functional working tools that were not handled with particular care.

Summarising all of the available information, it can be concluded that the study of stone grooved hammers from the Šumperk region represents an intriguing phenomenon, particularly regarding the discovery of these tools in North Moravia. Although a direct connection with metallurgical activity cannot be established, it is fairly certain that these two tools were mounted on a wooden axe handle in a functional working position, as indicated by use-wear analysis, secured with a tie made of plant fibres (Mitterberg type), and actively used for work with hard materials like stone or metals.

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