

Neolithic axe production in Central Germany: A first approach to technological aspects and lithic raw materials

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Zusammenfassung

Neolithische Beilproduktion in Mitteldeutschland: ein erster Ansatz zu technologischen Aspekten und lithischen Rohmaterialien

Beile und Dechselfn aus unterschiedlichen Arten von grünlichem Gestein wurden in Mitteleuropa seit dem Mesolithikum verwendet. Das Gestein – oft fälschlich als Amphibolit bezeichnet – wurde zu Werkzeugen zur Holzverarbeitung oder zum Schlachten und zu Waffen verarbeitet und diente vermutlich auch als Tauschmittel. Wenngleich die Typologie dieser Artefakte mehr oder weniger gut definiert ist, fehlt es bisher an umfassenden Untersuchungen zu Herkunft und Herstellungsprozessen.

Ein kollaboratives interdisziplinäres Forschungsprojekt des Landesamts für Denkmalpflege und Archäologie Sachsen-Anhalt und der Universitat Autònoma de Barcelona zielt darauf ab, neue Erkenntnisse zu den Rohmaterialquellen in Mitteleuropa zu gewinnen. Die bisherige Untersuchung von Herstellungsspuren an mehr als 350 Beilen aus Sachsen-Anhalt und Sachsen umfasst archäometrische, morphologische und technologische sowie petrografische und geochemische Analysen. Dies ermöglichte die Identifizierung zahlreicher frühneolithischer Werkstätten zur Beilherstellung in Mitteldeutschland, in denen eine besondere Art von Grünschiefer verarbeitet wurde. Petrografisch ähnelt dieses Gestein dem bekannten Metabasit, der während des Frühneolithikums im Isergebirge, Nordböhmen (Tschechische Republik) abgebaut wurde. Die Sägetechnik in der Frühstufe des Herstellungsprozesses vieler mitteldeutscher Beil- und Axtklingen wurde in den Werkstätten von Jizera jedoch nicht angewendet. Dort wurde Grünschiefer durch Schlagtechnik bearbeitet.

Das häufige Auftreten von Sägespuren an Rohlingen und Beilen aus den Siedlungen und Hortfunden sowie die Anzahl an Werkstätten in Mitteldeutschland lassen Zweifel an den Metabasit-Steinbrüchen des Isergebirges als einzige neolithische Rohstoffquelle für Mitteleuropa aufkommen. Die ersten Forschungsergebnisse weisen vielmehr auf die Existenz weiterer Gewinnungszentren für Rohmaterialien hin. Die vorliegende Untersuchung bestätigt zudem die abnehmende Bedeutung von Grünschiefer im Mittel- und vermutlich Spätneolithikum, als man begann, andere lokale Gesteinsarten aus sekundären klastischen Sedimenten zu gewinnen.

Schlagwörter neolithische Steinbeile, Herstellungstechniken, Austauschnetzwerke, variszischer Grünschiefer, Zentraleuropa

Summary

Stone axes and adzes made from various types of greenstones have been used in Central Europe since the Mesolithic. These rocks – often incorrectly labelled as amphibolite – were processed into tools for woodworking and butchering and into weapons, and they probably also served as exchange values. While their typology is more or less well defined, their provenance and manufacturing processes still lack comprehensive studies.

A collaborative interdisciplinary research project between the State Office for Heritage Preservation and Archaeology of Saxony-Anhalt and the Universitat Autònoma de Barcelona aims to bring new insights into the field of lithic raw material sources in Central Europe. The investigation of over 350 axe manufacturing remnants from Central Germany included archaeometrical, morphological, and technological studies, as well as petrographic and geochemical analysis. As a result, a large number of Early Neolithic axe production workshops could be identified in Central Germany, where a specific type of green schist was processed. In petrographic terms, this rock strongly resembles the well-known metabasite quarried during the Early Neolithic in Jizera, Northern Bohemia (Czech Republic). However, the technique of sawing, used during the early stages of the manufacturing process of many of the Central German axeheads, was uncommon in the workshops on the Czech quarry site, where flaking appears to have been the dominant technique.

The abundance of rock slabs with sawing traces, axe blanks, and manufacturing remnants in the settlements and hoards of Central Germany as well as the technological differences in the axe production techniques used in the workshops call into question whether the metabasite quarries in Jizera were the only raw material source for Central Europe during the Neolithic; the evidence points towards the existence of additional regional raw material production centres. The present study also confirms the decreasing importance of actinolite-hornblende-schist during the Middle and, probably, Late Neolithic, when other types of local rocks started to be obtained from secondary clast deposits.

Keywords Neolithic stone axes, production techniques, exchange networks, Variscan greenschist, Central Europe

Introduction

Stone axeheads offer one of the main archaeological indications of economic development from the Early Neolithic (5500–3950 BC) to the Bronze Age (2200–750 BC), when they were gradually substituted by copper and bronze equivalents, as G. Clark argued over 50 years ago (1965). They are one of the few archaeological materials that, in principle, offer the possibility to trace the whole economic cycle from the exploitation of the rocks in quarries or secondary deposits to the manufacturing spaces revealed by axe blanks and production debris, to their final use or loss in domestic contexts, fields, and natural spaces, as well as in intentionally created hoards and burials.

While economically oriented research on stone axeheads has been notable in Western Europe¹, the situation in Central and Eastern Europe shows a very uneven picture. Excellent petrographic studies of stone axes opened the first and third issues of the well-known »Jahresschrift für die Vorgeschichte der sächsisch-thüringischen Länder« (Luedecke 1902; Luedecke 1904), and notable research has recently been performed by Czech and Polish researchers to identify and investigate the Neolithic quarry sites in the Jizera Mountains (Šrein et al. 2002; Prostředník et al. 2005; Šída 2009), but geoarchaeological and technological studies are still relatively limited and discontinuous in most regions². Functional analyses have not been performed.

The present consensus concerning Neolithic axe production and circulation in Central Europe seems to be that most tools made from metabasite derived from quarries in the Jizera Mountains near Jistebsko, Jablonec nad Nisou district, where Early Neolithic quarrying is well documented³. However, this view overlooks the fact that, from early on, some researchers – most of them working in the former German Democratic Republic (GDR) and Czechia – pointed out a relative abundance of half-finished axeheads, axe blanks, and even rock slabs with sawing traces in Central Germany⁴. A study of the axes of the archaeological collection of the Friedrich Schiller University Jena has again revealed the abundance of these manufacturing remains, particularly in the area of the middle Saale and Unstrut Rivers (Martin 2020). The most eastern find spot of axe blanks in Germany is Dresden-Nickern (Baumann 1962), in Central Saxony, whereas there is a lack of such remains further east until we reach the Jizera region, c. 120 km further east as the crow flies. Consequently, considering the distribution pattern of the evidence of manufacturing alone already raises doubts concerning an exclusive provenance of Neolithic axeheads from the Northern Bohemian Variscan outcrops. The insight gained so far from axe manufacturing in Western Europe suggests that raw materials were usually processed in the region surrounding the exploited quarries

or secondary deposits and that axe blanks rarely circulated beyond distances of c. 40 km⁵, which is significantly less than the distance between the Saale-Unstrut manufacturing area and the Jizera quarries (> 200 km). Only in the case of the exceptionally resistant and hard Alpine jadeitite and eclogite or the dolerite of the Neolithic Sanganakallu quarries, state of Karnataka, in Central India, raw materials circulated across distances of up to 100 km, and occasionally even over 200 km (Pétrequin et al. 2012; Pétrequin et al. 2017; Risch et al. 2011, 200).

A second element of doubt towards the dominant interpretation arises from the technological study of the blanks in both regions. While the studies published so far on Jizera show that the raw material was processed predominantly by flaking (Šída 2009; Šída 2014), the characteristic working traces of the Saale-Unstrut slabs and blanks are the result of intense, mostly lengthwise sawing⁶.

Consequently, archaeological criteria alone strongly question the provenance of the majority of Neolithic axes of Central Europe from the Jizera quarry sites. More probably one or several raw material sources must have existed near the Saale-Unstrut region. In this sense, it might be worth recalling the already mentioned petrographic analysis of the mineralogist O. Luedecke (1902; Luedecke 1904). He pointed out that a possible source of the dominant hornblende schist might have been the crystalline complex of Ruhla, Wartburgkreis district, in Thuringia. However, he also noted that the mineralogical composition of the hornblende rocks in Ruhla is different from that observed along the sectioned axes, and its mineral size is larger (Luedecke 1902, 9–10). Following Luedecke's idea of a local raw material source, numerous researchers have suggested that the Harz Mountains (Saxony-Anhalt), or the Thuringian crystalline complexes (Kyffhäuser crystalline complex, Thuringian Forest, including the Ruhla crystalline complex), or the Thuringian Highlands, or the Fichtelgebirge (Bavaria), or the Saxonian crystalline complexes (Ore Mountains, Frankenberg-allochthonous unit), or even the Spessart (Hesse) were the provenance areas for the dominant hornblende schist⁷, but comprehensive geoarchaeological studies of these possible provenance areas are lacking.

Although the petrographic analyses of Central German axeheads, blanks, and raw materials is an ongoing project whose first results will soon be made public, the present study aims to offer a preliminary systematic presentation of all the manufacture evidence studied in the archive of the State Museum of Prehistory in Halle (Saale) and the State Office for Archaeology Saxony, as well as all the information published dispersedly over the last 150 years (since Schultheiß 1875).

1 E.g., Bradley/Edmonds 1993; Pétrequin et al. 2012; Pétrequin et al. 2017; Risch 2011; Delgado-Raack et al. 2020.

2 Kaufmann 2020; Schwarz-Mackensen/Schneider 1983; Schwarz-Mackensen/Schneider 1986.

3 Šída 2009; Ramminger/Šída 2012; Rammin-

ger 2007; Šrein et al. 2002; Šrein et al. 2003; Prostředník et al. 2005; Monik et al. 2021.

4 Esp. Pietzsch 1951; Quitta 1955; Baumann 1962; Vencel 1975.

5 Pétrequin/Jeunesse 1995, 61; 64; 66; Delage 2004, 36; Bradley/Edmonds 1993, 144–150; Risch/Martínez 2008.

6 Lehmann 1927; Wagener 1928; Pietzsch 1951; Herrmann/Schüller 1952; Quitta 1955; Küßner/Neumann 2008; Martin 2020; etc.

7 Stautz 1910; Kade 1931; Herrmann/Schüller 1952; Quitta 1955; Scholz 1986; Hesse 1969.

Materials and methods

The study of over 3000 polished artefacts from the collection of the State Museum of Prehistory in Halle (Saale), along with 1100 additional artefacts from the State Office for Archaeology Saxony, has allowed us to identify a total of 357 axe blanks and remnants of axe production processes. They come from over one hundred localities in Saxony-Anhalt and Saxony as well as from the border areas in neighbouring Thuringia, Saxony, and Brandenburg.

While the majority of these axe blanks are part of old surface find collections, a total of 119 artefacts, including blanks as well as finished axeheads and drillcores, can be assigned to sites where excavations have been performed by the State Office of Heritage Management and Archaeology Saxony-Anhalt and the State Office of Archaeology Saxony. In most contexts, pottery is used to assign a site to a certain culture and thus to a certain chronology. Moreover, the typology of the axe blanks can be used as a rough chronological classification. For example, axe blanks in the shape of shoe-last celts can be dated to the Early Neolithic, whereas the pecked battle axes can be classified as Late Neolithic (2700–2200 BC)⁸. The sites of Breitenbach (Wetterzeube), Burgenlandkreis district (Zamzow 2020; Siegl/Wunderlich 2013), Eilsleben⁹, Börde district, Niederröblingen, Mansfeld-Südharz district (Wollenweber 2020), Birmenitz¹⁰, Meißen district, Zwenkau-Harth, Leipzig district (Quitta 1955; Quitta 1958; Stäuble 2010) and Zauschwitz, Leipzig district (Stäuble 2010; Bergemann 2018) can be dated to the Early Neolithic; the sites at Halberstadt-Spiegelsberge, Harz district (Toepfer 1957) and Westerhausen-Jächtenberg, Harz district (Rinne/Schmidt 2006) can be assigned to Middle Neolithic cultures. Furthermore, one axe blank found in the Únětice settlement of Schiepzg, Saalekreis district, can be dated to the Early Bronze Age (Moser 2019).

All 357 axe blanks, drillcores, and production remnants have been inventoried according to analytical criteria adapted from the method of macrolithic analysis proposed by R. Risch (2002) and refined in successive research (Delgado-Raack 2008; Ache 2019; Vucković 2019; etc.). In addition to metrical and morpho-technical variables and production traces (sawing, flaking, and pecking marks), a first classification of the raw material of the artefacts was obtained by observation under a stereoscopic loupe (30/40 x). A sample of items from each of the identified material groups was selected and prepared for thin-section analysis. This allowed us to determine the mineral composition of 40 axeheads and 7 blanks by using a Nikon Eclipse E400 Pol Microscope. Accessories and opaque mineral phases could be identified via Scanning-Electron-Microscopy (EDS; using a Zeiss Merlin FE-SEM with 20 kV voltage and 1nA current). This two-step procedure allowed us to confirm and refine the initial petrographic classification.

In order to supplement the spatial distribution pattern of the axe blanks, specimens from hoard finds (for a reference

list, see Tab. 3) and published blanks¹¹ were also included in our database. Although there are many finds of finished and well-polished tools with remnants of sawing marks, only blanks are considered in this study.

Results

Morpho-technical observations

Manufacturing remains

The 357 axe blanks, axeheads with unfinished perforation, and manufacturing debris can be organised into different morpho-technical groups depending on the overall shape and the manufacturing traces (see Tab. 1; Pl.). Since the production of axeheads is a process with several overlapping steps, most blanks show a combination of different production traces. While sawing marks and flake extraction negatives are related to the initial working stages, axes with unfinished perforations and drilling cores provide information about later stages in the manufacturing or recycling of axes. The manufacturing evidence found in Central Germany can be grouped into a series of morpho-technical categories (see Pl.).

Slabs and axe blanks with sawing marks (S)

Natural slabs and axe blanks can feature a straight or concave sawing mark on at least one of the artefacts' sides. Axe blanks are further shaped by flaking or pecking, but remnants of the natural, weathered rock surface remain visible.

S_SI_S1_VU describes a rock slab (**SI**) with a natural, unprocessed surface featuring one unfinished sawing cut with a V- or U-shaped (**VU**) cross section on the slab's ventral surface (Pl. 1,2). The shape of the cross-section is dependent on the depth of the cut, starting with a wide U-shape and becoming more V-shaped with the increasing depth of the cut.

S_SI_S1_VU_Fr are fragments (**Fr**) of **S_SI_S1_VU** or **S_SI_S1** with an unfinished cut.

S_SI_S1 describes rock slabs (**SI**) with an unprocessed, natural surface and one straight sawing mark (**S1**) along the long side (cf. Pl. 1,1). So far, no slabs with more than one sawn side have been observed.

S_BI_S1 describes fully preserved blanks (**BI**) with one straight sawing mark on the longest side (cf. Pl. 1,3). The dorsal and ventral sides of the blank often feature remnants of the original, weathered rock surface while the top and bottom faces, as well as the side opposite of the saw mark, often show signs of flaking (cf. Pl. 1,3).

S_BI_S1_Fr are fragments of sawn axe blanks, featuring traces of sawing on one side and at least one broken side. It is unclear whether these fragments are remnants of axe blanks or rather leftovers from the production process.

8 Brandt 1967; Struve 1955; Kaufmann 2020; Behrens 1973.

9 Kaufmann 1981; Kaufmann 1982; Kaufmann 1983; Kaufmann 2010.

10 Hottenroth 1903; Herrmann/Schüller 1952; Fröhner/Strobel 2016; Strobel/Westphalen 2017.

11 Pietzsch 1951; Kaufmann 1959a; Höckner 1962; Vencel 1975; Küßner 2006; Jansen 2013; Petzold 2013; Kaufmann 2020; Martin 2020.

S_BI_S2 describes fully preserved blanks with two straight saw marks, usually on both longer, lateral sides (Pl. 2; Pl. 3,1). The dorsal and ventral sides of the blank often feature remnants of the original, weathered rock surface, while the shorter end-sides frequently show signs of flaking.

S_BI_S2_Fr are fragments of **S_BI_S2**.

S_BI_S3 are blanks and unfinished axeheads with sawing marks on three sides. So far, only one artefact belongs to this category. Polishing covers almost its entire surface, but does not obliterate the original sawing marks on both long sides and on the neck of the perforated axe (cf. Pl. 3,2).

S_BI_S3_Fr would be fragments of **S_BI_S3** but have not been observed so far.

S_BI_SC describes an axe blank with the shape of a shoe-last celt. This variety presents one strongly curved sawing mark along the long side of the shoe-last celt (Pl. 4,1). Shoe-last celts (also known as high adzes) are a common adze type in the Early Neolithic in Central Germany and are defined by their D-shaped cross-section and a height-to-width ratio of $> 1^{12}$.

Flaked axe blanks (F)

Axe blanks shaped exclusively by knapping (F). Remains of the natural rock surface can be observed in some blanks.

F_BI are fully preserved flaked axe blanks. The surface is covered in negative flake scars, and small remains of the weathered natural rock surface on the ventral and dorsal sides of the blank are often visible (cf. Pl. 4,2; Pl. 5,1).

F_BI_Fr are fragments of flaked axe blanks.

Axeheads (AH) with one or two unfinished perforations (UP)

This category is used for axes and adzes with traces of drilling. In most cases, the perforation is done by hollow drilling, and remnants of a drillcore are visible. These axes and adzes are fully shaped, and they can often be classified according to the conventional axehead typologies (Struve 1955; Brandt 1967). Their surfaces are pecked and/or polished. The unfinished perforations can often be observed on two opposite sides of the axehead and were supposed to meet in the middle to create the shaft hole.

BA_UP are tools in the shape of a battle axe (BA) (as defined by Struve 1955) with an entirely pecked surface yet without perforation (cf. Pl. 5,4; Pl. 6,1). Some artefacts show a pecked mark where the drill is going to be placed (cf. Pl. 6,1).

AH_UP are pecked and polished tools with an unfinished perforation (cf. Pl. 6,2–3). The perforation can be either done by full drilling or hollow drilling, whereby hollow drilling produces a conical core in the drill hole. Alternating unfinished perforations on both sides of the axeheads are very common in this category.

AH_UP_Fr are fragments of pecked and partly polished tools featuring an unfinished perforation.

SC_UP describes polished shoe-last celts with an unfinished hollow perforation and initial traces of a conical core (cf. Pl. 6,4). Alternating unfinished perforations have not

been observed for the shoe-last celts. Fragments of **SC_UP** have not been observed so far. Due to the complicated and often uncertain classification of fragments, **SC_UP** fragments have likely been identified as the more unspecific category of **AH_UP_Fr**.

Drillcores (DC)

Drillcores are the result of completed hollow perforations of axes and are frequently found in Neolithic settlements. As the traces of unfinished perforation, they do not necessarily relate to the initial manufacture of the axeheads but could be the result of later reshaping or, rather, rehafting processes of axeheads.

DC are drillcores (cf. Pl. 5,1–2).

DC_Fr describes fragments of drillcores. Here, the base of the core usually shows signs of breakage.

Manufacturing process

So far, no unprocessed raw materials have been found in Neolithic settlements and deposits. The largest known slabs of actinolite-hornblende-schist (henceforth AHS) with sawing marks are up to almost 400 mm in length and 100 mm in width, and can weigh over 2 kg. The height of these slabs (**S_Sl_S1**) ranges between 24–48 mm and provides a direct insight into the structure of the exploited metabasite outcrop. The natural rock surface can also be seen on many other flaked and sawn blanks and allows us to calculate an average slab thickness of 32.5 mm ($\sigma = 11.8$), although some slabs can even reach a thickness of over 60 mm (cf. Fig. 1).

One of the largest processed slabs comes from the deposit of Zwenkau-Harth (Quitta 1955). It has a more or less square shape and was sawn through on two sides perpendicular to each other. The other two sides had been prepared through flaking. All studied slabs of type **S_Sl_S1** feature only one prominent straight saw surface or groove on the longest side (cf. Fig. 3; cf. Pl. 1,1). On some specimens, remnants of a pre-pecked line can be identified, which probably aided the placement and stabilisation of the sawing blade at the beginning of the process (Pietzsch 1951; Ganslmeier 2021). The intention behind the sawing was to create a weak line along which the rock piece could be split in half by applying pressure. The depth of the sawing mark reaches, on average, half of the slabs' thickness.

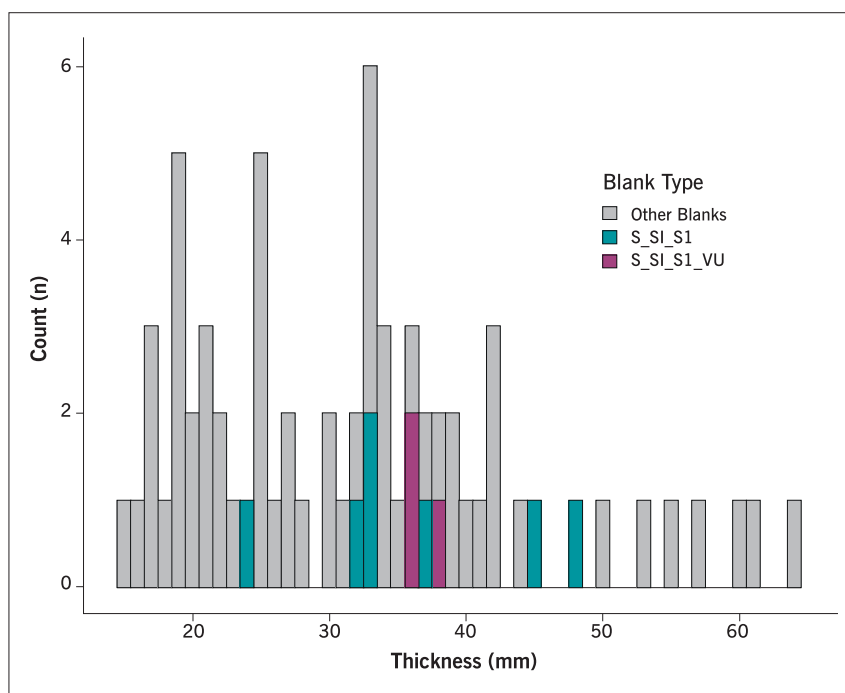
The size and shape of the natural rock slabs show a specific selection of suited material, since the slab thickness determines the height or width of the axehead. The lengthwise sawing of the rock slab allowed the manufacturers to make maximal use of the available raw material by cutting as many blanks as possible from one slab (Quitta 1955).

The relatively low number of slabs in contrast to the relatively abundant blank fragments found in the Neolithic settlements and deposits of Central Germany (Tab. 1) suggests that slabs were prepared and sawn at or near the quarry sites before being transported to the workshops. Here the slabs were either cut or directly flaked into blanks, depend-

12 Brandt 1967; Struve 1955; Weller 2014; Schauer 2018.

Fig. 1 Thickness of AHS rock slabs measured on natural rock slabs with sawing marks (types S_SI_S1 and S_SI_S1_VU) and on flaked and sawn blanks with visible remnants of the natural rock surface.

Abb. 1 Dicke von Steinplatten aus Aktinolith-Hornblende-Schiefer, gemessen an natürlich vorkommenden Steinplatten mit Sägespuren (Typen S_SI_S1 und S_SI_S1_VU) und an geschlagenen und gesägten Rohlingen mit sichtbaren Resten der natürlichen Oberfläche des Steins.



Axe manufacture evidence	Subgroup	Number (n)	Natural rock surface	Sawing marks	Flake extraction	Pecking marks	Polished surface
Axe blanks with sawing marks	S_SI_S1_VU, S_SI_S1_VU_Fr	9	x	x	(x)		
	S_SI_S1	8	x	x	x		
	S_BI_S1	11	x	x	x		x
	S_BI_S1_Fr	70	x	x	x		x
	S_BI_S2	4	x	x	x		x
	S_BI_S2_Fr	23	x	x	x		x
	S_BI_S3	1	x	x			x
	S_BI_SC	2	x	x	(x)	x	x
Subtotal		129					
Flaked axe blanks	F_BI,	97	x		x		x
	F_BI_Fr						
Production debris	DC,	101	x				x
	DC_Fr						
Axeheads with unfinished perforation	BA_UP	5				x	
	AH_UP, AH_UP_Fr	20				x	x
	SC_UP	5	(x)		x	x	x
	Subtotal	30					
TOTAL		357					

Tab. 1 The studied axe blanks and production remains have been grouped depending on their overall shape and manufacturing traces. Most blanks show a combination of different production traces. x = traces visible in over 75 % of studied artefacts; (x) = traces visible on single artefacts.

Tab. 1 Die untersuchten Beil- und Axtrohlinge sowie Produktionsreste wurde nach ihrer Gesamtform und den Herstellungsspuren gruppiert. Die meisten Rohlinge weisen eine Kombination unterschiedlicher Produktionsspuren auf. x = Spuren auf über 75 % der untersuchten Artefakte sichtbar; (x) = Spuren auf einzelnen Artefakten sichtbar.

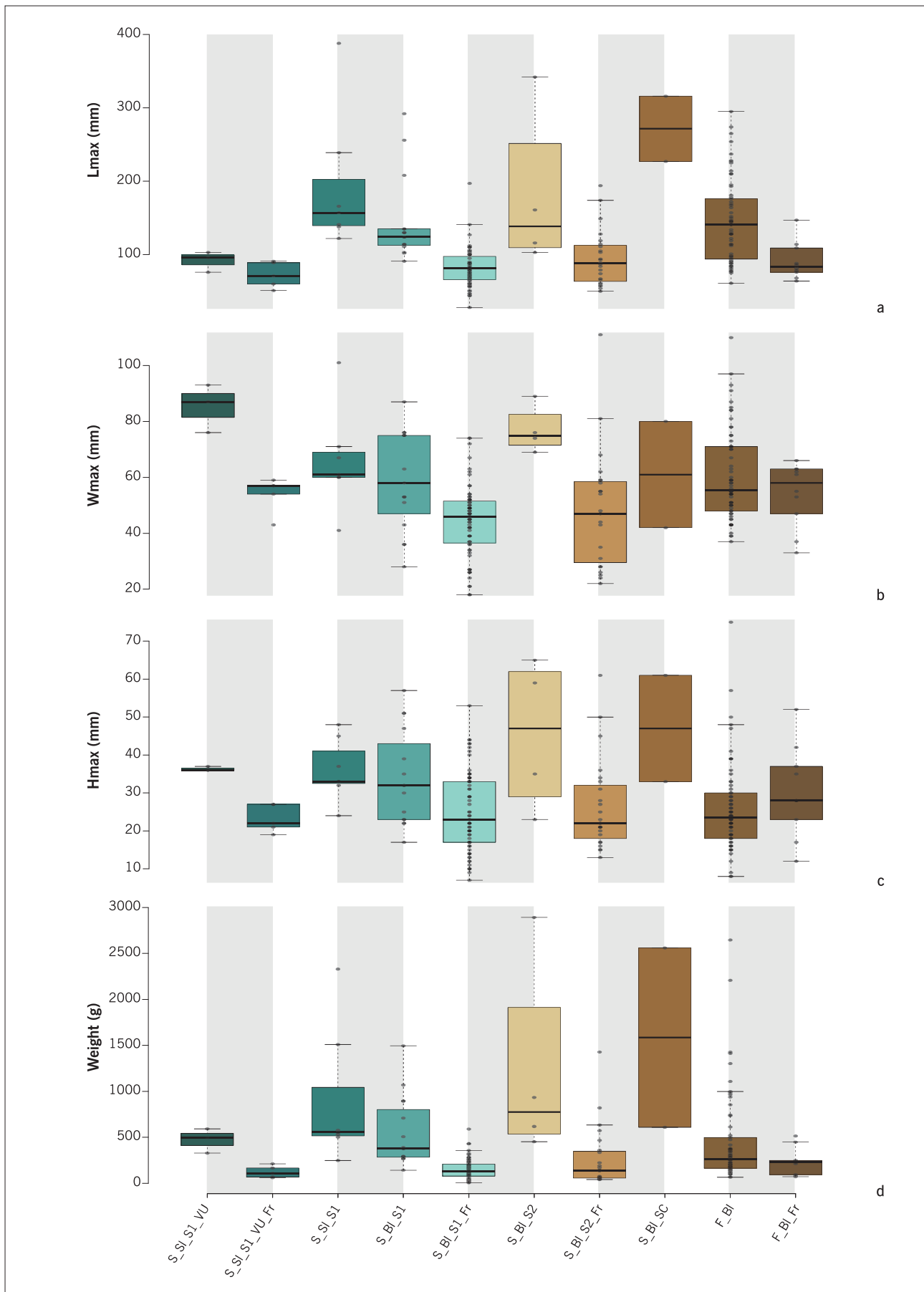


Fig. 2a–d Comparison of length (a), width (b), height (c), and weight (d) between sawn and flaked axe blanks made from AHS and metabasites.

Abb. 2a–d Vergleich von Länge (a), Breite (b), Höhe (c) und Gewicht (d) zwischen gesägten und durch Abschlüge geformten Rohlingen aus Aktinolith-Hornblende-Schiefer und Metabasiten.



Fig. 3a–c a 92:280e – shoe-last celt-shaped axe blank with curved sawing marks; besides the sawing mark, flaking and pecking traces are also visible on the blank; b 71:810 – natural rock slab with straight sawing marks along the longest side; c 41:1670 – axe blank with straight sawing mark along the longest side and traces of flaking on the surface.

Abb. 3a–c a 92:280e – schuhleistenkeilförmiger Rohling mit gebogenen Sägespuren; daneben sind auch Spuren vom Abschlagen und Picken sichtbar; b 71:810 – natürliche Steinplatte mit geraden Sägespuren entlang der längsten Seite; c 41:1670 – Rohling mit geraden Sägespuren entlang der längsten Seite und Spuren vom Abschlagen auf der natürlichen Oberfläche.

ing on the size of the original slab. The hoard of Vollersroda, Weimarer Land district, provides an example where two blanks in the shape of shoe-last celts were sawn from the same slab (Küßner/Neumann 2008).

Sawing in the settlements is also indicated by a small number of slabs and rock fragments with an unfinished incision on the ventral surface (S_Sl_S1_VU and S_Sl_S1_VU_Fr). Again, the raw material is exclusively actinolite-hornblende-schist (AHS) and related metabasites. The sawing groove of the slabs maintains a U-shaped cross-section up to a depth of 8–10 mm, after which the groove gradually becomes V-shaped.

The studied slabs of type S_Sl_S1_VU and S_Sl_S1_VU_Fr do not show traces of a pre-pecked line, suggesting a slightly different technical procedure than the processing of large slabs. The few complete remains of these partially sawn slabs show traces of weathered surfaces, implying that occasionally cobble stones from fluvial deposits were selected. Furthermore, another difference with the quarried slabs is their larger width and smaller length and weight, whereas their thickness is similar (Tab. 2; cf. Fig. 1; Fig 2). The collection

and processing of relatively small AHS clasts from fluvial deposits is another indication that the AHS source or sources are located relatively close to the Neolithic settlements.

Sawing marks are also visible along the longest side of a large number of blanks (S_Bl_S1) and blank fragments (S_Bl_S1_Fr). The axe blanks in the shape of shoe-last celts, which are typical of the Linear Pottery, Stroke Ornamented Pottery, and Rössen Cultures, were clearly manufactured by sawing at least one of the sides (S_Bl_SC). Some blanks present sawing marks on two or three sides (S_Bl_S2 and 3). These traces can be classified into two groups according to their orientation: 1) slightly curved or 2) straight traces. While the majority (~90 %) of the sawn pieces show rather straight sawing marks with parallel grooves, the shoe-last celts as well as some bigger axe blanks (one- and two-sided sawn blanks) and single fragments feature slight to markedly curved striations (Fig. 3a).

The sawing of rocks in Later Prehistory has sparked the interest of researchers since the late 19th century (Keller 1870), and a plethora of sawing devices have been discussed over the last 150 years, focusing on the saw blade used as

General Information					Measurements						
				Amount (n)	Wgt _{max} $\bar{x}$ (g)	σ (g)	L _{max} $\bar{x}$ (mm)	σ (mm)	W _{max} $\bar{x}$ (mm)	σ (mm)	H _{max} $\bar{x}$ (mm)
Site	Locality	Overall dating of site	Type								
EN sites: Breitenbach, Eilsleben, Niederröblingen, Birmenitz, Harth, Zauschwitz	Saxony-Anhalt and Saxony, Germany	LBK, SBK, Rössen	S_SI_S1_VU	1	592		103		93		36
			S_SI_S1_VU_Fr	5	128	63	77	23	55	6	21
			S_BI_S1	6	472	243	116	17	61	17	35
			S_BI_S1_Fr	34	130	114	76	28	43	13	23
			S_BI_S2_Fr	14	293	347	99	37	51	25	26
			F_BI	13	289	173	126	42	58	10	23
			F_BI_Fr	1	53		45		43		15
			AH_UP_Fr	1	41		30		23		29
			DC	13	14	8	23	7	18	3	
			DC_Fr	2	4	2	12	7	15	1	
			Total N	90							
MN sites: Halberstadt-Spiegelsberge, Westerhausen B6n	Saxony-Anhalt, Germany	Bernburger Culture, Schönfelder Culture, Salzmünde Culture	S_BI_S1_Fr	3	86	50	77	16	40	4	25
			S_BI_S2_Fr	1	820		103		81		61
			F_BI	18	228	486	96	40	44	10	23
			F_BI_Fr	4	260	157	86	17	53	11	36
			BA_UP	1	238		92		40		38
			AH_UP_Fr	1	367		118		65		32
			Total N	28							
BA sites: Schiepzig	Saxony-Anhalt, Germany	EBA, Aunjetitz Culture	F_BI_Fr	1	232		78		63		28
			Total N	1							
Single finds	Saxony-Anhalt, Germany	undated	S_SI_S1_VU	2	412	84	86	10	82	6	37
			S_SI_S1_VU_Fr	1	166		89		54		27
			S_SI_S1	8	924	653	201	84	69	18	36
			S_BI_S1	5	718	494	195	75	56	18	34
			S_BI_S1_Fr	34	174	109	85	21	45	13	27
			S_BI_S2	4	1224	978	181	96	77	7	46
			S_BI_S2_Fr	8	127	179	85	36	45	10	23
			S_BI_S3	1	982		233		70		37
			S_BI_SC	2	1585	976	272	45	61	19	47
			F_BI	55	452	471	145	58	61	17	27
			F_BI_Fr	5	219	135	98	29	53	11	26
			BA_UP	4	557	102	117	2	49	7	49
			AH_UP	13	523	629	127	54	47	15	38
			AH_UP_Fr	5	243	138	75	22	51	6	35
			SC_UP	5	476	318	174	50	29	7	42
			DC	70	20	9	32	9	19	3	
			DC_Fr	16	7	3	13	4	18	3	
			Total N	238							

Tab. 2 Overview of metric data and lithic raw materials of the studied axe blanks, manufacturing debris, and axeheads with unfinished perforation. Explanation of abbreviations: LBK = Linear Pottery Culture; SBK = Stroke Ornamented Pottery Culture; EBA = Early Bronze Age; Wgt = weight; L = length; W = width; H = height; max = maximum; $\bar{x}$ = average; σ = standard deviation; S1 = 1st saw mark; S2 = 2nd saw mark; S3 = 3rd saw mark; CURV_S = curvature of saw mark; RT = straight; CV = concave; $\bar{\phi}$ = average diameter; AHS = actinolite-hornblende-schist; MBAS = metabasites; WDS = Wiedaer Schiefer; MSED = metasediments; Mafic = mafic to intermediate rocks; Felsic = felsic to intermediate rocks.

													Lithic Raw Material (n)					
σ (mm)	$L_{\max} \bar{x}$ S1 (mm)	σ (mm)	$L_{\max} \bar{x}$ S2 (mm)	σ (mm)	$L_{\max} \bar{x}$ S3 (mm)	Depth $\bar{x}$ S1 (mm)	σ (mm)	Depth $\bar{x}$ S2 (mm)	σ (mm)	Depth $\bar{x}$ S3 (mm)	CURV_S	Drill Hole $\bar{\phi}$ $\bar{x}$ (mm)	AHS	MBAS	WDS	MSED	Mafic	Felsic
	52		56			2		10			RT, U		1					
4	61	22	61	3		10	4	2			RT, U, V		4	1				
9	91	25				17	5				RT		6					
11	64	26				14	5				RT, CV (3)		29	4			1	
11	85	31	70	30		14	4	10	7		RT, CV (3)		12	2				
8													11	2				
														1				
													1					
													13					
													2					
9	42	24				6	2				RT				3			
	82		67			39		36			RT	25		1				
14													1	1	16			
11														1	3			
																		1
												19		1				
													1					
1	74	11				12	2				RT, V		2					
	61		39			18		15			RT, V		1					
7	195	89				20	8				RT		7			1		
16	123	49				15	8				RT, CV (2)		5					
11	78	21				16	6				RT, CV(2)		30	2		1	1	
17	148	107	122	107		21	8	20	8		RT, CV (1)	18	4					
6	75	32	62	27		14	5	12	6		RT, CV (1)		8					
	225		188		68	21		20		15	RT-CV	17	1					
14	173	7				25	4				CV		2					
10													42	4	4	4	1	
10													4			1		
1														2			2	
14												17	2	5		1	3	2
9												19	3	1				1
14												17	5					
													61	2		5	2	
													13				2	1

Tab. 2 Übersicht der metrischen Daten und des lithischen Rohmaterials der untersuchten Rohlinge, der Herstellungsreste und der Axtklingen mit unvollständiger Lochung. Verwendete Abkürzungen: LBK = Linearbandkeramische Kultur; SBK = Kultur der Stichbandkeramik; EBA = Frühe Bronzezeit; Wgt = Gewicht; L = Länge; W = Breite; H = Höhe; max = Maximum; $\bar{x}$ = Durchschnitt; σ = Standardabweichung; S1 = erste Sägespur; S2 = zweite Sägespur; S3 = dritte Sägespur; CURV_S = Krümmung der Sägespur; RT = gerade; CV = konkav; $\bar{\phi}$ = mittlerer Durchmesser; AHS = Aktinolith-Hornblende-Schiefer; MBAS = Metabasite; WDS = Wiedaer Schiefer; MSED = Metasedimente; Mafic = mafische bis intermediäre Gesteine; Felsic = felsische bis intermediäre Gesteine.

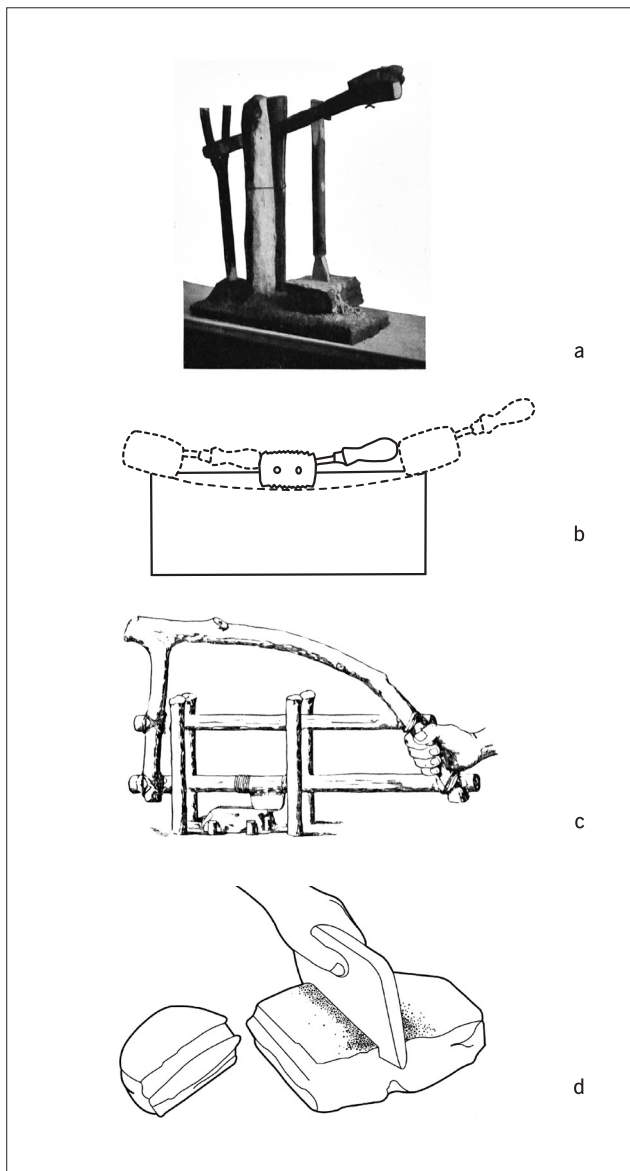


Fig. 4a–d a Pendulum stone saw as depicted by La Baume (1934, 73) explaining the strongly curved saw marks; b another explanation for the curved incision is provided by Pietzsch (1951, 32) and features a stair saw or a handheld blade where more pressure is applied in the centre of the artefact during the sawing process, causing a concave incision; c stone sawing device depicted by Pietzsch (1951, 33); a wooden sawing blade is moved back and forth with a handheld device, abrasing the rock material with a mix of sharp quartz sand and water, leading to a straight sawing mark as seen in many of the sawn artefacts; d a simple hand-held saw, as proposed by the Archaeological Museum of Chemnitz (Saxony), probably also leading to straight sawing marks (Wolfram et al. 2014, 98).

Abb. 4a–d a Pendelsteinsäge nach La Baume (1934, 73), welche die stark gekrümmten Sägespuren erklären würde; b eine weitere Erklärung für den gebogenen Schnitt liefert Pietzsch (1951, 32) mit einer Gratsäge oder einem handgeführten Sägeblatt, wo in der Mitte des Artefakts beim Sägen mehr Druck ausgeübt wird, was zu einem konkaven Schnitt führt; c bei Pietzsch (1951, 33) dargestellte Vorrichtung zum Steinsägen, bei der ein hölzernes Sägeblatt mithilfe einer handgehaltenen Vorrichtung vor- und zurückbewegt wird, sodass das Gesteinsmaterial mittels einer Mischung aus scharfem Quarzsand und Wasser abgeschürft wird, was zu einem geraden Sägechnitt führt, wie man ihn an vielen gesägten Artefakten sieht; d eine einfache Handsäge, wie sie das Staatliche Museum für Archäologie Chemnitz (Sachsen) vorschlägt, führte vermutlich ebenfalls zu geraden Sägespuren (Wolfram et al. 2014, 98).

well as the sawing techniques themselves¹³. Curved sawing marks have been interpreted as the result of a pendulum saw (Fig. 4a; La Baume 1934; La Baume 1943) or of a stair saw (cf. Fig. 4b; Pietzsch 1951). By contrast, the more frequent straight sawing marks have been explained by the use of a sawing device as depicted by Pietzsch in 1951 (cf. Fig. 4c), or a handheld saw blade (Weiner 1996; cf. Fig. 4d). The saw blade itself has also been part of the discussion since sawing in the Neolithic was rather a linear abrasion than what we know as sawing in later periods (Weiner 1996). While saw blades made of sandstone or quartzitic rocks have occasionally been found (Wessel 1996; Stolz 2016; Kaufmann 2020, 84–85), the dominant view is that wood devices were used in combination with sharp quartz sand and water to perform the abrasion task.

Due to the low number of dated artefacts, it is unclear whether the different sawing techniques correlate with different periods or cultures. However, since curved or straight (cf. Fig. 3; cf. Fig. 9) sawing marks can be found on the same axe type (shoe-last celts), both sawing techniques were definitely used during the Early Neolithic.

After sawing, the rock slabs were further shaped by flaking or pecking. The removal of excess rock material resulted in slightly smaller and lighter blanks (cf. Tab. 2; cf. Fig. 2). Both processes were carried out with hammerstones, which are abundant in any macrolithic record of Neolithic settlements of Central Germany.

The hafting of axeheads through circular perforations is known in Central Europe since the early Linear Pottery and Stroke Ornamented Pottery Culture (Rieth 1958) and can be observed on many types of Neolithic axes. Perforations were drilled vertically through the axes with a round and hollow cylinder, probably made out of elder wood or bone diaphysis, and the use of fine quartz sand and water (Rieth 1958; Ganslmeier 2021). A secondary product of this manufacturing process, which can take place at any stage in the use-life of an axehead, are cone-shaped drillcores. They have a cone-shaped body with an average inclination of 85.3° ($\sigma = 1.7^\circ$). While the minimum diameter can be as thin as 8 mm, the widest part can reach up to 25 mm in diameter. The average diameter of these drillcores lies between 18–19 mm, which matches the unfinished drillholes in perforated axes with an average diameter of 18.5 mm (cf. Tab. 2).

Raw Materials

Petrographic studies

The petrographic terminology used to describe the Neolithic axes in Central Europe is far from unified. The terms »amphibolite«¹⁴, »hornblende-schist« (Luedecke 1902; Behrens 1983), or »green rocks« (Herrmann/Schüller 1952; Quitta 1955) have regularly been used to describe the dominant raw material of Neolithic axes. They commonly show a greenish to greyish colour and often a slight deformation

13 Keller 1870; Schultheiß 1872; Pfeiffer 1912; La Baume 1934; La Baume 1943; Ischer 1941; Pietzsch 1951; Herrmann/Schüller 1952;

Schrickel 1952; Willms 1980; Weiner 1996; Lessig 2003.

14 Rieth 1958; Arps 1978; Behrens 1983; Scholz 1986.

and can be labelled as metabasites, a group of metamorphic rocks with a basic protolith origin covering all varieties of greenschist, greenfels, dolerite, (meta)cinerite, and amphibolite as well as the so-called actinolite-hornblende-schist (AHS).

Apart from AHS, macroscopic observation of the 3000 artefacts and petrographic studies of a total of 47 artefacts has allowed us to identify five additional rock categories: metabasites (other than AHS), mafic rocks, felsic rocks, metasediments, and Wiedaer Schiefer (WDS). These identifications have been confirmed through thin sections and SEM of axe blanks made of AHS and of finished artefacts made of all rocks.

Actinolite-hornblende-schist (AHS)

The term actinolite-hornblende-schist was established by G. Schwarz-Mackensen and W. Schneider (1983; Schwarz-Mackensen/Schneider 1986). This rock is the most common material used for Early Neolithic axes throughout Central Europe (Nowak 2008; Moník et al. 2021). It is part of the metabasite rock group and has also been referred to as »Jizera-type metabasite« (Šída/Kachlik 2009) with a known provenance in the Jizera Mountains near Jistebko, where it was quarried extensively during the Early Neolithic¹⁵.

Thin-section studies of the AHS samples revealed petrographic correspondence with the Jizera metabasites as described by P. Šída and V. Kachlik (2009). The rock shows a very fine-grained and highly deformed texture with elongated sigmoidal-shaped aggregates consisting of plagioclase and minor quartz surrounded by at least two generations of amphibole (see Fig. 5a–g,j). The amphibole shows a pale green to almost transparent colour and occurs in fibrous, decussate, almost felt-like mats of amphibole intergrown with single bigger amphibole needles. Opaque mineral phases and fibrous amphibole define the foliation, which can be more or less prominent depending on the sample (cf. Fig. 5a–g,j). The opaque mineral phases were identified, using SEM-EDS, as Mn-bearing ilmenite (Fig. 5m–n). The amount of ilmenite in the studied AHS samples can range between 5–15 %, while actinolite and hornblende account for up to 70 %. The content of plagioclase ranges between 15–25 % and shows an intermediate to Ca-rich composition (anorthite). Chlorite is often present as an accessory mineral, as well as apatite, epidote, and titanite, which rims the ilmenite crystals. SEM analysis also revealed orthoclase and pyrite as accessory minerals in some samples. The amphiboles could be further identified via SEM-EDS as clinoamphiboles, including the Ca-amphiboles actinolite and Mg-hornblende, and as cummingtonite. Petrographically, this rock would be classified as actinolite-hornblende-bearing foliated metabasite. However, actinolite-hornblende-schist (AHS) is the widely used definition of this rock in the geoarchaeological studies of Central Europe.

Metabasites (other than AHS)

Based on the thin sections of polished axes, metabasites other than AHS have been identified among Central German stone tools. Metabasites are a group of metamorphic rocks with a basic protolith origin. In the artefacts studied, amphibolites, (meta)dolerites, greenschists, and metacinerites could be identified. Some axe blanks could not be defined macroscopically as AHS and probably belong to these types of metabasite rocks. Amphibolites are rocks formed by the amphibolite facies metamorphism of basic protoliths. They usually contain amphibole group minerals (esp. hornblende and actinolite) and plagioclase, and show a weakly foliated structure. Garnet, biotite, epidote, quartz, and opaque mineral phases can be found as accessories. Dolerites are subvolcanic rocks with a basaltic/gabbroid mineral composition. They are often metamorphosed into greenschists featuring a foliated texture and a mineral composition typical for greenschist to amphibolite facies metamorphism – namely amphibole group minerals (esp. actinolite), plagioclase, epidote, chlorite, and quartz. Metacinerites are volcanic ashes or tuff featuring a very fine-grained isotropic-to-slightly-foliated texture. They can also be described as greenschists showing an abundance of chlorite with minor quartz and opaque mineral phases.

Mafic rocks

Mafic rocks were predominantly determined among axeheads and axeheads with unfinished perforation; in isolated cases, they were also observed macroscopically among axe blanks. The term »mafic rock« is used for a range of igneous and volcanic rocks with a mafic to intermediate mineral composition that includes diorite and basalt as well as gabbro.

Basalt is a volcanic rock featuring a general mineral composition of calcic plagioclase, pyroxene, and olivine with minor foids and interstitial quartz and a rather fine-grained texture. It is the volcanic equivalent to gabbro, which is a plutonic rock with an equigranular texture and a general mineral composition of calcic plagioclase, pyroxene, and iron oxides, and it often contains olivine. Diorite is also a plutonic rock with a coarse-to-medium-grained texture and a mineral composition of intermediate plagioclase and hornblende. Biotite and Augite are also often present.

It is of interest that, so far, no alkali olivine basalt has been identified among the axeheads, nor among the blanks of Central Germany. This basalt is the second most important raw material in the northern Hesse region, where it represents 29.5 % of all Early Neolithic axeheads and 92 % of the 36 recognised adze blanks (Kegler-Graiewski 2007, 143; 179). Although no quarry evidence has been found so far, most probably it was obtained from one of the many volcanic outcrops existing in the northern Hesse depression. In contrast to AHS, which accounted for 67.4 % of the adzes of northern Hesse despite its distant origin, the distribution of olivine basalt seems to have been much more limited.

15 Šída 2009; Rammingner/Šída 2012; Rammingner 2007; Šrein et al. 2002; Šrein et al. 2003; Prostředník et al. 2005.

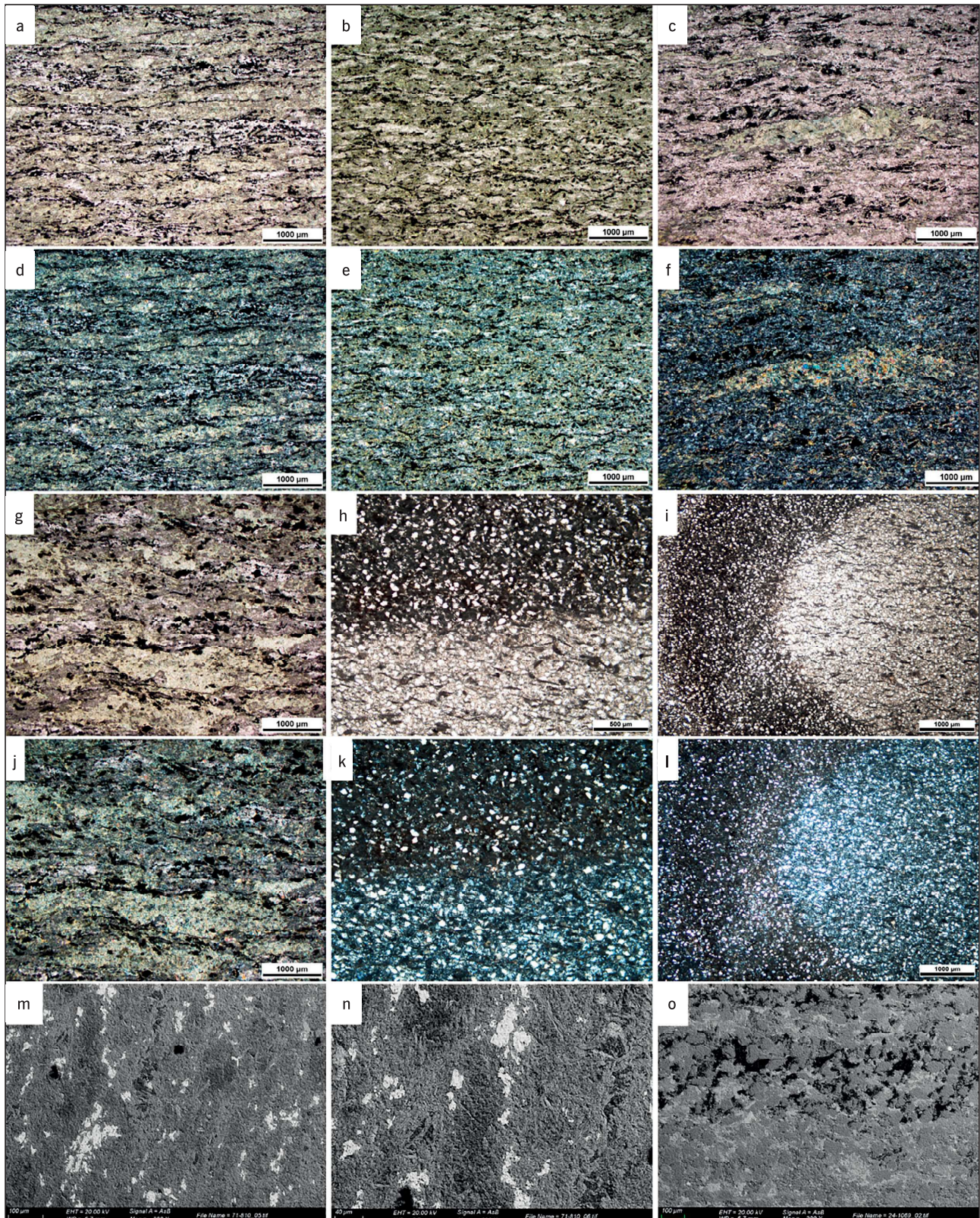


Fig. 5a–o Thin-section photos of axe blanks made of actinolite-hornblende-schist (a–g, j) and axes made of Wiedaer Schiefer (h–i, k–l) in PPL and XPL; SEM pictures of AHS (m, n) and WDS (o). Actinolite-hornblende-schist consists of pale green to transparent amphibole needles in decussate, fibrous mats, feldspar, ore minerals, and minor quartz. Ore minerals could be identified as Mn-bearing ilmenite (white) using SEM (m, n). The overall texture is fine-grained and highly deformed. Wiedaer Schiefer axes show a pale core and dark brown rim (h–l, k–l) consisting of fine quartz grains in a plagioclase-chlorite-quartz-carbonate matrix. The rim area is defined by a higher porosity (o).

Abb. 5a–o Dünnschliffaufnahmen von Rohlingen aus Aktinolith-Hornblende-Schiefer (AHS) (a–g, j) und Beilen aus Wiedaer Schiefer (WDS) (h–i, k–l) im Polarisationsmikroskop mit linear und gekreuzt polarisiertem Licht; Rasterelektronenmikroskopaufnahmen (REM) von AHS (m, n) und WDS (o). AHS besteht aus blassgrünen bis transparenten Amphibol-Nadeln in granulitischen, faserigen Matten, Feldspat, Erzmineralien und etwas Quarz. Die Erzminerale konnten mithilfe von REM als manganhaltiger Ilmenit (weiß) identifiziert werden (m, n). Die Textur ist insgesamt feinkörnig und stark verformt. Exemplare aus WDS besitzen einen hellen Kern und einen dunkelbraunen Rand (h–i, k–l); sie bestehen aus feinen Quarzkörnern in einer Plagioklas-Chlorit-Karbonat-Matrix. Der Randbereich zeichnet sich durch seine höhere Porosität aus (o).

Felsic rocks

Felsic rocks were only observed macroscopically among axeheads. Halle-porphry, rhyolite, and granodiorite are combined into the group of »felsic-to-intermediate rocks«. Granite is a coarse-to-medium-grained igneous rock with an often equigranular texture. The main minerals are plagioclase (sodic), potassium feldspar, quartz, mica, and amphibole group minerals. Rhyolite is the volcanic equivalent of granite usually featuring a porphyric texture and the same mineral composition of sodic plagioclase, potassium plagioclase, quartz, (biotite) mica, and amphibole group minerals. The Halle-porphry describes a specific type of Permian-to-carbonic rhyolite with a porphyric texture found in the area surrounding Halle (Frühauf 2006). The main minerals are plagioclase, potassium feldspar, and quartz forming single crystals in a fine-grained matrix. Biotite and opaque mineral phases are present as accessory minerals. Granodiorite is a plutonic rock, similar to granite, featuring a coarse-grained equigranular texture but with a higher content of plagioclase and a lower amount of potassium feldspar in comparison to granite. The main minerals are plagioclase, quartz, mica and amphibole group minerals.

Metasediments

Metasediments – such as greywacke, (hornfelsic) metapsammities, and quartzitic rocks – provide another important raw material source for Neolithic axe and adze production. Their fine-grained and quartz-rich mineral composition, as well as the influence of the metamorphism on minerals and texture, grant them a relatively high mechanical resistance. Metasediments such as hornfelsic metapsammite have been identified macroscopically among some axe blanks, axeheads with unfinished perforation, and production debris. They present a fine-grained, sedimentary relic texture and a mineral composition of varying ratios of quartz, feldspar, and lithic fragments identifiable in the hand specimen. Thin sections of metasediments with the same optical features have been identified among finished axeheads.

Wiedaer Schiefer (WDS)

One of the most notable metasediments used for Neolithic axes is the so-called Wiedaer Schiefer. It is easily recognisable by its white-to-cream colour and its relatively light weight. Historically described as adinole-rich rock (Toepfer 1957), microquartzite (Köppen 2006), and quartzitic hornblende schist or schistose limestone (Jürgens 2018), our thin section analyses showed a layered structure with an unaltered core area and a heavily altered and porous rim. The rock material shows an extremely fine-grained, homogeneous texture with coarser, rounded quartz grains (up to 90 µm in size) embedded in a finer matrix (cf. Fig. 5h–i, k–l, o). The composition of the matrix was identified as plagioclase,

chlorite, carbonate, and quartz with accessory portions of titanite, epidote, iron oxides, rutile, zircon, and amphibole. Chlorite and plagioclase are altered and oxidised, leading to the brownish colour in the thin sections. Contrary to their former identification as schistose limestone (Jürgens 2018), calcite could not be identified in the thin sections. Staining of the thin section with alizarin red revealed an accumulation of calcium carbonate in the transition zone between the rim and core area but no Ca-carbonate in the core area, which leads to the identification of dolomite as the main matrix carbonate. The rock can therefore be classified as an altered metasiltstone.

This material was used in the Middle Neolithic around the Harz Mountains, especially in the northern Harzvorland¹⁶. It is associated with the Funnelbeaker, Bernburger, Salzmünder, Elb-Havel, and Walternienburger Cultures¹⁷. In absolute chronological terms, this corresponds to the time between 3400–2650 BC. Wiedaer Schiefer represents 25 % of all documented flaked axe blanks found in the collection of the State Museum of Prehistory in Halle. Sawing marks are very rarely observed.

The use of raw materials

AHS represents around 75 % of the sawn and flaked axe blanks of Central Germany we studied. Interestingly, it was dominant in the Early Neolithic, for example among flat adzes and shoe-last celts and their blanks, whereas it seems to have been negligible in the Middle Neolithic, when Wiedaer Schiefer and different metabasites became more common (Fig. 6a). Good examples are the pecked axeheads we studied (BA_UP) – associated with the period of the battle axes (Brandt 1967; Struve 1955) and therefore with, e.g., the Central-Eastern European Corded Ware Culture or the Battle Axe Culture in Scandinavia – which show a higher variety in the use of raw materials favouring metabasites as well as mafic and felsic rocks (cf. Fig. 6b). This change in the use of lithic raw material over time was already observed in the area around Braunschweig and the northern part of the State of Hesse, located, respectively, to the north and southwest of the Harz Mountains (Schwarz-Mackensen/Schneider 1986; Kegler-Grajewski 2007, 143–144). In both areas, the importance of (meta)mafic rocks, especially diabase and basalt, increased during the Middle and Late Neolithic.

The different types of blanks show significant variations in the raw material used (cf. Fig. 6b). An abundance of AHS and other foliated metabasites can be seen especially among sawn axe blanks (95 %), while flaked blanks show a somehow higher variability of raw material. Pecked axe blanks and axeheads with unfinished perforation show the highest diversity of raw materials with a significantly increasing amount of mafic and felsic rocks. The only exceptions are the shoe-last celts with unfinished perforation, which are exclusively made from AHS.

Since sawing has been predominantly used for AHS and related metabasites (cf. Fig. 6c), it is no surprise that sawn

16 Bartels 1956; Töpfer 1957; Dirks 2000; Rinne/ Schmidt 2006; Jürgens 2017; Jürgens 2018. 17 Reuß 1907; Niklasson 1925; Sprockhoff 1926; Grimm 1938; Dirks 2000.

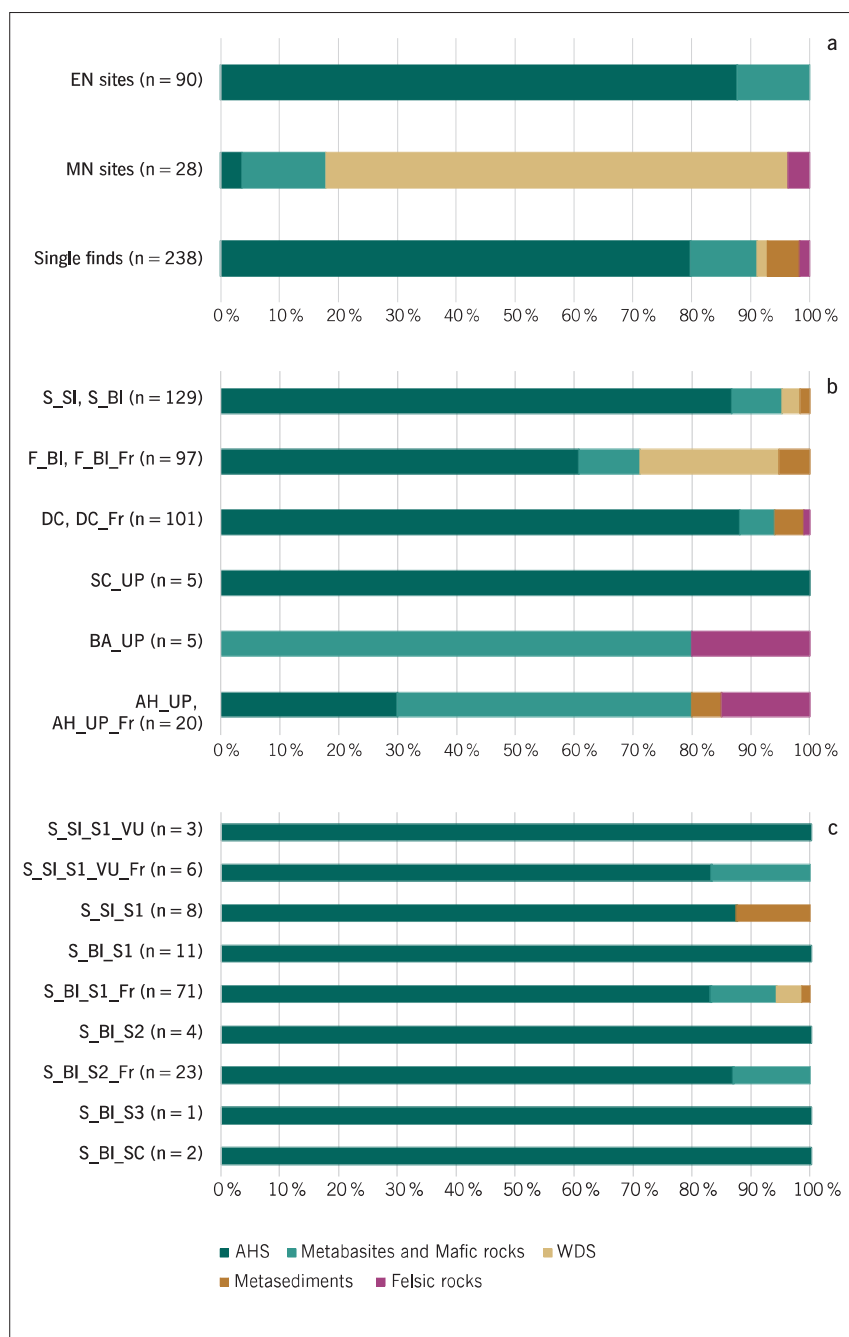


Fig. 6a–c Distribution of lithic raw material according to chronology and type of manufacturing remains. a distribution of lithic raw material according to chronology (EN = Early Neolithic; MN = Middle Neolithic; Single finds = undated); b distribution of lithic raw material according to type of manufacturing remains; c distribution of lithic raw material in sawn slabs and axe blanks.

Abb. 6a–c Verteilung des lithischen Rohmaterials nach Chronologie und Art der Herstellungsreste. a chronologische Verteilung des lithischen Rohmaterials (EN = frühneolithisch; MN = mittelnolithisch; Einzelfunde = undatiert); b Verteilung des lithischen Rohmaterials nach Art der Herstellungsreste; c Verteilung des lithischen Rohmaterials nach gesägten Platten und Rohlingen.

blanks are abundant in Early Neolithic sites, where AHS is the main lithic raw material used for the production of axes and adzes (cf. Tab. 2).

The drillcores also show a predominant relation with AHS, which represents 85 % of the petrographic identifications among these manufacturing remains (cf. Fig. 6b). This is indirect evidence that they possibly derived from the production of perforated shoe-last celts or Rössen-type adzes, since AHS is marginally represented among the analysed pecked battle axes or other Middle and Late Neolithic perforated axes. The pecked battle axes studied (BA_UP) are not made from AHS (cf. Fig. 6b). Their perforation could explain most of the 15 % of drillcores made of metabasites, metasediments, mafic, and felsic rocks.

Distribution of blanks and manufacturing debris

The spatial distribution of the sawn and flaked axe blanks made from AHS and, rarely, from metabasites in Central Germany clearly shows an intense clustering of remains in a core area between the Weiße Elster River around Zeitz and the Saale River from the north of Jena to around Naumburg (Fig. 7): a flat landscape with dense Neolithic occupation, high-quality soils, and an abundant supply of water and sand necessary for the production of axes. The dense distribution of artefacts found here indicates one production centre for axes and adzes consisting of several workshops, where all phases of the production process took place. This production centre can be dated to the Early Neolithic based on the shape of the sawn and flaked blanks related to axe

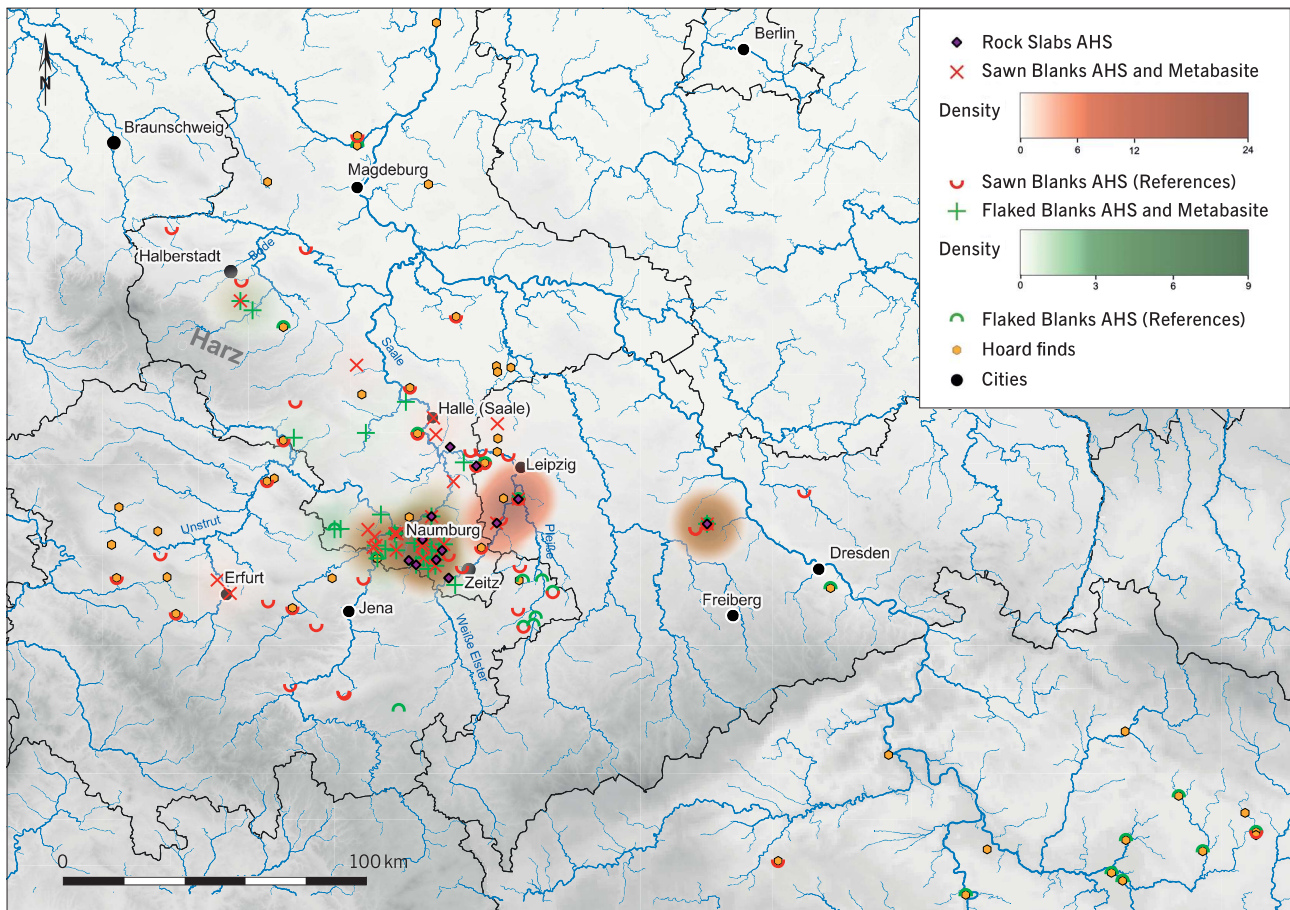


Fig. 7 Spatial Distribution of sawn and flaked axe blanks made from AHS and metabasites in Central Germany. Rock slabs refers to type S_Sl_S1, S_Sl_S1_VU and S_Sl_S1_VU_Fr. References refers to the sawn and flaked axe blanks published by Pietzsch 1951¹⁷; Kaufmann 1959a¹⁸; Höckner 1962¹⁹; Vencel 1975²⁰; Küßner 2006²¹; Jansen 2013²²; Petzold 2013²³; Kaufmann 2020²⁴; Martin 2020²⁵. The published blanks refer to the following sites from **Saxony-Anhalt**: Abtlöbnitz²⁴ (Burgenlandkreis district), Grana²⁴ (Burgenlandkreis district), Harsleben²⁴ (Harz district), Hessen am Fallstein²⁴ (Harz district), Oberschwödtitz²⁴ (Burgenlandkreis district), Oberthau²⁴ (Saalekreis district), Pölsfeld²⁴ (Mansfeld-Südharz district), Westeregeln²⁴ (Salzlandkreis district), Wehlitz²⁴ (Nordsachsen district), Wiederau¹⁷ (Borna district); **Thuringia**: Dittersdorf¹⁸ (Saale-Orla district), Fichtenhainichen¹⁹ (Altenburger Land district), Gößnitz²³ (Altenburger Land district), Gräfontonna²⁴ (Gotha district), Gröba¹⁹ (Altenburger Land district), Heldrungen²⁴ (Kyffhäuserkreis district), Hirschroda²⁵ (Saale-Holzland-district), Isseroda²⁴ (Weimarer Land district), Leina¹⁹ (Altenburger Land district), Löhmigen²³ (Altenburger Land district), Niedersynderstedt²¹ (Weimarer Land district), Nitzschka²² (Altenburger Land district), Öpitz¹⁸ (Saale-Orla district), Röthenitz¹⁹ (Altenburger Land district), Rudolstadt¹⁸ (Saalfeld-Rudolstadt district), Schlettwein¹⁸ (Saale-Orla district), Windischleuba¹⁹ (Altenburger Land district); **Czech Republic**: Chudonice²⁰ (Hradec Králové district), Čistěves²⁰ (Hradec Králové district), Jeřice²⁰ (Hradec Králové district), Kovanice²⁰ (Nymburk district), Křinec²⁰ (Nymburk district), Lipa²⁰ (Hradec Králové district), Liteň²⁰ (Beroun district), Lovosice²⁰ (Litoměřice district), Malá Černoc²⁰ (Louny district), Nudvojovice²⁰ (Semily district), Bubeneč²⁰ (Praha district), Poděbrady²⁰ (Nymburk district), Štěnovice²⁰ (Plzeň-jih district), Vitiněves²⁰ (Jičín district).

Abb. 7 Verbreitungskarte gesägter und geschlagener Rohlinge aus Aktinolith-Hornblende-Schiefer und Metabasiten in Mitteldeutschland. »Rock Slabs« meint die Typen S_Sl_S1, S_Sl_S1_VU und S_Sl_S1_VU_Fr. »References« bezieht sich auf an anderer Stelle veröffentlichte gesägte und geschlagene Rohlinge bei Pietzsch 1951¹⁷; Kaufmann 1959a¹⁸; Höckner 1962¹⁹; Vencel 1975²⁰; Küßner 2006²¹; Jansen 2013²²; Petzold 2013²³; Kaufmann 2020²⁴; Martin 2020²⁵. Die publizierten Halbfabrikate stammen von den folgenden Fundstellen: **Sachsen-Anhalt**: Abtlöbnitz²⁴ (Burgenlandkreis), Grana²⁴ (Burgenlandkreis), Harsleben²⁴ (Lkr. Harz), Hessen am Fallstein²⁴ (Lkr. Harz), Oberschwödtitz²⁴ (Burgenlandkreis), Oberthau²⁴ (Saalekreis), Pölsfeld²⁴ (Lkr. Mansfeld-Südharz), Westeregeln²⁴ (Salzlandkreis); **Sachsen**: Baderitz¹⁷ (Lkr. Nordsachsen), Birmenitz¹⁷ (Lkr. Meißen), Cunnersdorf¹⁷ (Lkr. Meißen), Leipzig-Wahren¹⁷ (Lkr. Leipzig), Wehlitz²⁴ (Lkr. Nordsachsen), Wiederau¹⁷ (Lkr. Borna); **Thüringen**: Dittersdorf¹⁸ (Saale-Orla-Kreis), Fichtenhainichen¹⁹ (Lkr. Altenburger Land), Gößnitz²³ (Lkr. Altenburger Land), Gräfontonna²⁴ (Lkr. Gotha), Gröba¹⁹ (Lkr. Altenburger Land), Heldrungen²⁴ (Kyffhäuserkreis), Hirschroda²⁵ (Saale-Holzland-Kreis), Isseroda²⁴ (Lkr. Weimarer Land), Leina¹⁹ (Lkr. Altenburger Land), Löhmigen²³ (Lkr. Altenburger Land), Niedersynderstedt²¹ (Lkr. Weimarer Land), Nitzschka²² (Lkr. Altenburger Land), Öpitz¹⁸ (Saale-Orla-Kreis), Röthenitz¹⁹ (Lkr. Altenburger Land), Rudolstadt¹⁸ (Lkr. Saalfeld-Rudolstadt), Schlettwein¹⁸ (Saale-Orla-Kreis), Windischleuba¹⁹ (Lkr. Altenburger Land); **Tschechische Republik**: Chudonice²⁰ (Okr. Hradec Králové), Čistěves²⁰ (Okr. Hradec Králové), Jeřice²⁰ (Okr. Hradec Králové), Kovanice²⁰ (Okr. Nymburk), Křinec²⁰ (Okr. Nymburk), Lipa²⁰ (Okr. Hradec Králové), Liteň²⁰ (Okr. Beroun), Lovosice²⁰ (Okr. Litoměřice), Malá Černoc²⁰ (Okr. Louny), Nudvojovice²⁰ (Okr. Semily), Bubeneč²⁰ (Okr. Praha), Poděbrady²⁰ (Okr. Nymburk), Štěnovice²⁰ (Okr. Plzeň-jih), Vitiněves²⁰ (Okr. Jičín).

types associated with the Linear Pottery and Stroked Pottery Cultures, as well as the Rössen Culture (shoe-last celts or flat adzes), in addition to the Early Neolithic date of artefacts found in the settlements of Zauschwitz, Harth, and Breitenbach.

A single, isolated workshop with sawn and flaked blanks could be located in Saxony, in the area around Birmenitz,

around 30 km north of Freiberg (cf. Fig. 7). This workshop might be part of a second production centre but so far only this single workshop could be identified. The settlement of Birmenitz has an approximate size of 0.4 km² (Hottenroth 1903) and can be dated to the Early Neolithic by pottery fragments featuring characteristic ornaments of the Linear Pottery and Stroked Pottery Cultures. Furthermore, shoe-

last celts and flat adzes typical of the Early Neolithic are abundant axe types found in the settlement. The occupation of this site continued during the Middle Neolithic, and even artefacts dated to the Bronze and Iron Age as well as Medieval periods have been found. Evidence for the production of Neolithic axes is present in a total of 27 sawn and flaked axe blanks, with sawing being the dominant production technique. Furthermore, a total of 13 drillcores have been documented on the site, indicating the perforation of the axeheads directly at the workshop.

Sawing is required mainly on metamorphic rocks, which cannot be flaked due to the high deformation and alignment of the minerals in the rock matrix (Weiner 1996). While the Jizera metabasites are rather isotropic (Šída/Kachlik 2009) and therefore suitable for flaking, some of the thin sections of the sawn axe blanks show a high deformation and sigmoidal rock texture. This slightly different texture could lead to different mechanical properties of the rock, which determine the production technique as well as its usability for tools (Moník et al. 2021). Even if the textural and mechanical differences are barely visible in the artefacts and the thin sections, the use of a different production technique indicates that the rock material used for the Cen-

tral German axe blanks was often not suitable for an overall flaking of the blanks.

The distribution of all known manufacturing remains identified so far in Central Germany provides direct insight into the organisation of axe production (cf. Fig. 7). Slabs with sawing marks, which appear to have been prepared at the »primary« quarry sites, are only found in a specific territory between southern Saxony-Anhalt and western Saxony. It can be expected that these settlements had direct access to the exploited rock deposits, which – based on the geology of the region – must have been found in one or several of the many greenschist outcrops of the central Saxo-Thuringian zone. In this »secondary« manufacturing area, slabs were transformed into blanks by sawing and flaking. These communities also polished part of the half-finished pieces into axes. But most of the blanks seem to have been handed over to a much larger »tertiary« manufacturing region, which included communities living over 50 km to the north and west of the first area. Such a pattern is an effective form to organise a stone axe manufacturing process: While the initial sawing and flaking can be carried out in a relatively short time and require specific expertise, the polishing implies high workloads but can be accomplished by practically any-



Fig. 8 Hoard from Naumburg, Burgenlandkreis district, Vorstädtischer Friedhof, containing flaked and sawn axe blanks as well as finished axes. This hoard represents the complete production process of axes beginning with the initial flaking/sawing (top left, middle, right, bottom second from left), followed by polishing, represented by the semi-polished artefact (bottom right), and ending in a finely polished axe (bottom left).

Abb. 8 Depotfund vom Vorstädtischen Friedhof in Naumburg, Burgenlandkreis, bestehend aus geschlagenen und gesägten Rohlingen und fertigen Beilen. Die Beile dieses Hortfunds weisen alle Schritte des Herstellungsprozesses auf, vom anfänglichen Abschlagen/Sägen (oben links, Mitte und rechts, unten 2. von links) über das Schleifen (halbgeschliffenes Exemplar unten rechts) bis hin zum sorgfältig geschliffenen Beil (unten links).

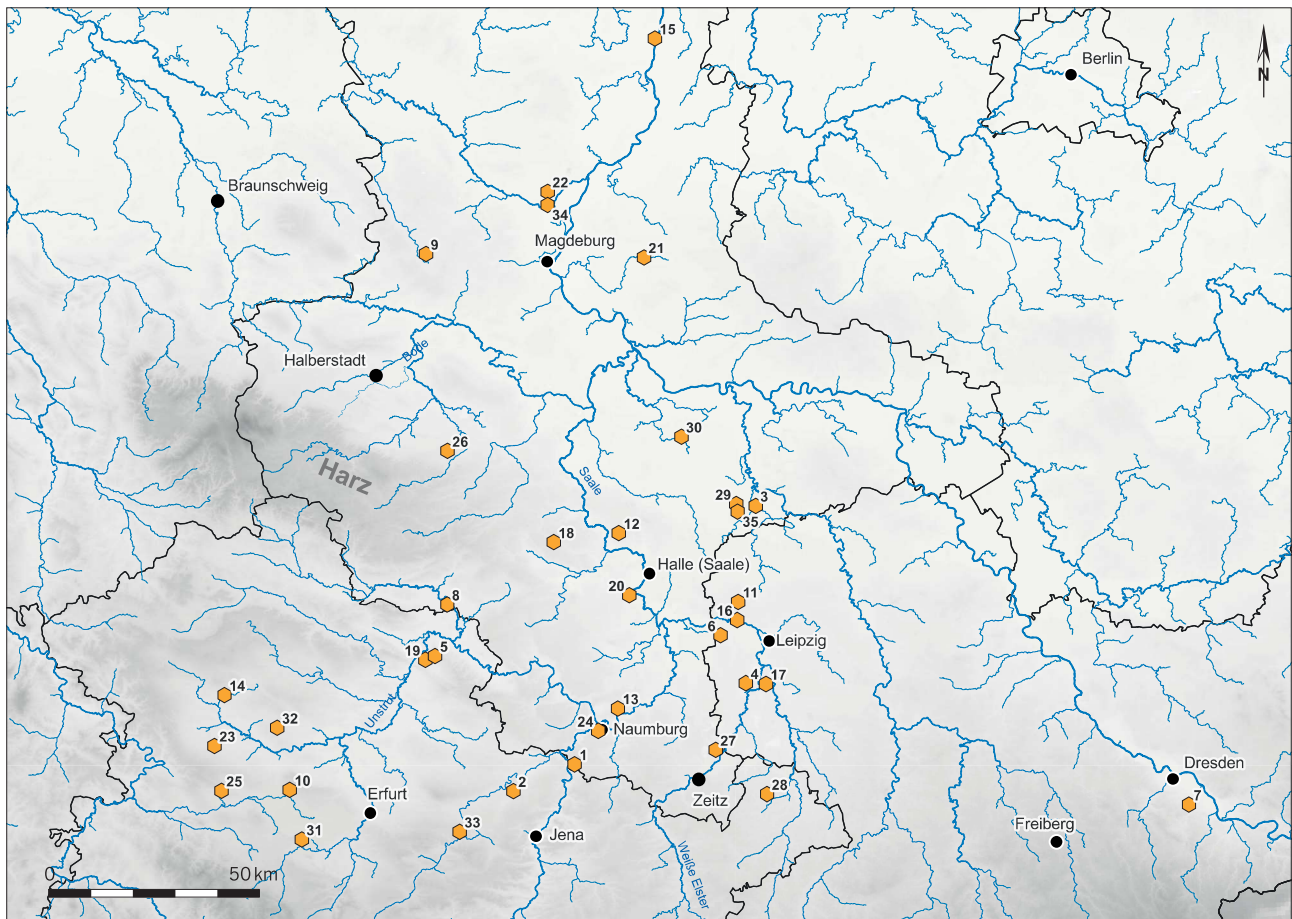


Fig. 9 Spatial distribution of Early Neolithic hoard finds from Central Germany, (1–35, see Tab. 3 for detailed information).

Abb. 9 Räumliche Verteilung frühneolithischer Depotfunde in Mitteldeutschland, (1–35, detaillierte Informationen siehe Tab. 3).

one in a community. The dividing of the time-intensive axe polishing processes over a wide territory can be explained as a strategy to increase the production of finished axes. The northward and westward direction of the secondary manufacturing area also points in the direction where the axes and adzes were required, whereas the absence of blanks east of the Birmenitz workshop might suggest that these regions were supplied by the Jizera quarry and production area.

Special attention needs to be paid to a group of hoards that, taken together, contain a total of 50 axe blanks. Almost half of the early Neolithic hoard finds in Central Germany contain at least one flaked or sawn blank (cf. Tab. 3; Fig. 7–9). In some cases, the combination of artefacts included in the hoards seems to elucidate the entire axe-production process. The deposit of Zwenkau-Harth, for example, is formed by the already mentioned large rock slab with straight sawing marks, one flaked and one sawn axe blank, and a finished shoe-last celt (Quitta 1955). This combination of sawn and flaked axe blanks together with the corresponding polished axes also appears in the hoard of Naumburg (cf. Fig. 8). Macroscopic inspection of these artefacts suggests that most blanks and finished adzes found in these hoards are made of AHS or different-textured metabasite. In terms of their spatial distribution, it is noteworthy that hoards with axe blanks appear distributed over a larger territory than in settlements (cf. Fig. 9). A 24 cm long AHS blank has even been found in the adze deposit of Kirchdit-

mold, city of Kassel (Kegler-Graiewski 2007, 179). This confirms the exceptional circulation distances and high value of AHS artefacts, both finished and unfinished.

The distribution of axe blanks made predominantly from Wiedaer Schiefer shows a Middle Neolithic production centre consisting of several workshops along the northern line of the Harz (Fig. 10). Here, flaked and isolated sawn axe blanks are abundant in the two Middle Neolithic sites of Halberstadt and Westerhausen. The restricted distribution of this rock type highlights the economic and social changes taking place during the 4th millennium BC, when the use of a multiplicity of local raw materials replaced the supraregional AHS network.

Most drillcores related to the perforation of axeheads are found in the south of Saxony-Anhalt (Fig. 11), which was a densely settled area where most axe blanks are found (cf. Fig. 7). Although drilling could take place at any stage of the use-life of axes, this spatial overlap of manufacturing remains suggests that the perforations for hafting were already prepared in the workshops along the Saale River and probably along the Weiße Elster River, in Saxony, where drillcores have not been mapped so far.

Axeheads with an unfinished perforation (BA_UP, AH_UP) are distributed more to the north of Saxony-Anhalt, and even finds from Brandenburg and Mecklenburg-Vorpommern could be documented. Shoe-last celts with an unfinished perforation are found in the south of Saxony-Anhalt

Nr.	Locality	Dating	Total amount of artefacts (n)	Sawn blanks (n)	Flaked blanks (n)	Blanks (undefined)	Natural rock slab with saw mark (n)	Raw Material	Reference
1	Abtlöbnitz (Burgenlandkreis district)	EN (LBK/SBK)	6		5	1		Greenish to greyish shistose rock	Herrmann 1934; Quitta 1955
2	Apolda (Weimarer Land district)	Neolithic	7			3			Vogel 1973
3	Bitterfeld (Anhalt-Bitterfeld district)	EN (LBK/SBK)	2					Hornblende-rich rocks/Hornblende-schist	Gustavs 1962
4	Bösdorf (Leipzig district)	EN (LBK/SBK)	3					–	Schmidt 1963
5	Braunsroda (Kyffhäuserkreis district)	EN (LBK/SBK)	7		6			–	Quitta 1955
6	Dölzig (Leipzig district)	EN (LBK/SBK)	5	1	3			–	Näbe 1908; Quitta 1955
7	Dresden-Nickern (total of 3 hoards)	EN (LBK/SBK)			1		1	Amphiboleschist	Baumann 1962
8	Edersleben (Mansfeld-Südharz district)	EN (LBK/SBK)	4	2				rock with greenish-grey colour and foliated texture	Quitta 1955
9	Eilsleben (Börde district)	EN (LBK)	3					–	Kaufmann 2002
10	Eschenbergen (Gotha district)	EN (LBK/SBK)	7					Amphibolite	Müller 1968
11	Freiroda (Nordsachsen district)	EN (LBK/SBK)	4					–	Götze 1896; Quitta 1955
12	Gimritz (Saalekreis district)	EN (LBK/SBK)	2	1				–	Schmidt 1959
13	Goseck (Burgenlandkreis district)	EN (LBK/SBK)	3					Amphibolite	Bertemes/Northe 2011
14	Grabe (Mühlhausen district)	EN (LBK/SBK)	6					Amphibolite	Hesse 1969
15	Hämerten (Stendal district)	–	3					tough schistose rock	Kupka 1913; Kupka 1931; Quitta 1955
16	Hänichen (Leipzig district)	EN (LBK/SBK)	4					greenish-grey, schistose rock	Quitta 1955
17	Harth (Leipzig district)	EN (LBK/SBK)	4	1	1		1	Diabase/Green-schist	Quitta 1955
18	Hedersleben (Harz district)	EN (LBK/SBK)	5			2		Greywacke, Gneis, quarzitic schist	Marschall 1965
19	Heldrungen (Kyffhäuserkreis district)	EN (LBK/SBK)	4	1				–	Lehmann 1927; Quitta 1955
20	Holleben (Saalekreis district)	EN (LBK/SBK)	8	1	3	1		Hornblendeschist	Götze et al. 1909; Schulz 1939; Quitta 1955
21	Möckern (Jerichower Land district)	EN (LBK/SBK)	11					Slate, green to grey rock with foliation	Quitta 1955 Hoffmann 1955
22	Mose (Börde district)	EN (LBK/SBK)	3	2				fine grained blueish-black rock	Schultheiß 1875; Dunker 1931; Schulz 1939; Quitta 1955
23	Mülverstedt (Unstrut-Hainich district)	EN (LBK/SBK)	2					Blueish-grey rock material	Kaufmann 1959
24	Naumburg (Burgenlandkreis district)	EN (LBK/SBK)	9	1	6			Blueish-grey rock material	Herrmann 1926; Herrmann 1934; Quitta 1955
25	Oesterbehringen (Wartburgkreis district)	EN (LBK/SBK)	4	1				light green shistose rock	Wagener 1928; Quitta 1955

Nr.	Locality	Dating	Total amount of artefacts (n)	Sawn blanks (n)	Flaked blanks (n)	Blanks (undefined)	Natural rock slab with saw mark (n)	Raw Material	Reference
26	Radisleben (Harz district)	EN (LBK/SBK)	4					–	Quitta 1955
27	Reuden (Burgenlandkreis district)	EN (LBK/SBK)	3	1				greenish-grey, schistose rock	Wilcke 1925; Quitta 1955
28	Rositz (Altenburger Land district)	EN (LBK/SBK)	8					Amphiboleschist	Frauendorf 1940; Quitta 1955
29	Sandersdorf (Anhalt-Bitterfeld district)	EN (LBK/SBK)	4					–	Quitta 1955
30	Scheuder (Anhalt-Bitterfeld district)	EN (Rössen?)	4					–	Schmidt 1969
31	Seebergen (Gotha district)	EN (LBK/SBK)	3	1				Amphibolite	Hennig 1963
32	Sundhausen (Gotha district)	EN (LBK/SBK)	3					Amphibolite	Vogel 1973
33	Vollersroda (Weimarer Land district)	EN	3	2				AHS ¹⁸	Küßner/Neumann 2008
34	Wolmirstedt (Börde district)	EN (LBK/SBK)	4		1			greenish-grey, schistose rock	Schultheiß 1875; Quitta 1955
35	Zscherndorf (Anhalt-Bitterfeld district)	EN (LBK/SBK)	2					Hornblende-rich rocks/ Hornblendeschist	Gustavs 1962
TOTAL			172	15	26	7	2		

Tab. 3 Hoards from Saxony-Anhalt, Saxony, and Thuringia often contain axe blanks. Due to the insufficient description of manufacturing traces in some publications, some blanks could not be defined clearly and have been categorised as »blanks (undefined)«. However, as sawing leaves easily recognisable marks, such marks would probably have been noted in the blank description. Therefore, it is to be assumed that these undefined blanks refer to flaked blanks. The total number of artefacts refers only to edge-ground tools and axe blanks.

Tab. 3 Depotfunde aus Sachsen-Anhalt, Sachsen und Thüringen enthalten oft Beil- und Axtrohlinge. Aufgrund der unzureichenden Beschreibung der Herstellungsspuren in manchen Publikationen konnten einige der Rohlinge nicht eindeutig definiert werden und wurden als »blanks (undefined)« bezeichnet. Da das Sägen jedoch leicht erkennbare Spuren hinterlässt, wären solche in der Beschreibung vermutlich genannt worden. Deshalb kann man davon ausgehen, dass sich diese undefinierten Rohlinge auf Rohlinge mit Abschlügen beziehen. Die Gesamtzahl der Artefakte bezieht sich lediglich auf Werkzeuge mit geschliffener Schneide und auf die Rohlinge.

but cannot be assigned with the Early Neolithic production centre. Where these partial perforations took place and why they were left unfinished remains unresolved. Maybe, drilling patterns were marked on axes or shoe-last celts in the production centres as an aid for an eventual future modification of their use or as a way to facilitate hafting, an option which, however, was not always chosen.

Conclusion

The study of 357 axe blanks and other production remains from Central Germany has allowed us to identify two axe production centres (one Early Neolithic and one Middle Neolithic) as well as one Early Neolithic workshop. The most important and extensive production centre is located in southern Saxony-Anhalt and western Saxony, between the Saale and White Elster Rivers, a region of ca 1000 km²

between the modern cities of Leipzig and the north of Jena in Thuringia. The main concentration of production remains is found around the present-day city of Naumburg, Burgenlandkreis district (cf. Fig. 7). The workshops of this production centre can be dated to the Early Neolithic but probably continued into the Middle Neolithic. A single Early Neolithic workshop was identified in central Saxony, in the settlement of Birmenitz, 65 km east of Leipzig. In view of the wide distribution of blanks and production remains, axe production appears to have been a decentralised activity. No particular community seems to have had control over the outcrops or the technological knowhow.

Actinolite-hornblende-schist was the dominant raw material processed in these workshops. Other metabasites, such as amphibolite and metadolerite, had a minor importance. Sawing and flaking were the main manufacturing techniques, and they appear combined on many axe blanks. In mineralogical and petrographic terms, these rocks are

¹⁸ The original petrographic identification as quartzitic greywacke is not reliable, as confirmed by Mario Küßner, LDA Thuringia. The

published photographs allow us to identify the artefacts as a typical greenschist or AHS.

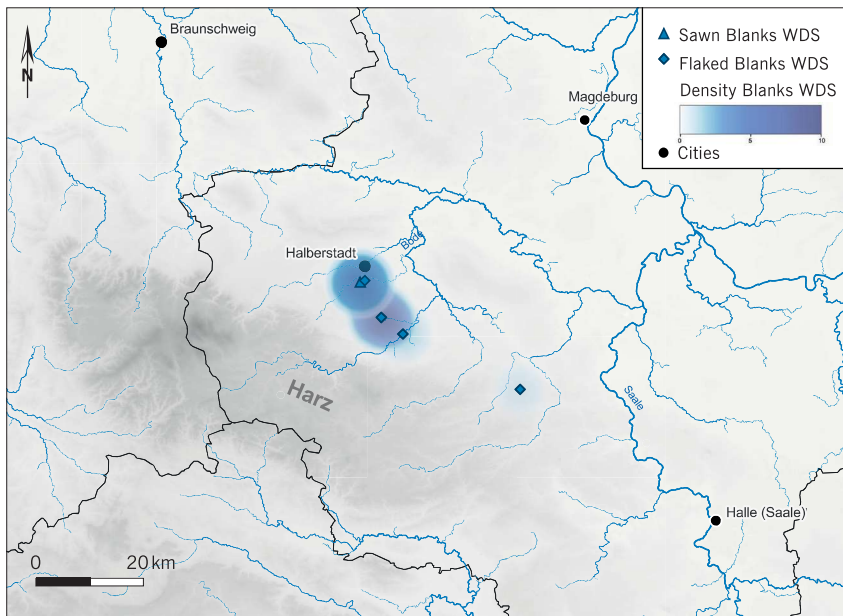
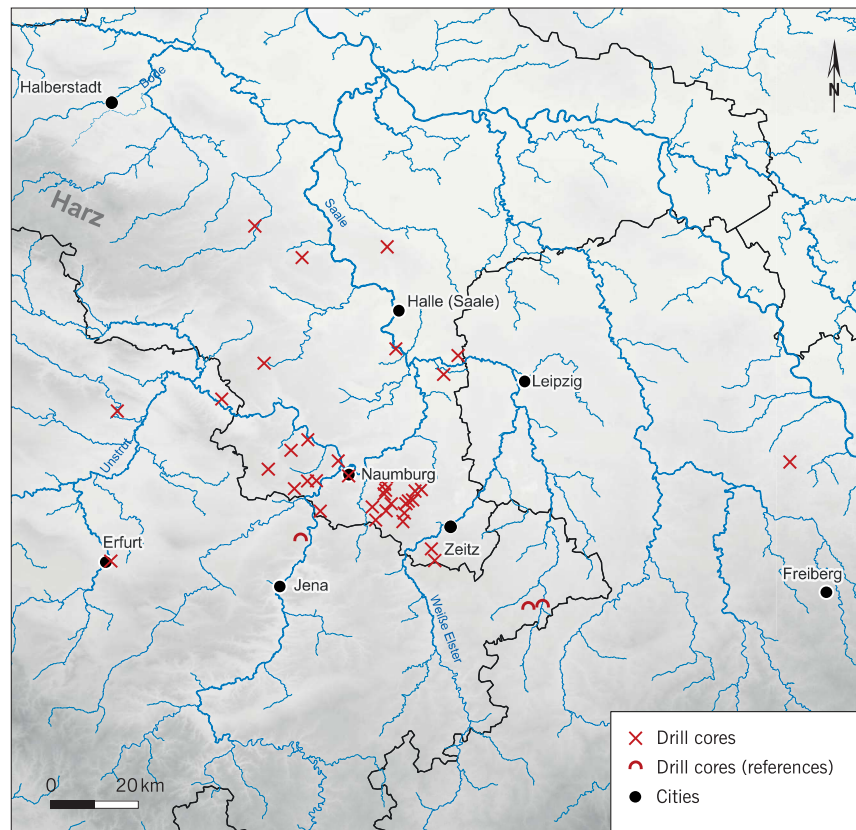


Fig. 10 Spatial distribution of flaked and sawn axe blanks made from Wiedaer Schiefer in Central Germany.

Abb. 10 Räumliche Verbreitung geschlagener und gesägter Rohlinge aus Wiedaer Schiefer in Mitteldeutschland.

Fig. 11 Spatial distribution of drill cores kept in the Museum of Halle and the City museum of Naumburg as well as from the studied site of Birmenitz in Saxony. The distribution of drill cores in Saxony and Thuringia is largely unknown.

Abb. 11 Räumliche Verteilung der Fundorte der Bohrkerne, die im Landesmuseum für Vorgeschichte in Halle und im Stadtmuseum in Naumburg aufbewahrt werden, sowie vom untersuchten Fundort Birmenitz in Sachsen. Die räumliche Verteilung von Bohrkerne in Sachsen und Thüringen ist weitgehend unbekannt.



highly similar to the material quarried during the Early Neolithic in the Jizera Mountains of Northern Bohemia (Christensen et al. 2006; Ramminger 2007; Šída/Kachlik 2009). The slightly more planar fabric observed in the thin sections of blanks and axes from Central Germany is not sufficient to assume a different geological origin. However, greenschists such as AHS are common rocks in Variscan formations and it is most likely that petrographically similar or even identical outcrops exist in different regions of the Saxo-Thuringian mountain range. In fact, they have been identified by geochemical analyses in the Fichtelgebirge, eastern Bavaria

(Christensen et al. 2006, 1653 Fig. 4–5; 11; Ramminger 2007). A notable variety of greenschists has been identified during ongoing fieldwork in the Variscan formations of the upper catchment areas of the Saale, Weiße Elster, and Striegis Rivers. As these outcrops can be easily reached from the identified axe production centres just 30–80 km to the south, it is much more likely that the required AHS was found in one or several of the hundreds of greenschist deposits existing in the Saxo-Thuringian mountain-chain rather than transported over 250–350 km, as the crow flies, from the Neolithic Jizera quarries to the workshops in the White Elster

and Saale Valleys. The Neolithic exploitation of metabasite outcrops in the Saxo-Thuringian mountain-chain is also supported by the dense distribution of flaked and sawn axe blanks along the Pleiße River (south of Leipzig) (cf. Fig. 7). Differences in the materials quarried and in the technology used to process the rocks further supports the exploitation of different greenschist sources. While blocks seem to have been extracted and transformed through flaking in the Jizera quarries, 20–60 mm thick slabs were first sawn into adequate preforms and then flaked and pecked or directly polished into axeheads in the Central German workshops. Evidence of sawing in Eastern Bohemia can be narrowed down to one axe found close to Jizera and exhibited in the Kittel-Museum in Krásná, Cheb district, around 10 km from the quarries, two hoards with axe blanks from Malá Černoc, and Čistěves, in north-western and eastern Bohemia, respectively (Vencl 1975) and five sandstone saws found in Zebrak, Beroun district, c. 140 km south of the quarries (Stolz 2016). The exceptional concentration of axe blanks and production debris in the Neolithic Saale–White Elster region, in contrast to the scarcity of such materials further east, also points to the exploitation of local resources.

In sum, both petrographical and archaeological criteria raise doubts about the current hypothesis that the Jizera quarry was the sole source of greenschist for Central Europe. The characteristic types of Early Neolithic AHS axeheads were definitely produced in the densely settled valleys north of the Saxonian Ore Mountains and the Thuringian Slate Mountains. Nor can it be ruled out that still other workshops existed in the Czech Republic south of this mountain range (Řídký et al. 2012). This production centre does not cast doubt on the dimensions and economic importance of the Jizera quarries of Northern Bohemia, but they do oblige us to revise the current model of a massive, long-distance axe circulation across more than 600 km during the Early Neolithic, covering, in particular, the extensive settlement territory defined by the LBK. Given the number of workshops and deposits containing axe blanks in Southern Central Germany, at least part of the AHS axeheads that have been found west of the Harz Mountains up to the Rhine River and even beyond (Nowak 2008) could have come from outcrops located in the central part of the Saxo-Thuringian Variscan zone, and not from the Jizera quarries. Such a multiplicity of sources would reduce the transport costs involved in axe circulation by a mean of 250 km, which corresponds to the distance between Jizera and Naumburg. A more limited axe circulation from one source also fits more neatly into the present picture of Neolithic exchange networks in Western Europe, where main supply distances beyond 150–250 km were problematic. Except jadeitite/omphacitite/eclogite from the western Alps and epidotised tuff from the Lake District in the north-west of England, rock types rarely represent more than 20 % of the locally used stone axes above ca 250 km from their sources (Risch/Martínez 2008; Delgado-Raack et al. 2020).

It is difficult to explain why Early Neolithic workshops specialised in processing almost exclusively AHS. At least in mechanical terms, this rock has not proven to have superior qualities when compared to other European rocks (Moník et al. 2021). That the production of axes and adzes with other Central European rocks was always an option becomes manifest from the Middle Neolithic onwards, when a larger variety of rocks were exploited. In Central Germany, the workshops identified north of the Harz Mountains led to a reduction in the importance of AHS. They processed the locally available »Wiedaer Schiefer.« Our petrographic studies have revealed that this rock is a homogenous, quartz-rich metasiltstone. It seems to have been collected from secondary deposits in the rivers draining Palaeozoic contact-metamorphic rock units (originally geologically mapped as »Wieder Schiefer« by K. A. Lossen in 1881) and processed within 50 km of this raw material source. Other local axe production centres in Central Germany seem to have used diorite, gabbro, basalt, etc. during the Middle and Late Neolithic, but they also continued to exploit AHS. This diversity of rocks of sufficient mechanical quality to produce adequate axes and adzes offered communities more economic alternatives and partners while simultaneously reducing the transport costs in comparison to those observed in the Early Neolithic.

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 5 S. Meinecke; L. Culí
 6 S. Meinecke
 7 S. Meinecke; base maps: dsm
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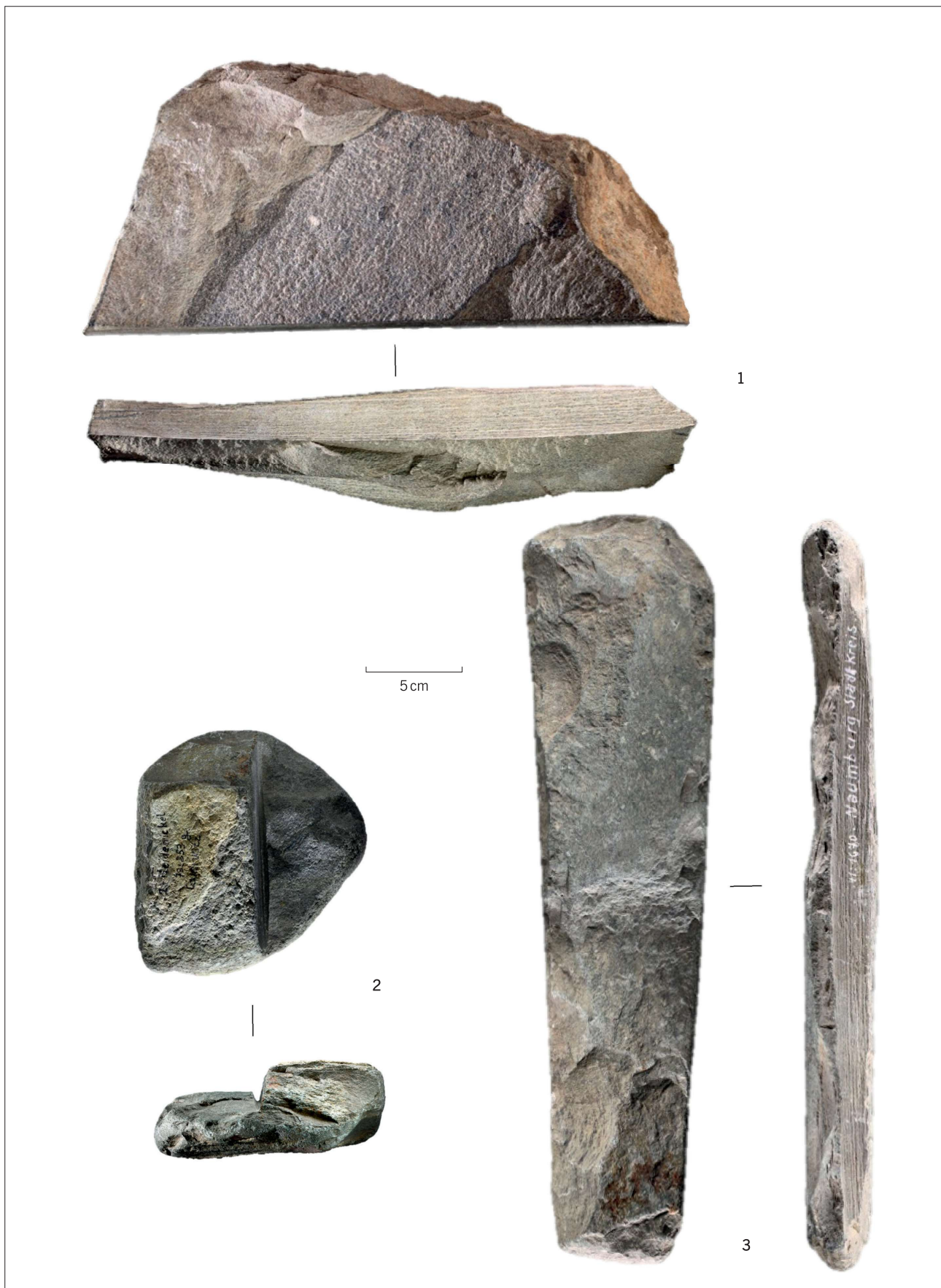
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Plates

Plates: Neolithic processed slabs, axe blanks, axeheads with unfinished perforation, and manufacturing debris of Central Germany. The finds are from the State Museum of Prehistory Halle (LV) and the Naumburg City Museum (SM).

Tafeln: Im Neolithikum bearbeitete Steinplatten, Rohlinge, Axtklingen mit unvollständiger Durchlochung und Herstellungsreste aus Mitteldeutschland. Die Funde stammen aus dem Landesmuseum für Vorgeschichte Halle (LV) und dem Stadtmuseum Naumburg (SM).

Plate 1



Pl. 1 1) (LV) 71:810 Günthersdorf, Saalekreis district, natural rock slab with sawing marks (S_Sl_Sl); 2) (LV) 73:253g Cauerwitz, Burgenlandkreis district, natural rock slab with unfinished incision (S_Sl_Sl_VU); 3) (LV) 41:1670 Naumburg, Burgenlandkreis district, axe blank with sawing mark on one side (S_Bl_Sl).

Taf. 1 1) (LV) 71:810, Günthersdorf, Saalekreis, natürliche Steinplatte mit Sägespuren (S_Sl_Sl); 2) (LV) 73:253g, Cauerwitz, Burgenlandkreis, natürliche Steinplatte mit unvollständigem Sägeschnitt (S_Sl_Sl_VU); 3) (LV) 41:1670, Naumburg, Burgenlandkreis, Rohling mit Sägespuren auf einer Seite (S_Bl_Sl).



Pl. 2 1) (LV) 48:671 Location unknown (area around Weißenfels, Burgenlandkreis district), axe blank with sawing mark on two sides (S_Bl_S2).

Taf. 2 1) (LV) 48:671, Fundort unbekannt (Gegend um Weißenfels, Burgenlandkreis), Rohling mit Sägespuren auf zwei Seiten (S_Bl_S2).

Plate 3



Pl. 3 1) (LV) 16:367 Saaleck, Burgenlandkreis district, axe blank with sawing mark on two sides (S_Bl_S2); 2) (LV) 71:11 Lengefeld, Burgenlandkreis district, axe blank with sawing mark on three sides (S_Bl_S3).

Taf. 3 1) (LV) 16:367, Saaleck, Burgenlandkreis, Rohling mit Sägespuren auf zwei Seiten (S_Bl_S2); 2) (LV) 71:11, Lengefeld, Burgenlandkreis, Axtrohling mit Sägespuren auf drei Seiten (S_Bl_S3).



Pl. 4 1) (LV) 92:280e Gerbstedt, Mansfeld-Südharz district, shoe-last celt-shaped axe blank with curved sawing mark (S_Bl_SC); 2) (SM) 1048 Abtlöbnitz, Burgenlandkreis district, flaked axe blank (F_Bl) with visible remnants of the naturally weathered rock surface.

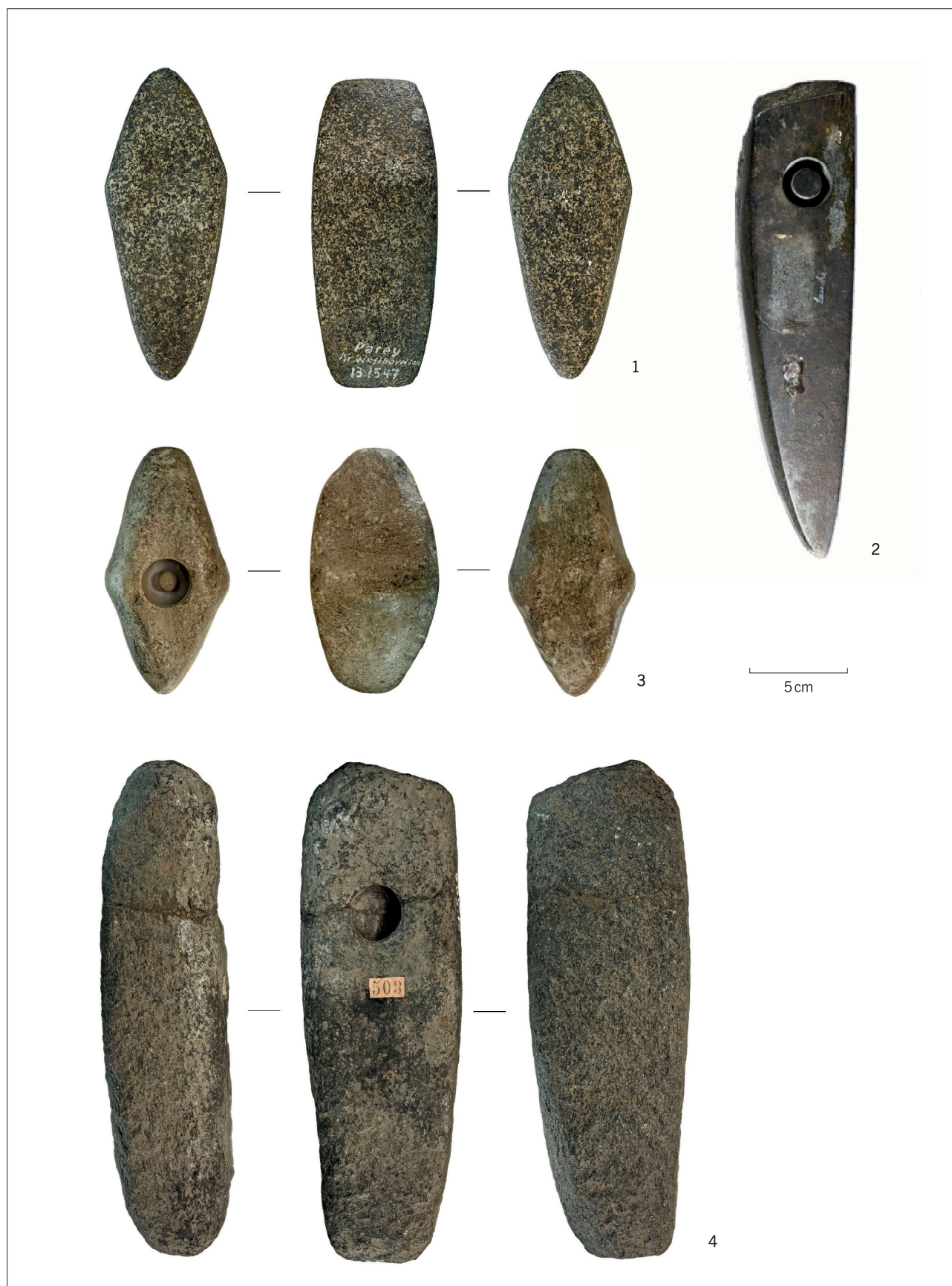
Taf. 4 1) (LV) 92:280e, Gerbstedt, Mansfeld-Südharz, schuhleistenkeilförmiger Rohling mit gekrümmter Sägespur (S_Bl_SC); 2) (SM) 1048, Abtlöbnitz, Burgenlandkreis, Rohling mit Abschlügen (F_Bl) und sichtbaren Überbleibseln der natürlichen, verwitterten Gesteinsoberfläche.

Plate 5



Pl. 5 1) (SM) 636 Braunsroda, Kyffhäuserkreis district, flaked axe blank (F_Bl) with visible remnants of the naturally weathered rock surface; 2) (SM) 1473 Naumburg, Burgenlandkreis district, drillcore (DC); 3) (SM) 343 Löbitz, Burgenlandkreis district, drillcore (DC); 4) (LV) 27:97 Durchwehna, Nordsachsen district, battle axe with a pecked surface and no visible traces of a perforation mark (BA_UP).

Taf. 5 1) (SM) 636, Braunsroda, Kyffhäuserkreis, Rohling mit Abschlägen (F_Bl) und sichtbaren Überbleibseln der natürlichen, verwitterten Gesteinsoberfläche. 2) (SM) 1473, Naumburg, Burgenlandkreis, Bohrkern (DC). Maßstab 1:1; 3) (SM) 343, Löbitz, Burgenlandkreis, Bohrkern (DC). 4) (LV) 27:97, Durchwehna, Nordsachsen, Streitaxt mit gepickter Oberfläche und ohne sichtbare Spuren einer begonnenen Lochung (BA_UP).



Pl. 6 1) (LV) 13:1547 Parey, Jerichower Land district, battle axe with a pecked surface and traces of a mark for the perforation (BA_UP); 2) (LV) 37:30 Heldrungen, Kyffhäuserkreis district, axe-shaped tool with unfinished perforation (AH_UP); 3) (LV) 31:592 Location unknown, axe-shaped tool with unfinished perforation (AH_UP); 4) (LV) 56:525 Laucha, Burgenlandkreis district, shoe-last celt with unfinished hollow perforation (SC_UP).

Taf. 6 1) (LV) 13:1547, Parey, Lkr. Jerichower Land, Streitaxt mit gepickter Oberfläche und Spuren einer Markierung für die Lochung (BA_UP); 2) (LV) 37:30, Heldrungen, Kyffhäuserkreis, axtförmiges Werkzeug mit unvollständiger Lochung (AH_UP); 3) (LV) 31:592, Fundort unbekannt, axtförmiges Werkzeug mit unvollständiger Lochung (AH_UP); 4) (LV) 56:525, Laucha, Burgenlandkreis, Schuhleistenkeil mit unvollständiger Lochung (SC_UP).