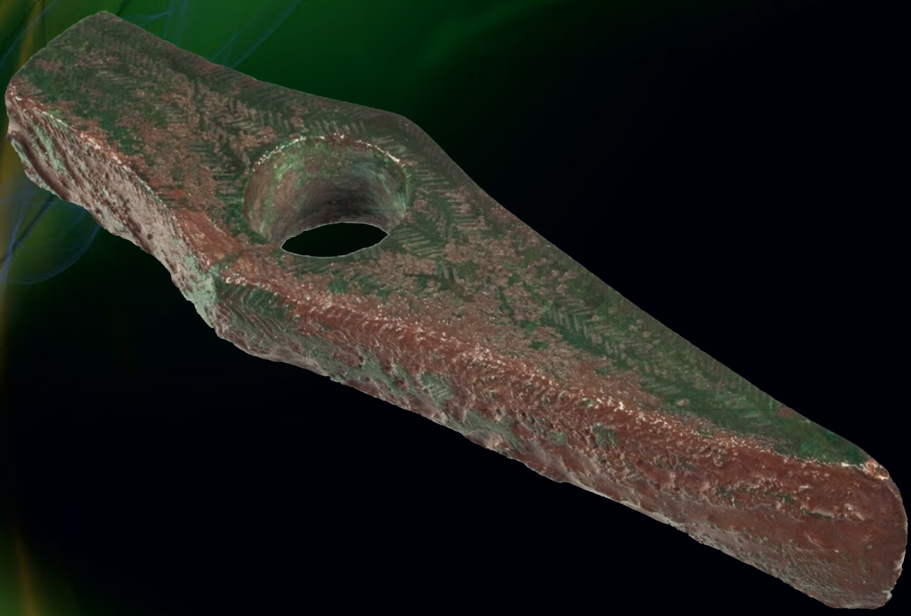
The Rise of Metallurgy in Eurasia

Evolution, Organisation and Consumption of Early Metal in the Balkans



Edited by

Miljana Radivojević, Benjamin W. Roberts, Miroslav Marić, Julka Kuzmanović Cvetković and Thilo Rehren

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Archaeopress Archaeology

Archaeopress Publishing Ltd
Summertown Pavilion
18-24 Middle Way
Summertown
Oxford OX2 7LG

www.archaeopress.com

ISBN 978-1-80327-042-5
ISBN 978-1-80327-043-2 (e-Pdf)

DOI: 10.32028/9781803270425

Cover: Ljiljana Dinić; Copper hammer-axe, type Pločnik, c. 4600 BC
(from Pločnik, Serbia) - Julka Kuzmanović Cvetković.
Inner back cover: Reconstruction of the world's earliest copper smelting. Green flames come from the extraction of metal from malachite. Experiments at Pločnik, Serbia (2013) - Marko Djurica

Copyeditor: Kate Sharpe

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To the memory of Borislav Jovanović, our colleague, friend and inspiration

(1930 – 2015)

Contents

Chapter 6

Introduction to Pločnik and the results of archaeometallurgical research 1996–2011

Miljana Radivojević

The site of Pločnik (43°12'35.72''N, 21°21'50.42''E) is situated beneath the eponymous modern village, 19 km west of the town of Prokuplje in south Serbia and 300 km south of the capital, Belgrade. It is set at about 300 m above sea level on the left bank of the Toplica river, whose shifting course presently erodes away the estimated 3.60 m thick cultural layer of the site (Stalio 1960: 34; 1962: 21). The village is surrounded by good quality agricultural land (Chapter 23, this volume) and thermal springs, and has good communication routes along the river Toplica. This is the major watercourse in this part of Serbia, which springs from Kopaonik, a mountain approximately 50 km away from Pločnik, whose rich iron veins were exploited in Roman and medieval times (Bogosavljević *et al.* 1988, 1989; Bogosavljević-Petrović and Tomović 1993; Bogosavljević-Petrović 1995; Mrkobrad 1989; Mrkobrad *et al.* 1989). More than 50 sites with archaeometallurgical installations from both periods were recognised around toponymic places like Suvo Rudište (in Serbian: 'Dry Mine') or Bakarnjača (in Serbian: 'Copper-rich'), indicating intensive metallurgical activities in the past.

The archaeological settlement of Pločnik was initially discovered in 1928, when the first group of metal artefacts was found during the building of the railway line between the towns of Prokuplje and Kuršumlija. Excavation campaigns commenced later the same year and then, after a considerable pause, continued between 1960 and 1978, under the jurisdiction of M. Grbić and B. Stalio respectively, both of the National Museum Belgrade (Grbić 1929; Stalio 1960, 1962, 1964, 1973). Most recently, field excavations resumed in 1996 under the joint supervision of D. Šljivar (National Museum Belgrade) and J. Kuzmanović Cvetković (Museum of Toplica, Prokuplje) (Šljivar 1996, 1999, 2006; Šljivar and Kuzmanović Cvetković 1997a, 1998a, 1998b, Šljivar *et al.* 2006; Kuzmanović Cvetković 1998). Over the course of two years, starting in 2012, field excavations at Pločnik were carried out under the joint supervision of the National Museum in Belgrade, the Museum of Toplica in Prokuplje and the UCL Institute of Archaeology.

Grbić's and Stalio's campaigns uncovered an area of *c.* 1800 m^2, to which another *c.* 650 m^2 from an ongoing campaign adds up to a total of *c.* 0.2 ha explored thus far. The estimated size of the uppermost cultural layer of the Vinča village at Pločnik was estimated to be *c.* 100 ha (Šljivar and Kuzmanović Cvetković 1998b: 80). Most recent geophysical prospection established its more accurate size to be almost a third of the initial estimate, as discussed in more detail in (Chapter 24, this volume).

The unique and abundant ceramic finds from the site inspired Milutin Garašanin to name the late Vinča culture phase after Pločnik (I, IIa and IIb) (Garašanin 1951: 12), corresponding to Vinča C, D1 and D2 (Milojčić 1949). Twenty massive copper implements, discovered by chance and also during the excavations in the 1928 campaign, prompted Grbić (1929) to entitle the first site publication: 'Pločnik, eine Prähistorische Ansiedlung aus der Kupferzeit' ('Pločnik, a prehistoric settlement of the Copper Age'). He assumed that Pločnik was an important metallurgical centre that existed at the dawn of the Copper Age and maintained intensive exchange networks with other contemporary communities in the region, such as those occupying Vinča-Belo Brdo, Gradac or Butmir (Grbić 1929: 7, 18). Nevertheless, these copper implements, having been unique and isolated finds from a location remote from the Near East, did not appeal to Garašanin as being of genuinely Vinča culture origin (Garašanin 1951; 1973: 185). He referred to them as intrusive 'hoards' belonging to the Early Eneolithic/Chalcolithic Bubanj-Hum culture[1] which, in his opinion, succeeded the Vinča culture sequence at the site of Pločnik. Stalio, coming across two more groups of massive metal artefacts in Pločnik, agreed that they belonged to the Bubanj-Hum culture (Stalio 1960: 35, 1964: 39–40).

In 1978, a single, well-contextualised copper metal implement was discovered associated with a Gradac Phase feature (dwelling?) but was only published almost two decades later (Šljivar 1996; Šljivar and Kuzmanović Cvetković 1997a). The resumed excavation campaign (from 1996) brought more evidence for dating metallurgical activities at Pločnik firmly within the Vinča culture sequence. In total, three building horizons were identified on the site, all of which

[1] This would translate into Middle Chalcolithic given the periodisation of contemporary cultures in Bulgaria, see Chapter 3.

belonged solely to the Vinča culture, with no detected intrusions from later periods (e.g. Šljivar 1996: 94; Šljivar and Kuzmanović Cvetković 1998a). Horizon III (the Gradac Phase) yielded a well-contextualised copper chisel typologically resembling some of the previous chance metal finds from Pločnik (Šljivar *et al.* 2006: 255, Plate VIII/3). This, and the chisel from 1978 (Šljivar 1996), demonstrated the Vinča culture origins for metallurgical activities in Pločnik.

The site of Pločnik has recently received the first AMS dates (see details in Radivojević and Kuzmanović Cvetković 2014: 17–18). The probability distribution for the start of the Vinča culture occupation in Pločnik was 5290–5140 cal. BC, with the highest probability of around 5200 BC. The highest probability for the end of the settlement is *c.* 4650 BC, suggesting it was active for *c.* 600 years. Significantly, one of the AMS dates is closely related to the copper chisel (here sample labelled as Pločnik 216, Table 1) (Šljivar *et al.* 2006: 255, Plate VIII/3). The preceding context is dated between 5040–4860 cal. BC (95% probability), thus marking the *terminus ante quem* for this and other metal artefacts in Pločnik, along with the start of the Gradac Phase on this site. This is consistent with the beginning of this phase at other sites (e.g. Belovode, Rudna Glava), placing it securely in the first century of the 5th millennium BC.

Three building horizons at Pločnik correspond to Vinča A, B1 and B2 respectively (Šljivar 1996). Horizons I and II (*c.* 2.5 m thick) include massive remains of dwelling structures (up to 6.5 m in length) and related postholes, including wide pits filled with ash, charcoal and bone fragments in the top layers, and including ceramic fragments characteristic of Vinča A and B1 phases (Šljivar and Kuzmanović Cvetković 1997a: 106). The Gradac Phase is represented by a cultural layer of about 1 m thickness at Pločnik, which, at around 0.4 m, exhibited visible damage due to agricultural activities (Šljivar and Kuzmanović Cvetković 1997a: 104). Dwelling structures are intersected with wide pits filled with charcoal and ash in several successive layers, some with bone and ceramic fragments in the upper layers (Figures 1 and 2) (Šljivar and Kuzmanović Cvetković 1998a: 5–6).

As for Belovode, the publication record for the 14 years of most recent excavations at Pločnik has been limited to attempts to interpret and explain archaeometallurgical activities. This volume presents a more detailed account of metallurgical activities on the site. In addition, a set of samples related to metallurgy from the 1998–2009 campaigns, from seven trenches in total (see Table 1), was analysed in depth (Radivojević 2012). The most extensively sampled is Trench 20 which, in the Gradac Phase of occupation, yielded exceptional evidence for the Vinča culture metallurgy (Šljivar and Kuzmanović Cvetković 2009a).

The studied collection consisted of copper minerals, malachite beads and copper metal artefacts. A single droplet (sample Pločnik 52) is likely evidence of primary copper production (Radivojević and Rehren 2016:

Table 1. Study materials from the site of Pločnik.

No.	Analytical No.	Excavation year	Field label	Field context	Type of Material
1	**Pločnik 43**	2007	Trench 20, spit 10	Workshop	Malachite bead
2	**Pločnik 51**	2006	Trench 19, spit 23	Household	Copper mineral
3	**Pločnik 52**	2000	Trench 14, spit 10	Household	Copper metal droplet
4	**Pločnik 54 (b, m)**	2002	Trench 16, spit 19	Household	Copper mineral and a malachite bead (blank)
5	**Pločnik 57**	2006	Trench 19, spit 13	Household	Copper mineral
6	**Pločnik 63**	2008	Trench 21, spit 5	Dwelling structure	Metal sheath/cover
7	**Pločnik 65**	2008	Trench 21, spit 6	Dwelling structure	Malachite bead
8	**Pločnik 66**	2004	Trench 18, spit 7	Stone structure	Malachite bead
9	**Pločnik 67**	2007	Trench 20, spit 7	Workshop	Copper artefact
10	**Pločnik 69**	2007	Trench 20, spit 4	Workshop	Copper metal droplet
11	**Pločnik 71**	2007	Trench 20, spit 7	Workshop	Copper mineral
12	**Pločnik 72 (b, m)**	2007	Trench 20, spit 3	Workshop	Copper mineral and malachite bead (roughout)
13	**Pločnik 73**	2007	Trench 20, spit 7	Workshop	Copper artefact
14	**Pločnik 75**	2007	Trench 20, spit 7	Workshop	Copper artefact
15	**Pločnik 143**	2004	Trench 18, spit 7	Stone structure	Copper artefact
16	**Pločnik 145**	2007	Trench 20, spit 7	Workshop	Copper artefact
17	**Pločnik 207**	2009	Trench 22, spit 17	Household	Malachite bead
18	**Pločnik 209**	2009	Trench 22, spit 15	Household	Copper mineral
19	**Pločnik 216**	2000	Trench 14, spit 7	Stone structure	Copper chisel

Figure 1. Southeast section of Pločnik, facing the river. Note the massive cultural layer bearing remains of dwelling structures intersected with pits (Photo by Jugoslav Pendić)

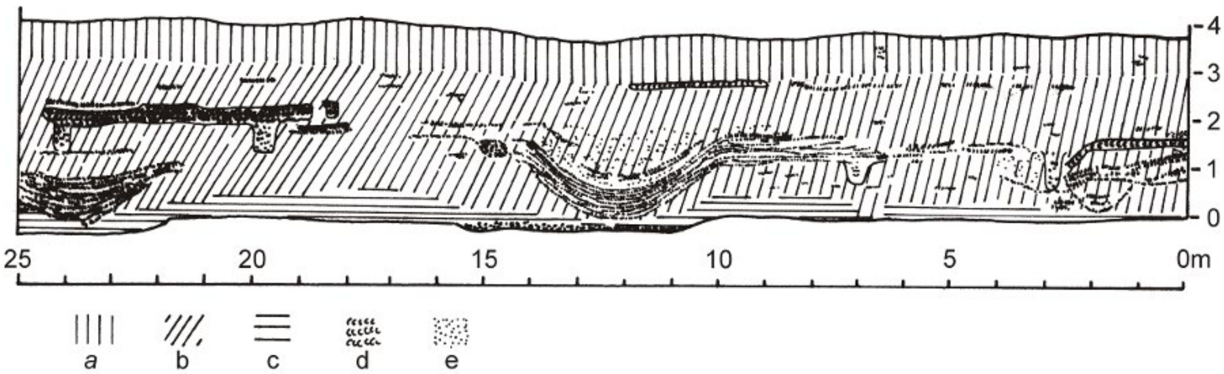

Figure 2. Southeast profile of Pločnik: a- dark brown soil; b- light brown soil; c- sterile soil; d- daub; e- ash (after Šljivar and Kuzmanović Cvetković 1998a: 4)

220). The same analytical methodology was applied as described in the introductory chapter on Belovode (see Chapter 5, this volume). Activities related to copper mineral use and metallurgy are also described here in three distinctive stages of the process: copper mineral processing, (s)melting debris, and copper mineral and metal artefacts. All technological analyses were carried out at the Wolfson Archaeological Science Laboratories at the UCL Institute of Archaeology.

Results

Copper mineral use

The use of copper minerals is evident from the early period of this site: green lumps of malachite are found scattered across the settlement as at Belovode, usually outside potential dwelling features, in the so-called 'workshop' areas. These workshops usually consisted of stone structures and the amorphous remains of floors for which insufficient evidence is present to ascribe them to either economic or dwelling structures. Šljivar and collaborators (2006: 256 ff.) reported finds of lumps of copper minerals of varying size, with altered structure, porous and mixed with charcoal, hence associating them with metallurgical activities. In addition to copper minerals, the use of cinnabar has also been recently confirmed (Gajić-Kvaščev *et al.* 2012), although used in the 'cold' process, that is without high temperature treatment like copper.

Six copper minerals were analysed in greater detail (Pločnik 51, Pločnik 54m, Pločnik 57, 7 Pločnik 1, Pločnik 72m, and Pločnik 209. See Table 1) Two of these (Pločnik 71 and Pločnik 72m), come from Trench 20 and belong to the Gradac Phase horizon (the trench was only excavated to this level). Other copper mineral finds were sampled in order to provide information on their use in earlier phases of Pločnik occupation. It is worth noting that all samples found in the field were of sizes varying between a few mm and a few cm, possibly indicating that they were already beneficiated and prepared for further processing.

The copper minerals form two distinctive groups: oxide and sulphide minerals (the latter only present in Pločnik 72). All oxide minerals are black and green and, excepting sample Pločnik 71, contain copper and manganese contents in ratios varying from 1:1 to 2:1 in favour of copper (Radivojević and Rehren 2016: 213 ff.). In addition, the ternary plot of MnO/ZnO/CuO (Radivojević and Rehren 2016: 15, Figure 5) clearly illustrates the striking compositional similarity of all studied minerals to those from Belovode. Sample Pločnik 72 contains significant sulfur readings contained in mineralisation of chalcocite (Cu_2S), pyrite (FeS_2) and sphalerite (Zn, Fe)S, besides copper oxide/carbonate content. Macroscopically, it appears more solid than the green-and-black oxide minerals although it, too, has distinctively coloured cross-sections in shades of green and grey with metallic lustre.

(S)melting debris

The only production evidence discovered at the site is sample Pločnik 52 (Figure 3a), which was uncovered on the floor of a collapsed burnt structure (Trench 14, spit 10), directly dated to *c.* 5040–4840 BC (Radivojević and Rehren 2016: 220, Figure 8). Sulfur-rich copper droplet, Pločnik (52), was initially thought to represent copper mineral, until the cross-section revealed a dark-red phase mixed with a thick, light-green layer. This amorphous piece does not exceed *c.* 1 cm in length. Compositional analysis revealed a complex structure of copper-based compounds, predominantly copper oxides (dross, tenorite), followed by a copper metal phase. The amorphous shape of the metal phase indicates that this sample was once molten copper, however it is now heavily corroded due to various post-depositional processes.

A copper metal droplet, Pločnik 69 (Figure 3b), was also initially assumed to be a copper mineral, due to its blocky shape and thick, light-green patina, until it exhibited a copper metal phase surrounded by a rich dark-red phase of copper oxides in the cross section (Figure 4). This, together with porosity holes in its polished section, indicates an intensive reaction with the atmosphere during cooling which, overall, points to this piece once being molten copper metal. The absence of any other phases but copper marks this sample as melting, rather than smelting debris, and it is the closest in nature to sample M14 from Belovode (Radivojević *et al.* 2010a; Radivojević 2012; Radivojević and Kuzmanović Cvetković 2014: 15).

Copper mineral and metal artefacts

Malachite beads of different sizes and shapes were recovered throughout all horizons of occupation in Pločnik, six of which were selected for the present study (see Table 1). A bead roughout (Pločnik 72) and a whole bead (Pločnik 43) were discovered in Trench 20, and together with two other whole beads (Pločnik 65,

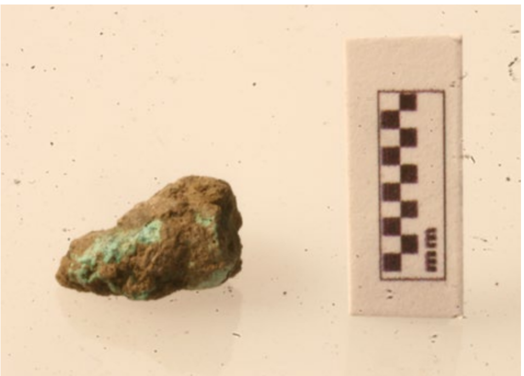

Figure 3. a) Pločnik 52, droplet; b) Pločnik 69, droplet.

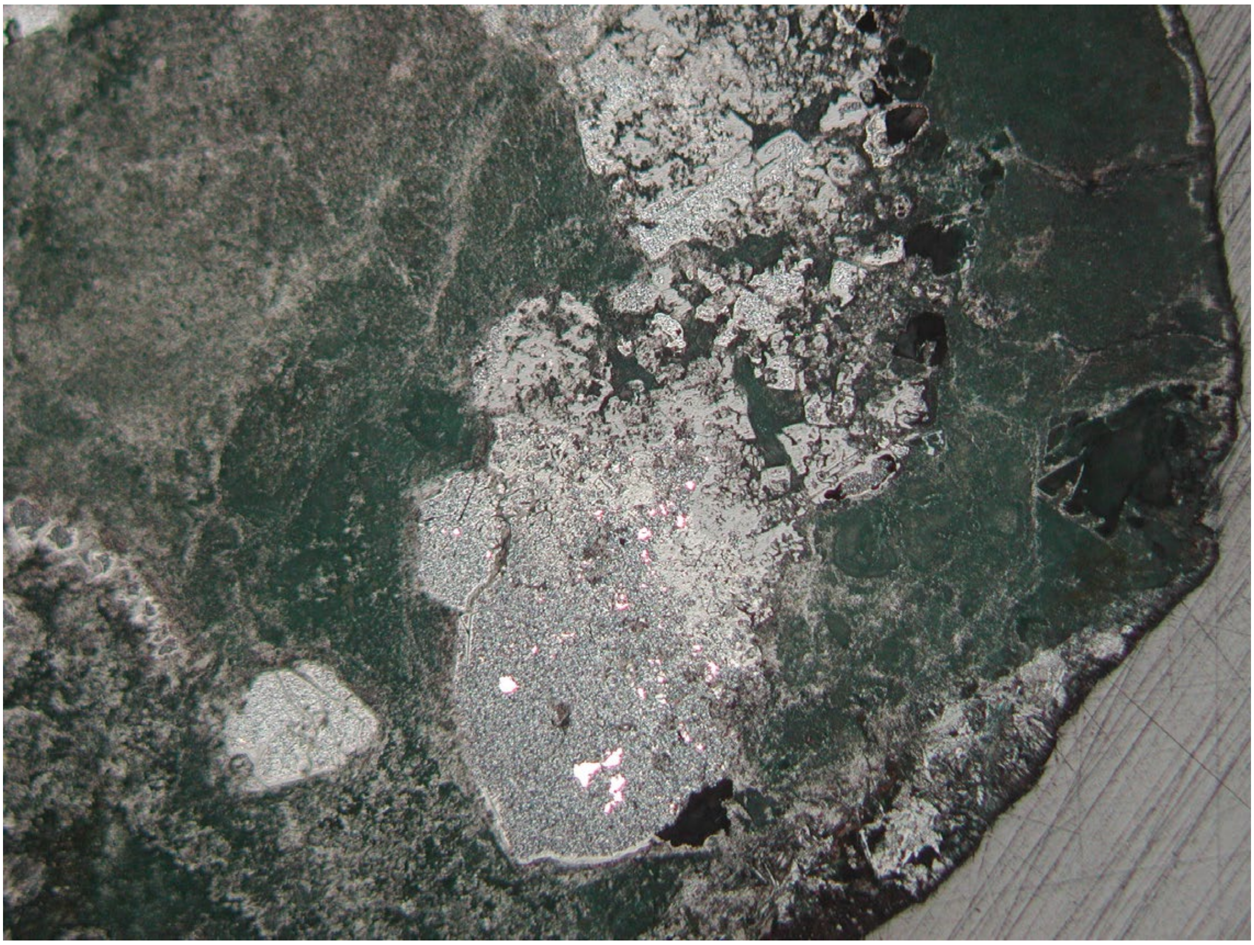

Figure 4. Photomicrograph of Pločnik 69 under plane polarised light. Note the copper metal phase (bright yellow islands) embedded in copper dross and surrounded by corrosion (green) (width 6.4 mm, magnification 25x).

Pločnik 66; see Figure 5) most likely date to the Gradac Phase (horizon III) in Pločnik (Šljivar and Kuzmanović Cvetković, 1996-2009). A bead blank (Pločnik 54b) and two whole beads (Pločnik 43, Pločnik 207) precede these finds (Table 1). The Pločnik beads cover only the last two building horizons (II and III) and appear spatially associated with copper minerals (Pločnik 54b, Pločnik 72b, Pločnik 207), a workshop (Pločnik 43, Pločnik 72b), or metal artefacts (Pločnik 65, Pločnik 66). Typologically, the beads can be roughly divided into two distinctive categories: (circular) cylindrical (Pločnik 65) and flat disc (Pločnik 43, Pločnik 66 and Pločnik 207) (cf. Wright and Garrard 2003; Wright *et al.* 2008).

Visually, all copper mineral ornaments exhibit a thick, light-green corrosion layer, with occasional macroscopically-visible oolithic formations on the surface, as in Pločnik 43 (Figure 5g). All beads are, judging by the bright green colour, made of malachite, and only four survived as finished objects (Pločnik 43, Pločnik 65, Pločnik 66 and Pločnik 207); the rest are found in various stages of processing (bead production stages after Lankton *et al.* 2003). A roughout (Pločnik 72b) belongs to the early stages of bead reduction. It is a subcircular artefact shaped into a bead form and has a shallow indentation in the middle (Figure 5e). Pločnik 54b represents a tabular preformed, but not finalised, bead blank: it is flaked and chipped around the edges and shows traces of drilling from both sides (Figure 5a/b). These samples contain important information for the Vinča culture bead-making technology: beads were most likely initially shaped into form (sawing, chipping, abrading), then drilled, and finally polished (Radivojević 2012).

The drilling process in finished beads is represented by fully preserved bead, Pločnik 66. Bead Pločnik 54b appears to have been drilled halfway through and then turned, so that the perforation could be completed from the opposite direction (Figure 5a/b), but the perforation was not finalised. Rotary drilling from both directions has been experimentally confirmed to produce regular perforations (cf. Gorelick and Gwinnett 1990). This was identified within this assemblage in Pločnik 66 (Figure 5d). The fine drill holes may have been the result of using a finer drilling tool (a bow?). Although no traces of polishing were observed on these beads, we can assume that the final products were finished in this way as it is a known practice in the Neolithic tradition

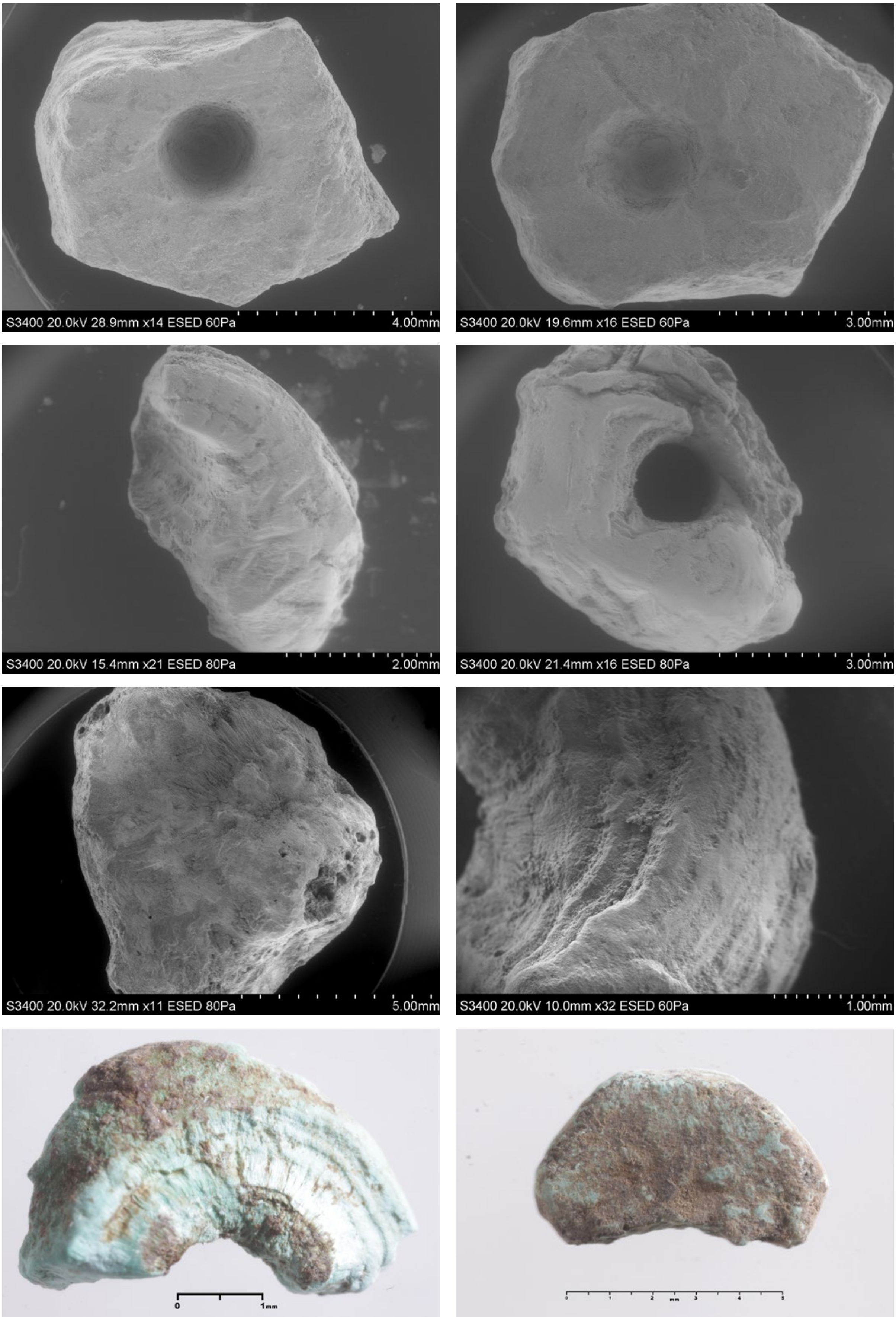

Figure 5. a) Pločnik 54b side 1; b) Pločnik 54b side 2; c) Pločnik 65; d) Pločnik 66; e) Pločnik 72m; f) Pločnik 43; g) Pločnik 43; h) Pločnik 207.

of bead making in the wider western Eurasia region (Lankton *et al.* 2003).

Chemical analyses reveal that the major constituents of all the artefacts are CO_2 and CuO, with the majority of readings compositionally closest to the malachite formula [$Cu_2(CO_3)(OH)_2$], which contains, besides water, 71.9 wt% of CuO and 19.9 wt% of CO_2. Silica readings are particularly important with regard to different values detected on the inside surface of the bead perforation, as they may indicate the use of stone tools for drilling. An elevated silica content was observed on the inside surface of Pločnik 43 and Pločnik 54b, in amounts two to three times higher than on the outside surface (Radivojević 2012). Such readings may imply the use of stone tools for both drilling and polishing of beads and pendants, however no such tools have yet been recognised in the context of these finds.

The most significant discoveries at Pločnik thus far are four groups of exceptionally massive copper metal implements, numbering 34 in total (Grbić 1929; Stalio 1964; Šljivar 1999; Šljivar *et al.* 2006). To this collection, four more implements can be added, all well-contextualised within the Gradac Phase occupation of this settlement (Šljivar 1996; Šljivar and Kuzmanović Cvetković 1996–2009). The term 'hoard' was introduced by Grbić (1929) however, but to avoid confusion they will be referred to here as 'groups'.

Group I was amongst objects donated by the Directorate of Yugoslav Railways in 1928, discovered during the building works for the railway station in Pločnik, at a presumed depth of *c.* 0.8–1.0 m (Grbić 1929). Stalio (1964) terms this group 'Hoard 1'. Šljivar and collaborators (Šljivar *et al.* 2006: 254) indicate that it consisted of nine objects, seven of which were made of copper metal: two hammer axes (Pločnik type), two chisels, two complete and one fragmented bracelets, and two stone axes made of magnesite (Figure 6).

Group II consisted of 18 objects, 13 of which were copper metal tools: one hammer-axe (Pločnik type), 12 chisels and five stone axes made of magnesite. Grbić (1929: 8–9) reported that they were found in the vicinity of a destroyed 'furnace', scattered over an area 5 m wide, at a depth of *c.* 1 m (see also Šljivar *et al.* 2006: 255).

Similar conditions were recorded for Group III: copper and stone tools were uncovered, scattered in an area of 5.0 x 0.5 m, at 0.7 m depth (Stalio 1964: 35). The find consisted of 11 objects, nine of which were made of copper metal: one hammer-axe (Pločnik type), five chisels, a bracelet, a pin with a forked end, a copper ingot bar and two stone axes made of magnesite (Figure 6). The resumed excavation of 1996 took place in the area of the Group III discovery, unearthing dozens of ceramic materials belonging to the early Gradac Phase, a small rectangular stone structure and one stone axe made of magnesite, identical to that accompanying the metal objects in Group III (Šljivar and Kuzmanović Cvetković 1998b: 82). The owner of the excavated land also donated a copper chisel to the National Museum Belgrade. He found the chisel during the building of his family house, in the vicinity of the Group III location.

Group IV was found in 1968 during the building of the Nis-Priština railway, at a depth of *c.* 0.3 m. It includes 14 objects: five copper chisels, eight stone axes made of magnesite and one miniature pottery vessel (a casting pot?) (Figure 6) (Stalio 1973). The casting (?) pot, however, did not show assumed traces of metalworking upon inspection by the author at the National Museum in Belgrade.

Together, the four Pločnik groups of metal finds amount to: four Pločnik type hammer-axes, 25 chisels, four bracelets, a copper ingot bar and a pin, weighing in total *c.* 16 kg (Šljivar *et al.* 2006: 255). As such, they are a unique and exceptional find of copper artefacts and, according to the most recent AMS dating, one of the earliest in this part of Eurasia (Radivojević and Kuzmanović Cvetković 2014: 23). Seventeen of the copper metal tools from Pločnik have previously been studied for chemical composition and lead isotopes, the results of which revealed an unexpected complexity of ore/metal exchange networks: at least three different copper deposits from east Serbia, Macedonia and across Bulgaria provided metal for their making (Pernicka *et al.* 1997: 93–94, Table 3).

Significantly, all finds originated from a single area of Pločnik, which excavators also call the 'industrial' zone due to the thick ash-and-charcoal deposit frequently encountered in Horizon III. A superbly preserved figurine head from the 'industry zone' was discovered with half of the face painted lengthwise with a light grey slip prior to firing (Figure 7). The excavators believe that the colour effect on its face symbolised the light (ground) and dark (underground) environments of early miners' life in Pločnik (Kuzmanović Cvetković and Šljivar 1998; Šljivar and Kuzmanović Cvetković 1998a).

The recent excavation campaign (1996–2011) uncovered two distinctive situations that yielded evidence for a potential metallurgical workshop in Pločnik: one in Trench 20 and the other in Trench 21 (Šljivar and Kuzmanović Cvetković 2009a; Radivojević *et al.* 2013). In Trench 20, a structure whose contours were followed over a 6 x 6 m area, appeared at a relative depth of 0.8 m, with a surface filled with rubble, stones, numerous pottery fragments and several metal artefacts and metal casting debris. A rectangular furnace (?), measuring 1.4

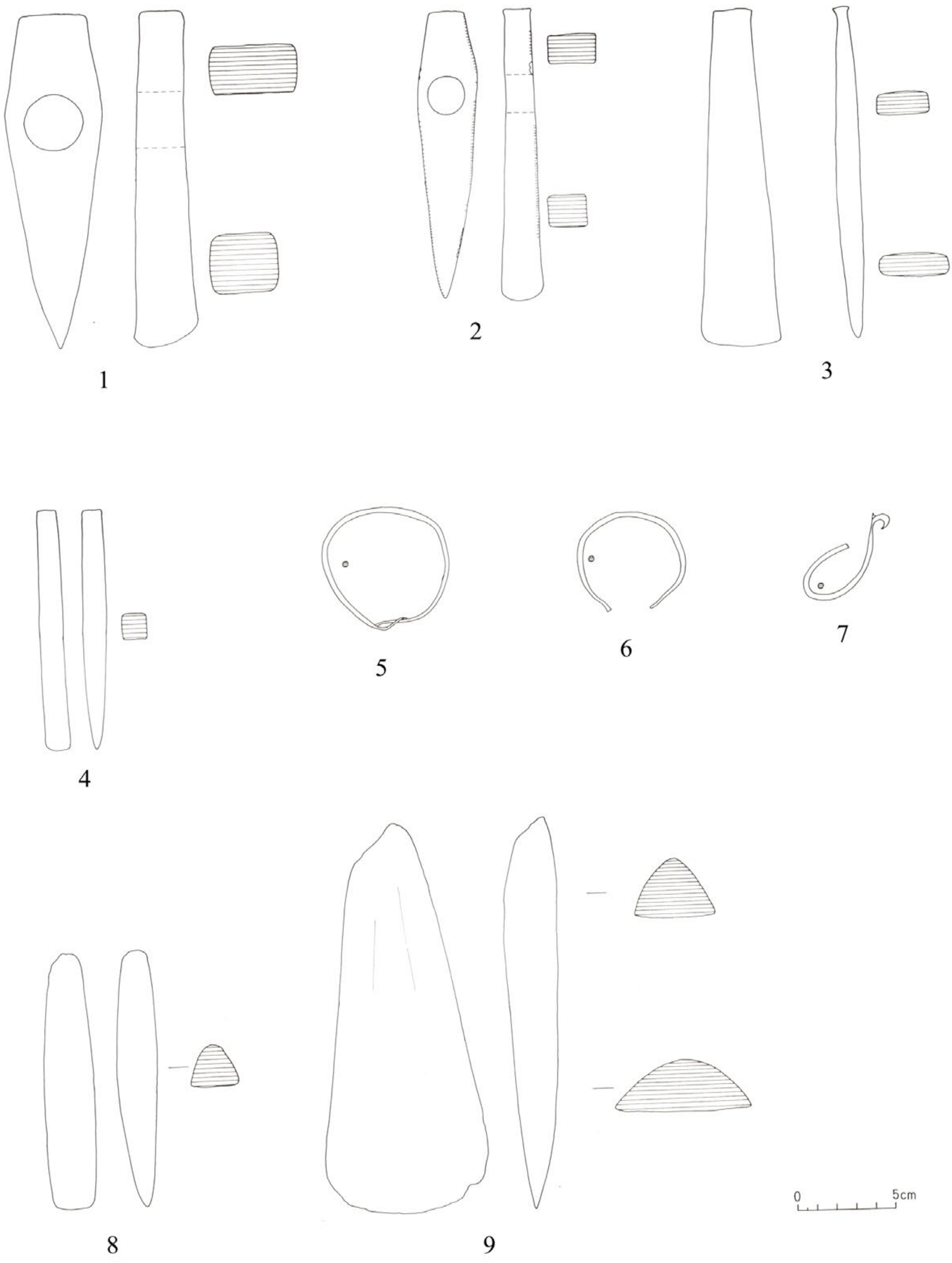

Figure 6. Four Pločnik groups: a. Group I (complete) (after Šljivar *et al.* 2006: 261–265).

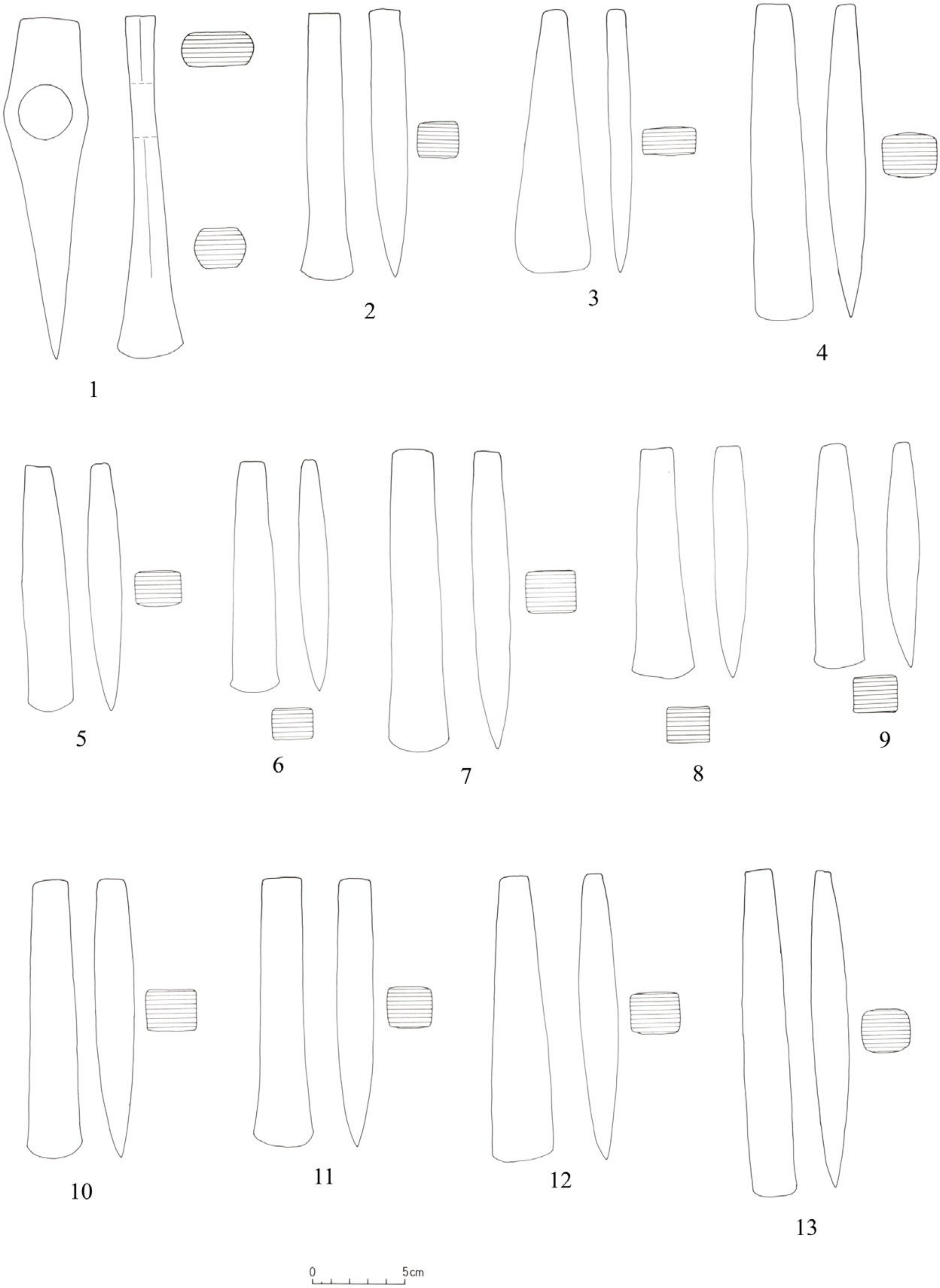

Figure 6. Four Pločnik groups: b. Group II (only 13 metal implements) (after Šljivar *et al.* 2006: 261–265).

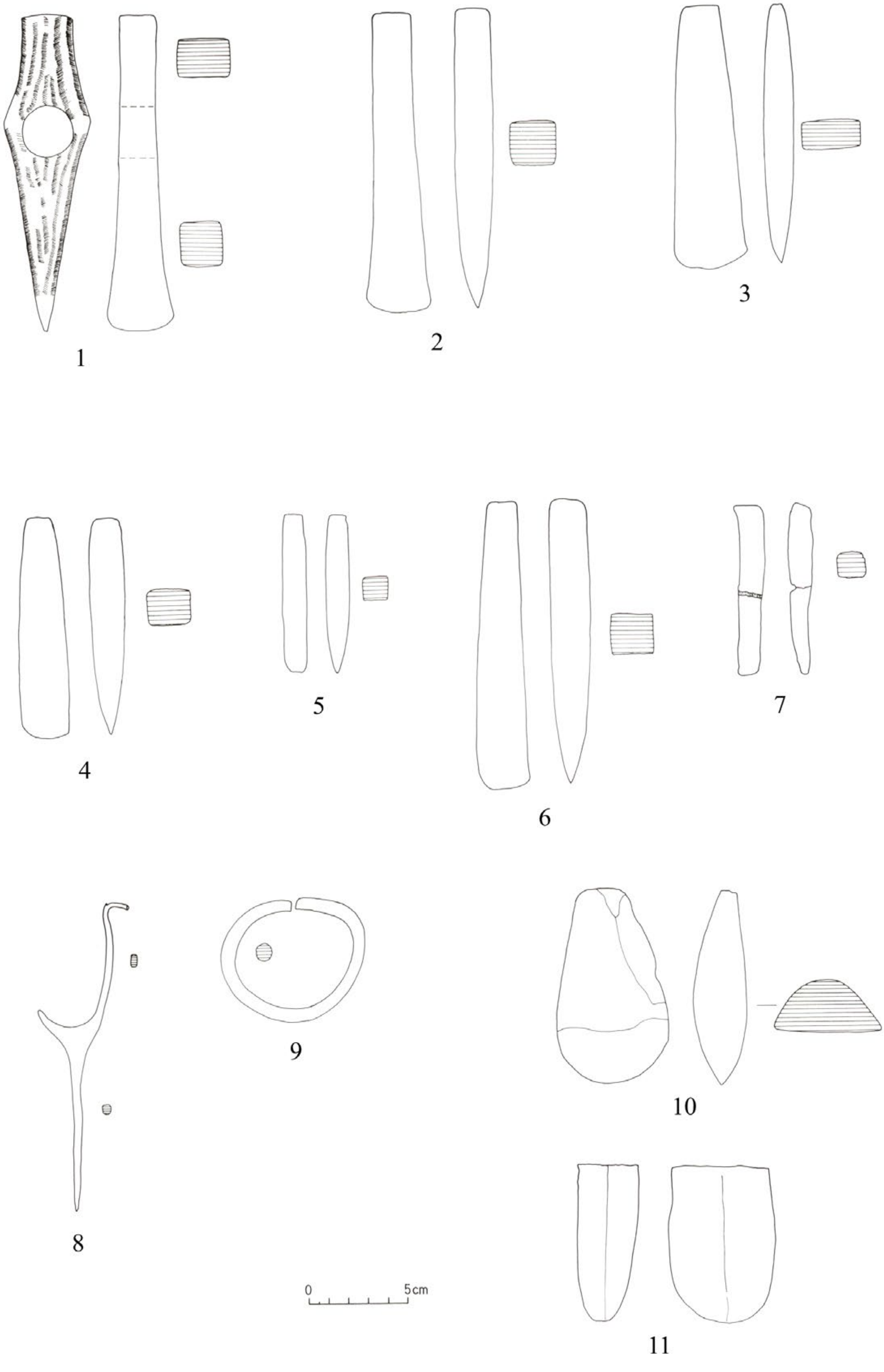

Figure 6. Four Pločnik groups: c. Group IV (complete) (after Šljivar *et al.* 2006: 261–265).

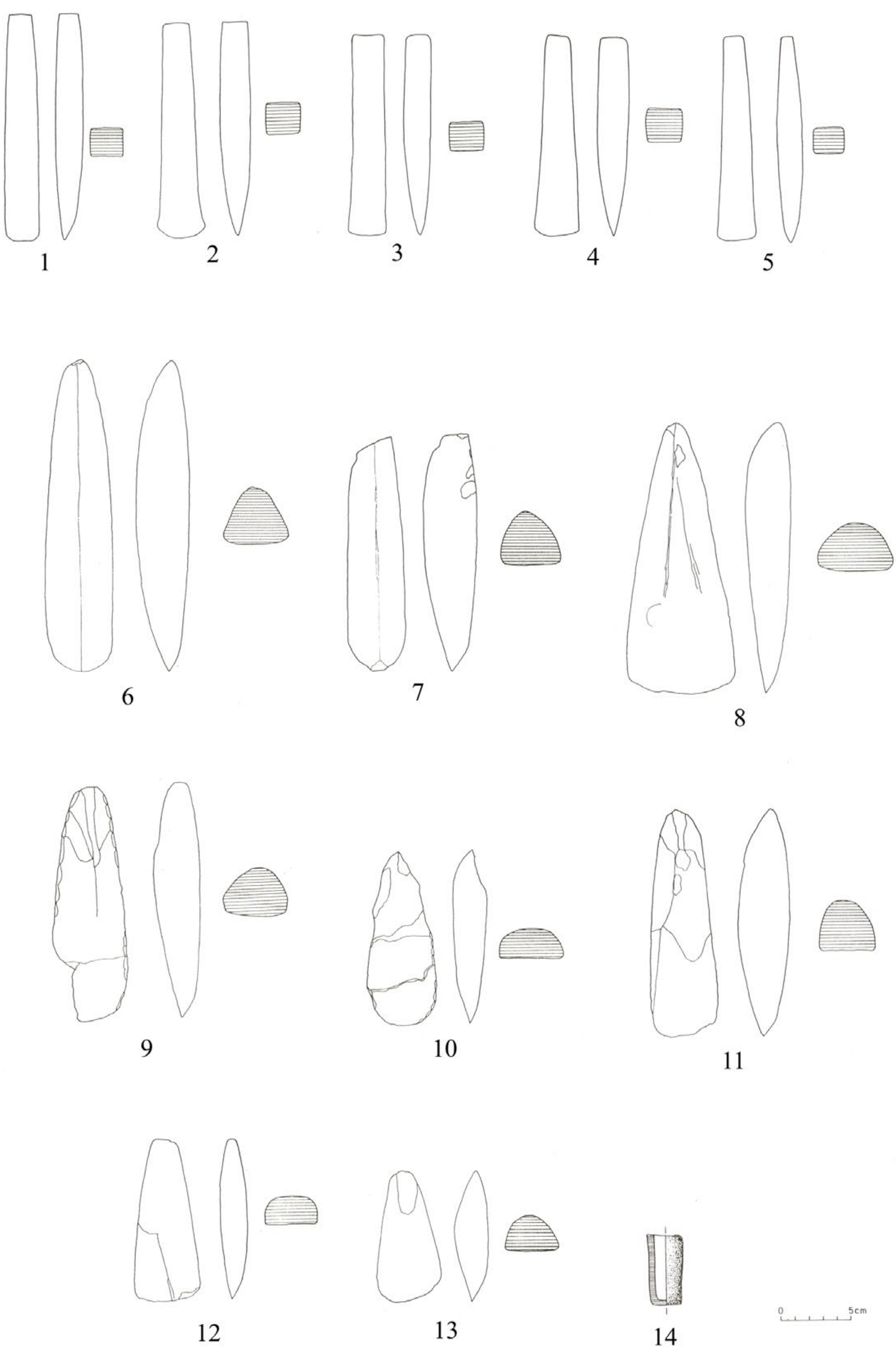

Figure 6. Four Pločnik groups: d. Group III (complete) (after Šljivar *et al.* 2006: 261–265).

Figure 7. A figurine head from Pločnik, painted lengthwise. Dimensions (in cm): height 20, face 10.7; face width 16.3; and neck width 11.6. (Courtesy of J. Kuzmanović Cvetković, Museum of Toplica, Prokuplje).

x 1.4 m dominated this structure, with massive walls preserved up to 0.5 m in height (Figure 8), visibly repaired several times (several clay layers), and with traces of intense firing. This, along with the discovery of a massive copper chisel (Pločnik 145; Figure 9), a fragment of a tool/ornament (?) (Pločnik 67), a fragmented bracelet (?) (Pločnik 73), a folded metal sheet (Pločnik 75) and copper minerals (one studied here, Pločnik 71) (see Table 2), led excavators to assume that the structure represented a metallurgical workshop (Šljivar and Kuzmanović Cvetković 2009a: 61).

Other finds in this structure included stone tools and large ceramic vessels, such as amphorae, jugs and similar water (?) containers. Of particular interest were ceramic 'tubes' (Figure 10), which did not contain indications of use in metallurgical processes but resembled the 'chimneys' from Belovode (Radivojević and Kuzmanović Cvetković 2014). The furnace (?) remains, although impressive in shape and size, did not offer sufficient evidence to confirm a metallurgical function. However, the coincidence of fragmented metal objects in the same structure could indirectly imply its use for casting or melting, for example. A comparable structure was discovered a year later in Trench 21. Its relationship with a securely contextualised tin

Figure 8. A workshop in Trench 20. Note the rectangular feature (furnace?) in the upper left corner. (Courtesy of Julka Kuzmanović Cvetković, Museum of Toplica, Prokuplje).

Figure 9. A copper chisel (Pločnik 145) *in situ* in Trench 20.
(Courtesy of J. Kuzmanović Cvetković, Museum of Toplica, Prokuplje).

Figure 10. A ceramic ‘tube’ (far left) from Trench 20.
(Courtesy of J. Kuzmanović Cvetković, Museum of Toplica, Prokuplje).

Table 2: Study materials from Trench 20 at Pločnik arranged by excavation levels and proposed chronology/building horizons.

No.	Analytical No.	Excavation year	Context	Type of Material	Chronology/building horizon
1	**Pločnik 72 (b, m)**	2007	Trench 20, spit 3	Copper mineral and malachite bead	Gradac Phase, horizon III
2	**Pločnik 69**	2007	Trench 20, spit 4	Copper metal droplet	Gradac Phase, horizon III
3	**Pločnik 67**	2007	Trench 20, spit 7	Copper artefact	Gradac Phase, horizon III
4	**Pločnik 71**	2007	Trench 20, spit 7	Copper mineral (flakes)	Gradac Phase, horizon III
5	**Pločnik 73**	2007	Trench 20, spit 7	Copper artefact	Gradac Phase, horizon III
6	**Pločnik 75**	2007	Trench 20, spit 7	Copper artefact	Gradac Phase, horizon III
7	**Pločnik 145**	2007	Trench 20, spit 7	Copper artefact	Gradac Phase, horizon III
8	**Pločnik 43**	2007	Trench 20, spit 10	Malachite bead	Vinča B1, horizon II

bronze foil and resemblance to a feature discovered in Trench 20 prompted researchers to argue for a similar metallurgical function (Šljivar and Kuzmanović Cvetković 2009b; Radivojević *et al.* 2013).

A detailed set of analyses was performed on seven copper and tin bronze artefacts (Table 1) (Radivojević 2012; Radivojević *et al.* 2013). Pločnik 143, the copper chisel (Figure 11), was discovered within a stone structure in Trench 18, together with a stone axe made of magnesite and a small pottery vessel, all of which correspond with the beginning of the Gradac Phase in Pločnik (Šljivar *et al.* 2006: 255–256). A massive copper chisel (Pločnik 145) was unearthed in a similar workshop setting in Trench 20, along with two fragmented pieces of a tool (Pločnik 67) and a bracelet (Pločnik 73) respectively, a folded metal sheet (Pločnik 75, see Figure 11), a copper mineral (Pločnik 71), and several stone tools. All of these were discovered scattered across the same surface, in spit 7 and in the vicinity of the 'furnace' (Šljivar and Kuzmanović Cvetković 2009a: 58–60). Pločnik 216 is a small, fragmented chisel discovered above a stone structure outside the potential dwelling feature in Trench 14, dated between 5040 and 4840 BC (95.4% probability). The emergence of copper metal artefacts in Pločnik thus coincides with the start of the Gradac Phase on this site.

All metal artefacts from this site studied by Pernicka and collaborators (1993, 1997) showed a copper composition of 99.9 wt% on average. A new set of the electron microprobe examination of another set of samples (see Table 1) confirmed these results, barring the tin bronze foil (Pločnik 63). The pure copper composition is followed by low trace element contents, most relevantly of iron, sulfur, gold and nickel, in varying ratios (Radivojević 2012).

The common microstructural feature of all samples is that they present a yellow/orange (copper) metal body, with green corrosion products developing on its edges. The main metal body shows a residual as-cast structure, preserved in the microstructure of the copper-copper oxide eutectic with α-grains of copper (see example in Figure 12a). Optically, the α-grains of copper are characterised by their highly reflective bright colour, embedded in the eutectic structure with grey particles within a bright matrix of metal grains.

The major differences among the sets of metal artefacts analysed stem from the varying combinations of working techniques, which appear carefully designed to respond to the desired function of the object in question. Pločnik 67 (a fragmented tool/ornament?), Pločnik 73 (a copper bracelet?), and Pločnik 75 (a folded metal sheet) display fully recrystallised structure and traces of several cycles of cold working and annealing (Radivojević 2012). The only two massive copper implements examined for microstructure in the most recent study are Pločnik 143 and Pločnik 145 (Figures 11a/e, 12b), both of which bear similar small traces of finishing work towards their tip and on the surface (Radivojević 2012). These massive copper chisels display only slight post-annealing working, which could be equally ascribed to either intentional hardening of the tip and along the surface area, or to hardening during the use of these objects. It could also be interpreted as the result of intense hot working with continuous re-heating during a forging process of some duration (cf. Kienlin 2010).

A tin bronze foil (Pločnik 63) was excavated from an undisturbed context, on the floor of a dwelling structure next to the likely copper metal workshop at the site, about 1 m from a fireplace, and was enclosed in several late Vinča culture pottery vessels (Radivojević *et al.* 2013: 1033, Figure 2). Compositional analysis demonstrated that this metal foil was made of a complex alloy of copper and tin, along with significant concentrations of elements including As, Sb, Co, Ni, Pb and Fe. This securely contextualised find comes from a single, undisturbed occupation horizon at Pločnik, dated to *c.* 4650 BC. This date is, according to the field evidence, the *terminus ante quem* for the Pločnik foil at present. The tin bronze foil from Pločnik is, therefore, the earliest known tin bronze artefact anywhere in the world (Radivojević *et al.* 2013: 1032).

Figure 11. a) Pločnik 143, a copper chisel; b) Pločnik 67, a fragmented tool/ornament? c) Pločnik 75, a folded metal sheet; d) Pločnik 73, a fragmented bracelet; and e) Pločnik 145, a copper chisel.

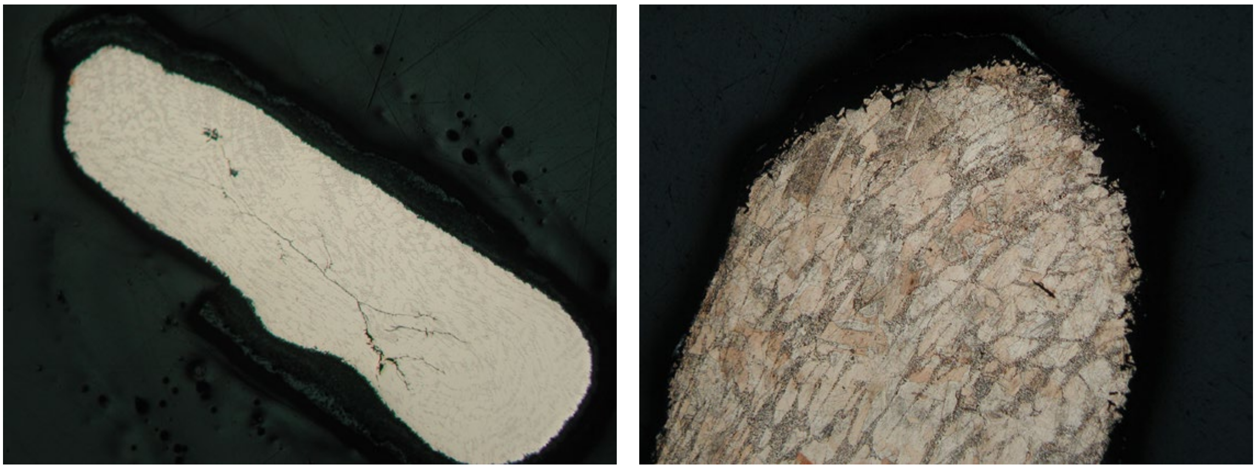

Figure 12. a) Photomicrograph of the unetched section of Pločnik 67 under plane polarised light. Note the intensive working on one side (left) exhibited by the elongated grains, as opposed to the oxide-inclusion abundant on the right side of the object (magnification 50x, width 3.2 mm); b) photomicrograph of the etched section of Pločnik 75 (a folded metal sheet) under plane polarised light (magnification 50x, width 3.2 mm).

Discussion

The archaeometallurgy of the site of Pločnik has been the most visible feature of this settlement in all previous studies, with very little attention paid to the everyday life of Pločnik communities beyond attempts to describe unique finds, like the figurine head mentioned above (Figure 7; Kuzmanović Cvetković and Šljivar 1998). However, metal producing and working activities in the site of Pločnik offer an insightful view into the life of a society with emerging pyrotechnology during a time of major cultural, economic and material changes in the 6th and 5th millennium BC in the Balkans (see Chapter 3, this volume).

Based on the recent analyses of archaeometallurgical materials from the site, the excavated items cover all major activities of metallurgical *chaîne opératoire.* The use of both oxide and sulphide copper minerals attests to the knowledge of Pločnik smiths of the properties of these materials, and this is further confirmed by the presence of both smelting and melting droplets discovered within a domestic context: Pločnik 69 was part of workshop activities in Trench 20, while Pločnik 52 indicates smelting of a sulfur-rich copper ore at another location within the settlement (Trench 14).

The presence of a sulfur-rich copper droplet (Pločnik 69) and sulphide copper mineral (Pločnik 72m) potentially implies that the latter was part of the ore batch used in smelting activities. The remarkable morphological similarities between these samples further strengthen this assumption. This, in effect, could imply that the craft workers of Pločnik were intentionally selecting copper sulphide minerals with an appealing green tint and that they were probably aware of their properties (Radivojević 2015; Radivojević and Rehren 2016).

The production techniques employed in malachite bead making are evidently consistent with the Neolithic stone bead industry (cf. Kenoyer *et al.* 1991; Lankton *et al.* 2003; Wright *et al.* 2008). This is best reflected in the various reduction sequences of bead manufacturing, identified across different domestic contexts: 1) the reduction of nodules into roughouts; 2) the shaping of roughouts into blanks by further flaking, sawing and rough grinding; 3) perforation; 4) the final shaping; and 5) the final polishing (Wright *et al*. 2008: 140). The Pločnik bead production material is particularly interesting since it could potentially represent workshop stocks or stored merchants' goods (Kenoyer *et al.* 1991: 57). The distribution pattern of finished and semi-finished beads in Pločnik nevertheless appears more scattered than concentrated at this site (see Table 1), hence implying limited— if any—administrative control over the bead production. However, bearing in mind the small quantity of these finds, as well as the lack of sufficiently integrated contextual evidence within the settlement, the presence of a specialised bead workshop remains a matter of speculation.

The striking feature of these ornamental artefacts is the strong preference for the green colour. It has already been emphasised in previous research that pure green beads were used for minerals, while black and green were more utilised for copper metal extraction (Radivojević 2015; Radivojević and Rehren 2016). The same pattern is apparent at Pločnik. and is corroborated by provenance studies from the site of Belovode, which also indicated two different mineral sources for bead making and copper smelting at this site as well (Radivojević *et al.* 2010a: 2784), confirming that these practices were part of a shared system of values among the Vinča culture communities.

A common feature of the metal artefacts from Pločnik is that, regardless of their composition, it was their function and shape that dictated the combination of techniques applied in their making and working, suggesting a good level of understanding of different material properties of copper, tin, and bronze. All seven copper metal artefacts studied here were made of high purity molten copper metal; a detailed comparison of trace element data from other Vinča culture metal artefacts indicates that they were very likely made of metal smelted from copper ores (Radivojević 2012). The ores typically had low (but diagnostic) levels of impurities, allowing their differentiation from native copper. The tin bronze foil is yet another reminder of remarkable skills and control over different material properties of the Pločnik smiths. This object was made from natural alloy, produced from complex copper-tin bearing ores, and worked at temperatures at least twice as high as those required to make copper (Radivojević *et al.* 2013). It testifies that the Pločnik smiths were aware of the different requirements of the newly acquired metal and developed skills in order to master these.

Conclusions

This overview of activities related to copper mineral use and extractive metallurgy at the site of Pločnik reveals the very close similarities in terms of technology with those established for the sites of both Belovode and Vinča-Belo Brdo (Radivojević and Kuzmanović Cvetković 2014; Radivojević 2015; Radivojević and Rehren 2016). Particularly striking is the common preference for the green and black copper minerals used for malachite bead making and the green copper minerals, used for copper smelting.

In terms of the field interpretation of these minerals, it is important to emphasise their domestic use. Only in the Vinča culture (from the Gradac Phase onwards) can we observe household-based pyrometallurgical activities. Significantly, some minerals studied here co-occur with bead-making activities, with no indication for their use as bead nodules. The distinction between the bead minerals and ores ('metallurgical minerals') has already been mentioned and will be further discussed in later chapters in the light of the production debris and malachite bead analyses.

Although the most convincing evidence for the distinctive roles of green and black and green copper minerals comes from the site of Belovode, there is a great likelihood that black and green minerals were used to make the (s)melting droplets Pločnik 52 and Pločnik 69. The excavations at Pločnik, however, have produced the greatest number of finished artefacts discovered in groups with others implements, which prompts us to assume a predominantly consumer role for the settlement within the broader organisation of metal production and distribution.

Regarding the organisation of metal production, there is little field evidence reported thus far that can shed light on any kind of specialisation or different lifestyles of occupants of dwellings, with or without evidence of metal working or consumption. Trenches 20 and 21 revealed unusual square features in dwelling objects that were termed 'furnaces', since there were metal objects in their vicinity (Šljivar and Kuzmanović Cvetković 2009a). Although no direct evidence was found to prove this assumption, the coincidence of these features with semi-worked objects, as in Trench 20, raises the likelihood of them being used for metalworking activity. Remains of a fragmented tool/ornament (Pločnik 67), a fragmented bracelet (Pločnik 73), and a folded metal sheet (Pločnik 75), together with a well-preserved massive copper implement (Pločnik 145) in a single structure in Trench 20 further suggest that this object could have been occupied by a metal smith. This workshop setting was, nevertheless, not used for primary metal production but, based on the present evidence, possibly only for the casting and/or repair of metal tools.

The rectangular structure from Trench 20 was also used for malachite bead making, as evidenced by the presence of a bead roughout (Pločnik 72b). The bead blank (Pločnik 54b) from Trench 16 a few metres from the metal workshop in Trench 20, may suggest the presence of yet another bead making workshop.

The quantity and type of pottery assemblage found in structures from Trenches 20 and 21 has not been previously reported as different to any other dwelling discovered at the site of Pločnik during the most recent excavation campaigns (e.g. Šljivar *et al.* 2006; Šljivar and Kuzmanović Cvetković 1998a, 1998b; Šljivar and Kuzmanović Cvetković 1996-2009). This theoretically implies that, for instance, metalworkers in Pločnik did not lead a different life to that of a farmer or, more accurately, that these two roles were not exclusive. The concept of a specialised metallurgical workshop appears later in prehistory (e.g. Bronze Age), and earlier suggestions of the presence of specialists need to be treated with caution until they are supported by a more detailed research on site formation (see Chapter 3, this volume).

Based on current evidence, the crafters from Belovode and Pločnik were each covering different ends of the same metal making process, which strengthens the likelihood of their potential collaboration. The lead isotope match of the Belovode slag samples with the Pločnik copper chisel (Pločnik 216) strengthens this assumption (Radivojević 2012); this will be explored in detail in Chapter 41, and in future publications. The quantity and quality of collected and sampled materials is currently unprecedented in academic work and provides an excellent resource for studying the emergence, evolution and transmission of metallurgical skills both within the Vinča culture and across the Balkans.

As with Belovode, there is a lack of AMS data on specific contexts related to diverse metallurgical activities at Pločnik (cf. Radivojević and Kuzmanović Cvetković 2014: 25). Also, as at Belovode, metallurgical activities are visible only from the start of the Gradac Phase, which highlights the need for Vinča archaeologists (and others) to investigate the circumstances and mechanisms through which this particular cultural phase emerges. It is important to emphasise that metallurgy was not the only novelty occurring within the Gradac Phase, and that over-arching social and economic changes are detected throughout the Balkans around the early 5th millennium BC (cf. Garašanin 1994/1995).

The following chapters will investigate in more detail the claims and interpretations stemming from commendable pioneering work at the site of Pločnik, conducted by Grbić, Stalio, Šljivar and Kuzmanović Cvetković. We will attempt to give, for the first time since the start of the Pločnik excavations, a general overview of all subsistence and economic activities at this site, and we will address the broader questions of the everyday life of the metal-producing and consuming communities of the Vinča culture and beyond.

The bibliographic reference for this chapter is:

Radivojević, M. 2021. Introduction to Pločnik and the results of archaeometallurgical research 1996–2011, in Radivojević, M., Roberts, B. W., Marić, M., Kuzmanović Cvetković, J., and Rehren, Th. (eds) *The Rise of Metallurgy in Eurasia*: 60–76. Oxford: Archaeopress.

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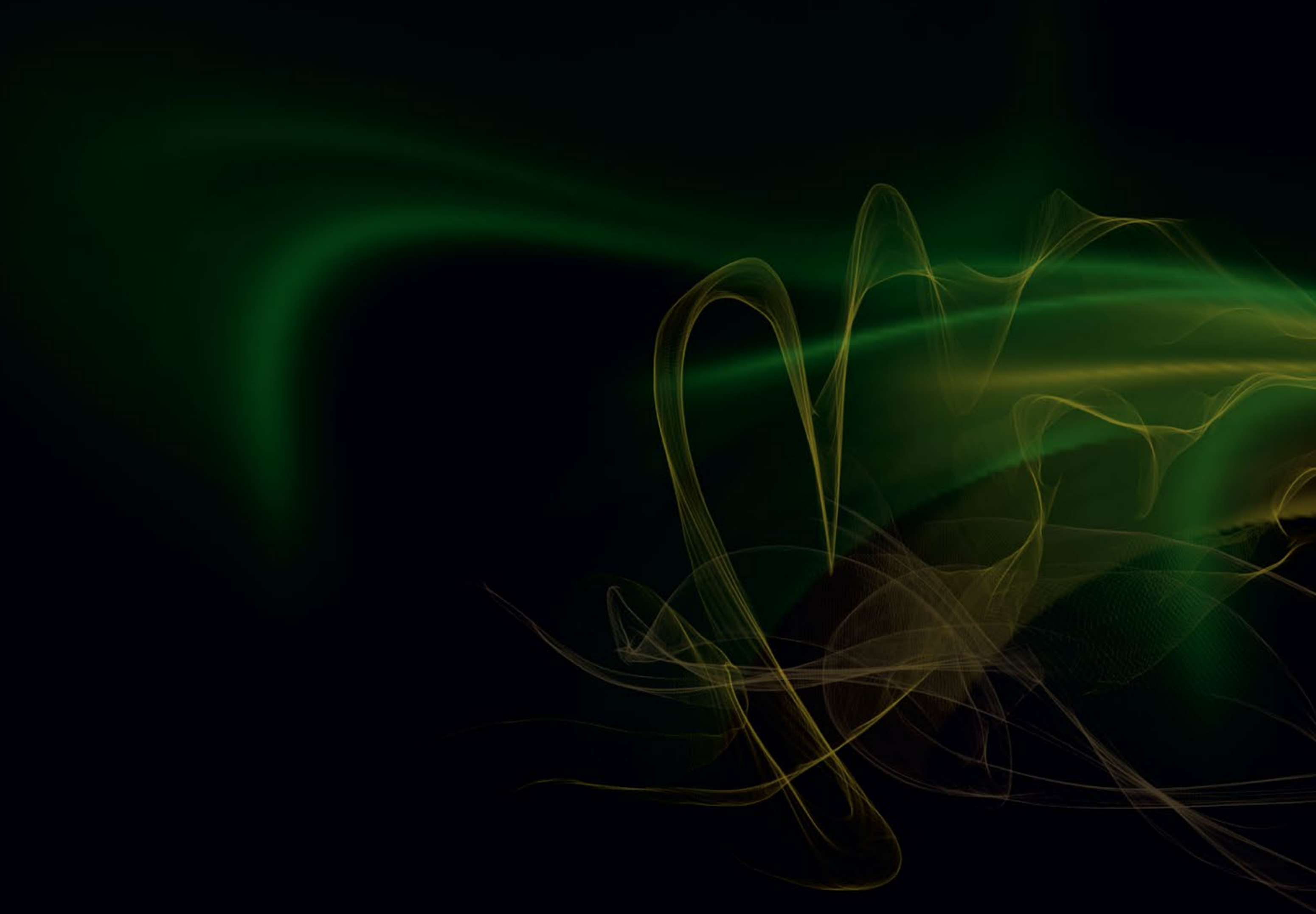

The Rise of Metallurgy in Eurasia is a landmark study in the origins of metallurgy. The project aimed to trace the invention and innovation of metallurgy in the Balkans. It combined targeted excavations and surveys with extensive scientific analyses at two Neolithic-Chalcolithic copper production and consumption sites, Belovode and Pločnik, in Serbia. At Belovode, the project revealed chronologically and contextually secure evidence for copper smelting in the 49th century BC. This confirms the earlier interpretation of c. 7000-year-old metallurgy at the site, making it the earliest record of fully developed metallurgical activity in the world. However, far from being a rare and elite practice, metallurgy at both Belovode and Pločnik is demonstrated to have been a common and communal craft activity.

This monograph reviews the pre-existing scholarship on early metallurgy in the Balkans. It subsequently presents detailed results from the excavations, surveys and scientific analyses conducted at Belovode and Pločnik. These are followed by new and up-to-date regional syntheses by leading specialists on the Neolithic-Chalcolithic material culture, technologies, settlement and subsistence practices in the Central Balkans. Finally, the monograph places the project results in the context of major debates surrounding early metallurgy in Eurasia before proposing a new agenda for global early metallurgy studies.

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