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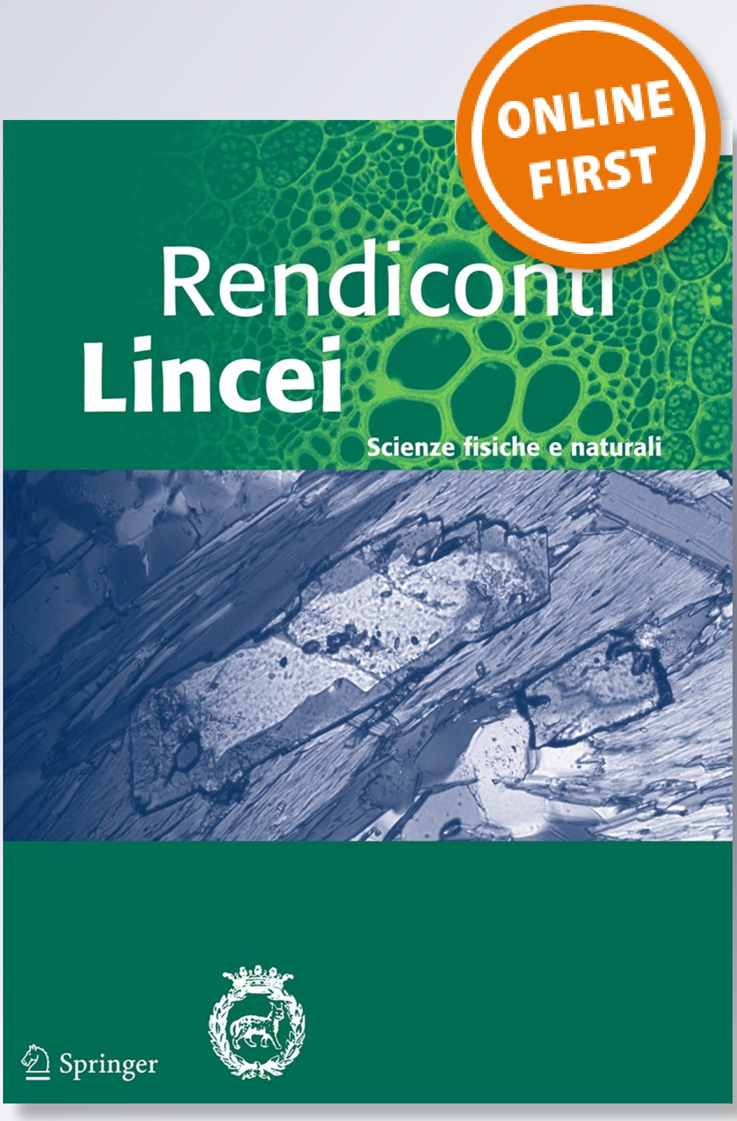

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GEOSCIENCES AND CULTURAL HERITAGE

Copper Age axe-hammers, other tools and their raw materials in the sub-Apenninic area east of Bologna (Italy)

Claudio D'Amico[1] · Gabriele Nenzioni[2] · Saula Casadei[3] · Fiamma Lenzi[4]

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Abstract During this study, about two hundred stone tools from the Bologna territory—particularly from the S. Lazzaro di Savena area—were studied. They comprise perforated axe-hammers, axes/adzes and other variously polished complete or fragmentary tools of Copper Age typology, mostly coming from surface survey. They are mostly manufactured from basic magmatic rocks (in order of abundance: diabases, dolerites, gabbros, basalts and basic porphyrites) typical of the Apennine ophiolites outcropping upstream to the local mountains/hills, as well as in several areas of the Northern Apennines. Other lithologies, such as ophiolitic ultramafics (serpentinites, steatite and one Ca-pyroxenite) and non-ophiolitic lithologies, are poorly represented. The petrographic features of the studied artefacts are compatible with those of the ophiolitic rocks outcropping in the nearby Apennines and include varying degrees of low-grade, both of continental (various green and bright amphiboles, chlorite, saussurrite etc.) and oceanic metamorphism (typically brown hornblende and rare mylonitic textures). Some basic porphyrites with large phenocrysts, uncommon in the Apennine ophiolites, are also present. The few non-ophiolitic lithologies (siliciclastic arenites, calcarenites, limestones and siliceous stones) were probably supplied from the nearby Apennine, with the exception of a spotted slate of unknown origin. Based on their morphotypological features, some ophiolitic and not-ophiolitic artefacts may suggest some exchange and importation from—or simply some prehistoric cultural links with—Tuscany, Marche and occasionally Southern Italy and South Tyrol/Alto Adige.

Keywords Copper Age stone tools · Shaft holed hammer axes · Bologna territory · Apennine ophiolites · Petro-archaeometric analyses

This contribution deals with topics considered in the session "Archaeometry and Cultural Heritage: the contribution of Geosciences" held during the conference "The future of the Italian Geosciences, the Italian Geosciences of the future", organized by the Società Geologica Italiana and the Società Italiana di Mineralogia e Petrologia, Milano, September 10–12, 2014.

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1 Introduction

Many Neolithic and Copper Age artefacts have been collected in the territory between Bologna and Imola, and in particular around S. Lazzaro di Savena, and are now held in the below mentioned Museums. Part of these tools was examined in two dissertations (Fabris 1997; Casadei 1997); the first of these were studied by D'Amico et al. (2013), in terms of their petro-archaeometric definition, provenance and circulation. Such materials belong to the rich series of

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"greenstone" collections studied by D'Amico and collaborators (e.g. reviews by D'Amico et al. 2004; D'Amico 2011; D'Amico and Starnini 2006, 2012 and references therein).

This paper deals with Copper Age materials found in the S. Lazzaro area [Fig. 1; Table ESM1 (Online Resource 1)], first described by Casadei (1997) and recently revised by the authors of this paper with the addition of new findings. Some detrital cobble/pebbles within the same lithological range of the archaeological material have been gathered and positively examined for comparison. The following repertory takes into consideration all polished stone findings (207), which can be ascribed, on a techno-typological basis, to the Copper Age (Figs. 2, 3, 4, 5), and the morphotypological and lithological distributions of which are reported in Tables 1 and 2. Nineteen of them [9 % of the studied materials; labels MA in Table ESM1 (Online Resource 1)] are stored in the Museo Archeologico of Bologna, 27 tools [13 % of the studied materials; labels IM in Table ESM1 (Online Resource 1)] in the Musei Civici of Imola, one [labels BO in Table ESM1 (Online Resource 1)] in the Soprintendenza Archeologica of Emilia-Romagna, and 161 [77 % of the studied materials; labels SL in Table ESM1 (Online Resource 1)] in the Museo della Preistoria of S. Lazzaro di Savena. This latter collection includes a series of 46 stone working tools, e.g.: strikers, burnishers, as well as working waste. The main aim of this work is to petrographically characterize the Copper Age stone tools of the territory around Bologna and to constrain the provenance sources of rock used to produce them.

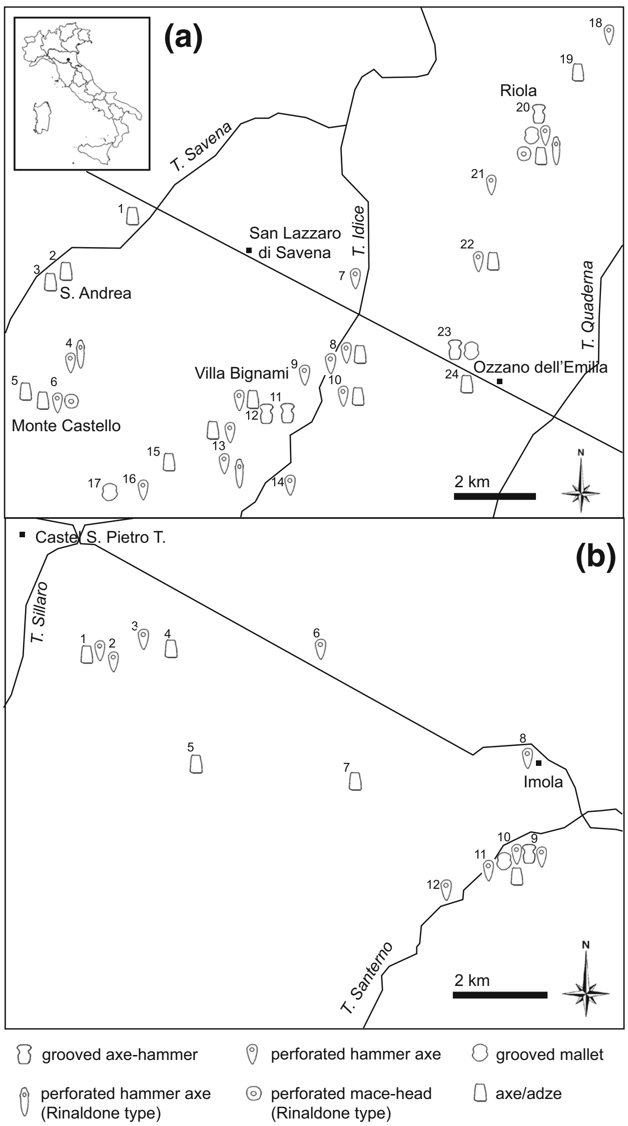

Fig. 1 Distribution map of the copper age artefacts in: **a** Bologna-S. Lazzaro area. *Bologna territory*: n.1; *S. Lazzaro di Savena territory*: nn. *2*, *4*, *5*, *7*, *8*, *9*, *10*, *11*, *12*, *13*, *14*, *15*, *24*; Pianoro territory: nn. *3*, *6*, *16*, *17*; *Ozzano dell'Emilia* territory: nn. *18*, *19*, *20*, *21*, *22*, *23*; **b** Imola area: *Castel S. Pietro Terme territory*: nn. *1*, *3*; Dozza territory: nn. *2*, *4*, *5*, *6*; Imola territory: nn. *7*, *8*, *9*, *10*, *11*, *12*

2 Archaeological context and types of Copper Age instruments

The first mention of Copper Age stone artefacts in the Bologna territory dates back to the second half of the 19th century (Capellini 1870; Scarabelli 1887; Colini 1892, 1896; Brizio 1893, 1896). Some decades later, new findings attributed to the Copper and the initial Bronze Ages, from the territory between the Reno and Santerno valleys, lead to the development of a first organic distribution model of these artefacts (Malavolti 1948; Scarani 1960, 1963; Bagolini 1981; Bagolini et al. 1982; Steffè 1984; Nenzioni 1985; Bermond-Montanari et al. 1988; Morico and Steffè 1993; De Marinis 1996; Mengoli 1996; Morico 1997; D'Amico et al. 2000; Carrisi 2003).

These studies outline a diffusion model from the central Adriatic area (Connelle culture) northeastward to the Bologna territory. Artefacts found west of Bologna (e.g. in the Cumarola necropolis near Modena) show morphological features similar to those of the Tuscan-Latial Rinaldone culture (Bagolini et al. 1982). Recently more details about the complex dynamics of "eneolithization" in the eastern Po plain between the middle 4th and the end of the 3rd millennium BC, although an accurate chronological seriation of artefacts is difficult because they have only rarely been found in their original stratigraphic contexts (Ferrari and Steffè 2005; Ferrari et al. 2008; Bernabò-Brea et al. 2010). Most of these materials were collected from the surface. Under a morphotypologic point of view, the materials presented in the present paper belong to six main tool classes (Figs. 2, 3, 4, 5, 6), in addition to a few ornaments derived from isolated discoveries, some manufacturing tools and a consistent number of working flakes (Table ESM1; Table 1). A description of these assemblages and of their cultural significance is given below.

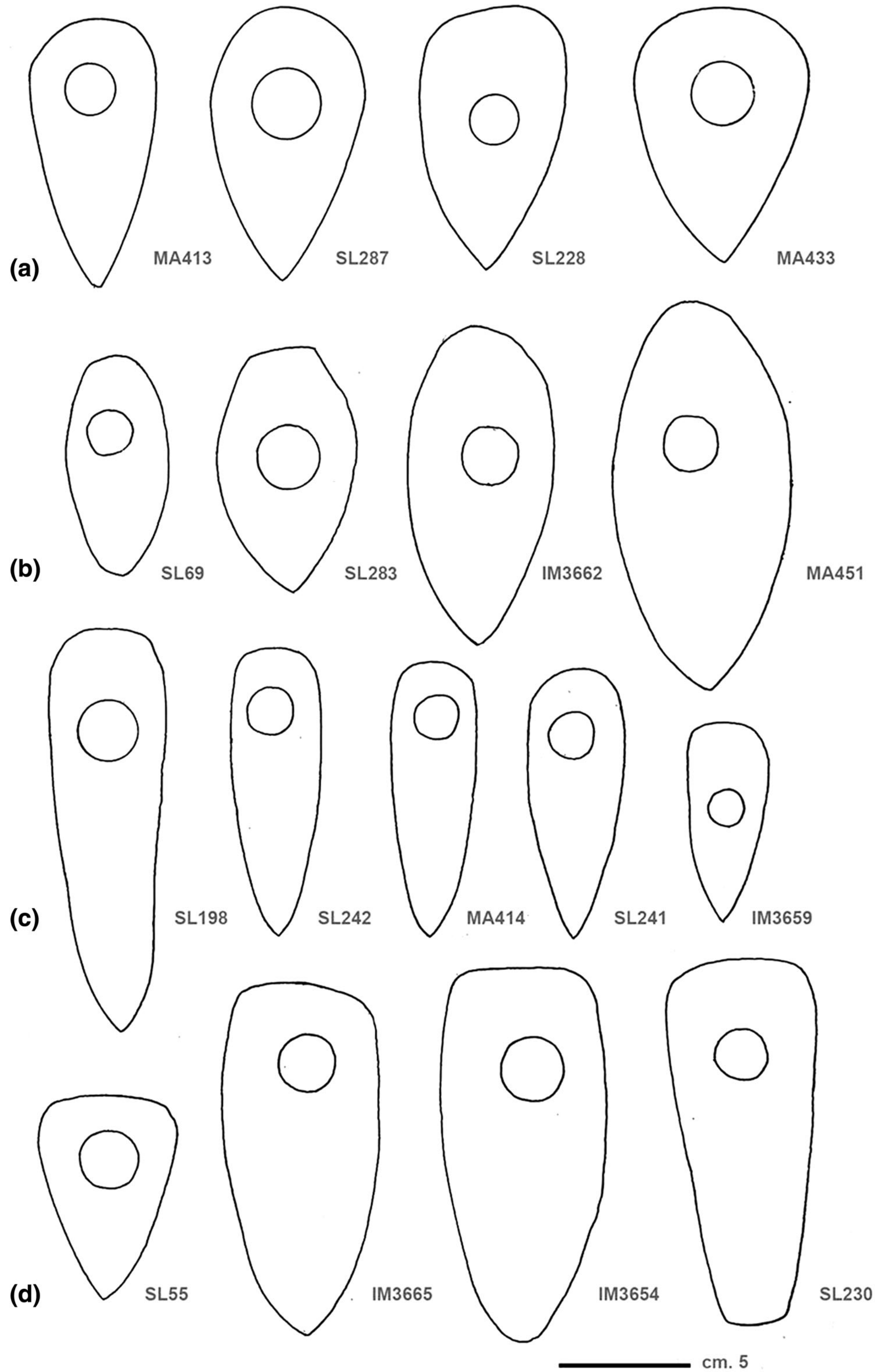

Fig. 2 Perforated axe-hammer triangular shape, frontal sight; **a** With *rounded butt*: *MA413* dolerite), *SL287* (dolerite) *SL228* (diabase) *MA433* (doleritic diabase); **b** *Biconvex shape* with *sub-rounded butt*: *SL69* (dolerite), *SL283* (dolerite), *IM3662* (calcarenite), *MA451* (basalt?); **c** *Triangular elongated shape*: *SL198* (diabase), *SL242* (basalt), *MA414* (gabbro-dolerite), *SL241* (basalt-diabase) *IM3659* (dolerite-gabbro); **d** *Triangular shape with squared butt* blunted at the corners:*SL55* (diabase), *IM3663* (diabase), *IM3654* (dolerite-gabbro), *SL230* (diabase)

2.1 Perforated axe-hammers

This is the largest group of tools (∼40 %), mostly as fragmentary finds (63.4 %), distributed over a wide territory. Based on the morphological codes elaborated by Roe (1966) and Zàpotocký (1992) and taking into account the adaptations by Peloi (1996–1997) and Carrisi (2003), the so-called "flat-iron" type, characterized by a triangular shape and by some variants of the butt, prevails. Both the elongated and short types are present; truncated-conical holes prevail over

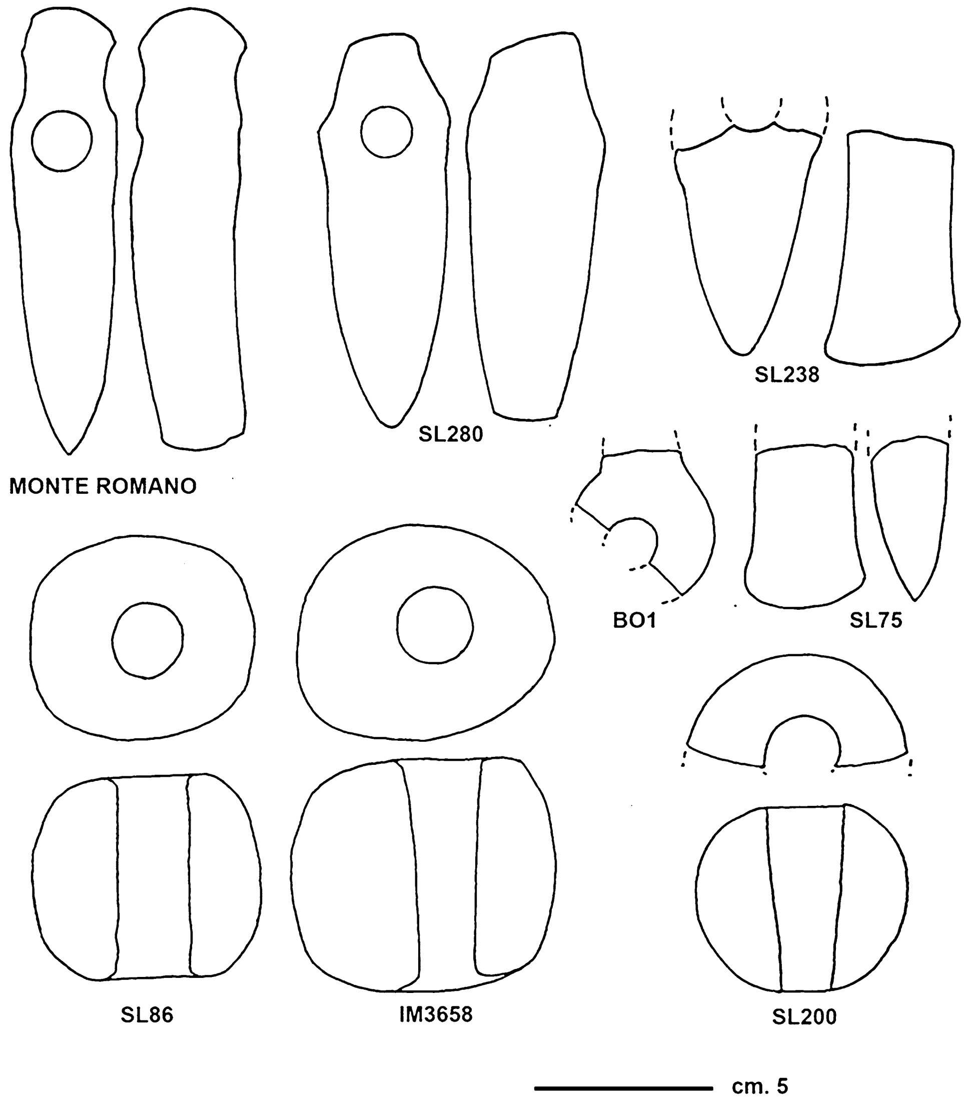

Fig. 3 Axe-hammers, "Rinaldone" derivation: *Monte Romano*, *SL280* (diabase), *SL 238* (dolerite), *BO1* (gabbro), *SL75* (gabbro), *SL86* (gabbro), *IM* (gabbro), *SL200* (diabase-dolerite)

cylindrical ones and are incomplete in a few cases. The cutting edge is usually linear or slightly arched. Perforated axe-hammers are widespread, from the central Adriatic areas (Marche region) up to the eastern Po plain of Emilia-Romagna (Morico 1997); only sporadic evidences have been found further west in Emilia. In particular, this class of materials shows strong analogies with the group of nearly sixty artefacts unearthed from the stratigraphic series of Connelle di Arcevia (Marche region), dated from the onset of the Copper Age to its late phases (Cazzella and Moscoloni 1999).[1] More sporadic finds of the same type are known in southern areas of the same region. Particularly significant is an artefact from Santa Maria in Selva di Treia, dated to the end of the 5th—early 4th millenium BC, or another similar example found in the pluri-stratified site of Maddalena di Muccia (Marche region)—dated to the very last phases of the Copper Age (Silvestrini et al. 2005; Cazzella and Silvestrini 2005; Manfredini et al. 2005), confirming the long-lasting usage of this kind of instrument.[2] Analogous examples of perforated axe-hammers are also known from surface collections in Tyrrhenian Tuscany (Sammartino 2006; Sarti 1997).

These morphotypologies, either massive and with squared butt (Fig. 2d) or with an elongated triangular shape and a rounded butt (Fig. 2c), are much more common in

[1] Under a chronological point of view this type of materials have strong similarities with those from the stratigraphical series of Conelle d'Arcevia attested both in the lower layer E (Rome—952, 4585 ± 60 BP, 3495–3105 cal. ±16 BC, 3510–3065 cal. ±26 BC; Rome—953, 4555 ± 60 BP, 3365–3100 cal. ±16 BC, 3500–3040 cal. ±26 BC) and, with increasing frequency, in the upper layers D–C–B (As an example of Connelle B dating, Rome-190–4390 ± 70 BP, 3250–2905 cal. ±16 BC, 3335–2885 cal. ±26 BC).

[2] The perforated axe-hammer from the pluri-stratified site of Maddalena di Muccia (MC) yielded the following radiomeric dates: Ua 1900/US 9, 2580–2280 a.C. cal.26; Ua-21095/US 86, 2460–2190 a.C. cal 26).

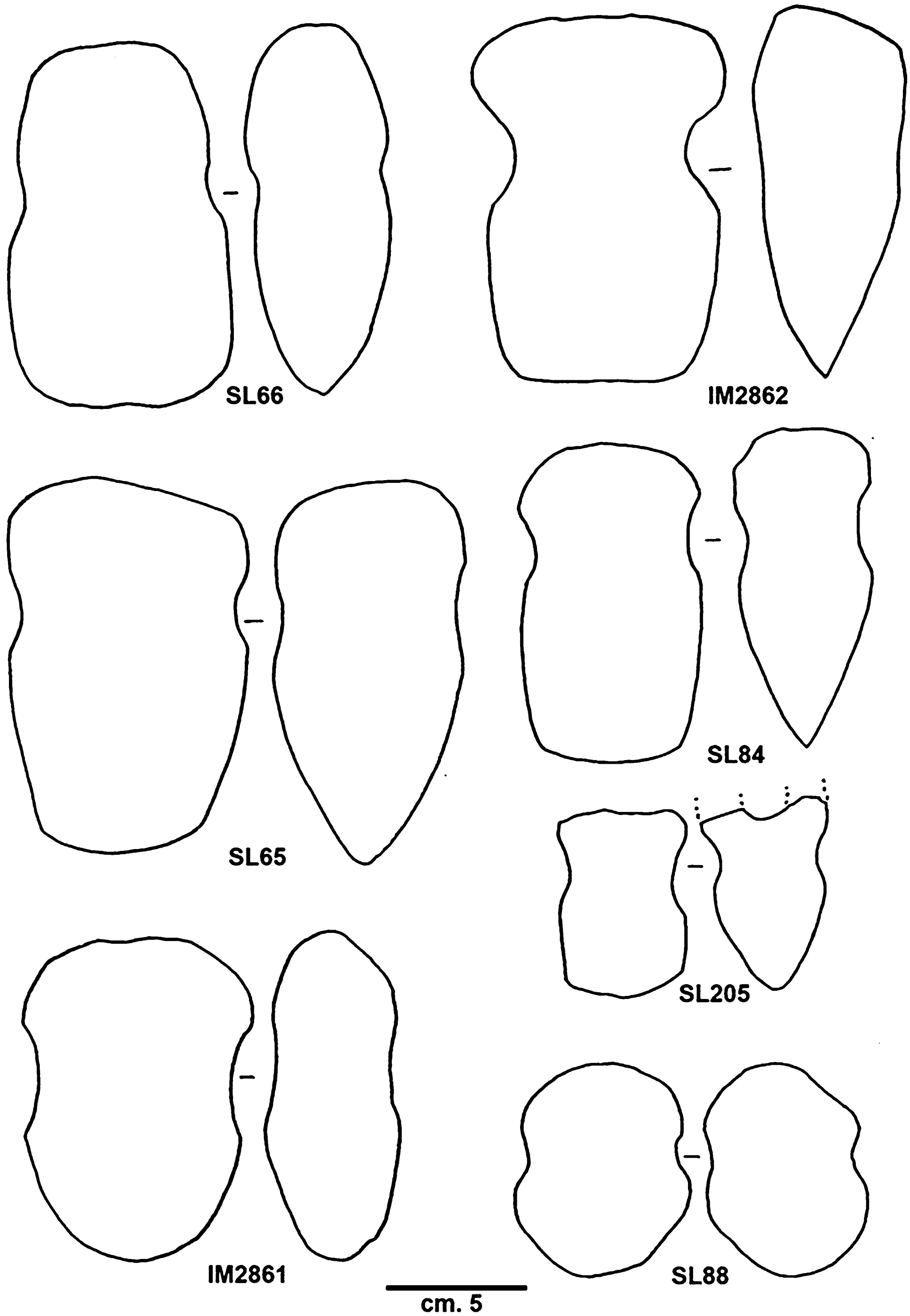

Fig. 4 Grooved axe-hammer and grooved mallets: *SL 66* (gabbro), *IM2862* (dolerite-gabbro) *SL65* (basic porphyrite), *SL84* (diabase), *SL205* basic porphyrite), *IM2861* (dolerite-diabase), *SL88* (gabbro)

the "*Caput Adriae*" area (Friuli-Venezia Giulia region, in NE Italy, and Slovenia: D'Amico et al. 1996; Bernardini 2007–2008; Bernardini et al. 2011, 2012, 2014; Schmid 1910; Koršec and Koršec 1969; Lubšina-Tušek 1993; Velušček 2004) and resulted to be manufactured from various metamorphic rock, in particular serpentinites and volcanics. Contacts and consequent circulation of these models in the trans-Adriatic area appear evident from the second half of the 4th millennium BC (Cazzella 2003).

A small but important group of artefacts (Fig. 3) shows a clear affinity with some tools of the Rinaldone Culture characterizing the middle-Tyrrhenian, Tuscany-Latium and Umbria areas.

The axe BO1, found in the Eneolithic context of via Ugo Bassi (Bologna) and characterized by an enlargement of the body at hole-level, is very meaningful, since ascribed to the cultural context of the Spilamberto Group, attributed to the middle-late Eneolithic (Morico and Steffè 1998). This

Fig. 5 Axes: *SL81* (basalt), *SL225* (basalt), *SL85* (gabbro), *SL224* (diabase-dolerite), *MA442* (basic porphyrite), *SL77* (dolerite), *SL281* (diabase)

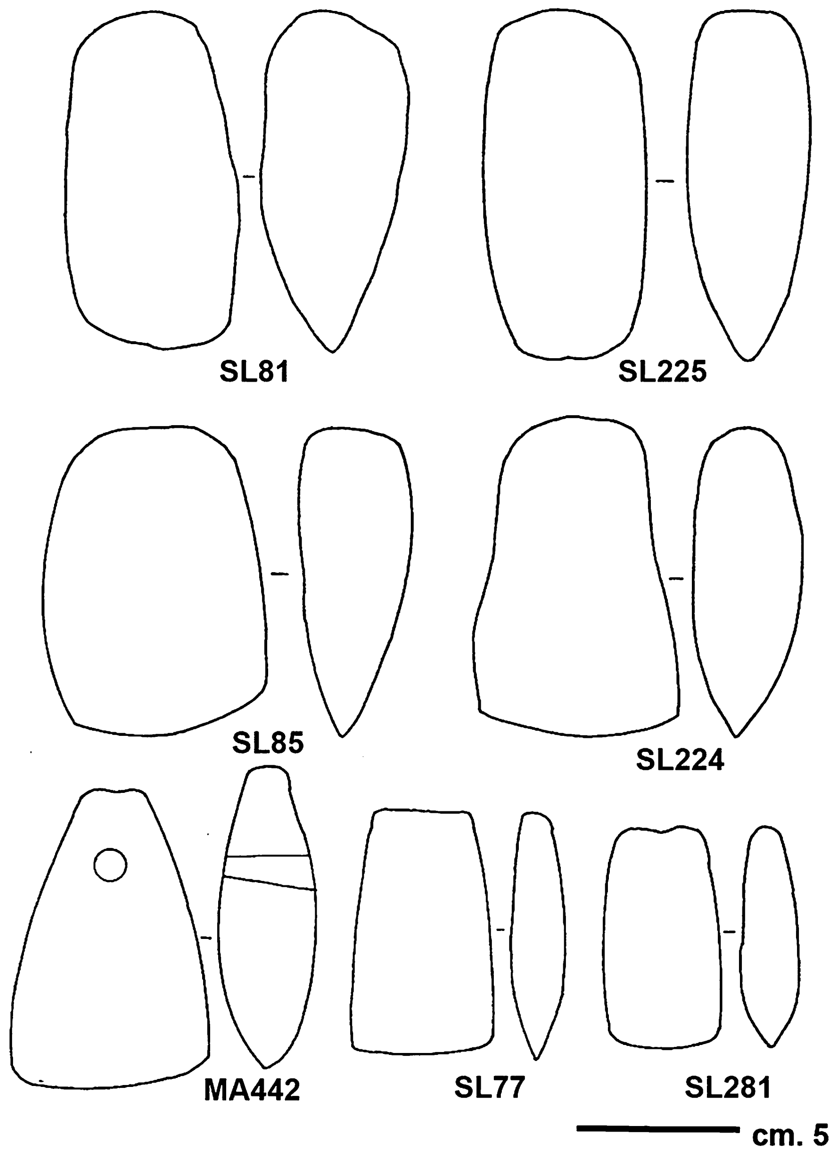

Table 1 Tool typology

Typology	Number	%
Perforated axe-hammers	85 (*31*)	40.9
Grooved axe-hammers	7 (*5*)	3.4
Axes	28 (*13*)	13.5
Adzes	24 (*16*)	11.5
Perforated mace-heads (one in form of ring)	6	3.0
Grooved mallet	4	1.9
Ornaments	4	1.9
Polishers	5	2.4
Strikers	7	3.4
Debitage flakes	34	16.3
Various	4	1.9
Total	208	100.0

In column 2: in italics between brackets: number of complete axes

tool shows some morphotypological affinities with the axe-hammers from Fontanile and Guardistallo (Tuscany) (Schiff Giorgini 1915) and with another one from the necropolis of Ponte San Pietro, near Viterbo (Lazio) (Miari 1993; Rendini et al. 2001). The diffusion of similar instruments in the Monte Romano-Romagna Apennines (upper Lamone and Senio valley) was mentioned by Bentini (1990), referring to a tool from the burial n.1 of the Rinaldone necropolis, attributed to a “not final phase” of the Copper Age (Dolfini 2004).

2.2 Perforated mace-heads

This typology of tools is rare in the Copper Age contexts of the whole Emilia-Romagna region and here it includes only five examples (SL86, SL200, SL221, SL222 and IM658), two of them complete and three fragmentary. Perforated

Table 2 Summary lithology of copper age 207 artefacts

Lithological supergroups	Lithologic groups	Finds	Repertory (SL, BO, MA, IM)
Apenninic Ophiolites	Basalts, metabasalts	20 (16 SL–4 MA)	SL17, 40, 81, 213, 225, 234, 241, 242, 255, 268, 271, 272, 273, 275, 276, 277; MA33533, 441, 450, 451
	Basaltic tufite	1 (SL)	SL229
	Magmatic breccia	1 (SL)	SL203
	Diabases	70 (62 SL–2 MA–7 IM)	SL3, 14, 15, 22, 29, 30, 55, 56, 80, 84, 106,108, 112, 197, 198, 200, 202, 206, 215, 216, 224, 227, 228, 230, 232, 235, 237, 240, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 256, 257,258, 259, 260, 261, 262,263, 264, 265, 266, 267, 269, 270, 274, 278, 279, 280, 281, 282, 284; MA430, 455; IM 857, 2858, 2869, 3638, 3655, 3656,3665(15, 30, 80, spilitic)
	Dolerites	41 (31 SL–6 MA–7 IM)	SL11, 13,16, 21, 23, 24, 27, 28, 34, 35, 41, 43, 68, 69, 70, 73, 74, 77, 82a, 83, 87, 114, 20, 207, 214, 239, 283, 287; MA412, 413, 416, 432, 433, 452; IM2859, 2861, 2862, 2864, 3653, 3654, 3659
	Basic Porphyrites	20(14 SL–1 MA–3 IM)	SL10, 12, 19, 37, 44, 50, 64, 65, 67,205, 238, 286, 288,289, 290, 291 MA442;IM2860,3657, 3664
	Gabbros, metagabbros	24 (173SL–3, 3 MA–13BO–3 IM)	SL2, 4, 18, 20. 66, 72, 75, 82b, 85,86, 88, 89, 110, 199, 209, 211, 220; BO1; MA 414, 415, 453; IM2856, 2870, 3658
	Ca-Pyrossenite	1 (SL)	SL204.
	Serpentinite,	4 (2 SL–2 IM)	SL 95, 217; IM3666, 3667
	Steatite	3 (3 SL)	SL45, 218, 285.
Sandstones	Litharenite	4 (2 SL–2 IM)	SL36, 233; IM3630, 3663
	Siltites, Fine sandstones	3 (1 SL -2 MA)	SL76; MA454, 466
Limestones	Calcarenites	6 (5 SL–1 IM)	SL113, 221, 222, 223, 231; IM3662
	Silicic limestones	2 (2 SL)	SL208, 210
	"Nummulite" limestone	1 (SL)	SL90
Cherts	(chert, jasper, microbreccia)	3(3 SL)	SL212, 226, 236
Contact-rock	Spotted slate	1 (SL)	SL71
Green porphyry	Green porphyry	1 (IM)	IM3670[a]
HP metaophiolite	Eclogite	1 (IM)	IM3634

[a] Miniaturistic axe IMO 3670 is a porphyrite, but reasonably an extraneous "porfido verde antico" from Greece, probably from a roman villa

mace-heads are considered typical of the Rinaldone culture and all those found in the Bologna territory are ascribable to the "globular" model from the same facies (Negroni-Catacchio et al. 1992, 1993).

Sample IM658 was found in the Senio valley, near the Tuscany border, where other Eneolithic occurrences are attested (Scarani 1963; Bentini 1990). In the archaeological context of Monte Castello/Cava Filo, one perforated mace-head (SL200) was found together with some fragments of perforated triangular-shaped hammers (SL203, SL213) and to the so-called "a squame" (scale decorated) pottery (Bardella and Busi 1978). These lithic materials are comparable to those of the Rinaldone necropolis, especially to the globular mace-heads from burial n. 3, dated to the first half of the 3rd millennium BC and, in any case, not earlier than the last quarter of the 4th millennium BC (Dolfini 2004). Other Rinaldone mace-heads, made of sandstone or chert, were found isolated in Tuscany and Latium (Levi 1930; Pennacchioni and D'Ercole 1977; Di Gennaro and Pennacchioni 1988; Cocchi-Genik and Grifoni-Cremonesi 1989; Negroni-Catacchio 1993; Negroni-Catacchio et al. 1993; Amadei and Grifoni-Cremonesi 1986–1987).

Fig. 6 Some photos as examples of perforated axe-hammers (*Sl 280*, *SL228*, *SL69*, *SL198*), one perforated mace-heads (*SL86*), one axe (*SL224*), one grooved axe-hammer (*SL84*)

2.3 Perforated ring mace-head

This type of tool is only represented by a single and isolated find (SL71), deeply worn-out, with a sub-circular shape and an accurately polished hole. Direct comparison can be drawn with some isolated perforated ring mace-heads discovered in the Senio Valley, Ravenna territory (Bentini 1990), and in the surroundings of Massa Marittima, southern Tuscany (Levi 1930; Cocchi-Genik and Grifoni-Cremonesi 1989).

2.4 Grooved axe-hammers

This typology is rather rare in the eastern Po plain context. It is characterized by one groove positioned at about one-third of the tool length. In this work, seven artefacts of this type (3.4 % of total, Fig. 4: SL65, SL66, SL84, SL205 and IM2862) are analysed. One of them was clearly re-manufactured from a previous perforated axe-hammer. Similar objects are quite common in the Calabria region of southern Italy, are connected with mining exploitation (Salerno and

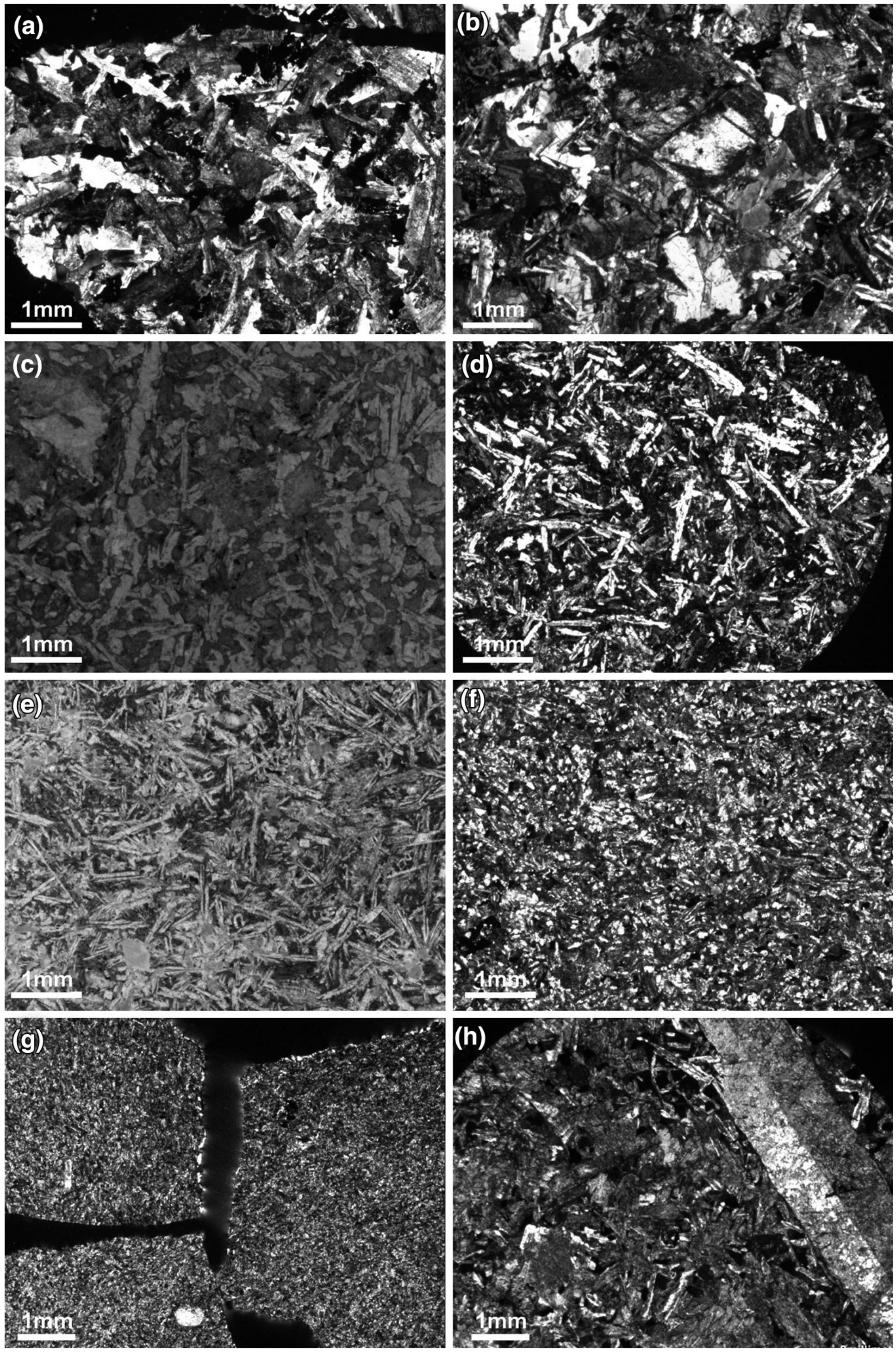

Fig. 7 Photomicrographs of examples of: **a**, **b** microgabbros (SL18 and 20); **c** dolerite (SL70); **d** diabases (SL 15); **e** spilitic diabase (SL 22); **f** basalt (SL 17); **g** oceanic metabasalt with brown hornblende and no a pyroxenes (SL 40); **h** doleritic porphyrite (SL65)

Vanzetti 2004; Salerno and Pessina 2004; Nicoletti 2004; Pacciarelli 2011), and were identified also identified in Apulia and Sicily (Bacci et al. 2003). Very similar morphological features of SL 66 were observed for the bulky tool with median continuous grove from Castellazzara-Miniera di Cornacchino, south-east of Grosseto, Tuscany (Mochi 1915; Minto 1938; Negroni-Catacchio 1988; Cocchi-Genik and Grifoni-Cremonesi 1989). Another artefact belonging to the same group is worth of note: a grooved axe-hammer discovered in the hoard of S. Lorenzo di Sebato, South Tyrol, attributed at the late Eneolithic, mid-3rd millennium BC (Lunz 1996).

2.5 Axes and adzes

Making a distinction between these two type of objects is far from easy. In the present study, axes are empirically distinguished from adzes for their larger size, thicker body and sub-rectangular-trapezoidal shape. Some axes tend to be similar to the non-perforated axe-hammers. The sum of these two types of tools reaches about 25 % (Fig. 5: SL77, SL81, SL85, SL224, SL225, SL281 and MA442). Some examples come from archaeological contexts where the so-called "a squame" (scale decorated) pottery is present (SL224 and SL281). The only example of adze (MA33533) from a funerary context was found in the Sottoroccia del Farneto site (Fantini 1959).

The here discussed axes are very akin to the models of the central Po plain, in particular to those of the Remedello, Fontanella and Volongo burial grounds (De Marinis 1992, 1996), for their sub-trapezoidal-rectangular standard shape and size.

Axe MA442 is a remarkable item because of its perforation near the butt (Fig. 5). Similar artefacts were found near Sassello, Liguria (Rossi 1992, 1996), in the site of Castelbadia, S. Lorenzo di Sebato, South Tyrol, dated to the late Copper Age, mid-3rd millennium BC (Lunz 1996), and in the Rinaldone necropolis, burial n. 2 attributed to the late 3rd millennium BC, partly coinciding to the diffusion of the Bell-Beaker culture (Dolfini 2004). Further items which are worth mentioning are three miniaturized hachettes (SL64, SL106 and SL220), two of which overpolished.

2.6 Grooved mallets, ornaments, strikers, polishers, debitage materials and various materials

All four grooved mallets are complete but worn-out on their outer parts; two of them are sub-spherical and grooved at one-third of their body, the other two are ovoid with a median groove and enlarged extremities (Fig. 4: SL88, IM2861).

Ornaments represent an heterogeneous group, including one drilling cylinder from a perforated axe-hammer which was later itself perforated (a pendant?), one steatite-fragmented necklace element, one sub-rectangular object, one disc with a hole.

Strikers are represented by seven pebbles [Table ESM1 (Online Resource 1)] reduced to sub-spherical or ovoid shape by a long-term usage.

Polishers include five pebbles [Table ESM1 (Online Resource 1)] reduced to sub-cubic-rounded shape and with strongly polished faces.

Thirty-four elements attributed to debitage [Table ESM1 (Online Resource 1)], consist of both flakes and pebbles with negatives of one or more removals (cores). High concentrations of working waste in a restricted area suggest the existence of small manufacturing atéliers.

Other materials, consisting in one perforation cylinder, two pebbles with lateral narrowing, one miniaturized triangular tool [Table ESM1 (Online Resource 1)], were also analysed in this study.

All mentioned instruments from other localities cited in this chapter are made of local or regional rocks of various nature. Some of them may belong to LP-ophiolite stones (e.g. several Tuscan and Ligurian stones), many others are instead made from limestones, sandstones, plutonic or metamorphic rocks etc.

3 Petrography and typology of the studied Copper Age artefacts

3.1 The artefact assemblages

Most artefacts are made of Apennine magmatic ophiolitic rocks, such as basalts, diabases, dolerites, gabbros, often variously affected by low-pressure semi-metamorphic to low-grade metamorphism [Table 2 summarizes the lithological assemblages, more extensively listed in Table ESM1 (Online Resource 1)]. Basaltic porphyrites (defined by abundant conspicuous phenocrysts in a basaltic diabasic or doleritic matrix) are less frequent. A few different ultrabasic Apennine ophiolites, precisely four serpentinites, three steatites and one Ca-pyroxenite are also present.

Non-ophiolitic lithologies are relatively few (about 10 %) and include siliclastic sandstones, calcarenites, limestones, siliceous rocks and one-spotted slate.

The ophiolitic lithologies can be attributed to the Apenninic ophiolitic bodies, which crop out as medium-size to very small bodies in the mountains and hills south of the area between Bologna and Imola, whereas more abundant and larger bodies crop out in many areas of the Apenninic chain in Western Emilia and Eastern Liguria. The first provenance interpretation obviously points to the same Bologna-Imola territory, where ophiolitic detritus is abundant. Samples of such detritus were collected for comparison, resulting lithologically akin to the artefact stones.

In the following Sect. 3.2 a short introduction to the Apennine ophiolitic rocks is given, in order to offer a correct basis to the essential lithological descriptions of the ophiolitic artefacts treated in Sect. 3.3, whereas the other lithologies are considered in Sect. 3.4.

3.2 Synthesis of the petrographic nature of the Apennine ophiolites

The Apennine ophiolite complexes are made of low-pressure ophiolites markedly different from the high-pressure metaophiolites diffusely used during the Neolithic period (e.g. D'Amico et al. 2013) and represent the remnants of an ancient (Jurassic) ocean floor. They widely crop out in the Northern Apennine (central to western Emilia and Liguria), in Tyrrhenian Tuscany and in the Southern Apennine (the latter partly affected by moderately high-pressure metamorphism), locally with a sedimentary cover of jaspers and pelagic limestone levels. Ophiolitic rock masses, ranging from a few metres—or less—to many hundreds metres or kilometres, are tectonically enclosed and fragmented, together with other rock bodies (limestones, sandstones etc.), within the chaotic mélange of the Ligurian Nappe, formerly "Argille Scagliose". They are formed by basic magmatic rocks, locally accompanied by ultrabasic rocks, in particular serpentinites with residual peridotites and pyroxenites. All of them are usually and diffusely altered into secondary minerals by low-pressure metamorphic/hydrothermal transformations of various types.

Based on grain size and texture, basic magmatic rocks are classified as basalts, diabases and dolerites (Biermanns 1995) as Table ESM1 (Online Resource 1), Table 2 and microphotos in Fig. 7 clearly show, from the finest-grained interlaced textures of the basalts to the medium coarse-grained dolerites, in turn grading to coarser or diversely textured gabbros of various grain size. All transitions from aphyric to porphyritic textures occur.

These four lithologies are different products of the same basaltic magmatic melt, as a result of (1) rapid chilling of surface lavas (basalts), (2) slower chilling of minor subvolcanic magma bodies and dykes (diabases and dolerites), or (3) variable degrees of slow solidification of magma intruded at shallow depth under the ancient oceanic surface (gabbros). Numerous transitions among these rock types are present [e.g. Table ESM1 (Online Resource 1)], but their detailed distinction hardly has any archaeometric significance because this entire petrologic suite is genetically related and provides coherent indications as to provenance and archaeological interpretation.

All these rocks are primarily composed of high-temperature labradorite plagioclases, augite, magnetite/ilmenite, and occasionally subordinated orthopyroxenes, olivine and other minerals. Such mineral paragenesis is usually more or less strongly substituted with low temperature–low-pressure metamorphic/hydrothermal minerals.

A first transformation of pyroxenes into brown or green brownish hornblende is typical of the oceanic deep phase (oceanic metamorphism) followed in time by neoformation of green hornblende, actinolite, tremolite, chlorite, albite, fine aggregates of saussurite, epidotes, zeolites, titanite, pyrite, haematite and locally rare minerals.

During these transformations the primary magmatic texture is usually maintained, with various relics of its minerals (labradorite, pyroxenes etc.). Rare is a complete alteration leading to a strongly deformed or confuse texture accompanied by some rare neo-minerals (see D'Amico and Felice 1989, 69–78, for simplified descriptive notes).

Among the Apenninic ophiolites ultrabasic rocks such as serpentinites, peridotites, pyroxenites and related rocks may be present, locally giving rise to huge bodies, in particular serpentinites. Peridotites and pyroxenites have a very minor archaeometric interest. Because of their low hardness, serpentinites and—to a larger extent—the genetically linked soapstones are suited for polishing and ornamentals aims. In some regions, however, e.g. in *"Caput Adriae"* (NE Italy and Slovenia; e.g. D'Amico et al. 1996, 2001; Bernardini et al. 2011) serpentinites were widely exploited also for manufacturing hammer axes.

All ophiolites derive from old oceanic floor overprinted by later geodynamic events: subduction (i.e. the progressive deepening of oceanic lithosphere within the mantle) produces HP-metaophiolites, whereas obduction (i.e. the emplacement of oceanic lithosphere onto a continental margin) produces LP-ophiolites. Such different processes can cause the emplacement of different ophiolitic complexes in relatively close geographic sectors. For example, in Italy the Western Alps are characterized by HP-metaophiolites (greenstones: eclogites, jades etc.), whereas the Northern Apennine feature LP-ophiolites (basalts to gabbros). Serpentinites may belong to both situations. The two different processes gave rise to different aestethic and functional products, as well as to chronologically distinct exploitation, such as the fine to splendid greenstone artefacts in the Neolithic and the rather rough axe-hammer in the Copper and Bronze ages.

3.3 Ophiolite lithologies of the studied artefacts

One hundred seventy-seven Eneolithic finds out of two hundred seven (85 % of the studied samples) are made of LP-ophiolites (Table 2) in the range gabbro—dolerite—diabase—basalt-basic porphyrites, and only eight of ultramafic rocks (four serpentinites, three steatites and one Ca-pyroxenite).

Sixty-five LP-ophiolitic artefacts [upper part of Table ESM1 (Online Resource 1)] were studied in thin section, most of them with XRPD and several through bulk chemical analysis (Table 3). All other artefacts, usually easy to recognize anyway, underwent naked eye, lens and/or surface microscopy examinations. Their identification may be considered confidently certain, within the limit of

Table 3 Schematic bulk chemical compositional range of Apennine ophiolite tools from S. Lazzaro (Casadei 1997)

Lithology	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
4 Gabbros	45.5–56.1	0.1–1.9	17.2–19.3	4.9–9.1	0.1–0.1	4.2–9.5	6.4–10.0	0.9–3.0	0.6–1.9	0.0–0.3	2.6–5.8
5 Dolerites	50.3–52.1	1.0–1.4	15.9–17.1	8.4–9.3	0.2–0.2	6.1–7.7	8.8–9.7	2.0–4.1	0.2–0.5	0.1–0.2	2.4–3.1
7 Diabases	47.0–51.4	0.9–1.2	16.3–19.9	6.8–9.0	0.1–0.2	6.0–12.6	7.6–9.0	2.1–3.8	0.2–0.5	0.1–0.2	1.5–4.2
1 Metabasalt	56.2	1.7	14.4	10.4	0.2	4.9	6.3	2.2	0.2	0.1	3.6

Lithology	V	Cr	Co	Ni	Rb	Sr	Y	Zr	Nb	Ba	La	Ce
4 Gabbros	42–13	30–332	28–48	15–289	4–69	355–1057	24–36	0–229	1–9	66–916	3–26	7–56
5 Dolerites	204–245	232–331	38–44	116–158	2–7	183–275	24–36	86–122	1–3	4–86	0–10	7–16
7 Diabases	15 230	237–363	29 4	90–199	0–12	196–365	20–31	81–125	2–3	12–76	0–7	5–20
1 Metabasalt	265	326	46	149	7	305	61	209	5	408	4	22

Major and trace elements expressed as weight % and ppm, respectively

an archaeometric examination and considering their transitional nature [Sect. 3.2 and Table ESM1 (Online Resource 1)].

The twenty-three gabbros are heterogeneous. Their texture may grade from rare medium-grained to prevalent fine-grained microgabbros (Fig. 7a, b), whereas the geologically well-known coarse-grained "euphotides" are lacking. A number of fine-grained gabbros may grade towards dolerites if having a partly intersertal texture. Only few of them are true metagabbros, very rich in brown hornblende and/or stretched into a flaser texture. Primary magmatic minerals are whitish labradorite plagioclases and dark augitic pyroxenes in about similar quantity (40–45 %) or less frequently with plagioclases > pyroxenes (e.g. leucogabbros). Other minerals include magnetite, ilmenite, apatite, zircon, orthopyroxenes and altered olivine. Primary components are variously, often strongly, altered to secondary metamorphic hydrated minerals. Plagioclases are partially or completely filled with "saussurite", a fine to submicroscopic mixture of albite, sericite and other components and locally with individual albite. Various amphiboles (hornblende, actinolite and tremolite), in minor part chlorites, serpentine, titanite, etc., substitute pyroxenes (tremolite also from olivine). Brown hornblende (sometimes grading to green) is present in a few samples (metagabbros, metabasalts etc.) and is attributed to oceanic metamorphic events, very evident in the deformed SL 66 and 86 tools but absent or scarce in the other samples. Other much more abundant amphiboles represent alteration products in the continental tectonic phases; when very abundant, they make the stone green in colour. The distribution of secondary minerals may vary on every scale. Other minerals, like quartz or chalcedony fillings, are rare.

The forty-four dolerites show medium-grained intersertal-ophitic texture (Fig. 7c), not rarely grading to finer-grained diabases, or to coarser-grained microgabbros. They may show variable degrees of porphyritic textures, often with millimetric plagioclase phenocrysts, or be aphyric, rarely displaying a rather confused alteration texture. Tectonic deformations are practically absent in this group. The mineralogical association is very similar to gabbros. The relics of primary minerals labradorite (locally zoned) and augite (and very rarely orthopyroxenes) are more abundant than in the gabbros. A few tremolite+chlorite aggregates are probably olivine pseudomorphs. Opaque minerals are usually abundant but may also be practically absent in a few cases.

The seventy diabases (Fig. 7d, e) have texture similar to dolerites, with a finer grain size but also rather frequently gradational. They also are mostly porphyritic with millimetric plagioclase phenocrysts, or more rarely aphyric. Primary and secondary mineralogy is quite similar to dolerites, except for the presence, among the studied specimens, of three spilitic diabases (SL15, SL30, SL80) very rich in individual albite instead of saussurite. These features are recognizable only in thin section and therefore other spilitized specimens cannot be excluded among the diabases microscopically not examined.

The twenty-one basalts (Fig. 7f, g) display both aphyric and porphyritic textures within a finer-grained intersertal-ophitic matrix, diffusely altered (more than dolerites and diabases) up to confused fine-grained alteration aggregates, poor or lacking in primary minerals. Albite is more abundant than in previous groups, revealing a spilitic tendency; epidotes, prehnite and possibly zeolites were XRD detected. Tool SL40 is a typical oceanic metabasalt rich in brown hornblende.

Twenty artefacts are made of basic porphyrites, with a groundmass grading from basaltic to doleritic. The strong porphyricity (Fig. 7h) differentiates these stones from the preceding groups, although the possibility exists of minor gradation. They are characterized by abundant plagioclase phenocrysts (almost 20 %) up to one centimetre long and more or less irregularly distributed. They have a look rather similar to the Greek classic "porfido verde antico", save the whitish and not green colour of the phenocrysts.

Similar lithologies are poorly known among the Apenninic ophiolites, as ascertained by consulting a number of specialists. In Val Cecina (Tyrrhenian Tuscany) dykes of similar rocks are present but unfortunately not published (R. Tribuzio, Pavia Univ., pers. comm.). Such basic porphyrites were formerly unknown in the Bologna Apennine bodies. However, a relatively abundant number of these lithologies was found by one of the authors (G.N.) in some detrital deposits along the Zena and Idice torrents. Thin-section observations confirmed that the detrital and the artefact porphyrites are very similar, with a basaltic-to-diabasic matrix or subordinately a coarser (doleritic) matrix. Two singular cases of probably rarer and/or less useable lithologies are a laminar basaltic tuffite (SL229) and a magmatic breccia (SL203).

The chemical compositional range of the ophiolites in the S. Lazzaro artefacts is reported in Table 3, a simplified list of bulk chemical data from Casadei (1997). Although far from being systematic, these chemical data represent on the whole the range of the Apennine magmatic ophiolites. Gabbros are rather heterogeneous along a modest differentiation line evidenced by the Fe/Mg ratio, including leucogabbros and metagabbros, probably complicated by intense alteration. On the contrary, the dolerite group appear very homogeneous. Among diabases a single Mg-rich sample differs from the relatively homogeneous intermediate geochemical character of the remaining assemblage. Unfortunately, no chemical data are available for the spilitic samples. The single metabasalt is somewhat less basic and enriched in Fe, representing a differentiate analogous to a gabbro sample and therefore probably not representative of the entire line of the basalts. Basic porphyrites were not analysed. On the whole the chemical dataset is coherent with the known compositional range of the LP-ophiolitic outcrops.

Four serpentinites, three steatites and one pyroxenite complete the ophiolites assemblage.

The only pyroxenite (SL204) is rare both among artefacts and within geological bodies. For its technical features, it was exploited similarly to a compact gabbro.

Among serpentinites only SL95 was analysed in thin section and XRD. It has a common middle- to fine-grained felty serpentine texture, relatively abundant magnetite and no relics. The other two serpentinites (SL217 and IM3666) have a similar look. IM3667 appears rather different, but was not studied in thin section. Contrary to the situation in outcrop, serpentinites are scarce with respect to basic magmatites among the tool assemblages. The reason for this is their softness, which make them good manufacturing material for burnishers or polishers but not so suitable for making axes.

The three steatites have rather different look, as it is common in nature. Only the ornamental ring SL 45, grey-beige with black spots, was analysed. It has a felty texture of talc $\gg$ chlorite and serpentine, crossed by chlorite diablasts and spotted with magnesite holoblasts and minor magnetite grains. The more homogeneous steatite fragment SL218 and the vagus SL 285 are brighter and probably richer in talc.

3.4 Non-ophiolitic lithologies

The twenty-one artefacts (15 %) manufactured with non-ophiolitic lithologies are eleven hammer axes, complete or fragmented (SL36, SL113, SL208,SL223, SL231, SL236, MA454, MA466, IM3630,IM 3662 and IM3663), four grooved tools (SL90, SL210, SL210bis and SL221), two adzes (SL76 and SL212), one more or less complete axe (SL226), one ring mace-head (SL71), one perforated mace-head (SL222) and one Greek green porphyry (IM3670). Only four of them were studied in thin section and XRD, and the following lithologies were recognised, whereas the other ones was only examinated through naked eye, lens and surface microscope.

- One litharenite, texturally immature, rather rich in mono- and poly-crystalline quartz, feldspars, slate lithoclasts (foliated and oriented siltstones and argillites), chert, felsites, within a siliciclastic matrix; a carbonate component is missing (tool SL36 axe-hammer fragmented).
- A silicic limestones, very fine hybrid (i.e. with both siliciclastic and carbonate framework grains) arenite, rich in turbid micritic grains, echinoderms and foraminifera bioclasts with sparitic calcite, rhombohedral dolomite, quartz, feldspar and white micas, some framboidal pyrite, a few glauconite grains (tool SL90 grooved tool). The microfossils in tool SL90 have a Late Palaeocene-Middle Eocene age, whereas the other silicic limestones macroscopically examined are Upper Jurassic in age.
- A Biocalcarenitic limestone, very massive, rich in micrite with minor sparitic cement (tool SL113—hammer axe butt). Mio-Pliocene planktonic foraminifera are associated with coastal benthic species. Biotic components (bryozoans, globigerinids, orbulinids, echinoderms and melobesiae algae) suggest paleoenvironments generally related to an open carbonate platform.
- One-spotted slate, low-grade contact-metamorphic, very fine-grained to aphanitic, maculated, with several small-to-medium neoblasts of muscovite, biotite, albite, andalusite, quartz and opaque minerals (samples SL71—ring perforated mace-head).

By considering all artefacts, the following groups may be distinguished, on the basis of a probable or possible geological attribution. SL113, SL221, SL222, SL223 and SL231 are siliciclastic- and microfossil-bearing calcarenites, probably attributable to the Miocene Bismantova Formation. The same assignment can be proposed for the artefacts MA454, MA466 and IM3662, as well as for MA254 and MA466, tentatively attributable to the finest-grained levels of the same formation.

SL208, SL210, SL210bis and SL223 are ascribable to the Upper Jurassic silicic limestones of the Tuscan nappe. SL90 could possibly derive from the Eocene "Calcari a nummuliti" of the same Tuscan nappe.

SL36, IM3630, IM3683 and possibly SL229 could be tentatively attributed to the Oligocene Macigno Formation. SL236 is a microbreccia, likely from the base of the same Macigno Formation.

SL76 complete adze is made of "ftanite", an impure chert common in the Apennines.

SL226 is possibly an axe made of jasper, probably from the sedimentary succession overlying some ophiolite body.

The spotted slate mentioned above (SL71) is extraneous to the Apenninic domain.

IM3670, a miniaturistic axe made of «porfido verde antico» is also extraneous (Sect. 4.2).

4 Interpretation about sources and circulation of the Copper Age stones

4.1 Apenninic ophiolites

Several small- and medium-size ophiolite bodies crop out upstream of the area between Bologna and Imola, whereas detrital pebbles/cobbles/blocks from the same rocks are present and locally abundant in alluvial/fluvial deposits along the valleys and in the ancient coastal deposits along the Apennine foothills. Introductory geological references on the Apenninic ophiolites are in Bettelli et al. (2002), as well as—in greater detail—Bocchi et al. (1976), Cortesogno et al. (1977, 1982, 1992), Calanchi et al. (1987), and many papers in the journal "Ofioliti". D'Amico et al. (2000) gave preliminary information about several tools.

The presence of primary ophiolitic bodies and, more commonly, secondary detrital materials strewn in the valleys, plains and low hills of the area is a strong argument in favour of a relatively local provenance. However, literature data (*op. cit.*) indicate that similar lithologies are much more abundant in the central-western Emilia and eastern Liguria Apennines and in Tyrrhenian Tuscany. Importation from some of these areas cannot be excluded a priori, although it seems logistically improbable for the bulk of the artefacts, but possible for singular cases, at least for the tools having the very specific Tuscan-Latial morphotypology (Sect. 4.3).

In conclusion, it seems strongly likely that most artefact stones were collected within the Apenninic watershed in the areas of Bologna and Imola, in particular in the area around S. Lazzaro di Savena. Minor importation from Tuscany-Latium are proved by archaeological data and this makes possible, but at the moment undemonstrable, that other tools of standard morphologies may have the same provenance.

Basic porphyrites, very rare in the entire Apennine, represent a special case. The only known occurrence of porphyritic basaltic dykes rich in large plagioclase phenocrysts—extraordinarily similar to some of those examined here—is from Val Cecina, Tuscany (R. Tribuzio, Pavia, pers. comm.). The possible importation from Tuscany, supported by the presence of a few artefacts (Sect. 4.3) peculiar of the Rinaldone culture of Tyrrhenian Tuscany-Latium, was taken into serious consideration during this study until one of the authors (G.N.) discovered a number of pebbles, cobbles and blocks of basic porphyrites along the Zena and Idice creeks, not far from S. Lazzaro di Savena. Primary bodies of these basic porphyrites are yet unknown in the literature. We hypothesize that the original outcrops of basic porphyrites have probably been completely dismembered by the inner dynamics of the "*Argille Scagliose*" Ligurian Units or by the recent geological surface evolution, leaving behind only detrital remains.

4.2 Other lithologies

Some formational provenance interpretations of a number of sedimentary tools have been suggested in Sect. 3.4. In general, a local or nearby provenance may be proposed also for the sedimentary lithologies, taking also in account two interpretative variants. First, it must be taken into account that the "*Argille Scagliose Unit*" bear or include many fragmented portions of its sedimentary cover as well as of other detrital deposits. Second, the Plio-Pleistocene conglomerates and the Holocene fluvial/alluvial deposits of the Apenninic foothills recycled practically all older formations, thus becoming local sources of pebbles and cobbles of various rock types for manufacturing artefacts.

It cannot be completely excluded, being however indemonstrable, that some lithologies may have been imported, anyway from nearby areas. An example is given by the silicic limestones, ascribable to the Upper Jurassic limestones of the Tuscan nappe and the Eocene "Calcari a nummuliti" of the same nappe.

Only the spotted slate SL71 is completely out of the context and its provenance is un-interpretable, being this rock type is completely extraneous to any Apenninic lithology, without excluding, however, a casual presence of similar unusual lithology, within the chaotic *Argille Scagliose* formation, or again within the ancient coastal deposits of the Po plain detrital pebbles.

Peculiar is the miniaturistic axe IM3670, made with a typical *porfido verde antico* (intensely green, with lighter full-green phenocrysts), found in the fields near Dozza. In the absence of similar findings, a Greek Copper Age importation is not reasonable. A provenance from some Roman villas, known in that territory, as testimonial of a collection culture of prehistoric finds in Roman times, similarly to the cases described in an Hellenistic—Roman context by Leighton (1989) in Sicily, seems more probable.

Relationships between lithology and morphotypology features are shown in Table 4.

4.3 The few references to the archaeological context

Table 5 presents some essential information about the sites of origin of the here discussed polished tools, mainly perforated axe-hammers, axes and adzes, found together with ceramics and knapped stone artefacts. The context of Viale Cavina (Bologna) is very significant. There bowls with straight rounded rim and other fragments of pottery with nail impress or scale ("*a squame*") decoration have been found together with one rectangular adze with a slightly concave butt (Fig. 5: SL281). This site shows precise cultural reference to the nearby Copper Age structure of Cava Due Madonne (Bologna territory), which has yielded several working wastes from the shaping out of polished tools. Radiocarbon dated it at R 720 4640 ± 50 BP (not calibrated date: Alessio et al. 1976; Bardella et al. 1980).

The site of Monte Castello/Cava Filo is particularly interesting because of the presence of one perforated mace-head (SL200) typical of the Rinaldone culture, together with perforated triangular-shaped axe-hammers (SL203, SL213) and pottery with a straight rim and an underlying impressed or "*a squame*" (scale) decoration. Equally interesting is the axe-hammer from Bologna/via Ugo Bassi (BO1) showing an enlargement of the body around the shaft hole. This context further confirms the penetration of elements typical of the Rinaldone tradition in the local Eneolithic substratum. The only evidence ascribable to a burial context is the adze (MA33533) from Sottoroccia del Farneto, a collective burial in a cave (so-called "*a grotticella*" typology), generally ascribable to the final phase of the Copper Age.

Finally, areas with very high concentrations of evidence on the surface (e.g., podere Riola in the Bologna territory) and historical collections (Monte Castellaccio—Imola) (Scarabelli 1877; Mengoli 1996) are rich in materials of clear Copper Age typology (foliates, bifacial harrowheads and scale-decorated pottery) and polished tools, so that the latter can be considered as belonging to this same Period.

5 Conclusions

In the area between Bologna and Imola Apenninic LP-ophiolites (gabbros, dolerites, diabases, basalts and basic porphyrites, a few serpentinites, soapstones and one pyroxenite) are dominant over sedimentary lithologies (limestones, calcarenites, sandstones, silicic rocks and one-spotted slate) for manufacturing Copper (to Bronze) Age tools, prevalently perforated hammer axes, axes/adzes, mace-heads and other minor tools, accompanied by debitage elements.

The basic and ultramafic lithologies have their source from a LP-ophiolite geological units, dismembered into bodies of extremely variable size, included within a chaotic geological unit (*Liguride Unit* or *Argille Scagliose*) together with a number of other lithologies also coming by dismembering of geological formations of similar or younger age during a prolonged tectonic transport.

The original magmatic rock textures were mostly maintained despite variable degrees of diffuse mineral alteration. Such hydrothermal or low-grade metamorphic alterations are trivial from an archaeometric point of view because all lithologies belong to the same geological complex, and thus provide, in spite of their variety, the same provenance information.

The Apennine sector south of the Bologna-Imola area is rich in LP-ophiolites, both in the tectonic mélange of the *Argille Scagliose* and in sedimentary deposits along valleys and plains. The raw material provenance may be thus considered local or from not too far sources. Similarly for most of the less abundant tools manufactured with sedimentary lithologies.

However, the interdisciplinary collaboration of archaeology and archaeometry reveals its potentiality also in this case, as shown by the result of crossing petro-archaeometric data with morphotypological features of some of the artefacts. Most artefacts belong to a unitarian ample phenomenon of cultural model circulation from the Marche region (where only sedimentary lithologies were exploited) to the eastern Po Plain and sub-Apennine region, where more resistant ophiolite lithologies were exploited, as shown by the present study. This implies an evident selection of more suited raw materials.

Rather similar morphotypological characters—hammer axes with a triangular or elongated triangular shape and squared or rounded butt—are shown by many artefacts in the *Caput Adriae* region (NE Italy and Slovenia), where very different lithologies—such as Alpine serpentinites, basic metamorphics and some acid volcanic rocks—were

Table 4 Typology vs. lithology of the Copper Age instruments

Perforated hammer axes 84

Gabbros, basalts		Dolerites		Diabases		Others	
Gabbros and connected 14		Dolerites 28		Diabases 25		Serpentinites 2	
SL2	Fragment	SL12	Fragment	SL3	Fragment	IM3666	Fragment
SL75	Fragment	SL20	Fragment	SL10	Fragment	IM3667	Fragment
SL82b	Fragment	SL21	Complete	SL14	Fragment		
SL203	Fragment	SL23	Fragment	SL15	Fragment	Sandstones and limestones 10	
SL204	Complete	SL34	Fragment	SL16	Fragment	SL36 (litharenite)	Cutting edge
SL241	Fragment	SL37	Fragment	SL22	Fragment	SL113 (biocalcarenite)	Butt
SL242	Fragment	SL41	Fragment	SL29	Fragment	SL223 (Qtz-calcarenite)	Fragment
BO1	Fragment	SL68	Fragment	SL30	Fragment	SL231 (calcarenite)	Fragment
MA451	Complete	SL69	Complete	SL55	Complete	SL233 (sandstone)	Fragment
MA453	Fragment	SL70	Fragment	SL56	Fragment	MA454 (siltite)	Fragment
IM2856	Fragment	SL82a	Fragment	SL197	Complete	MA466 (sandstone)	Fragment
IM2860	Unfinished	SL83	Complete	SL198	Complete	IM3630 (sandstone)	Complete
IM3657	Complete	SL201	Fragmen	SL202	Fragment	IM3662 (calcarenite)	Complete
IM3664	Fragment	SL238	Fragment	SL227	Complete	IM3663 (sandstone)	Complete
		SL239	Fragment	SL228	Complete		
		SL283	Complete	SL230	Complete		
Basalt s 4		SL287	Complete	SL232	Fragment	Polygenic chert microbreccia 1	
SL208	Fragment	MA412	Complete	SL235	Fragment	SL236	Cutting edge
SL213	Fragment	MA413	Complete	SL240	Fragment		
SL229	Complete	MA414	Complete	SL280	Complete		
SL234	Fragment	MA415	Fragment	MA455	Complete		
		MA416	Fragment	IM2857	Fragment		
		MA432	Fragment	IM2858	Fragment		
		MA433	Complete	IM3655	Complete		
		MA452	Complete	IM3656	Complete		
		IM2859	Fragment				
		IM3654	Complete				

Perforated mace-heads 6

Gabbros, basalts		Dolerites		Diabases		Others	
Gabbros 2		Dolerites 0		Diabases 1		Others 3	
SL 86	Complete			SL200	fragment	SL221 (calcarenite)	Fragment
IM3658	Complete					SL222 (calcarenite)	Fragment
						SL71 (spotted slate)	Complete

Grooved hammer axes and mallets 11

Gabbros, basalts		Dolerites		Diabases		Others
Gabbros 4		Dolerites 5		Diabases 2		Others 0
SL66	Complete	SL65	Complete	SL84	Complete	
SL211	Fragment	SL205	Fragment	MA430	Complete	
SL88	Complete	IM2862	Complete			
SL199	Complete	IM2864	Fragment			
		IM2861	Complete			

Axes—adzes 52

Gabbros, basalts		Dolerites		Diabases		Others	
Gabbros 5		Dolerites 14		Diabases 18		Others 7	
SL4	Fragment	SL11	Fragment	SL19	Fragment	Serpentinite 2	
SL85	Complete	SL13	Fragment	SL44	Cutting edge	SL95	Complete
SL110	Fragment	SL24	Fragment	SL64	Complete	SL217	Fragment
SL220	Complete	SL27	Fragment	SL80	Complete		
IM2870	Complete	SL35	Fragment	SL108	Fragment	Siltite 1	
		SL43	Fragment	SL206	Fragment	SL76	Complete

Table 4 continued

Axes—adzes 52

Gabbros, basalts Gabbros 5		Dolerites Dolerites 14		Diabases Diabases 18		Others Others 7	
Basalts and connected 8		SL77	Complete	SL216	Fragment		
SL81	Complete	SL87	Complete	SL224	Complete		
SL40	Fragment	SL89	Complete	SL237	Fragment	Jasper 1	
SL106	Complete	SL114	Complete	SL243	Fragment	SL226	Rough-out
SL225	Complete	SL207	Fragment	SL244	Fragment		
MA441	Complete	SL288	Complete	SL245	Fragment	Chert 1	
MA442	Complete	SL290	Fragment	SL247	Complete	SL212	Complete
MA450	Fragment	SL291	Complete	SL281	Complete		
MA33533	Complete			SL282	Fragment	"Porfido verde antico" 1	
				SL 89	Complete	IM3670	Complete
				IM2869	Fragment		
				IM3638	Complete	Eclogite 1	
						IM3634	Complete

Ornaments 4

Gabbros, basalts Gabbros, basalts 0	Dolerites Dolerites 0	Diabases Diabases 1	Others Others 3	
		SL284 complete	SL45(steatite)	Complete
			SL218(steatite)	Complete
			SL285(steatite)	Fragment

Polishers 5

Gabbros, basalts Gabbros 1		Dolerites Dolerites 2		Diabases Diabases 2		Others Others 0
SL72	Complete	SL73	Complete	SL67	Complete	
		SL74	Complete	SL246	Fragment	

Strikers 7

Gabbros, basalts Gabbros 2		Dolerites Dolerites 3		Diabases Diabases 2		Others Others 0
SL18	Fragment	SL28	Fragment	SL254	Complete	
SL209	Complete	SL50	Complete	SL215	Fragment	
		IM3653	Fragment			

Debitage flakes 34

Gabbros, basalts Basalts 9	Dolerites Dolerites 0	Diabases Diabases 25	Others Others 0
SL17, 255, 268, 271, 272, 273, 275, 276, 277		SL112, 248, 249, 250, 251, 252, 253, 254, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 269, 270, 274, 278, 279, 286	

Various 4

Gabbros, basalts Gabbros, basalts 0	Dolerites Dolerites 1	Diabases Diabases 1	Others Others 2			
	SL214	Completeminia-uristic triangular tool	IM3665	Complete boring cylinder	SL90 (limestone) Grooved tool from a pebble	Complete
					SL210 (silicic limestone) Grooved tool from a pebble	Complete

Table 5 Polished tools from the Bologna territory found in a demonstrated Copper Age contexts together with "a squame" pottery" (scales decoration)

Inventory	Site	Typology	Lithology	References
BO1	Via Ugo Bassi (Bologna)	Perforated axe-hammer, fragment	Gabbro	Morico and Steffè 1998
SL203	Monte Castello/Cava Filo (S. Lazzaro)	Perforated axe-hammer, fragments	Magmatic breccia	Bardella and Busi (1978)
SL213			Basalt-diabase	
SL200		Mace-head ring, fragment	Diabase-dolerite	
SL254	Pod. Sgalara (Pianoro)	Perforated axe-hammer, fragment	Diabase	Unpublished
SL224	Cà delle Donne (S. Lazzaro)	Axe	Diabase-dolerite	Scarani (1963)
SL281	Viale Cavina (Bologna)	Adze	Diabase	Nenzioni (1985) and De Marinis (1996)
MA33533	Farneto (S. Lazzaro)	Adze	Porphyritic basalt?	Fantini (1959), Scarani (1963, 1964)
SL44	Podere Cavedagna (S. Lazzaro)	Axe	Dibase-dolerite	Nenzioni (1985)
SL232	Prunaro di Sotto (Ozzano)	Perforated axe-hammer, distal fragment	Diabase	Unpublished

used. It seems therefore clear that cultural similarity occurred, even if no raw material exportation took place.

A second argument regards some other tools, such as the grooved axe-hammers, which are typical of Southern Italy but rare, although locally present, in Emilia and Tuscany. Such tools are quite well-represented in the Bologna-Imola area and therefore raw material importation (of non-ophiolitic stones) or a diffusion of models may be taken into consideration.

Some other instruments made of ophiolitic lithologies, e.g. a few elongated axe-hammers and globular perforated mace-heads, have many affinities with the Rinaldone Tuscan-Latial culture and may suggest: (1) material importation from the ophiolitic occurrences of Tyrrhenian Tuscany; (2) cultural diffusion of the same morphological models; or (3) a combination of the two processes.

Finally, the presence of working waste, strikers and preforms in a few strategic locations (Villa Bignami, Podere S. Andrea, Podere Riola) gives evidence of some workshop sites devoted to the manufacturing of local stones.

From the overall analysis of the archaeological data discussed in this paper it is possible to draw the following considerations:

- both the rare archaeological context (Table 5) and the areas of surface collection show the frequent associations of different polished tools—mostly perforated axe-hammers, axes and adzes—with scale-decorated (*a squame*) pottery, characterizing the local Eneolithic *facies*;
- radiocarbon dates (both published and unpublished) show how this link is already evident from a fully developed phase of the Copper Age (last centuries of the 4th—first half of the 3rd millennium BC);
- a coexistence is attested between triangular-shaped axe-hammers, particularly diffused in the Emilia-Romagna area, and the perforated mace-heads present in the Rinaldone Culture. This data are also confirmed by the rare axe-hammers whose elongated shape closely recalls that of the Rinaldonian types;
- regarding the triangular-shaped hammers of the "flat-iron" type there is not yet, in the area considered, evidence confirming the survival of such tools in the very early Bronze Age.
- the typological variability of the polished stone tools recorded in the eastern Bologna territory shows the wealth and the breadth of the contacts established by the Eneolithic communities with the different contexts and cultural milieus of the Adriatic and Central-Tyrrhenian areas.

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