

From mould to object... The metallurgists' workshops of the Late Bronze Age in Montélimar and Aubervilliers (France)

Muriel MÉLIN and Éric NÉRÉ

Abstract: Places dedicated to bronze casting are mostly revealed indirectly, through material that is often very discrete, such as fragments of moulds, crucibles or tuyères, as well as rare metal waste. These objects are generally found where they were discarded. Direct traces that would indicate the precise location where the casting took place, and the work spaces related to it, remain extremely rare.

This paper highlights two particular sites from the Late Bronze Age, "Rue Saint-Denis" at Aubervilliers in Seine-Saint-Denis and "Rue du Bouquet" at Montélimar in the Drôme. Those two sites have yielded remains related to important metallurgical activities, one thanks to the exceptional preservation of cultural layers, the other through a significant quantity of clay mould remains.

At Aubervilliers, no space dedicated to casting has been located, but evidence of casting was found in a secondary position; at Montélimar, at least one casting area has been identified through concentrations of droplets of cuprous material thanks to very well-preserved layers. At Aubervilliers, the evidence of casting consists of numerous well-preserved clay moulds, a few fragments of crucibles and of a tuyère, and small metal residues. In contrast, at Montélimar, the remains of moulds are very degraded (mostly millimetre-sized fragments). The site has yielded an interesting number of copper-alloy items, among which are numerous finished objects. Some of them were destined for remelting; some may have been used on post-casting activities (punches, a chisel...). At Montélimar, the post-casting phase is also well attested by macrolithic tools. At Aubervilliers, up to three thousand fragments of clay moulds were found; it can be established that a minimum of 120 objects were produced on site, showing a certain variety (weapons, ornaments, tools) with a specialisation in pins and chapes. On both sites, the bronzesmith's workshop was probably part of a settlement.

Finally, the comparison of these two sites accentuates how the difference in the data acquired is directly linked to the differences in preservation conditions.

Keywords: craftsmanship, metallurgy, bronze workshop, copper alloy, Late Bronze Age.

Résumé : Les sites dédiés à la fonte du bronze sont le plus souvent mis en évidence de manière indirecte, grâce à des vestiges souvent très discrets, tels que des fragments de moules, de creusets ou de tuyères, ainsi que de rares déchets métalliques. Ces objets sont généralement retrouvés là où ils ont été jetés. Les traces directes permettant de localiser précisément le lieu où la fonte a eu lieu, ainsi que les espaces de travail qui y sont liés, restent extrêmement rares.

Cet article met en lumière deux sites particuliers du Bronze final, Aubervilliers, « rue Saint-Denis », Seine-Saint-Denis, et Montélimar « rue du Bouquet », Drôme, France. Ces deux sites ont livré des vestiges liés à d'importantes activités métallurgiques, l'un grâce à la conservation exceptionnelle des niveaux archéologiques, l'autre grâce à une quantité significative de vestiges de moules en argile.

À Aubervilliers, aucun espace dédié à la fonte n'a été localisé, mais des traces ont été découvertes en position secondaire ; à Montélimar, au moins une zone de fonderie a été identifiée grâce à la concentration de gouttelettes de matière cuivreuse, identification rendue possible par des couches très bien conservées. À Aubervilliers, les témoins en lien avec la fonte consistent en de nombreux moules en argile bien conservés, quelques fragments de creusets et d'une tuyère, ainsi que de petits résidus métalliques. En revanche, à Montélimar, les restes de moules sont très dégradés (principalement des fragments de l'ordre du millimètre). Le site a livré un nombre intéressant d'objets en alliage cuivreux, parmi lesquels figurent de nombreux objets finis. Certains d'entre eux étaient destinés à la refonte ; d'autres ont peut-être été utilisés pour des activités post-fonderie (poinçons, ciseaux...). À Montélimar, la phase post-coulée est également bien attestée par des outils macrolithiques. À Aubervilliers, jusqu'à trois mille fragments de moules en argile ont été trouvés ; on peut établir qu'au moins 120 objets ont été produits sur place, présentant une certaine variété (armes, parure, outils) avec une spécialisation dans les épingles et les bouterolles. Sur les deux sites, l'atelier du bronzier faisait probablement partie d'un habitat.

Enfin, la comparaison de ces deux sites met en évidence le fait que les différences observées dans les données recueillies sont directement liées aux différences de conditions de conservation.

Mots-clés : artisanat, métallurgie, atelier de bronze, alliage de cuivre, Bronze final.

Bronze Age metallurgy is mainly approached indirectly, through the study of objects which, thanks in particular to the quantities of metal diverted to become part of hoards, allow us to understand manufacturing processes. Much less is known about the actual places of production, the metal-casting areas or the post-casting areas and their links to other archaeological structures, including settlements.

While there has been a significant increase in discoveries in France relating to Bronze Age settlements over the last twenty years, linked to development-led archaeology (Lemerrier et al., 2018), the same cannot be said for metallurgical production: it appears that those remains are particularly difficult to apprehend in the field.

CURRENT STATE OF KNOWLEDGE IN FRANCE

For a long time, the site of Fort Harrouard at Sorel-Moussel, Eure, has been the main reference site for Bronze Age metallurgy in France, as it provided numerous elements related to metallurgy: moulds, crucibles, tuyères, metal residues and even furnaces (Mohen and Bailloud, 1987). Over the last two decades the corpus of remains linked with metallurgy has grown, mainly for the Late Bronze Age period, although it is still very sporadic on each site, with remains often few in number and small in size. Apart from the sites of Montélimar and Aubervilliers presented here, other recent discoveries can be mentioned, in particular the sites of Ifs, Calvados, which have yielded a considerable number of clay mould fragments dating from the Late Bronze Age: from two pits at ‘Object’Ifs Sud’ come 593 fragments of moulds, weighing 4.4 kg (Besnard-Vauterin, 2020). Moulds used to make swords, spearheads, bracelets, among other things, were identified, representing a minimum number of individuals (MNI) of 86 objects cast on the site (Gomez de Soto in Besnard-Vauterin, 2020). In addition to those mould remains, crucible fragments (MNI = 6) and metal residues, numbering 26 including semi-finished products, were also discovered.

From slightly earlier in the Late Bronze Age than the sites of Ifs, the site of Mathieu, a BFIIIa-IIIb enclosed settlement located a dozen kilometres further north in Calvados, yielded 172 fragments of clay moulds (1.4 kg). These were used to cast weapons (swords, spearheads) and maybe tools. Other traces of metallurgy include four crucible fragments, a few metal scraps and a possible tuyère, complemented by lithic tools. These remains come from several pits and ditches (Giazzon et al., forthcoming).

While archaeological indicators of metal casting are recurrent, they remain erratic on each site and unstructured: they are essentially movable (moulds, crucibles, etc.), tenuous (even when fragments of moulds are numerous, this rarely if ever allows the restitution of complete valves) and often poorly preserved (subject to

weathering). As for metal remains like casting jets or mis-casts, they could be easily remelted and are less frequent. Thus, if fragments of moulds, of crucibles, metal residues or tuyères are regularly discovered, excavations more rarely provide a combination of all. Moreover, these are often the only clues to metalworking activity on the sites and they are mainly recovered dispersed in refuse pits, and not in a structured way. As with many other crafting activities, related archaeological structures, impacts in the ground, are extremely rare. On the other hand, lithic studies and analyses can sometimes help to determine whether casting and/or metalworking was carried out on a site, or even bring it to light where there is no mould or crucible to do so (Hamon et al. 2021; Hamon and Delgado-Raack, this volume).

Evidence of furnaces or melting hearths, and thus precise locations of the casting works, are virtually non-existent. A very recent discovery is worth mentioning: the site of Saint-Avé (Morbihan), where the remains of a furnace have been unearthed, in association with a construction on posts. The few, rare associated remains (tuyère fragments, a mould fragment) suggest that this was a bronzesmith’s furnace, as does the presence nearby of 12 copper-alloy objects grouped together in a small pit, as a hoard, which can, in this context, be considered a metal reserve (Blanchet, 2026).

The bronzesmith’s workshop therefore remains difficult to grasp in France. These observations are also valid on a wider scale, as can be seen from the European overview recently produced by B. Molloy and M. Mödinger (2020).

Two recent discoveries, which are exceptional in terms of their degree of preservation, help to explain why this production remains so elusive (Mélin and Néré, 2021). These are two Late Bronze Age sites (fig. 1): one in the Paris region, at Aubervilliers, Seine-Saint-Denis, dated to the second stage of LBA or BF IIB–IIIA (Ha A2–B1), and the other in the Rhône valley at Montélimar, Drôme, dated to BF IIA (Ha A1).

AUBERVILLIERS

Context

The site of “Rue Saint-Denis” in Aubervilliers was first revealed in 2008 by an evaluation/*diagnostic* (Caparros et al., 2010). The subsequent excavation was then carried out in 2014 over an area of around 8,000 m² by Arkemine (Mélin, 2016). Two distinct loci comprising traces of metallurgical activity were identified (Mélin et al., 2017): the one we present here is attributed to the second stage of the Late Bronze Age (ca. 1150–950 BC), possibly more precisely to the BF IIIa (Ha B1) considering the associated ceramics, while the second includes structures dated to the Late Bronze Age/Early Iron Age transition (fig. 2). These two loci with metallurgical installations seem to be directly linked to the presence in the subsoil of pockets

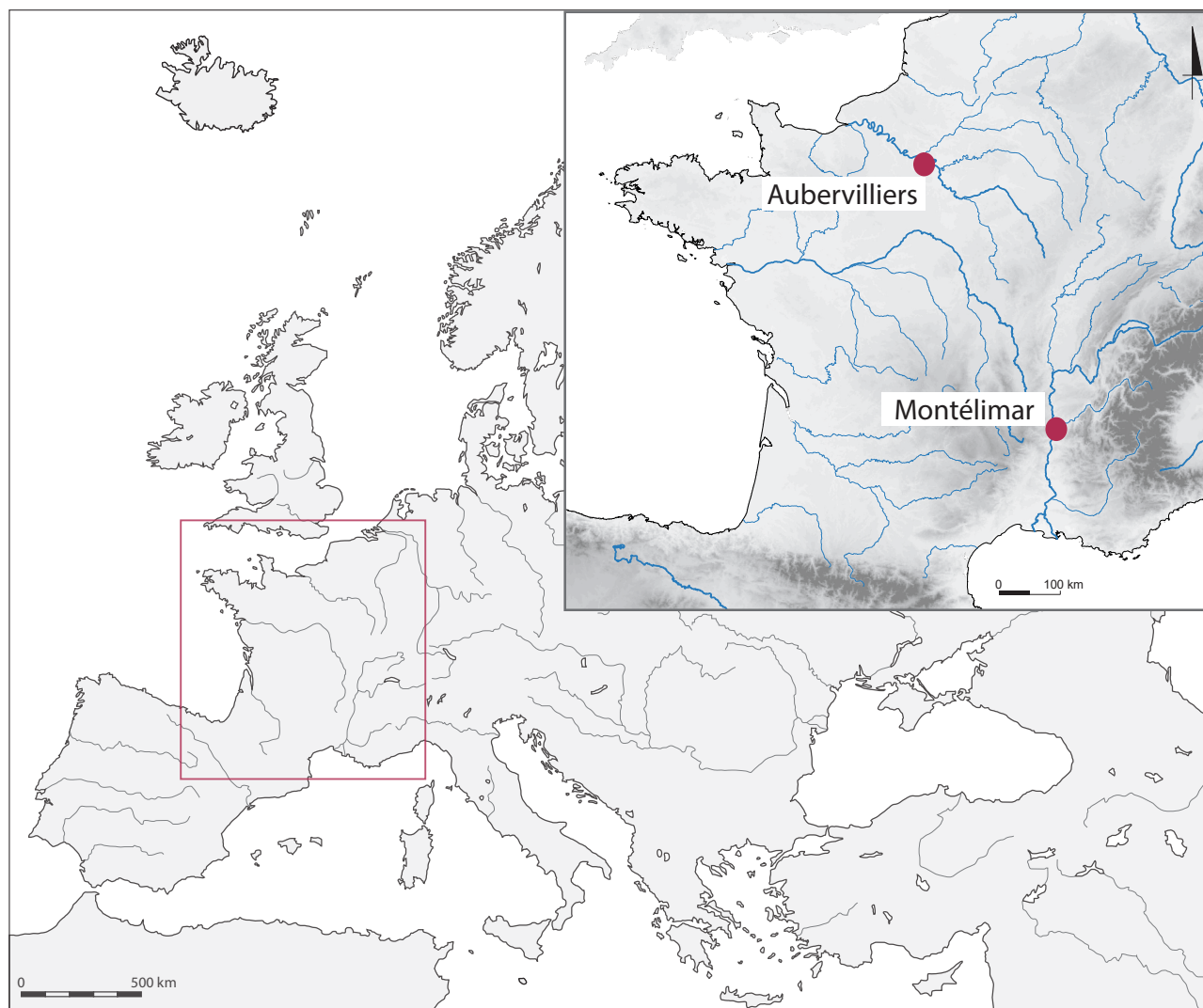


Fig. 1 – Location of the sites of Aubervilliers, “Rue Saint-Denis”, Seine-Saint-Denis, France, and Montélimar, “Rue du Bouquet”, Drôme, France (CAD M. Mélin).

of sand and clay, two constituents necessary for the manufacture of clay moulds. Tests on raw materials present on the site and petrographic analyses carried out on the moulds and crucibles point in this direction (Mélin et al., 2020).

The features

The first locus saw a great deal of metallurgical activity, as evidenced by the abundant and relatively well-preserved clay moulds, which were found discarded into pits. The typology of the metal artefacts cast on site is typical of the second stage of the Late Bronze Age.

There are no features directly linked to casting, no soil levels and no hearths or furnaces. The structures associated with the metallurgical remains are extraction pits and/or silos that have been reused as dumping grounds. Close to these are two or three small buildings on posts (one of which has been truncated by recent excavation: see fig. 2). The contemporaneity of these with the workshop, if possible, is not certain (Mélin et al., 2020).

The pits in which the evidence of metallurgical activity was found also included ceramic sherds, faunal remains common to settlement sites, fragments of lithic macro-tools and loom weights; the assemblage thus bears witness to activities other than the production of metal objects alone. The presence of four bronze objects, only one of which seems to be linked to the castings made on site (see below), a fragment of glass bead and a fragment of a lignite bracelet also illustrate other aspects of daily life and a certain status for the site.

Although the actual location of the casting place(s) is not known, the nature and concentration of the remains suggest its presence in the immediate vicinity. Traces of hearths can be particularly fleeting; at Aubervilliers, numerous modern disturbances in several places on the site easily obliterated them. The Aubervilliers workshop can therefore only be seen through the remains it left behind. These remains, linked to the foundry work carried out on the site, consist of a large number of clay mould fragments, crucibles, tuyères and metal residues.

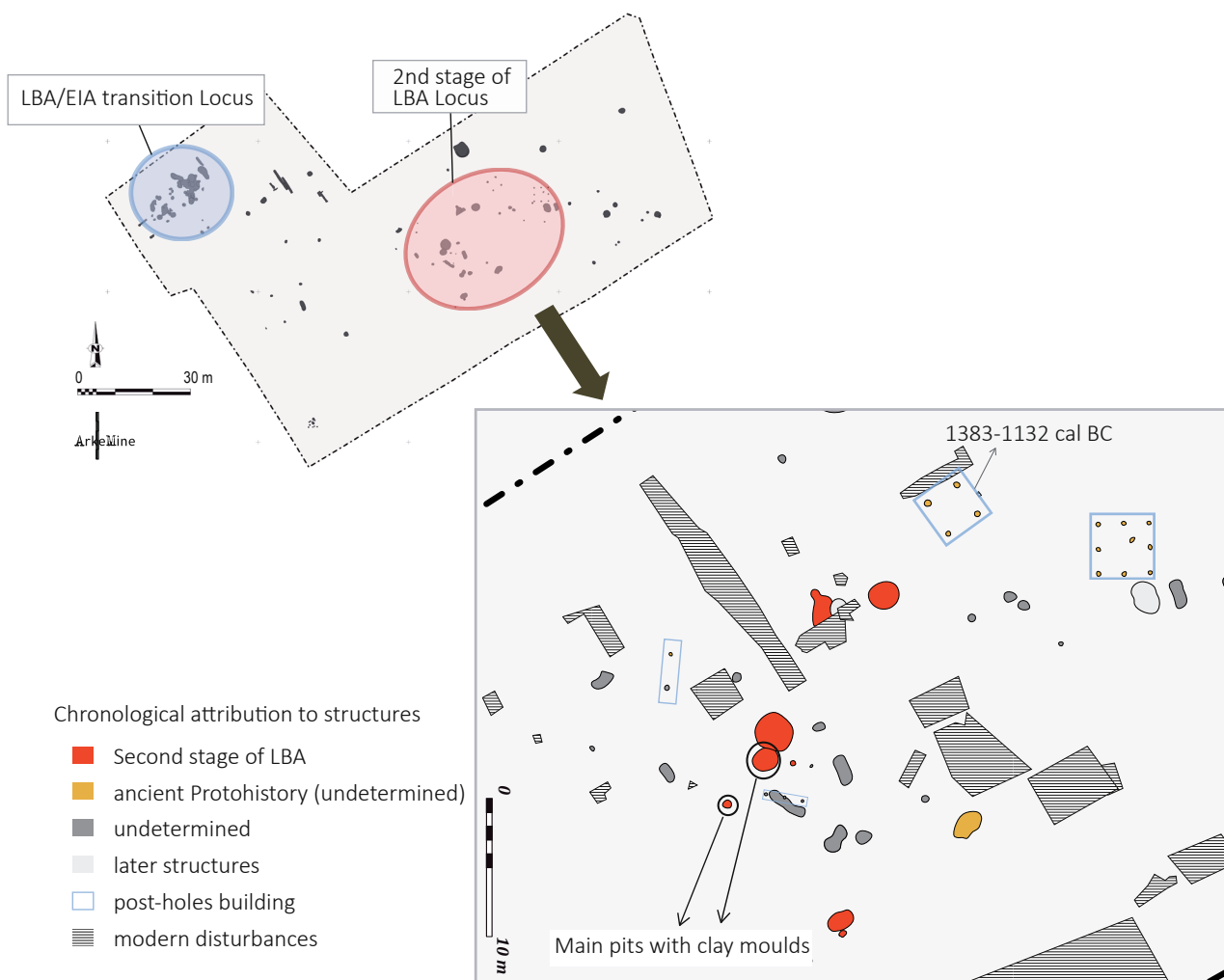


Fig. 2 – Aubervilliers, “Rue Saint-Denis”. Plan of the excavation with the two protohistoric bronze metallurgy loci. Focus on the workshop area dated to the second stage of the Late Bronze Age: French BF IIB-IIIa (CAD Arkemine and M. Mélin).

Ceramic remains

Numerous clay moulds

Almost 3,000 fragments of moulds made exclusively of clay, weighing over 10 kg, were found, scattered across 7 structures, including one in particular, a large silo-type structure whose stratified filling included heaps of moulds (Mélin et al., 2020, fig. 3). These figures are particularly significant compared with what is known elsewhere in France, such as at Fort Harrouard in Sorel-Moussel or at the site of Ifs mentioned above. The preservation environment has enabled these elements to be preserved in such a way that a fairly large number of objects produced on the site can be identified (around 30% identified). This also makes it easier to establish the minimum number of objects cast on the site: over 120 objects were made in the Aubervilliers workshop (table 1).

A variety of artefacts were produced (fig. 3), but two in particular were made several times, some in series (Mélin et al., 2020): at least 80 nail-headed pins (pins of the same type were produced at Fort Harrouard), at least 16 lozenge-section chapes, small hemispherical-headed nails, two

spearheads, one or two swords, a possible sickle, as well as many other items not precisely identified. The objects produced here are of typically Atlantic affinities (Mélin et al., 2020).

Other ceramic remains

The other clay remains, which are much less numerous, consist of highly fragmented remains of crucibles, recognisable by their scorified appearance and their coarser paste than that of the moulds (NR = 21, for a weight of 99 g). Unfortunately, it is not possible to estimate the volume of metal originally contained in those crucibles from these small preserved parts. Fragments of a *tuyère* were also discovered in the same levels (fig. 4).

Copper-alloy remains

Metal waste

The residues, droplets and other shapeless metal waste, are few in number, 19 elements, and very small in size and weight: around 8 g, to which must be added a few

Aubervilliers « Rue Saint-Denis » clay moulds	Number of rest	Minimal number of individuals
Ornaments		
Pins	422	80
Weapons		
Chapes	299	16
Spearheads	30	2
Swords	9 ?	2 ?
Tools		
Sickle ?	1	1
Other		
Small nails	13	18
Object decorated with concentric circles	10	1
Others (funnel...) and undetermined	2214	-
Total	2998	120

Table 1 – Aubervilliers, “Rue Saint-Denis”. Determination, number of remains and minimum number of individuals of the clay moulds found at locus 2 (M. Mélin).

miscast pieces still caught in moulds (fig. 4). No casting jets were found.

Compositional analyses⁽¹⁾ carried out on 13 samples (metal waste and objects) at the Laboratoire Iramat d'Orléans (Arles in Mélin, 2016; Mélin et al. 2020) show that the metal used at Aubervilliers was a ternary alloy, a lead bronze, which began to circulate from this second stage of the Late Bronze Age in Atlantic metallurgy (Northover, 1982; Briard, 1988, fig. 5). Similar alloys were used at the contemporary site of Fort Harrouard (Queixalos et al., 1987). Interestingly, in Aubervilliers, there are differences between the recipes for the alloys used at the BF IIIa locus and the Late Bronze Age/Early Iron Age locus (much lower level of impurities, no deliberate addition of lead for the latter), potentially indicating different raw materials. One particularly interesting small metal residue from the BF IIIa locus is a centimetre-sized piece of a Pb/Sn alloy, with over 70% lead (fig. 5). Such lead-tin alloys were also found at the Late Bronze Age Swiss site of Hauterive-Champréveyre, in the form of rings and wires (Rychner-Faraggi, 1993, p. 21 and 57); tin was dominant in this case. It is difficult to know the nature and role of this residue, but it is consistent with the alloy used on the site at this time, which included an addition of lead. It could be a clue to the form in which the metals used in the alloy were transported (in small, pre-alloyed pieces) and to the way in which these alloys were made.

Bronze objects

Four copper-alloy objects were collected during the excavation, a pendant, a gouge and two pins; three of them were found in a large pit and one pin was found in another pit among remains of moulds. Only the latter is directly linked to the workshop: a pin with a nail head, the type of which corresponds to that cast on numerous occasions on the site and the alloy of which is similar to that found in the metal remains from the workshop, unlike the other three objects. In the case of those other three objects, no moulds were found that could correspond to these products. The second pin does not belong to the type with a nail head melted on the site; its different alloy (without added lead, and containing different trace elements) also suggests that it should not be linked to the production at Aubervilliers, but rather to the domestic occupation of the site.

MONTÉLIMAR

Located in the Rhône Valley, commune of Montélimar, the “Rue du Bouquet” excavation was carried out between April and November 2015, covering an area of 8,000 m². The site, largely stratified, corresponds to different levels of a multi-phase settlement with occupations ranging from the Middle Neolithic to Antiquity. A number of areas were selected for detailed excavation, covering a total surface area of 800 m², and yielding over 16,000 finds (ceramics, fauna, macro-lithics, flint, bronze). Two particular

1. Analyses were carried out at Orléans, Centre Ernest Babelon by Laser ablation inductively coupled plasma mass spectrometry (LA-HR-ICP-MS).

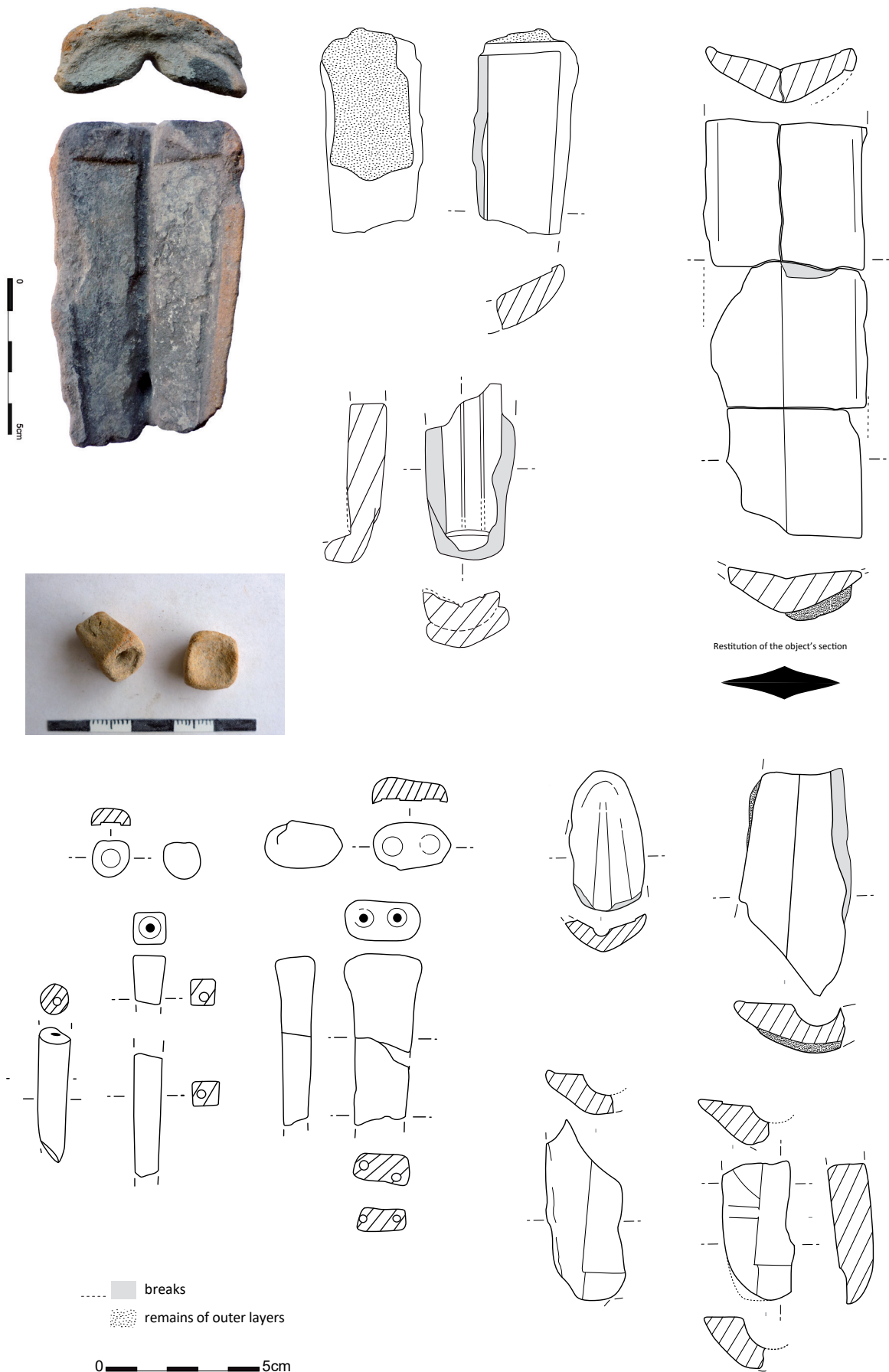


Fig. 3 – Aubervilliers, “Rue Saint-Denis”. Selection of fragments of clay moulds used to cast chapes, pins, swords and spearheads (photos and CAD M. Mélin).

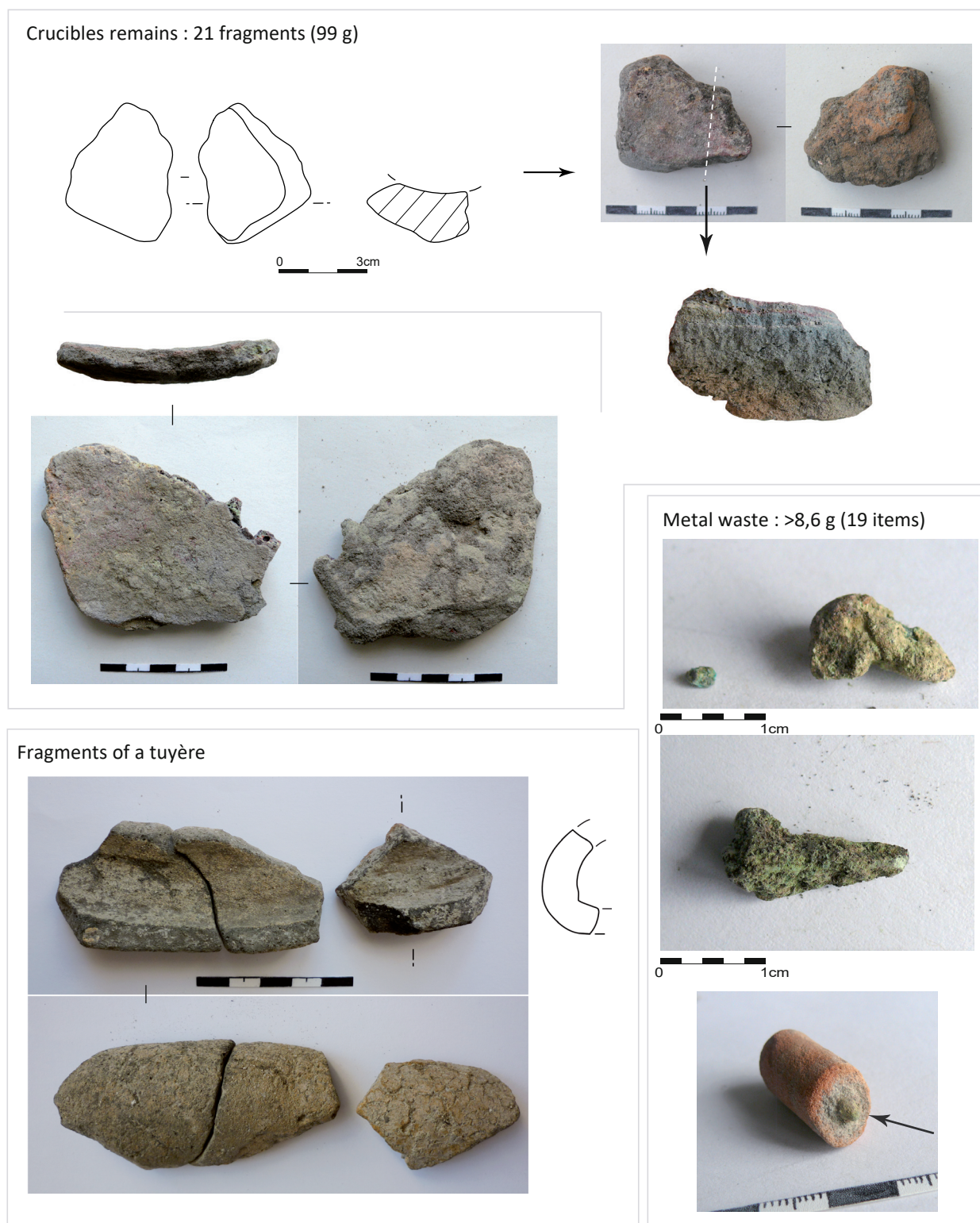


Fig. 4 (up) – Aubervilliers, “Rue Saint-Denis”. Fragments of crucibles, copper-alloy remains and fragments of a *tuyère* (photos and CAD M. Mélin).



Fig. 5 (left) – Aubervilliers, “Rue Saint-Denis”. Small metallic piece composed of a lead-tin alloy (photo M. Mélin).

areas illustrate the site's remarkable degree of preservation, one of which contained a bronzesmith's workshop. To the south-west of the site (fig. 6), a floor level dated by ceramics and bronze artefacts to Hallstatt A1 yielded numerous objects that reveal a work area devoted to the production of copper-alloy objects (fig. 6). This in situ discovery of identifiable evidence of a "bronzesmith's workshop" is exceptional. However, without careful conservation of these levels and an extensive and appropriate excavation protocol, this workshop could not have been studied.

General excavation protocol

In order to fully understand how this workshop was studied, we felt it important to return to an overview of the

excavation protocol we implemented, without going into detail as we have already done (Néré et al., 2016). Three levels of survey were defined in order to preserve as much information as possible within the time constraints imposed by preventive archaeology.

1) Once mechanical stripping had been completed, the entire area was manually cleaned in 5 to 10 cm layers to reach the highest soil level densities. Each find thus identified was recorded, labelled, sampled and topographed. In all, just under 16,500 artefacts (notated PI for « Pièces Isolées ») were georeferenced, covering an area of 750 m², or more than 9% of the total right-of-way. The workshop area alone accounts for almost 500 m² of this total.

The presence of numerous copper-alloy objects and remains, as well as the discovery of a large ceramic frag-

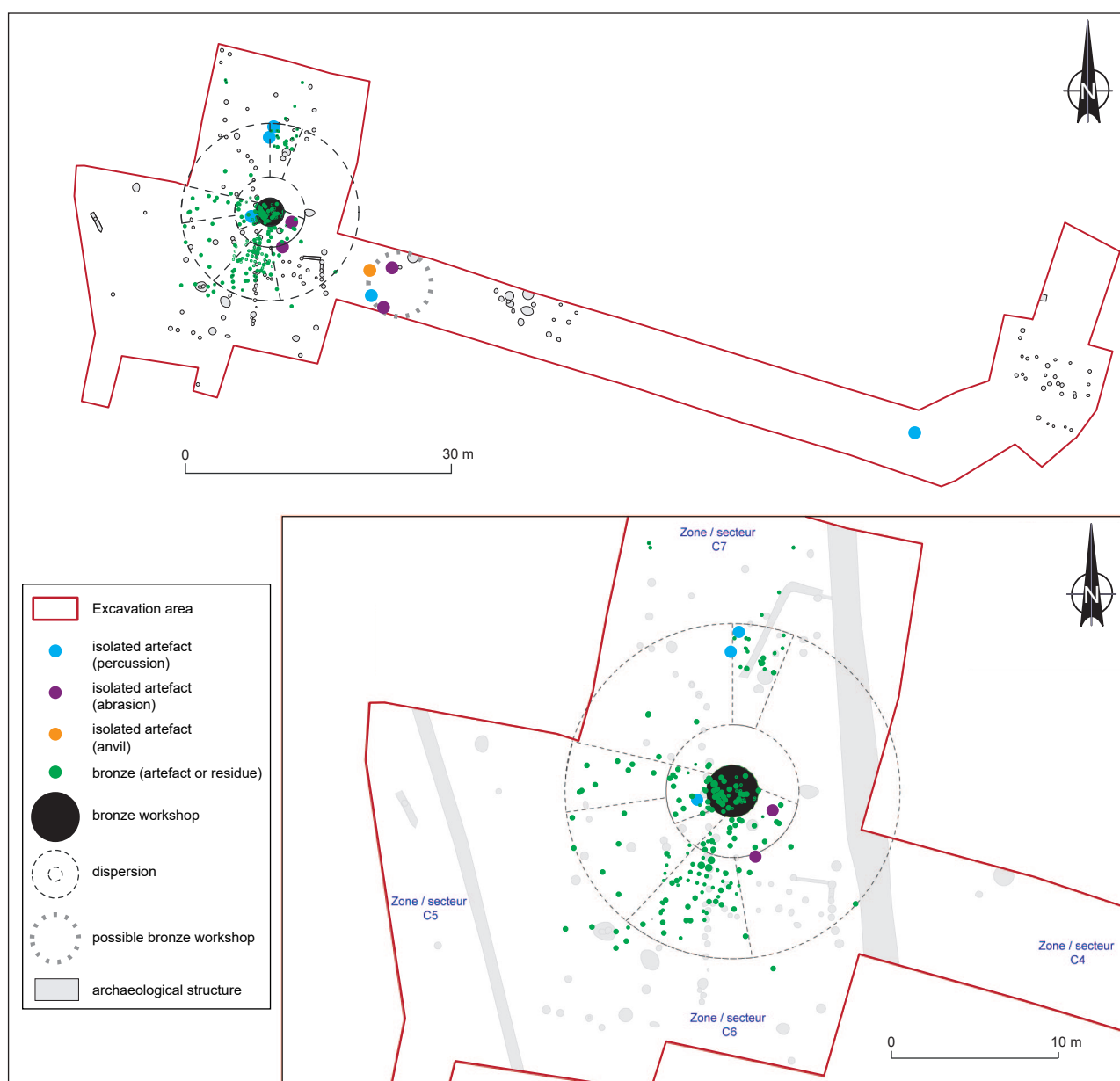


Fig. 6 – Montélimar, “Rue du Bouquet”. Plan of the area and detail plan of the Late Bronze Age (Bronze final IIa) bronze workshop (CAD F. Notier, Inrap).

ment with traces of copper (PI 1246 and 1247, Néré, 2017), were the first indications of the presence of a bronze-related metallurgical workshop. The over-representation of wood charcoal compared with other sectors gave further weight to this hypothesis. It was then decided to reinforce the basic protocol. For this reason, a grid was set up in this sector.

2) An orthophotographic survey was carried out using a gantry crane, using the grid to correct for distortion due to the focal length of the lens. Soil levels were then drawn from this survey.

3) A flotation/sieving station was set up next to the area during excavation: sediment samples were taken in quarter-m² increments, based on this grid, over the equivalent of layers 2 and 3 (from 5 to 20 cm amplitude), notably around PI 1246 and 1247. They were processed in the field by flotation (to obtain charcoal for anthracological analysis) and sieving (to obtain rejects linked to metallur-

gical activity and to collect snails for malacological study and seeds for carpological analysis).

4) Additional surveys were attempted, such as an archaeomagnetic survey, but the results proved negative, as the methods used detected nothing, which in itself is an important result: the workshop is not detectable by archaeomagnetism (Hulin in Néré, 2017).

Copper-alloy remains

Of the 9,000 objects recovered from the area, 119 copper-alloy remains were found, with 217 casting elements for a total mass of around 460 grams (Nordez in Néré, 2017). Table 2 shows the distribution of copper-alloy elements within the various object categories identified. 79 fragments were identified, excluding shapeless residues, foundry waste and unidentified fragments. The Minimum number of individuals (MNI) is 65 items.

	Montélimar "Rue du Bouquet"		
	Number of rest	Minimal number of individuals	Weight (g)
Ornament and clothing	40	33	232
Pins	21	11	206
Annular ornaments	9	6	14
Pendant	3	3	3
Pearl	1	1	4
Belt buckle	1	1	3
Buttons	2	2	2
Toiletries	1	1	2
Razors	1	1	2
Tools	15	11	61
Sickles	3	1	31
Chisels/ Punches	12	10	30
Weapons	2	2	5
Arrowheads	2	2	5
Rings	21	18	36
Others	42		25
Foundry	215		92
Cast residues	2		3
Total	335	65	451

Table 2 – Montélimar, "Rue du Bouquet". Inventory of metal remains by functional category according to number of remains (NR), minimum number of individuals (MNI) and mass in grams (M. Nordez, CNRS).

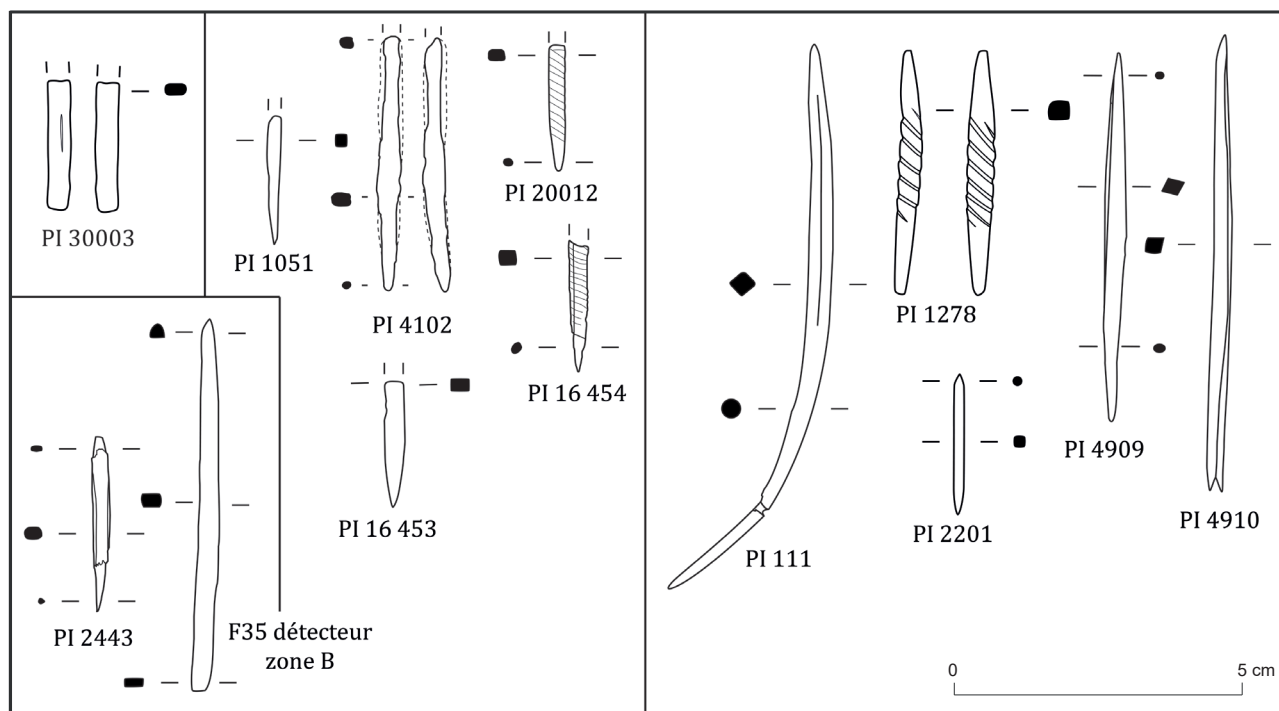


Fig. 7 – Montélimar, “Rue du Bouquet”. Drawings of part of the workshop’s copper-alloy tools (Drawings M. Nordez, CNRS).

Tools

Many of the bronze tools are related to metallurgical activity, but we cannot exclude wood, textile, bone and ceramic crafts either. Ten punches and chisels (NR = 12) of various shapes and sizes may have been used in the workshop (fig. 7). The active ends of these tools are badly weathered, severely limiting traceological observations.

Three sickle fragments, which may initially have belonged to the same object though this cannot be confirmed, were scattered around the site: one is a point, another is a blade with a rib but no preserved edges, and the third is a handle and knob.

Rings

Rings (fig. 8), which are also well represented (21 fragments for an MNI of 18 individuals), are considered here as a category in their own right: they may be suspension or belt elements, but also semi-finished products used in exchange or raw material reserves. These last two hypotheses are quite attractive at Montélimar: in fact, the rings are on the whole quite irregular, sometimes unfinished, or even found in the form of half-rings (incomplete rings on which no break is visible). At the contemporary site of Hauterive-Champréveyres, Switzerland, seven rings were made not of bronze but of copper or pure tin, or a tin-lead alloy with tin predominating (Rychner-Faraggi, 1993, p. 57). While there are many possible explanations for these particular alloys, the possibility of raw material reserves is quite tempting. However, as analyses are still in progress on the objects and foundry residues from

Montélimar, we cannot go any further into these considerations.

Ceramic fragments

The locations of ceramic fragments do not form a visible concentration around a single point, but rather a heterogeneous coating over the entire area. However, given the density of metal finds, we have studied in detail the ceramic fragments that may relate to metallurgy, and more specifically to casting. A few fragments of objects bear direct witness to this activity. Firstly, there is a ceramic conglomerate mixed with evidence of copper castings located in the centre of the workshop. Secondly, at least one fragment of a crucible handle has been identified. It is made of fairly fine ceramic and was manufactured for



Fig. 8 – Montélimar, “Rue du Bouquet”. Pre-study photograph of part of the rings in the bronze workshop area (photo F. Notier, Inrap).



Fig. 9 – Montélimar, “Rue du Bouquet”. Photograph of a *tuyère* (photo F. Notier, Inrap).

this activity alone. Next, the longitudinal half of a *tuyère* (7 cm long and 4 cm in diameter) was found (fig. 9). One of these ends is badly altered by the object's close proximity to the fire. It must have been moulded directly on the rod into which the founder blew. Finally, several ceramic objects show traces of overheating with regular shapes showing that they are crucible fragments. Several of these small fragments have trapped droplets of copper alloys. The ceramic is partly vitrified, due to the very violent temperature rises. A possible fragment of mould can be added, on which three fine, elongated parallel hol-



Fig. 10 – Montélimar, “Rue du Bouquet”. Fragment of a clay mould (photo F. Notier, Inrap).

lows can be discerned (fig. 10). The nature of the object produced remains difficult to determine given the modest size of the fragment (a sickle?).

The stone tools of a bronze maker

Tools from outside the workshop

Stone tools clearly distinguish the two types of contemporary occupations within the site (Cousseran-Néré

in Néré, 2017): for example, there are numerous finds related to milling associated with domestic areas. Thanks to the preserved ground level, it can be seen that milling elements are systematically close to buildings. In one case, the mill is located close to a building, but also in a work area, perhaps a courtyard associated with numerous seeds and fragments of charred flatbreads.

Workshop tools

Other objects amongst the lithic tools highlight specific metallurgy-related equipment (Cousseran-Néré et al., 2020), outside the settlement but only a few dozen metres from it. Whether it's the different types of percussion tools, striking supports or abrasive tools, we can see that the objects studied are specific and that they are concentrated around the observed combustion zone, in association with objects made of copper alloys, and that they enable us to trace a real *chaîne opératoire*.

We also note that, more than the raw material, it is the specific granulometry of the various elements that distinguishes this corpus and seems to have guided the choice of Bronze Age craftsmen.

As far as shapes are concerned, the tools used for percussion are completely different from those used for the plastic deformation of metals (brasswork or goldsmithery), as they appear in the Gélénard hoard (Cousseran-Néré et al., 2020), for example. This is not very surprising, since plastic deformation of sheet metal seems to have been fairly limited, if not non-existent, in Montélimar: several striking supports of different sizes have been identified, but they are small.

Polishing tools

Use-wear analysis shows that seven tools may have been used for post-casting abrasion or abrasive finishing of bronze objects. Their shape varies from quadrangular to triangular to circular (fig. 11).

Three groups of abrasive tools can be distinguished. This classification is independent of part morphometry. It takes into account only the granulometry of the rocks used to support the objects. All rocks have a grainy texture, ranging from very fine to coarse. A fine-grained rock is more likely to be used to finish the object at the end of the casting process, or to maintain metal blades, while a coarser rock is more likely to be used for deburring at the end of the mould. Abrasive tools are quite common on Bronze Age sites (Hamon and Blanchet, 2015) and are therefore directly linked to the development of metallurgy and the use of metal objects.

Striking supports (anvils)

Probably linked to this activity, two striking supports were found in the workshop floor level, along with a limestone chip, probably detached from another striking support. The first is a small, whole tool fashioned from a block of white limestone (fig. 12), marked by sparse,

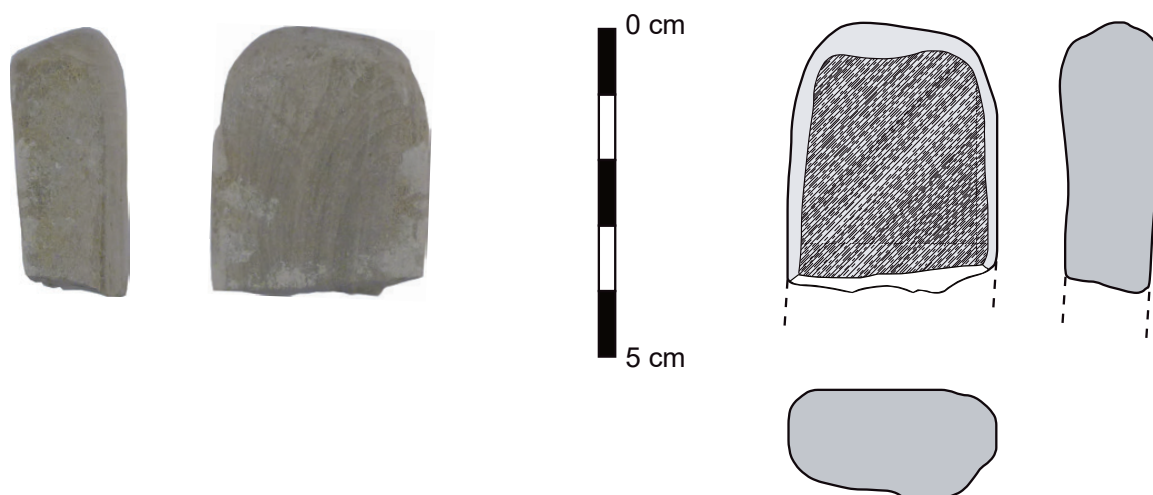


Fig. 11 – Montélimar, “Rue du Bouquet”. Photograph and drawing of a polisher from the workshop (photos S. Cousseran-Néré, drawings L. Boutoille and S. Cousseran-Néré, Inrap).



Fig. 12 – Montélimar, “Rue du Bouquet”. Photograph of an anvil from the workshop (photo S. Cousseran-Néré, Inrap).

random micro-percussion marks characteristic of a striking support. This small artefact was probably used as a striking support for two small bronze objects (e.g. rods or pins) shaped with a percussion tool (see above). The second is a fine sandstone striking support angle, larger than the first. Quadrangular in shape, it is concave on one side. This working surface has a uniformly smooth surface. Lastly, a small chip probably produced by hitting a striker on an anvil, from which it would have originated, was found in the area of the bronzesmith’s workshop.

Hammers

Hammers from Montélimar can be divided into 4 defined types (Cousseran-Néré et al., 2020). Type III (fig. 13), in particular, may be characteristic of these bronze workshops. It stands out from the other hammer-



Fig. 13 – Montélimar, “Rue du Bouquet”. Hammerstone from the workshop (photo S. Cousseran-Néré, Inrap).

Montélimar “Rue du Bouquet”	
Lithic artefacts	
Percussive tools	14
Anvils	2
Abrasive tools	7
Undetermined	1

Table 3 – Montélimar, “Rue du Bouquet”. Inventory of lithic tools by functional category (S. Cousseran-Néré, Inrap).

stones observed to date in this geographical area. Three Type III firing pins were found in the workshop and four more in the rest of the excavation (table 3). Their loca-

tion—outside the workshop identified in a soil level also attributed to Hallstatt A1, and found near several larger bronze drops and casting elements, or, in another area, near well-dated bronze objects—suggests that the metal-worker's workshop extended beyond the area originally identified, marking several work zones. This not only supports the hypothesis of discriminating tools with a specific function in one of the stages of the bronze production chain, but also demonstrates that the site certainly included several bronze workshops outside the prescription zone.

Several workshops in one area

As we have suggested, it is highly probable that the workshop excavated in detail was not isolated, but belonged to a group of small workshops located in the midst of settlements (several houses were identified—fig. 6). At least two other workshops in the excavation area are more than likely. But others seem to be possible in the area, as suggested by nearby archaeological operations, evaluations not followed by excavations as here. These include the large evaluation operation directly to the west (Vermeulen et al., 2006), which yielded traces of bronze castings and fragments of objects in two areas, and the operation 100 m to the northwest, which once again uncovered a fragment of a cut-out pin (Néré, 2017). In all, this represents 5 locations outside the excavated workshop, at least 3 of which make it easy to imagine other work areas.

COMPARISON OF THE TWO SITES

Due to their different preservation conditions, these two Late Bronze Age sites show a number of differences (table 4).

Soils

At Aubervilliers, no stratigraphy was preserved, unlike at Montélimar. At Montélimar, in the absence of the preserved occupational floor it would not have been possible to identify the workshop at all, as there are virtually no excavated structures apart from postholes: all the remains were found on the ground level (Néré, 2017). The site would have been recognised as a Late Bronze Age settlement, but the metal production aspect would have been impossible to see. This finding is extremely important to emphasise because generally none of the sites with metallurgical remains have preserved occupational floors, and only a few significant remains are found in hollow structures mixed with domestic material, as is the case at Aubervilliers. This clearly demonstrates the fleeting nature of the structures left behind by the bronze workshops.

Casting hearths

At Aubervilliers, no space dedicated to casting has been found; at Montélimar, at least one casting area has been

identified. In the very well-preserved soils, concentrations of droplets of cuprous material have made it possible to locate the work 'centre' from very discrete traces. In the case of Montélimar, contrary to the proposals of Michel Pernot (1998), this space dedicated to the foundry was not located inside a building, but outside, albeit well sheltered along a palisade. Similarly, no pit was dug to install the hearth, which must have been on the ground, and most of the remains of this work area have disappeared, easily washed away by the weather.

Experiments show that a simple flat hearth is sufficient to bring the alloy up to the required temperature and, if it is not used many times, it will leave very little mark on the ground. The hearth could be more 'constructed' and delimited by stones, as proposed at Fort Harrouard (Mohen and Bailloud, 1987, p. 128, fig. 70). The case of Montélimar confirms that the probability of finding the actual location of the casting remains low, even under favourable conditions.

Evidence of casting

At Aubervilliers, evidence of casting predominates, although found in a secondary position. It can be presupposed that the casting was located in the immediate vicinity, in a place destroyed by modern excavations noticed on site. The finds consist mainly of fragments of clay moulds, together with a few small fragments of crucibles and a tuyère. The very small metal residues are also undeniable evidence of casting activity. However, of the four bronze artefacts found on site, three do not seem to be linked to casting activity per se, as seen through composition analysis of the metal and the differences observed with the moulds.

At Montélimar, these casting indicators are elusive; several hundred fragments of clay have been discovered, but they are usually millimetre-sized and only one large crucible fragment has been found. Slag (as in vitrified

Type of remains	Aubervilliers	Montélimar
Furnaces	-	-
Workshop floor	-	+
Moulds	+++	+
Crucibles	+	+
Tuyères	+	+
Metal residue	+	+++
Lithic tools	-	++

Table 4 – Comparison of metallurgical remains between the sites of Aubervilliers and Montélimar (M. Mélin and E. Néré).

clay), which is more abundant, is associated with several hundred droplets. A fragment of a tuyère was found in the immediate vicinity of the workshop. Many of the bronze rings and fragments of rings found in the same area may have been used as raw material for remelting, and the conglomerate of clay and mixed copper droplets found in the centre of the area may correspond to the heart of the melting zone.

Evidence of post-casting working

At Montélimar, the post-casting phase is well attested and is mainly represented by macrolithic tools: polishers, hammers and anvils make up a whole range of stone objects used for plastic deformation work. The corpus of tools from Montélimar contrasts with that found at Gênelard, and there are very few tools in common between the two groups. The famous Late Bronze Age hoard find of Gênelard contains numerous bronze and stone tools for fine metalwork. Being a collection of objects selected for their symbolic aspects, no doubt, but also for their preciousness, their specificity, these are not objects abandoned or deposited at random (Thevenot, 1998). One could almost say the opposite of the Montélimar objects, because even if the technical investment is certain, for example in the case of the hammers, most of the objects (the polishers, for example) are little invested, they come from simple pickings. These are undoubtedly the ‘everyday’ objects used by the craftsmen, providing evidence of part of the bronze-making process, but it is certain that the more sophisticated tools were not abandoned on site. The only objects in common with Gênelard are punches and other small finishing tools made of copper alloys. Those from Montélimar, which are very worn, are abandoned objects that are of little or no use. It is still difficult to confirm that all the stages of bronze working were carried out here; that of removal of the excess of metal (flashing and casting jets) and that of primary hammering were carried out on site, as shown by the lithic tools, but also by the fragments of casting jets, and other casting elements made of copper materials. Anvils also confirm the existence of this phase.

Finished objects are present on the site, sometimes fragmented (which suggests remelting), but sometimes whole, although it is difficult to know, with rare exceptions, which objects were made on site.

At Aubervilliers, anvils and polishers are missing, but some lithic tools could have been used as hammers; post-casting work may have been carried out on the site, following the opening of the moulds. No finished objects have been found: the pin that was potentially produced on site is whole and does not appear to be in a finished state. However, it is difficult to be certain given the preservation of the metal.

Artefacts from the workshop

At Montélimar, there are many finished objects, but the lack of unity makes it impossible to know whether they

all came from the on-site workshops or whether they were destined for remelting. Apart from the large number of rings, there are few identifiable objects, and for the former, there is a strong probability that they were indeed there as raw material: their cutting into halves or quarters suggests this.

The only well-identified objects that may have been cast in Montélimar are the alpine-type sickles. In addition to three parts of their blade, a casting jet and two fragments of clay moulds (very degraded) relating to this type of object were discovered. A large whole pin with a flat conical head, found in another area, combined with numerous traces of a probable other workshop, seems to indicate that pins of this type may have been cast here. Shortly after the excavation, an identical pin was found a few kilometres further north, in Lorient, Drôme, in a cremation burial, confirming their probable local origin (Gaillard, 2020). As well as objects made from copper-based materials, it seems that gold objects were also cast in the same workshop, as evidenced by a fragment of a small plate found in the same area.

Unlike Montélimar, production at Aubervilliers was identified mainly on negatives of clay moulds. This production shows a certain variety (weapons, ornaments, tools), even if a specialisation in pins and chapes can be established (Mélin et al., 2020). There are objects of various sizes (from swords to nails), as well as a variety of casting techniques (cluster casting, for example). It has been noticed that for the same nail-headed pin shape, several types of moulds have been implemented. Analyses of the composition of residue alloys and castings have also revealed that a similar recipe (a ternary alloy) was used to cast these objects.

Context of the workshop

At Aubervilliers, as at Montélimar, the bronzesmith's workshop was probably part of a settlement. The domestic nature of the associated remains and the possible presence of two or even three buildings support this view. The site of Aubervilliers is neither fortified nor in a high position, contrary to the models proposed on the basis of the rare sites that provided such evidence in northern France: Fort Harrouard (Mohen and Bailloud, 1987), Caesar's Camp at Catenoy, Oise (Blanchet and Talon, 1987) or Saint-Pierre-en-Chastre, Oise (Blanchet, 1984) in particular. The ‘exclusive role that has often been attributed to fortified hilltop sites in the production and distribution of bronze objects during the Late Bronze Age’ (Delrieu, 2013, p. 144) therefore needs to be nuanced.

Despite the lack of ore in the Paris Basin, the Aubervilliers site was able to acquire metals (copper, tin and lead) through its trading network. In Montélimar, there were many regional sources of supply: there were numerous copper mines in the Alps, and the Rhône Valley traffic routes made it easy to obtain supplies. Initial physico-chemical analyses (study by C. Le Carlier in Néré, 2017) have shown that some of the copper came from the mines at Saint-Véran in the Queyras (Hautes-Alpes), which is almost 200 km away

but easily accessible via the valleys leading into the Rhône valley, directly to Montélimar.

CONCLUSION

The information on the bronze workshops identified from the two sites presented is varied. Firstly, the data acquired is directly linked to the differences in preservation conditions between the two sites: the site of Aubervilliers benefits from very good preservation of the moulds, making it possible to estimate production in detail and determine an MNI, an essential element for subsequent inter-site comparisons. This is rarely possible due to the rapid deterioration of fragments after unmoulding, as is the case at Montélimar. On the other hand, the preservation of the occupational level at the Montélimar site made it possible to spatialise various elements linked to metallurgy, and thus to estimate the location of a casting place, which is rarely recognised.

On any excavation, the archaeologist is extremely dependent on the conditions in which the remains are preserved, and the recognition of metallurgical activity is particularly subject to this. Such activity remains

truly fleeting in the Bronze Age, no doubt because it is not yet structured in the way that will be seen in the historical periods (at Autun or Bibracte, for example: Chardron-Picault and Pernot, 1999; Duval et al., 1991). It is common for a single element to be indicative of metallurgical activity (a fragment of a crucible, a tuyère, a fragment of a mould valve, etc.), the quantity of metal remains being generally very small. The casting sites themselves are remarkably rare, as are the post-casting sites, which are mainly revealed by the presence of lithic tools.

At the same time, technological studies carried out on the metal objects themselves (traceology, metallography, etc.) have made it possible to make significant progress on the question of the manufacturing process, but these studies are still mostly disconnected from the production sites. Studies of the lithic macro-tools used in metallurgy have also expanded considerably in recent years (Hamon and Delgado-Raack, this volume). Experiments have provided a wealth of information too on technical issues, organisation and the traces left by bronze castings. All these studies, whether or not they are directly linked to a workshop, are therefore complementary to what can be found in excavations and together contribute to our understanding of the production chains for bronze objects.

BIBLIOGRAPHICAL REFERENCES

- BESNARD-VAUTERIN C.-C. (ed.) 2020 – *Évolution d'un terroir au cours de la Protohistoire. Les fouilles préventives de lfs « ZAC object'ifs Sud », 2008 (Calvados)*, Rennes, Presses universitaires de Rennes, 384 p.
- BLANCHET J.-C. (1984) – *Les premiers métallurgistes en Picardie et dans le Nord de la France : Chalcolithique, âge du Bronze et début du premier âge du Fer*, Paris, SPF (Mémoires de la Société préhistorique française, 17), 608 p.
- BLANCHET J.-C., TALON M. (1987) – L'éperon barré du « Camp de César » à Catenoy (Oise) à l'âge du Bronze final : Premiers résultats, in J.-C. Blanchet (ed.), *Les relations entre le continent et les îles Britanniques à l'âge du Bronze*, proceedings of the session of the 22nd Congrès préhistorique de France (Lille, 2-7 September 1984), Amiens, RAP (Supplément à la *Revue archéologique de Picardie*), p. 119–210.
- BLANCHET S. (2026) – *Saint-Avé (56). Kerozer. Des occupations du Néolithique et de l'âge du Bronze*, excavation report, Inrap – SRA Bretagne.
- BRIARD J. (1988) – La métallurgie du groupe Saint-Brieuc-des-Iffs, in P. Brun and C. Mordant (eds.), *Le groupe Rhin-Suisse-France Orientale et la notion de civilisation des Champs d'Urnes*, proceedings of the international conference (Nemours, 1986), Nemours, APRAIF (Mémoire du musée de Préhistoire de Nemours, 1), p. 533–538.
- CAPARROS T., NALLIER R., FRANEL Y., GLEIZE M.-F. (2010) – Un ensemble exceptionnel de vestiges métallurgiques de l'âge du Bronze final à Aubervilliers (Seine-Saint-Denis), *Bulletin de l'Association pour la promotion des recherches sur l'âge du Bronze*, 7, p. 38–50.
- CHARDRON-PICAULT P., PERNOT M., dir. (1999) – *Un quartier antique d'artisanat métallurgique à Autun. Le site du Lycée militaire*, Paris, Maison des Sciences de l'Homme (Documents d'archéologie française, 76), 318 p.
- COUSSERAN-NÉRÉ S., BOUTOILLE L., NÉRÉ E. (2020) – L'outillage lithique de l'atelier de bronzier du site du Bronze final de Montélimar la rue du Bouquet (Drôme, France) : un témoin de l'activité métallurgique ?, in F. Manclossi, F. Marchand, L. Boutoille, and S. Cousseran-Néré (eds.), *Stone in Metal Ages*, proceedings of the Session XXXIV-6 of the XVIIIth UISPP World Congress (4-9 June 2018, Paris), Oxford, Archaeopress, p. 95–109.
- DELRIEU F. (2013) – Chronologie et statut des sites fortifiés de hauteur au Bronze final et au premier Fer ancien dans le Nord-Ouest de la France (Haute-Normandie, Basse-Normandie, Bretagne), in S. Krausz, A. Colin, K. Gruel, I. Ralston and T. Dechezleprêtre (eds.), *L'âge du Fer en Europe : Mélanges offerts à Olivier Buchsenschutz*, Bordeaux, Ausonius (Mémoires, 32), p. 131–146.
- DUVAL A., PERNOT M., CONCHE F., LACOSTE D. (1991) – Les fouilles du Mont-Beuvray. Les fouilles dans le secteur extramuros : l'atelier de bronzier, *Revue archéologique de l'Est*, 42, p. 274–284.
- GAILLARD C. (2020) – *Loriol-sur-Drôme (Drôme) Extension du Parc d'activités économiques de Champgrand*, survey report, Bron, Inrap Rhône – Alpes – Auvergne; Lyon, Service régional de l'Archéologie, 136 p.
- GIAZZON D., CHÉBROU A., GHESQUIÈRE E., MARCIGNY C., MOUGNE C., TORRADO ALONSO A. (forthcoming) – Atelier métallurgiste du Bronze final à Mathieu « Le Clos des Châtaigniers », Calvados.

- HAMON C., BLANCHET S. (2015) – Le macro-outillage lithique sur les sites de l'âge du Bronze armoricain : quelques hypothèses fonctionnelles pour aborder la notion d'artisanat, in S. Boulud-Gazo and T. Nicolas (eds.), *Artisanats et productions à l'âge du Bronze*, proceedings of the conference (Nantes, 8 October 2011), Paris, SPF (Séances de la Société préhistorique française, 4), p. 63–82.
- HAMON C., REGUER S., BRISOTTO V., LE CARLIER DE VESLUD C., DONNART K., BLANCHET S., PAILLER Y., ESCATS Y., BELLOT-GOURLET L. (2021) – Des outils de métallurgistes dans le Bronze ancien de Bretagne ? Révéler le rôle du macro-outillage lithique en associant analyses tracéologiques et de spectroscopie de fluorescence X, *Bulletin de la Société préhistorique française*, 118, 4, p. 697–737.
- HAMON C., DELGADO-RAACK S. (this volume) – Stones in the toolkit. Contribution of use-wear and residues analysis to the identification of Copper and Bronze Age metal objects production in Europe between the 3rd to 1st millennium BC.
- LEMERCIER O., SÉNÉPART I., BESSE M., MORDANT C., eds. (2018) – *Habitations et habitat du Néolithique à l'âge du Bronze en France et ses marges*, proceedings of the 2nd Rencontres Nord/Sud de Préhistoire récente (Dijon, 19-21 November 2015), Toulouse, Archives d'écologie préhistorique, 715 p.
- MÉLIN M., ed. (2016) – *Aubervilliers (Seine-Saint-Denis), « Rue Saint-Denis, Rue du Port, Rue du Chemin Vert »*. Un atelier de bronzier du Bronze Final IIb-IIIa, excavation report, Paris, Arkemine & Service régional d'Archéologie Île-de-France, 2 vols.
- MÉLIN M., ARLES A., ROGUET G., FLAMENT J. (2017) – Un important atelier de fonte du Bronze final IIb-IIIa à Aubervilliers, la Rue du Port (Seine-Saint-Denis), *Bulletin de l'Association pour la promotion des recherches sur l'âge du Bronze*, 15, p. 43–45.
- MÉLIN M., ARLES A., COUTELAS A., FLAMENT J., ROGUET G. (2020) – L'atelier de bronzier de la Rue Saint-Denis à Aubervilliers (Seine-Saint-Denis) : un artisanat spécialisé de l'étape moyenne du Bronze final, in R. Peake, S. Bauvais, C. Hamon and C. Mordant (eds.), *La spécialisation des productions et les spécialistes*, proceedings of the Session XXXIV-2 of the XVIIIth Congrès mondial de l'UISPP (Paris, 5 June 2018), Paris, SPF (Séances de la Société préhistorique française, 16), p. 109–122.
- MÉLIN M., NÉRÉ É., et al. (2021) – L'atelier du bronzier, quoi de neuf depuis vingt ans ? La question des lieux de production métallurgique vue par les sites de Montélimar (Drôme) et d'Aubervilliers (Seine-Saint-Denis), in C. Marcigny and C. Mordant (eds.), *Bronze 2019, 20 ans de recherches*, proceedings of the international conference (Bayeux, 19–22 June 2019), Paris APRAB (*Bulletin de l'APRAB*, Supplément 7), p. 112–124.
- MOHEN J.-P., BAILLOUD G. (1987) – *La vie quotidienne, les fouilles du Fort-Harrouard*, Paris, Picard (L'âge du Bronze en France, 4), 352 p.
- MOLLOY B., MÖDLINGER M. (2020) – The Organisation and Practice of Metal Smithing in Later Bronze Age Europe, *Journal of World Prehistory*, 33, p. 169–232.
- NÉRÉ É., ed. (2017) – *Montélimar (Drôme), rue du Bouquet*, excavation report, Bron, Inrap Rhône – Alpes – Auvergne; Lyon, Service régional de l'Archéologie, 3 vols.
- NÉRÉ É., COUSSERAN-NÉRÉ S., NORDEZ M., NOTIER F. (2016) – Un vaste habitat à niveaux de sol conservés de l'âge du Bronze à Montélimar (Drôme), *Bulletin de la Société préhistorique française*, 113, 1, p. 155–157.
- NORTHOVER P. (1982) – The metallurgy of the Wilburton hoards, *Oxford Journal of Archaeology*, 1, p. 9–109.
- QUEIXALOS I., MENU M., MOHEN J.-P. (1987) – Creusets pour la fonte des alliages à base de cuivre du Bronze final au Fort-Harrouard à Sorel-Moussel (Eure-et-Loir), *Bulletin de la Société préhistorique française*, 84, 1, p. 23–30.
- PERNOT M. (1998) – L'organisation de l'atelier du bronzier, in C. Mordant, M. Pernot and V. Rychner (eds.), *L'atelier du bronzier en Europe du XX^e au VIII^e siècle avant notre ère, 2. Du minerai au métal, du métal à l'objet*, proceedings of the international conference Bronze'96 (Neuchâtel et Dijon, 4-9 March 1996), Paris, Editions du CTHS (Documents préhistoriques, 10, 2), p. 107–116.
- RYCHNER-FARAGGI A.-M. (1993) – *Hauterive-Champréveyres, 9. Métal et parure au Bronze final*, Neuchâtel, Musée cantonal d'archéologie (Archéologie neuchâteloise, 17), 124 p.
- THEVENOT J.-P. (1998) – Un outillage de bronzier : le dépôt de La Petite Laugère, à Gélénard (Saône-et-Loire, France), in C. Mordant, M. Pernot and V. Rychner (eds.), *L'atelier du bronzier en Europe du XX^e au VIII^e siècle avant notre ère, 2. Du minerai au métal, du métal à l'objet*, proceedings of the international conference Bronze'96 (Neuchâtel et Dijon, 4-9 March 1996), Paris, Editions du CTHS (Documents préhistoriques, 10, 2), p. 123–144.
- VERMEULEN C. (2006) – *Montélimar (26) « Le Bouquet » rue André-Malraux*, survey report, Bron, Inrap Rhône Alpes Auvergne, Service régional de l'Archéologie, Lyon, 25 p., 11 figs.

Muriel MÉLIN

Service départemental d'archéologie

du Morbihan,

chercheuse associée UMR 6566 CReAAH

Rennes, France

muriel.melin@morbihan.fr

Éric NÉRÉ

Inrap, Centre de recherches archéologiques

de Valence

chercheur associé UMR 8215 Trajectoires

Nanterre, France

eric.nere@inrap.fr