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Iron, Fuel and Slags: Reconstructing the Ironworking Process in Iberian Iron Age (Valencian Region)

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In this paper we present the archaeological data related to ironworks in the territory of Kelin (4th-3rd centuries BC). We have analysed the different phases of the process through the distribution of raw materials, iron oxides, production waste and manufactured products as well as some structures such as furnaces and forges. Furthermore, metallographic analysis allows us to know the nature and the phases of the ironworking process. Our goal is to reconstruct the operative chain from the mines to the resulting iron tools and weapons in order to approach deeply the importance and organization of ironworks in the Iberian society.

KEYWORDS
IBERIAN PENINSULA, SIDERURGY, MINES, ORE, PRODUCTION WASTE, WORKSHOPS

En este trabajo se presenta toda la información disponible en la actualidad sobre la siderurgia del territorio de Kelin entre los siglos IV y III a.C. Se analizan las diferentes fases del proceso de producción desde la distribución de materias primas, los desechos de producción y los productos manufacturados así como los hornos y forjas. Además, los análisis metalográficos aportan información sobre las fases del proceso siderúrgico. El objetivo es reconsruir la cadena operativa desde el trabajo en las minas a las herramientas y armamento, así como profundizar en la importancia y la organización de lo talleres siderúrgicos en la sociedad ibérica.

PALABRAS CLAVE
PENÍNSULA IBÉRICA, SIDERURGIA, MINAS, MINERAL, RESIDUOS DE PRODUCCIÓN TALLERES

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Introduction

The Second Iron Age begins in the East of the Iberian Peninsula in the 6th century BC. It is known as Iberian Culture due to the fact that ancient Greek and Latin writers named these people Iberians. The Iberians were the native pre-roman inhabitants of the Mediterranean *façade* of the peninsula, from Andalusia until the Pyrenees, including partly the inlands of the Ebro basin and SE France until the Hérault river.

The concept of Iberian Culture is then an archaeological coinage and it's widely defined as different peoples who developed a high degree of urbanization, complex and complementary economic strategies (agricultural practice, metallurgy, stockbreeding, crafts, etc.), exchanges and trade in different scales, standardised funerary rituals, existence of elites and independent sociopolitical territories based on hierarchical urban societies (for further reading in English: Ruiz and Molinos, 1998; Grau, 2003; Sanmartí, 2004; Buxò, 2008). The classical written sources give different ethnic names (Bastetani, Cessetani, Contestani, Edetani, and Turdetani among others), but offer some contradictions on the description and distribution of these peoples and their territories. The Iberian territories are characterised by a complex, hierarchical settlement pattern which includes *oppida* (high rank settlements), farmsteads and rural hamlets, hill forts, ritual places (caves, sanctuaries) and necropolis (Bonet, 1995; Ruiz, 1997; Asensio *et al*., 1998; Mata *et al*., 2001: 309-326; Grau, 2002).

The current Valencian region was inhabited by three main ethnics: *Ilercavoni*, *Edetani* and *Contestani* (from North to South). The territory we study was not explicitly named by the Roman and Greek writers so we do not know which was the ethnicity or the name given to their inhabitants. Nevertheless, after two decades of surveys and excavations, we can affirm that these people were Iberians, but not *Edetani* as some authors have suggested (Mata, 2001; Uroz, 1983). Despite the fact that they occupied the inland of the current Valencian province, this community presents the main socio-cultural features that respond to an Iberian entity, namely wheel-made pottery productions, different types of Mediterranean imports, standardised decorations and productions, metallurgy, complex town planning and hierarchical settlement pattern, social inequality, cremation as the funerary ritual, epigraphic evidences on stones, pottery and lead, and local monetary coinage among others characteristics. In this sense, we approach the definition of the territory through the settlement pattern and the material culture recovered.

Los Villares (Caudete de las Fuentes, València) is an Iberian *oppidum* (7th-1st BC), which becomes the central place of a large territory from the 5th century BC. This site has been identified through the numismatics as the ancient Iberian city of *Kelin* (Ripollès, 1979, 1980 and 2001). As other Iberian cities, *Kelin* organised a large territory through a hierarchical settlement pattern and complex socioeconomic strategies and relationships (mines, saltmines, metallurgy, kilns, wine and olive oil production, local productions and imports) (Lorrio [ed.], 2001; Mata *et al*., 2001: 309-326; Mata *et al*., 2009; Moreno & Quixal, in press). This area is located between two cultural and biogeographical zones: the coast,

occupied by Iberians and the inlands, the Meseta, by Celtiberians. The territory, in a macrospatial perspective, is geographically well delimited by Sierra de las Cabrillas in the East, Turia river in the North, Cabriel river in the South and West. Culturally, the territory has been defined through the presence of local pottery productions (Iberian red glaze ceramics, impressed decorations), numismatics and other features such as the existence of surpluses, exchanges and trade, viewshed patterns and a net of interdependent settlements and sites (Mata,1991; Mata *et al*., 2001: 309-326; Moreno, 2006 and 2008).

From the surveys and excavation projects that have been carried out, we can offer a better and deeper knowledge of the territorial organization and the emergence of sociopolitical complexity. All these archaeological evidences reflect a hierarchical settlement pattern and the construction of a cultural identity through the appropriation of the landscape. Our intention here is to offer an example of this kind of strategies through the analysis of the ironworking activities, putting the emphasis in the reconstruction of the whole process and offering unpublished data.

In this regard, as from the 6th century, perhaps earlier, Iberian peoples developed iron technology in order to make complex tools and weapons. The known repertoire of these iron pieces is remarkable (Pla, 1968; Sanahuja, 1971), although archaeological records on mining activities and workshops are scarcer than expected.

The study of craft activities in Iberian archaeology, such as metallurgy or pottery production, has advanced more slowly than research on food production and paleoenvironment. In addition, the waning popularity of works on material culture, *sensu stricto*, has led to a reduction in publications on other topics, this in turn resulting in poor knowledge of documented repertoires whether in pottery, metalwork, or others. As a consequence, research on workplaces and resource procurement includes little documentation, apart from mere cataloguing and description. It was not until the last decade of the 20th century that research developed subjects related to technology and metalwork processes. As a result, appendixes inclusive of archaeometallurgical studies of specific pieces were introduced, but syntheses of the whole process are still rare (Rovira Llorens, 2000: 215-216; Rovira Hortalà, 2000).

We do not know much about metallurgical workshops despite the fact that —based on the amount and variety of metal objects known in the Iberian world— this type of work must have been a specialised task developed in many settlements. Information and documentation on mining at the time is even scarcer, both in relation with practices and the location of mining and extraction sites. Traditionally, their study did not raise much interest in the Valencian region, possibly because it is an area poor in metals if compared to other regions in the Iberian Peninsula.

Consequently, we believe the novelties offered by the survey project "Kelin's territory between the 6th and 1st century BC" and here presented to be important and enriching to approach closely ancient ironworks (Fig. 1). Based on the data obtained in this region, by prospecting and excavating, we can now offer a preliminary reconstruction of the operative chain of the iron process taking into account different scales and activities.

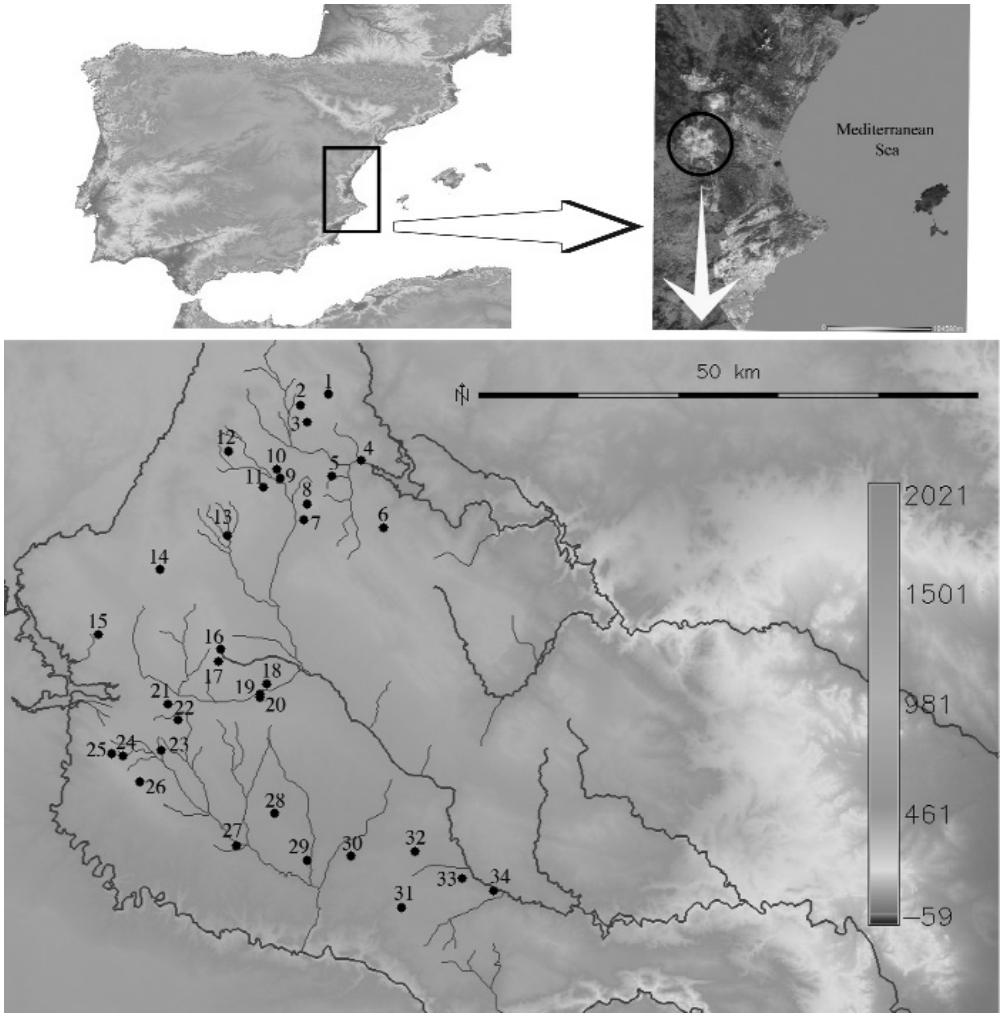

Fig. 2. (a) On the top left a map of the Iberian Peninsula. (b) On the top right, a magnification of the squared area in the previous image which refers to the current Valencian region. (c) Below, a map of the study area with the sites concerned in this paper: 1, La Mina (Tuéjar); 2, Loma de la Laguna (Talayuelas); 3, Campo de Herrerías (Sinarcas); 4, Charco Negro II (Benagéber); 5, El Carrascal (Sinarcas); 6, Punto de Agua (Benagéber); 7, Los Chotiles (Sinarcas); 8, Cerro de San Cristóbal (Sinarcas); 9, Cerrito Cavero (Sinarcas); 10, La Maralaga (Sinarcas); 11, La Relamina (Sinarcas); 12, Collado de la Plata (Aliaguilla); 13, Tinada Guandonera II (Aliaguilla); 14, El Molón (Camporrobles); 15, Casas del Alaud (Mira); 16, Hoya de la Escoria (Utiel); 17, Cerro de la Peladilla (Fuenterrobles); 18, Escuela 1 (Caudete de las Fuentes); 19, Kelin (Caudete de las Fuentes); 20, La Atalaya (Caudete de las Fuentes); 21, Cuesta de los Civiles (Villargordo del Cabriel); 22, La Atalayuela (Venta del Moro); 23, Casa Sevilluela (Venta del Moro); 24, PUR-2 (Villargordo del Cabriel); 25, El Moluengo (Villargordo del Cabriel); 26, Casillas del Cura (Venta del Moro); 27, El Zoquete (Requena); 28, Muela de Arriba (Requena); 29, Casa de la Alcantarilla (Requena); 30, Cerro de la Cabeza (Requena); 31, Casas del Carrascalejo (Requena); 32, Los Alerises (Requena); 33, Cerro Santo (Requena); 34, Hortunas de Abajo (Requena).

Thus, from a macro-spatial perspective, we will deal with how mining resources were exploited and then processed on an inter-site basis, and finally we will analyse the presence of iron-related activities and manufactured products in domestic contexts.

Ironworking: Approaching the Process

The command of ironworks was an important development in comparison with other metallurgies, as the possibilities of ferric metals are more varied and effective. Technological innovations behind this practice brought along higher farming and stockbreeding productiveness as a result to more effective tools, and general improvements in construction, transport and craftsmanship, apart from the new dimensions that they meant for panoplies (for further reading: Mohen, 1990; Feugère & Gustin, 2000; Pleiner, 2000, 2006).

The lack of historical sources that could help us understand metalwork processes in Iberian Culture causes us to resort to empirical archaeological evidences and their metallographic analyses in order to reconstruct the iron process: raw materials such as fuel and ore (charcoal and iron oxides), production waste (slag), related waste (furnace walls) and manufactured products. Prospecting and excavation work in Kelin has documented ironworking evidences in 34 sites between the 6th and the 1st century (Fig. 1 and table 1). Some of the materials recovered have been analysed by Metallographic Microscopy, Scanning Electronic Microscopy (SEM) and Energy Dispersive X-ray Microanalysis (EDX), identifying draining slag from direct reduction furnaces, slag from domestic forges, and slag embedded in the metal structure and wall lining of the furnace (Ferrer, 2000: 283-289; Ferrer *et al*., 2002a, 2002b). Consequently, the existence of these evidences are the main variables and arguments to reconstruct the production chain.

These data will be used as a thread in this paper and to analyse and complement recent novelties.

Extraction sites

It is difficult for archaeologists to track down mineral extraction sites. Although iron ore is abundant on the earth's crust, the iron production technique used in protohistory consisted in mining the oxidised outcrop, i.e. exploitation of the superficial layer of the vein (surface mining). This variety was in operation until the 19th century possibly due to its easy access. However, although many of these mining sites are either exhausted or no longer profitable nowadays, the toponymy of some places can actually help us track down possible mining areas, for instance *Rincón de la Mina* (Mining Corner), *Hoya de la Escoria*

Table 1. Archaelogical sites described in the paper. The Sites Id. refer to the number in the figure 1.

ID.	Ore	Reduction Slag	Smithing Slag	Nozzle	Furnace	Iron tools	Ingots	Chronology
1	x	x						Indet.
2		x	x			x		V-IV BC
3		x						IV-II BC
4			x					V-III BC
5			x					V-I BC
6						x	x	II-I BC
7		x				x		IV-II BC
8			x	x		x		VI-II BC
9			x					IV-II BC
10		x						II-I BC
11			x					IV-II BC
12		x	x					V-III BC
13	x		x					II-I BC
14		x				x		VII-I BC
15			x			x		VI-IV BC
16	x							Indet.
17			x			x		IV-II BC
18			x					VII-I BC
19		x	x		x	x		VII-I BC
20			x			x		VII-I BC
21		x						IV-II BC
22			x					V-IV BC
23			x					V-I BC
24	x		x					II-I BC
25	x		x			x		V-I BC
26	x	x	x					V-IV BC
27			x	x				V-III BC
28				x		x		V-II BC
29			x					VI-I BC
30			x					V-II BC
31			x					IV-II BC
32	x		x			x		V-II BC
33	x		x			x		V-II BC
34			x					V-IV BC

(Slag Fields), *Campo de Herrerías* (Blacksmith's field) or *Collado de la Plata* (Silver Col). Besides, tool documenting for these processes in *Kelin* (picks) and the presence of iron ore in some sites makes us think that extraction and supply took place locally.

Mining resources are mainly found in mining sites with seams formed by the deposition of mineral solutions in crevices and joints. These mineral concentrations have a heterogeneous composition. They include both ore and gangue (earthy part of the ore), in our case limestone, sandstone and clay. They are also composed of poly-metal ore with

Fig. 2. Limonite from the Iberian site of El Puntal dels Llops' hinterland.

mineral associations (lead, silver, and copper, among other). The iron ore collected in prospecting work had oxide and hydrated oxide forms (limonite, grey haematite, red haematite) (Fig. 2), which are the only ones that can be transformed into iron by reducing them in a low-temperature furnace and with charcoal.

Fieldwork allowed us to identify two possible iron extraction sites. On the one hand, surface mineralizations in Hoya de la Escoria (Utiel) and, on the other, surface and subsurface poly-metal veins in La Mina (Tuéjar) (Fig. 3). The latter is known in the literature

Fig. 3. Open-cast ore mine (La Mina, Tuéjar) (2003).

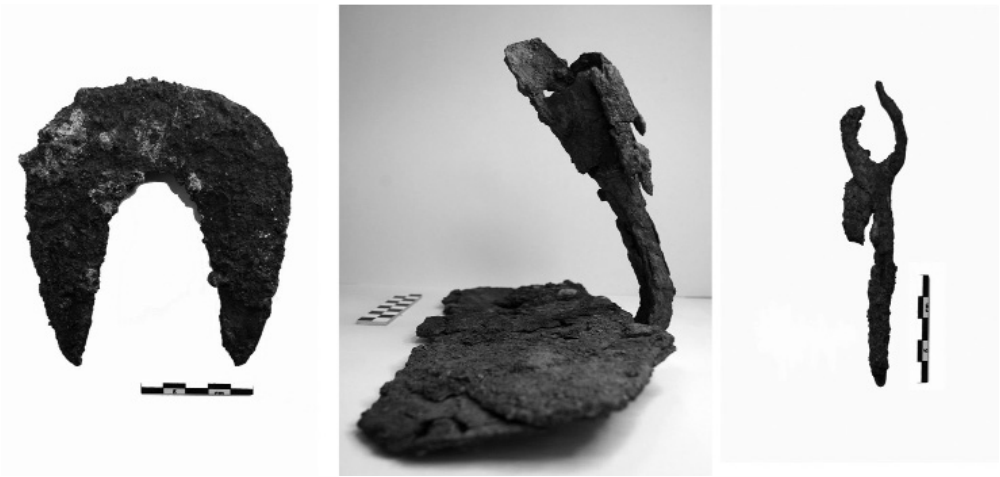

Fig. 4. (a) An indeterminate piece, (b) a hoe and (c) a pair of tongs from Kelin archaeological site. (Photos by Hèctor Juan).

as being Roman (Palomares, 1966: 243), but it is likely to have been exploited by the Iberians in its more superficial levels due to the fact that the techniques and utensils needed in these processes were well known and used by the Iberians (Fig. 3).

Reduction

In protohistory, iron was obtained from direct solid-phase reduction of the ore (oxides) using furnaces with temperatures under the melting point of iron (1536 ºC), this resulting in a metal with a "high" carbon content (steel). Conditions in the furnace had to be very reducing, which required the use of charcoal (iron oxide and fluxes). It was also necessary to filter out the fluxes of the gangue, which constitute the liquefied slag contained in the mineral. This operation produces the sponge iron, which is little homogeneous and has a great deal of slag; once hammered and compacted, it is called lump. It is the previous step to an ingot.

The presence of draining slag or slag from the inside of the furnace identifies reduction practices in the area studied. The number of sites (10) with remains from this phase points to the existence of many furnaces that met local demands with mineral extracted in the surroundings (Fig. 1 and table 1).

There are evidences that suggest specialisation in this process in certain sites, covering two spheres: craft workshops and settlements. On the one hand, we can differentiate places with abundant tapping slag remains with a black or dark grey outer surface and soft lines, a flowing appearance indicative of a first reduction phase conducted at the mine

(Fig. 1, no. 1), near it (Fig. 1, no. 3 and 7) or in combination with pottery production (Fig. 1, no. 10 and 26); on the other, in some habitat areas (Fig. 1 and table 1, the rest) primary bloom-smithing slag —a step previous to forging— has been identified. This type of slag is more angular and fragmented. Not many material culture elements related to domestic life and permanent habitat have been found in the first group, whereas the habitat areas of the second group —at a higher level and walled— have numerous material remains of a domestic nature. Alternatively, there are excavations in these areas that identify them as settlements, as is the case with *Kelin*, El Molón and Muela de Arriba (Mata, 1991; Lorrio, 2001: 151-170; Valor, 2004).

Post-reduction

It is interesting to see how the operative chain seems to develop in different scenarios. While extraction and direct reduction would take place near raw materials and fuel, refining and forging would be done in the settlements, as the latter tasks do not require large facilities and the amounts of raw materials and fuel needed can be transported to the workshop.

Post-reduction slag has been found in 25 sites (Fig. 1 and table 1). This task was probably thoroughly spread in the territory, although not all houses had their own workshop, as happened in *Kelin*, where only one out of three excavated ones had a furnace.

Kelin's smithing workshop. The valorisation work done in *Kelin* in 2004 recovered a small workshop in one of the rooms of house no. 2 (a dwelling of the 3rd century), possibly used for tool repairs and maintenance. The workshop consists of an oblong smithing hearth with walls coated with a layer of clay with combustion marks and a U section with a slight NW inclination. The size preserved is: 10 cm maximum height, 13 cm wide, and 60 cm long, as it is cut by an Islamic pit at the NE end.

A meter away, towards the W of the fireplace, there was a rectangular 30 × 20 cm slab used as an anvil; a pair of tongs were found next to it (Figs. 4c and 5). The set-up is completed by a small circular pit (40 cm diameter, 10 cm deep) surrounded by small stones whose operational relationship with the fireplace we ignore, as no remains were found in it that could evidence its use for the storage of solid materials (sand, charcoal, lime or excrements) (Rovira Hortalà, 2000: 268). A nail, riveted plate, a hook, a hoe, an undetermined horse-shoe shaped piece with pointed ends, a possible iron ingot, several amphorae and large jars were also found in this room (Fig. 4b, 4a and 5).

Based on its size, this forge hearth was probably used temporarily to repair and maintain the tools of the owners. In fact, it seems that, when the house was destroyed and abandoned it was not being used, as no remains from the elevation have been found and there was very few charcoal and slag inside; besides, most of the pottery in the room was on the NE corner, which would hinder the operation of the furnace (Fig. 5).

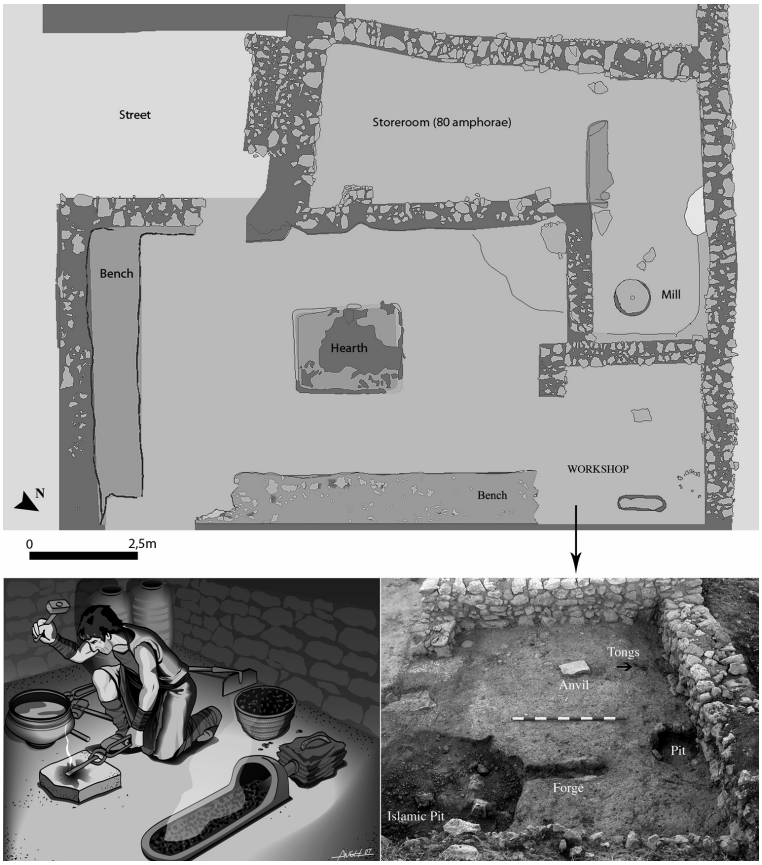

Fig. 5. House 2 of *Kelin* and its workshop (reconstruction by Ángel Sánchez)..

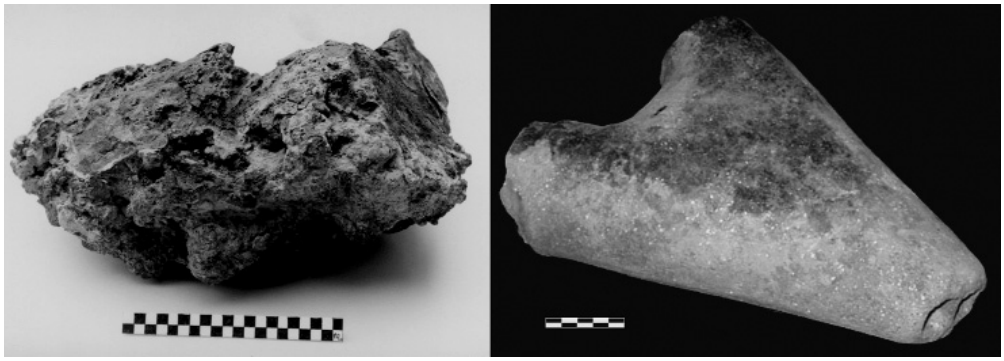

Fig. 6. (a) Iron Lump from Kelin; (b) Ceramic Nozzle from Muela de Arriba (Photo by Jeroni Valor).

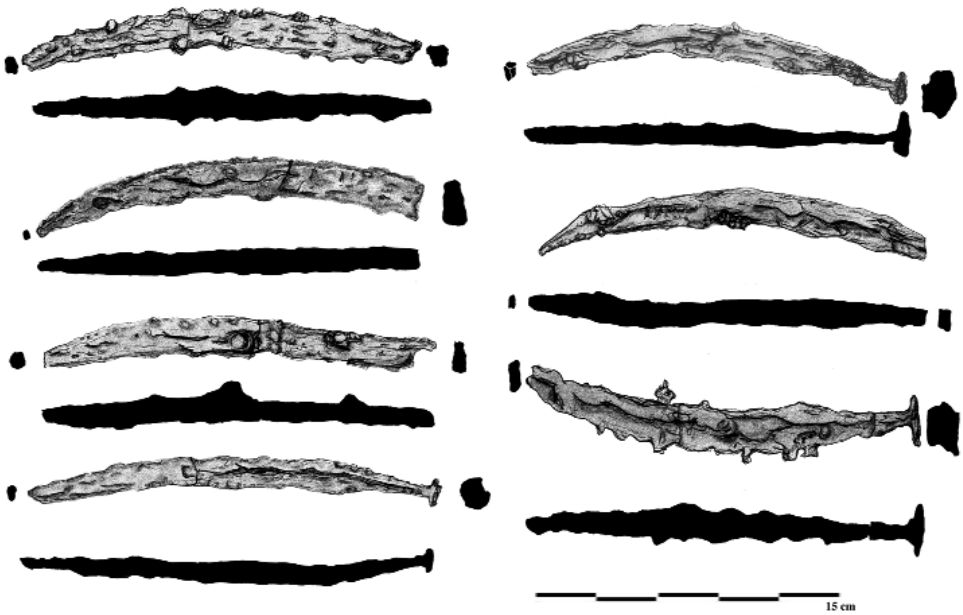

Fig. 7. Indeterminated iron objects from La Muleta de Arriba (drawings by Jeroni Valor)..

Possibly, this was not the only metal workshop in *Kelin*, since surface excavations and prospecting have provided remains of bronze and iron slag as well. In sector F, for instance, proto-ingots in hot-cutting process were found, together with forging slag, worked iron and some other evidences (Fig. 6a). This points to the existence of another forge, which would be bigger than the one described before.

In this regard, revising old excavations and recent interventions in the area have provided complementary information on the size and nature of the workshops. In Muela de Arriba, metalwork activity was identified in the two excavated sectors. In Sector no. 1, there is one forge furnace, associated with a double nozzle (25 cm), nails, farming tools, rivets, and a set of seven iron objects with a slightly curved edge, triangular section and a riveted end (Figure 6b and 7).[1] While in Sector no. 2 another forge may have existed, as per the presence of iron slag (Valor, 2004: 269-273). A large double nozzle (42 cm) was also found in Cerro de San Cristóbal (Iranzo, 2004: 232) and fragments of another one have been documented in El Zoquete, a farm excavated recently (2007-2008). These double nozzles are used in works requiring continuous air supply for the temperature to remain stable, two people at least having to work in the forge: the blacksmith and his assistant, who operates the bellows.

1. The function of these items is still unknown. They could be semiproducts, currency bars, socket bars or unfinished objects.

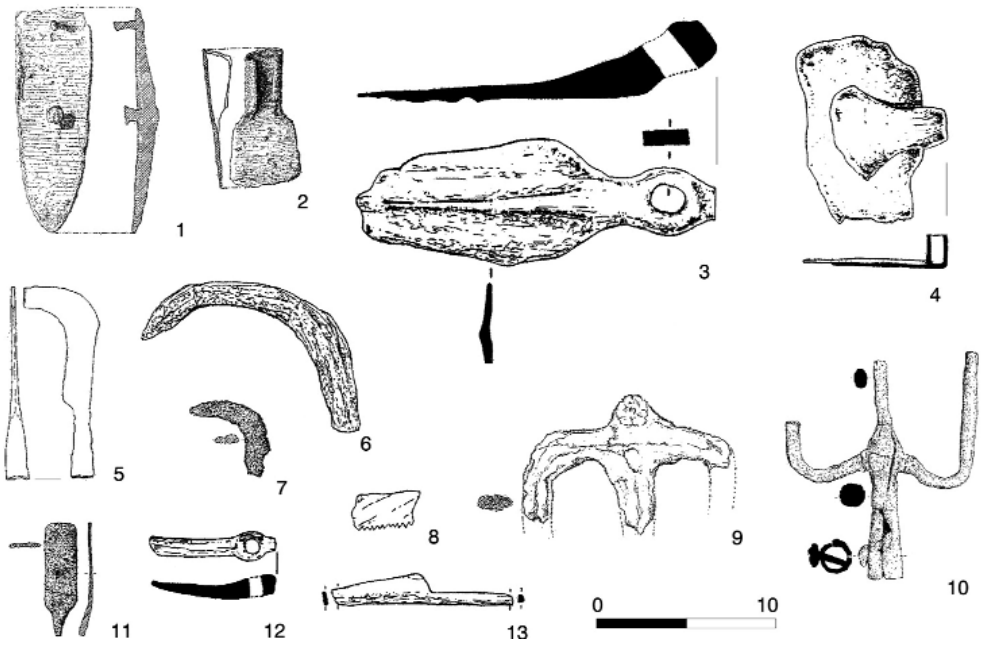

Fig. 8. Iron tools from Iberian sites: 1 and 2, Plow-share and paddle of plow staff from La Bastida de les Alcusses (Moixent); 3 and 4, Two types of hoes from Kelin; 5, "Corquete", special kind of pruning-hook from El Xarpolar (Alcalà de la Jovada); 6, Sickle from *Kelin*; 7, Pruning-hook from *Edeta* (Llíria); 8, Saw from *Kelin*; 9, Rake from Puntal dels Llops (Olocau); 10 and 11, Hay-fork and sower spoon from Edeta; 12 and 13, Chip-axe and scissors from *Kelin*.

Final product

The Iberian repertoire of iron utensils, tools and weapons is most varied and quite standardised for the chronology addressed here (4th-3rd centuries BC). The greatest problems in the recognition of specific forms and objects is the poor condition of the iron, the fragmentation of the remains, and the fact that, in many cases, we deal with individual components of more complex objects.

In the territory of *Kelin* there is a wide range of farming implements (sickle, hook, mattock, hoe), craft tools (chisel, gimlet, axe-hammer, saw, pointer, cobblers' awl, scissors, spatula, hook), building elements (nail, ring, door ironwork) and weapons (knife, dagger or short sword, spear, head tube nipple, arrowheads, falcata). These artefacts have been documented in the central place, *Kelin,* as well as in others sites and settlements of the territory (Mata, 1991: 167-169; Lorrio *et al.*, 1998: 149-161; Valor, 2004: 272) (Fig. 8).

Based on the metallographic analyses conducted, no homogeneity seems to exist in metal working, as not all products have the same finish. This is the case with different "quality" steels, excessively cemented materials, poorly purified materials and materials

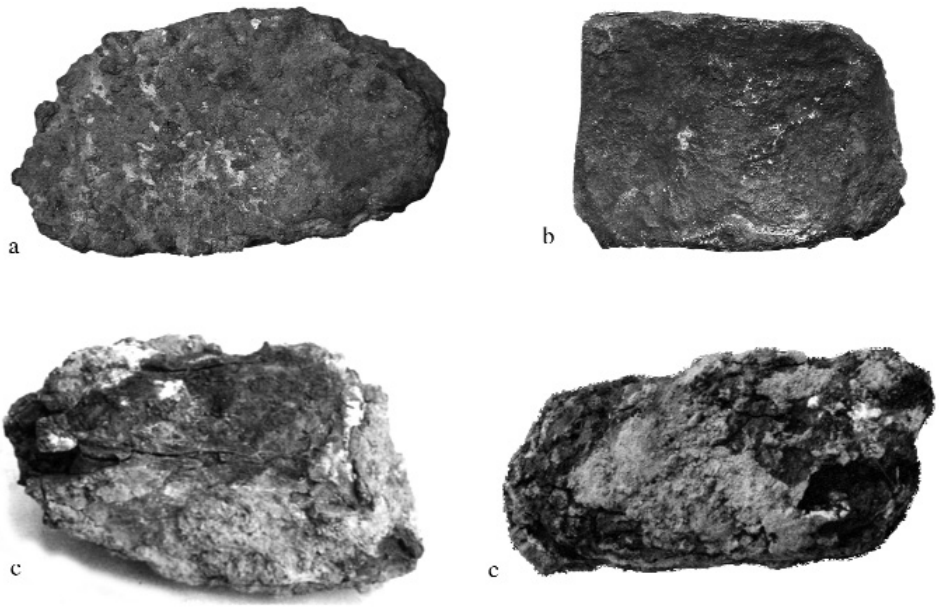

Fig. 8. Iron ingots from Iberian sites. From left to right and top to bottom: a.- Oreto de Faquirola (Buñol) (Pphotos by Hèctor Juan); b.- La Seña (Villar del Arzobispo) (Pphotos by SIP); c.- El Puntal dels Llops (Olocau) (Pphotos by SIP).

re-heated and cooled with little accuracy. Which evidences that not all blacksmiths were skilled and so we could conclude that there were specialised workshops, given the diversity and quality of the existing products. In these sense, some authors have suggested the existence of skilled itinerant smiths in Iberian world to explain the existence of the two different decorative styles and qualities of *falcatas* (Quesada *et al*., 2000). Pleiner states the existence of this duality in the ancient Greece as well: "In small communities there were people who made beds, doors, ploughs, tables… but they were not capable of making these things particularly well… But in large towns, where there is a large number of consumers, a single craft is sufficient for one's livelihood; very often it need only be part of a craft" (1969: 23).

Economic and Social Interpretation

The available information and data on ancient metallurgy in the area studied is enough to argue that the practice and organisation of metalworking responds to a complex social, economic and territorial reality, which characterises the Iberian Culture.

The recovered metal production indications are slag, minerals, and manufactured products. Their analysis allow us to make some progress as regards the organisation of iron production and its subsequent distribution:

— The specific localisation of the mine, the raw materials, and fuel implies moving to these points, where the operative chain would start and then branch out. For economy reasons, direct reduction furnaces are usually near the extraction and supply site, although the need for fuel may condition their presence, having to move them to more abundant wood sources. As pointed out by Serneels, perhaps for volume reasons rather than weight ones, the mineral might have been transported to the coal bunker (Serneels, 1997: 29-42). Accordingly, slag remains from the reduction phase have been found near the mines and in sites close to other raw materials. The relationship between pottery kilns and metal furnaces —identified in Casilla del Cura or La Maralaga (Fig. 1 and table 1)— also illustrates the interest in installing this type of productive activity —with similar water and fuel needs— in shared spaces. The association of both activities is also logical if we think that the thermal use of charcoal is intended to save fuel and time in both processes, as well as due to the noxiousness of the fumes and debris associated with these activities.

— We do not know the ownership regime of mining resources, but the phases of metal production —though independent— are interrelated. The different products —associated to the stages of the production chain— are transported to the places where each stage is developed, to finally reach consumers. This is proved by the differential localisation of supply and first transformation sites, and of the forges, as we see in *Kelin* and Muela de Arriba. Besides, the existence of iron proto-ingots and ingots implies they were distributed from direct reduction furnaces to the forges (Ferrer, 2002: 200-201; Lorrio *et al*., 1998-1999: 149). In addition, Pleiner suggests that the miners could be specialised groups, probably extended family units, working temporarily in order to extract and smelt the raw material and come back to their communities with the semi-product ready (ingots, bars, blooms/lumps) (2000: 104-105).

— Within the chain, charcoal was essential as a fuel. The importance of coal bunkers is obvious if we take into account the volumes necessary for this activity, but further research is needed from the archaeological point of view. In our case, charcoal remains on a lump from *Kelin* were studied and identified as *Pinus halepensis*, an abundant species that may have been used despite its low heat yield. On the other hand, in the dump located to the outside of the gallery of La Mina we found coal identified as *Juniperus* sp. and *Pinus* cf. *halepensis*[2] (Fig. 1, no. 1).

— As for the last phase in the chain, two workshop types have been defined. Those that produced weapons and/or tools on a full-time basis, which would supply the most

2. Identified by Dr. E. Badal (Universitat de València).

immediate territory and possibly trade with other territories. Examples of this workshop type are found in Cerro de San Cristóbal and Muela de Arriba, as said earlier (Figs. 1 and 6 no. 2). And those of a more domestic nature that operated on a part-time basis, where tools and weapons could be produced, but above all, were repaired and maintained as is the case with *Kelin* and El Zoquete (Fig. 5).

Based on these considerations, the socioeconomic reality we are faced with is complex, with blacksmiths and miners who possibly developed other productive activities too, for instance forest resource exploitation (felling, charcoal production) and the distribution of materials, semi-finished products (ingots) and finished objects (tools, utensils, weapons).

From the social viewpoint, the blacksmith is not a member of a marginalised group, since workshops were fully integrated into the urban fabric; in some cases, blacksmiths even got rich. This is the case with the family living at house no. 2 in *Kelin*, who stored 92 amphorae (7460 litres), a silver bracelet, two bronze cauldrons, a set of farming implements, imported dishes, a mill and loom weights. Finally, it is worth pointing out, as other authors do, that all these evidences point to a differentiated purchasing power or social status (Giles, 2007).

Conclusion

Ironworking in Iberian society stands out as a pointer of status and social hierarchy due to its meanings as a productive and symbolic labour restricted to some individuals or families with the knowledge and ability to transform iron and create utensils, weapons and other tools. The documentation of workshop areas, the control of fuel and raw materials, the existence of standardised manufactured objects and evidences of exchanges, especially through the presence of ingots, allow us to consider the process as a well organised and planned activity that articulates the territory in a macrospatial scale and consequently it becomes an complement of the rest of economic strategies and practices.

This article has only been able to touch on the most general features of the ironworks in the Iberian Culture. Thus, we can conclude that even a preliminary study, such as the one reported here, has highlighted the importance of this activity and the need for further studies. Nonetheless, the information presented provides interesting data for the reconstruction of this activity at different levels, as it allowed us to tackle this problem in a well defined territory. Despite the incompletion of the records and the fact that there is still a long way to go, we are now in a position to analyse ironworks by interrelating it with other economic activities namely agriculture and stockbreeding, exploitation of forest resources, craftsmanship, and other social and territorial processes.

Appendix: Other Iberian Workshops in Valencian Region

To complete this overview, we have briefly compiled the news published about other metal workshops in Valencian region.

Valencia province

In the nearby area of *Edeta* a similar organisation to that of *Kelin* was found. Mineral extraction areas were located near El Puntal dels Llops (Olocau), a hill fort where a cupellation oven and seven iron ingots were also found (Figs. 2 and 9c). The metallurgy process started in this habitat would be completed by two metal workshops: a cupellation oven and a smithing forge in El Castellet de Bernabé (Llíria), and another smithing forge in *Edeta* (Llíria) and La Seña (Villar del Arzobispo) (Bonet, 1995: 361-362; Ferrer, 2002: 190-206; Adelantado, 2003: 314-324).

La Bastida de les Alcusses (Moixent). The re-survey of old excavations has allowed to identify at least a cupellation workshop (Fletcher *et al.*, 1965-1969; Díes and Álvarez, 1998: 334-336, dep. 210; Díes *et al.*, 1997: 243-244).

Alacant province

Tossal de les Basses (Alacant). Urgent excavations in 2004 provided a number of large smithing forges together with pottery kilns and adjacent artisan structures (Rosser, 2007: 53).

Another possible forges have been identified in El Oral (San Fulgencio) (Arana *et al.*, 1993: 189-203) and El Puntal (Salinas) (Hernández & Sala, 1996: 43-44). La Serreta (Alcoi) offers lead and other metallurgical remains (Grau & Reig, 2002-2003: 105).

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Short text

Hierro, combustible y escorias: una reconstrucción del proceso siderúrgico ibérico en el País Valenciano

Introducción

El proyecto de investigación «El territorio de *Kelin* entre el s. VI y el I a.C.» ha proporcionado mucha información sobre las actividades siderúrgicas antiguas. *Kelin* (Caudete de las Fuentes, València) es el lugar central de un amplio territorio (2000 km^2) con una compleja organización (fig. 1) (Lorrio, 2000; Mata, 1991; Mata *et al*., 2001: 309-326, y 2009; Moreno, 2006, y Moreno y Quixal, e.p.).

La investigación de las actividades artesanales ha avanzado más lentamente que los estudios sobre la producción de alimentos y el paleoambiente; no será hasta la última década del siglo XX, cuando la investigación desarrolle temáticas relativas a la tecnología y los procesos de fabricación metalúrgicos y se empiecen a introducir apéndices con análisis arqueometalúrgicos.

Sabemos poca cosa de los talleres metalúrgicos, a pesar de que, por la cantidad y variedad de objetos metálicos conocidos en el mundo ibérico (Pla, 1968), este trabajo debía de ser una tarea especializada y presente en muchos asentamientos. Menos información y documentación tenemos sobre la minería de esta época, tanto sobre las prácticas como sobre la ubicación de los lugares de extracción.

Con los datos obtenidos en el territorio de *Kelin*, mediante prospección y excavación, podemos ofrecer una reconstrucción de la cadena operativa del proceso siderúrgico, atendiendo a diversas escalas y actividades. Así, abordaremos cómo se explotan los recursos mineros del territorio, y cómo éstos se procesan a escala *intersite* para, finalmente, analizar la presencia de actividades siderúrgicas y de productos manufacturados en los contextos domésticos.

Aproximación al proceso siderúrgico

El dominio de la siderurgia representó un avance importante sobre otras metalurgias, pues las posibilidades de los metales férricos son más variadas y eficaces. Esta innovación tecnológica aportó un incremento de la productividad agrícola y ganadera, al hacer más eficaces las herramientas, así como un favorecimiento general de otras (Mohen, 1990; Feugère y Gustin, 2000, y Pleiner, 2000 y 2006).

Debido a la falta de fuentes históricas sobre el proceso siderúrgico, hemos de recurrir a las evidencias arqueológicas y sus análisis metalográficos para reconstruir la cadena operativa: materias primas como el combustible y el mineral (carbón vegetal y óxidos de hierro), residuos de producción (escorias), residuos asociados (paredes de horno) y productos manufacturados. Los trabajos de prospección y excavación en el territorio de *Kelin* han documentado actividades siderúrgicas en 34 yacimientos, entre los siglos VI y I a.C. (fig. 1 y cuadro 1). Alguno de los materiales recuperados se ha analizado mediante microscopio óptico metalográfico, microscopio de barrido electrónico (MED) y microanálisis por rayos X por dispersión de energías (EDX), habiéndose identificado escorias de sangrado de horno de reducción directa, escorias de hogar de forja, escorias incluidas en la estructura del metal y revestimientos de pared de horno escorificadas, que nos permiten reconstruir la cadena de producción siderúrgica (Ferrer, 2000: 283-289, y Ferrer *et al*., 2002*a* y 2002*b*).

Lugares de extracción

La identificación de los lugares de extracción de mineral es difícil para el arqueólogo. El mineral de hierro es muy abundante, pero la variedad empleada para producir hierro durante la proto-

historia estaría constituida por la montera oxidada; es decir, la parte superficial del filón explotable a cielo abierto al ser de fácil acceso. Contamos con topónimos que nos ayudan a rastrear posibles áreas de recursos mineros, como Rincón de la Mina, Hoya de la Escoria, Campo de Herrerías, Collado de la Plata, etc. Además, las herramientas para estos procesos recuperadas en *Kelin* (picos y picoletas), así como el mineral de hierro en algunos yacimientos, permiten suponer que el proceso de extracción y abastecimiento se realizaba a escala local.

Los recursos mineros se localizan en yacimientos filonianos, formados por deposición de disoluciones minerales en grietas y diaclasas. Estas concentraciones son de composición heterogénea. También existen menas polimetálicas con asociaciones de minerales (plomo, plata y cobre, entre otros). Los minerales de hierro recogidos en prospección tienen forma de óxidos y óxidos hidratados (limonita, hematites parda y hematites roja) (fig. 2), que son los únicos que pueden ser transformados en hierro mediante la reducción en horno bajo y con carbón vegetal.

Nuestro trabajo de campo nos ha permitido localizar dos posibles puntos de extracción de hierro: mineralizaciones superficiales en la Hoya de la Escoria (Utiel) y vetas polimetálicas explotadas al aire libre o en galería en La Mina (Tuéjar). Ésta última, que se conoce como romana, pudo ser explotada por los iberos (fig. 3).

La reducción

El hierro se obtenía por reducción directa en fase sólida del mineral (óxidos), empleando hornos bajos que ofrecían un metal con un «alto» contenido de carbón (acero). Las condiciones del horno tenían que ser muy reductoras, cargándolo con carbón vegetal. Además, era necesario facilitar la evacuación de los elementos fundibles de la ganga (escoria licuada). Como resultado, se obtiene la esponja ferrífera, que se caracteriza por ser poco homogénea y tener abundantes inclusiones de escoria; una vez martillada y más compactada se denomina lupia, paso previo al lingote.

La presencia de restos de escorias de sangrado, escorias del interior de los hornos, etc. identifica la práctica de la reducción. Los 10 yacimientos con estos restos indican la existencia de bastantes hornos destinados a satisfacer la demanda local con mineral extraído en sus inmediaciones (fig. 1 y cuadro 1).

Hay una especialización de este proceso, en determinados yacimientos, que engloba dos esferas: establecimientos artesanales y poblados. Así, podemos diferenciar lugares con abundantes restos de escoria de colada, que indican una primera fase de reducción a pie de mina (Fig. 1, 1), en sus proximidades (Fig. 1, n.os 3 y 7) o en combinación con la alfarería (Fig. 1, n.os 10 y 26); por otro lado, en algunos lugares de hábitat (fig. 1 y cuadro 1, los demás) hay escorias de reducción, producto del proceso de refinado de la lupia previo a la forja, más angulosas y fragmentadas. En el primer grupo se encuentran pocos elementos de cultura material relacionados con el hábitat permanente, mientras que en el segundo se refieren a lugares de hábitat permanente en alto, amurallados o excavados como en *Kelin* y El Molón Arriba (Mata, 1991; Lorrio, 2001: 151-170, y Valor, 2004).

La post-reducción

La cadena operativa siderúrgica parece desarrollarse en diferentes espacios. Así, mientras la extracción y la reducción directa se realizarían cerca de las materias primas y el combustible, el refinado previo y la forja se producirían en los poblados, ya que no necesitan grandes instalaciones, y de materia prima y combustible.

Hemos encontrado escorias de forja en 25 yacimientos (Fig. 1 y cuadro 1), por lo que esta tarea debía de estar bastante extendida a escala territorial.

El taller de forja de Kelin. En una de las habitaciones de la casa 2 (siglo III) se encontró un taller de forja utilizado para la reparación y mantenimiento de herramientas de la familia pro-

pietaria. El taller se compone de un hogar en cubeta, de forma oblonga, con las paredes cubiertas de arcilla y sección en U. A un metro hacia el W, había una losa rectangular que funcionó como yunque y, junto a él, se encontraron unas tenazas de herrero (Figs. 4 c y 5). El conjunto se completa con una pequeña fosa circular rodeada de pequeñas piedras, de funcionalidad desconocida. También se encontraron cerámicas y varios objetos de hierro (figs. 4 a, b y 5).

Éste no debió ser el único taller metalúrgico de *Kelin*, pues tanto en excavaciones como en prospecciones se han encontrado restos de escorias de bronce y hierro, protolingotes en proceso de corte en caliente, escorias de forja, hierro trabajado, etc. (Fig. 6 a).

También la revisión de excavaciones antiguas e intervenciones recientes en el territorio han aportado información complementaria. Por un lado, en la Muela de Arriba se ha identificado actividad metalúrgica en los dos sectores excavados (figs. 6 b y 7) (Valor, 2004: 269-273), también se ha encontrado una tobera doble de grandes dimensiones (42 cm) en el Cerro de San Cristóbal (Iranzo, 2004: 232), así como fragmentos de otra en El Zoquete. Estas toberas dobles se utilizan para trabajos que precisan de un flujo de aire continuo con el fin de mantener una temperatura estable, por lo que son necesarias al menos dos personas trabajando en la fragua: el herrero y el ayudante que insufla aire.

Producto final

El producto final de utensilios, herramientas y armas de hierro es variado y bastante estandarizado para los siglos IV-III a.C. En el territorio de *Kelin* contamos con una gran variedad de útiles agrícolas (hoz, podón, legón, azadón y azuela), herramientas artesanales (escoplo, barrena, martillo-hacha, sierra, puntero, lezna, tijeras, espátula y gancho), elementos constructivos (clavo, anilla y herraje de puerta) y armas (cuchillo, puñal o espada corta, lanza, contera, punta de dardo y falcata) (Mata, 1991: 167-169; Lorrio *et al*., 1998: 149-161, y Valor, 2004: 272) (fig. 8).

A partir de los análisis metalográficos realizados, no parece existir una homogeneidad en el trabajo siderúrgico, pues no todos los productos tienen el mismo acabado. Es el caso de aceros de diferentes "calidades", materiales excesivamente cementados, materiales recalentados y enfriados con poca precisión, materiales poco depurados, etc. Por tanto, no todos los herreros debieron de tener la misma pericia, de manera que habría talleres especializados de acuerdo con la diversidad y calidad de los productos existentes (Quesada *et al*., 2000, y Pleiner, 1969: 23).

Interpretación económica y social

La práctica y organización del trabajo metalúrgico responden a una realidad compleja, social, económica y territorial, característica de la cultura ibérica.

Los indicios de producción siderúrgica recuperados son escorias, minerales y productos manufacturados. Su análisis permite avanzar algunas propuestas sobre la organización de la producción y su posterior distribución:

— La mina, las materias primas y el combustible implican el desplazamiento hasta estos puntos, y empezar allí la cadena operativa que después se ramifica. Por economía, los hornos de reducción directa suelen estar cerca de los lugares de extracción y abastecimiento, aunque la necesidad de combustible puede condicionar su presencia y desplazarlos a donde la madera sea abundante (Serneels, 1997: 29-42). En el territorio de *Kelin* hay restos de escoria de reducción cerca de las minas y en yacimientos cercanos a otras materias primas. La relación horno cerámico-horno metalúrgico (Casilla del Cura y La Maralaga) (fig. 1 y cuadro 1) ilustra el interés en ubicar ambas actividades productivas cerca de las fuentes de agua y combustible.

— No conocemos el régimen de propiedad de los recursos mineros, pero todas las fases del proceso siderúrgico, aunque independientes, están interrelacionadas. Los diferentes productos, asociados a las etapas de la cadena productiva, se transportan a los lugares adonde se realiza cada una de ellas, para finalmente llegar a los consumidores. Evidencia de ello es la localización diferencial de los lugares de abastecimiento y primera transformación del mineral, y de las forjas, como las de *Kelin* y Muela de Arriba. La existencia de protolingotes y lingotes de hierro implica su distribución desde los hornos de reducción directa hasta las forjas (Ferrer, 2002: 200-201, y Lorrio *et al*., 1998-1999: 149).

— El carbón vegetal como combustible es esencial. La importancia de las carboneras es evidente, pero su estudio es una asignatura pendiente. Los restos de carbón adheridos a un fragmento de lupia de *Kelin* se identificaron como *Pinus halepensis*, el cual pudo utilizarse a pesar de no destacar por su rendimiento calorífico.

— Para la última fase de la cadena operativa, hemos definido dos tipos de talleres: los dedicados a la fabricación de armas y/o herramientas a tiempo completo, que se encargarían de suministrar productos al territorio inmediato y al intercambio con otros territorios (Cerro de San Cristóbal y Muela de Arriba) (figs. 1; 6, n.º 2, y cuadro 1) y, en segundo lugar, los talleres domésticos a tiempo parcial, donde se podrían fabricar herramientas y armas, pero que, sobre todo, se dedicarían a su reparación y mantenimiento (*Kelin* y El Zoquete) (fig. 5).

Constatamos, pues, una realidad socioeconómica compleja, donde los herreros y mineros debían estar en conexión con otras actividades productivas como la explotación de recursos forestales (tala de madera y producción de carbón) y la distribución de los minerales y los productos semielaborados (lingotes) y finales (herramientas, útiles, armas, etc.).

Desde un punto de vista social, el herrero no forma parte de un grupo marginado, puesto que los talleres están totalmente integrados en la trama urbana y, además, la actividad desarrollada le permite enriquecerse. Es el caso de la familia residente en la casa 2 de *Kelin*, donde además se encontró un almacén con 92 ánforas (7460 litros), una pulsera de plata, dos calderos de bronce, un lote de herramientas agrícolas, vajilla importada, un molino, pesas de telar y fusayolas, etc. (fig. 5), evidencia todo ello de un alto poder adquisitivo (Giles, 2007).

Otros talleres ibéricos

Otros talleres metalúrgicos en el ámbito valenciano:

— En el territorio de *Edeta*, las áreas de captación de mineral se han localizado en las cercanías del Puntal dels Llops (Olocau), asentamiento donde además había un horno de copelación y 7 lingotes de hierro (Fig. 9). El proceso metalúrgico iniciado en este hábitat se completaría en los talleres metalúrgicos del Castellet de Bernabé (Llíria), *Edeta* (Llíria) y La Seña (Villar del Arzobispo) (Bonet, 1995: 361-362; Ferrer, 2002: 190-206, y Adelantado, 2003: 314-324).

— En La Bastida de les Alcusses (Moixent), la revisión de excavaciones antiguas ha permitido identificar talleres metalúrgicos (Fletcher *et al*., 1965-1969; Díes y Álvarez, 1998: 334-336, dep. 210, y Díes *et al*., 1997: 243-244).

— En el Tossal de les Basses (Alacant) las excavaciones de urgencia de 2004 han proporcionado un conjunto de hornos metalúrgicos de grandes dimensiones junto con hornos alfareros y estructuras anexas (Roser y Fuentes, 2007).

— Otras noticias son una posible forja en El Oral (San Fulgencio) (Arana *et al*., 1993: 189-203) e indicios de trabajo metalúrgico en El Puntal (Salinas) (Hernández y Sala, 1996: 43-44) y en La Serreta (Alcoi) (Grau y Reig, 2002-2003: 105).

Conclusión

La siderurgia es un aspecto de los pueblos iberos todavía poco conocido. La información presentada aporta datos de gran interés para la reconstrucción de esta actividad a diferentes escalas, y nos ha permitido abordar esta problemática en un territorio bien definido. Estamos en disposición de analizar la siderurgia interrelacionándola con otras actividades económicas, como la agricultura-ganadería, la explotación de recursos forestales, la artesanía y otros procesos sociales y territoriales.

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