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DACIAN IRON BLOOMS DISCOVERED IN THE AREA OF SARMIZEGETUSA REGIA

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Résumé: Cet article passe en revue les découvertes de loupes de fer ayant appartenu aux Daces de la région de Sarmizegetusa Regia. Certaines ont été découvertes à la suite des fouilles systématiques tandis que certaines autres, une bonne partie, ont été déterrées à la suite des actions frauduleuses des « chercheurs de trésors ».

On constate que ces loupes ont des poids variables mais une forme commune, ce qui prouve le fait qu'elles ont été obtenues dans des fourneaux avec hauteur et diamètre variables et dont la cuve se trouvait à la partie inférieure.

On y discute le terme «loupe» et on y combat la thèse selon laquelle ce terme provient du latin «lupus» (loup).

Le nombre impressionnant de loupes découvertes dans les alentours de la capitale dace constitue une preuve de l'ampleur de la métallurgie du fer au I[er] siècle ap. J.-C. Toutes ces loupes ont la forme d'un fromage rond dont manque une tranche triangulaire, ce qui est du au fait que juste après les avoir sorties du fourneau, tandis qu'encore brûlantes, le forgeron découpait le morceau trouvé du côté du soufflet, partie contenant des impuretés indésirables. La partie découpée pouvait être recyclée tandis que les nouvelles parois de la loupe permettaient l'inspection du contenu de celle-ci. C'est pourquoi on estime que le terme anglais «split blooms» par lequel on désignait ce type de loupes devrait être remplacé par celui de «clipped blooms», loupes à découpage, terme beaucoup plus suggestif.

On doit aussi remarquer le fait que dans la région de la capitale de la Dacie libre ce genre de loupes sont beaucoup plus nombreuses que dans l'ensemble de l'Europe - même si on inclut dans cette catégorie des loupes qui s'ensuivent chronologiquement jusque dans la période moderne. On constate aussi que les loupes à découpage de Dacie sont les plus anciens artéfacts de ce type, une vraie tête de série pour les découvertes européennes du genre.

Mots-clés: Sarmizegetusa; métallurgie; loupes à découpage; Daces.

Over 80 years have elapsed since the beginning of the archaeological research in the area known in specialized literature as "the fortresses and settlements from the Orăştie Mountains"[1].

The research, conducted on a very extensive area, sometimes on a large budget and lasting several months while other times lasting only several weeks, was

[1] On this occasion the museums from Deva and Cluj-Napoca organized a retrospective exhibition including spectacular Dacian artifacts and recalling images of either the specialists that brought them to light or of various moments throughout the excavations. A symposium followed by the release of the volume Daco-geţii, Deva 2004, was organized in Deva.

extremely important in order to discover the "way of life of the Dacians from the Orăştie Mountains"[2] as well as the significance of this 2000 years old civilization.

Due to the archaeological investigations in this area one can claim knowing a great deal about its specific fortifications system[3], architecture[4], religious beliefs[5], astronomical knowledges[6], and medicine[7] as well as about the various processing techniques of materials[8] and first of all about iron processing techniques[9].

The resemblances between the Dacian civilization and contemporary ones as well as the various features of the former have been highlighted on more than one occasion.

The development of archaeological research towards excavations sites on both the inner and the outer Carpathian arc, has allowed for some subtle observations as well as for comparisons between the level of civilization of the capital and that of the outlying areas of the Dacian kingdom.

Similarly, at a European level, an exceptional development of the archaeological and historical knowledge is also due to geologists, chemists, physicists and so on who are now able to put to test various hypotheses and ideas previously advanced.

As regards iron smelting, the rebuilding and experimental usage of devices similar to those used in the ancient world were decisive in obtaining new data about the *"chaîne opératoire"*: from gathering the minerals until the final output. Even though most experiments and analysis we possess originate from other countries and refer to other civilizations, we believe they may also prove useful to those interested in Dacian blacksmithing.

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[2] C. Daicoviciu. et alii, *Studiul traiului dacilor în Munții Orăștiei (șantierul arheologic de la Grădiștea de Munte)*, SCIV 2, 1, 1951, p. 95-126.

[3] C. Daicoviciu, H. Daicoviciu, Sarmizegetusa - Cetățile și așezările dacice din Munții Orăștiei, București 1962; H. Daicoviciu, Dacia de la Burebista la cucerirea romană, Cluj 1972.

[4] I. Glodariu, Arhitectura dacilor, civilă și militară, (sec. II î.e.n.-I e.n.), Cluj-Napoca 1983; D. Antonescu, Introducere în arhitectura dacilor, București 1984.

[5] I. H. Crișan, Spiritualitatea geto-dacilor. Repere istorice, București 1986; H. Daicoviciu, op. cit., p. 201-224; V. Sîrbu, G. Florea, Imaginar și imagine în Dacia preromană, Brăila 1997; a work that also concerns the religious beliefs of the Geto-Dacians, but without placing archaeological discoveries at the center of the historiographical discourse - Z. Petre, Practica nemuririi. O lectură critică a izvoarelor grecești referitoare la geți, București 2004; D. Dana, Zalmoxis de la Herodot la Mircea Eliade. Istorii despre un zeu al pretextului, București 2008.

[6] Fl. Stănescu, *Considerations concerning possible modalities to establish the astronomical directions in Dacian sanctuaries*, in E. Iaroslavschi (ed.), Studii de istorie antică. Omagiu profesorului Ioan Glodariu, Deva 2000, p. 325-335; idem, *Posibile orientări astronomice în marile sanctuare dreptunghiulare de la Sarmizegetusa Regia, România. Rezultate preliminare*, ActaMN XXXIV, 1997, p. 808-817; idem, *Absida centrală a marelui sanctuar rotund de la Sarmizegetusa Regia*, ActaMN XXIV-XXV, 1987-1988, p. 124-138.

[7] I. H. Crișan, Momente din trecutul medicinei. Studii, note și documente, București 1983; C. Váczy, *Nomenclatura dacică a plantelor la Dioscorides și Pseudo-Apuleius (partea I)*, ActaMN V, 1968, p. 59-73, idem, *Nomenclatura dacică a plantelor la Dioscorides și Pseudo-Apuleius (partea II)*, ActaMN VI, 1969, p. 115-129; idem, *Nomenclatura dacică a plantelor la Dioscorides și Pseudo-Apuleius (III)*, ActaMN VIII, 1971, p. 109-133; idem, *Nomenclatura dacică a plantelor la Dioscorides și Pseudo-Apuleius (IV)*, ActaMN IX, 1972, p. 107-117; L. Suciu, Habitat și viață cotidiană, PhD thesis, mss., Cluj-Napoca 2009.

[8] E. Iaroslavschi, Tehnica la daci, Cluj-Napoca 1997; A. Rustoiu, Metalurgia bronzului la daci (sec. II î. Chr.-sec. I. d. Chr.). Tehnici, ateliere și produse de bronz, București 1996.

[9] I. Glodariu, E. Iaroslavschi, Civilizația fierului la daci, Cluj-Napoca 1979.

This article presents the iron blooms crafted in Dacia prior to the Roman conquest, the raw material of workshops that produced a large array of tools, weapons, construction materials etc.

The number of iron blooms discovered in the said area has significantly increased in the past 15-20 years, particularly due to the unfortunate appearance of treasure hunters. Equipped with detection gear, they invaded the ancient settlements and, mostly at nighttime, they cross mountains and valleys. Traces of their activity can be observed in the form of small or medium sized holes dug where their detectors signaled the presence of metals. They obviously search for precious metals or highly valuable artifacts but they often realize their nature and size only after digging them out. Treasure hunters will only keep the objects they are interested in and discard heavy and large objects made out of common metals. Among the latter, a special case is that of the iron blooms. While out on the field, recovering Dacian artifacts discarded by treasure hunters it was noticed in the past years that such iron blooms are found in the area of the fortresses Costești-Cetățuie, Costești-Blidaru as well as Fața Cetii, Fețele Albe, Dealul Grădiștii, Căprăreața, Piciorul Muncelului, Tâmpu and so on (Pl. I/1).

Sometimes, after being brought to light, the iron blooms are thrown down the steep slopes of the hills. Due to their round shape they roll far away from the hole they were dug out from and their color, similar to that of dead leaves that end up covering them, makes their retrieval difficult. We are aware that the retrieval process is far from being complete and that a possibly large number of artifacts still lie undiscovered in the forests and valleys of the Orăștie Mountains, this time covered not by a stratum of protecting earth but by a thin layer of decomposing leaves.

A possible solution in this respect would be to equip archaeologists with metal· detectors so as to allow them to recover these unearthed artifacts.

The recovered iron blooms ended up in the storage rooms of the history museums in Cluj-Napoca and Deva. It was observed that the depth at which they were buried varied between 20 and 100 cm and that each pit contained several such items. It would seem that those who buried them did so in a hurry as they did not dig a regular shaped hole. Usually the hole had a rounded or oval section, without being lined in any way (with stone slabs for example). At times, after removing the iron blooms, the disappointed treasure hunters throw them away from their original location. Quite frequently they don't check the whole content of the hole so that part of it remains *in situ*. This allowed for observations regarding the way in which the original hole was made and the arrangement of the items placed inside of it. Such an example is a certain discovery from Sarmizegetusa Regia: close to the area known as "Tău", a few tens of meters away from a spring, towards the edge of the hill, tens of iron blooms were deposited in an almost cylindrical pit, dug in the stone-free loess. A similar hole was found on one of the slopes of the Muncel peak, close to the walking path (at approximately the same height as the metallurgic workshop from "Căprăreața")[10]. A significant number of iron blooms were found here, most of them whole, others broken in half. Discoveries of iron blooms, albeit in smaller deposits, were also reported

[10] I. Glodariu, *Un atelier de făurărie la Sarmizegetusa dacică*, ActaMN XII, 1975, p. 107-134.

in Dealul Grădiştii, on both the side towards Valea Albă and that towards Apa Godeanului (Pl. I/2). However, the recovered items were isolated and had been removed from their primary position so that it was impossible to say whether they initially belonged to a deposit.

In deposit holes that were not voided of their content by treasure hunters we noticed that the iron blooms had been stacked in a manner so as to fit in as many as possible (the rough, concave side was placed downwards and the convex, smoother side upwards; similarly the halves weren't carelessly thrown in, they were nestled so as to properly fit in the remaining space) (Pl. II/3 a-c; III/4).

At first sight the undisturbed deposits seemed to be rather small in size; in truth they are quite large and heavy[11] (/Pl. III/5). The villagers from Grădiştea de Munte mention a deposit located not far from the present road (close to the forestry building, in a cluster of fir trees) which is said to have been carried by truck to a metal collection center.

Many iron blooms discovered in the mid 20th century are mentioned in the bibliography but are hard to identify in the collections of museums. For example, the storage location of the seven iron blooms originating from a supposedly metallurgic workshop at *Poiana Rădăcinii* (a high terrace of the Stânişoara Mountains[12]) is currently unknown. Similarly, we have little information about the "iron battering rams" (name given by archaeologist to the first iron blooms that were thought to be parts of siege engines) from Sarmizegetusa[13] or about those said to have been found inside earthen walls at Costeşti-Cetăţuie.

As for the blooms that we did have the chance to observe, their weigh, size and shape have all been noted. In fact, these artifacts could be divided in three lots: the first lot belongs to the collection of the Museum of Dacian and Roman Civilization from Deva; the second, comprising items recovered from the Sarmizegetusa area, is in the keeping of the National History Museum of Transylvania, Cluj-Napoca. Similarly, the third lot, constituted by iron blooms discovered at Căprăreaţa, close to the metallurgic workshop investigated in 1971[14] is now part of the patrimony of the same museum.

The shape of the iron blooms that we were able to examine is similar. However, there are numerous variations in terms of weight, diameter and size.

Most of these artifacts have an almost circular shape but many exhibit uneven diameters and a vaguely oval contour. All items present a triangular clipping in the middle. The clipping was produced with a sharp tool (a chisel or an axe), immediately after the extraction of the iron bloom from the furnace, while still hot and, thus, more malleable (Pl. IV/6; V/7; VI/8; VII/9). The clipping does not generally exceed the center of the iron lump, but there are pieces where the removed "triangle" is almost as extensive as the diameter of the bloom, making it fragile and allowing for it to be

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[11] Rangers reported finding in several spots iron blooms or even massive iron tools unearthed by the treasure hunters and then abandoned.

[12] C. Daicoviciu, Al. Ferenczi, Aşezările dacice din Munţii Orăştiei, Bucureşti 1951, p. 28.

[13] C. Daicoviciu, *Şantierul Grădiştea Muncelului. Studiul traiului dacilor în Munţii Orăştiei*, SCIV 3, 1952, p. 304.

[14] I. Glodariu, op.cit., p. 107-134.

broken it half. Almost all of the analyzed fragments are equal halves of iron blooms whose excessively large clippings led to their fracturing.

The upper part is concave, with a rough, irregular aspect, while the lower part is convex and has a smoother surface (in what follows, we shall explain exactly how this shape was obtained).

The maximum diameter (30 cm) was recorded in two iron blooms; one belongs to the collection of the Museum from Deva, the other can be found at the National History Museum of Transylvania. The minimum recorded diameter is of 16 cm (the item belongs to the Museum from Deva). As for the great majority of blooms, 88% have a diameter of 20-25 cm. Their thickness or height varies from 8 to 16 cm, 73% of them measuring 10 to 13 cm (Pl. VII/10; VIII/11). We must nonetheless take into consideration the fact that most of these items were measured before being completely cleaned so that after proper restoration their dimensions will suffer a slight reduction (Pl. VIII/12).

The items weigh between 4.5-14.2 kg and are unevenly distributed in weight categories.

I. For the pieces from Museum of Deva, resulting mostly from the activity of treasure hunters, the situation is as follows:

Weight	5-6 kg	6-7 kg	7-8 kg	8-9 kg	9-10 kg	10-11 kg	11-12 kg
Number of artifacts	7	10	17	13	15	9	4

The items under 5 kg as well as those over 12 kg are scarce (only 2 blooms, one weighting 4.5 kg, the other 13.5 kg) (Pl. IX/13).

II. In the storage rooms of the National History Museum of Transylvania, Cluj-Napoca, there are 61 whole iron blooms, most of them being treasure hunting retrievals. The situation stands as follows:

Weight	5-6 kg	6-7 kg	7-8 kg	8-9 kg	9-10 kg	10-11 kg	11-12 kg	12-13 kg
Number of artifacts	3	7	7	8	9	7	10	5

Similarly to the Deva lot, the artifacts weighting under 5 kg and respectively over 13 kg are few (only 2 for the first category and 3 others weighting 13.5 kg, 14.1 kg, and 14.2 kg each) (Pl. IX/13).

III. Artifacts resulting from the systematic investigations at Căprăreața:

Weight	6-7 kg	7-8 kg	8-9 kg	9-10 kg	10-11 kg	11-12 kg
Number of artifacts	4	6	6	8	8	2

As can be seen, the size and weight of iron blooms varied. However, most of them belong to the category 7-12 kg (129 out of 172 intact artifacts[15]) (Pl. IX/14). The halves

[15] The numbers quoted by the present article refer to whole blooms or bloom fragments discovered until 2010. Last year as well as this year, 32 more whole blooms and 4 more fragments have been discovered in various areas of the Orăștie Mountains Dacian fortresses region.

that were analyzed confirm the statistics. In the Căprăreața lot, 44 halves belong to blooms that weighed 5-6 kg when whole while another 25 belong to 4-5 kg blooms. In the Deva lot, 40 out of the 73 bloom halves are part of 4-6 kg blooms and similarly the 17 halves in the Cluj-Napoca lot belong to 4-6 kg blooms (Pl. IX/15; X/16). As the rupture usually follows the axis of the clipping two equal parts resulted. Multiplying the resulting weight by 2 we may conclude that, for the most part, the weight of the Dacian iron blooms varied between 7 and 12 kg.

A noteworthy exception is the iron lump discovered at the entrance of the Tâmpu Valley. This one weighs 46.7 kg, has a diameter of 33 cm and a height of 21 cm[16] (Pl. X/17 a). Examples of artifacts weighing less than 5 kg are very rare.

The shape and size of iron blooms are due to the type and size of the furnace they were obtained in. The remains of many metallurgic workshops were found on extensive areas. Chronologically, they range from prehistoric times to the modern age, but their poor state of conservation gave rise to many debates as their type, proportions and usage.

Before proceeding to a comparison between Dacian iron blooms and contemporary blooms discovered in other geographical areas we believe it useful to briefly present our current knowledge of ironworking in Dacia.

Researchers agree that the Iron Age begins when the technology needed to work iron is discovered and not when the crafting of iron tools and weapons becomes a widespread practice. In Romania[17], the Iron Age is thought to begin as early as the Hallstatt A period. However, it is only in middle La Tène that iron gains actual supremacy of use, phenomenon mostly related to the development of the Dacian civilization and the rise to power of the Dacian kingdom.

Such as the case of other ancient civilizations from Europe or the Middle-East, the use of iron by the Dacians proved to be a key factor in gaining access to material goods and military power[18].

Iron ore can be found in many places in Dacia. Though the quality was not necessarily the best and the resources were rather modest, it was more than enough to supply the needs of that period. The ore was close to the surface, easily recognizable and readily gathered. It could also be mined through very small and shallow holes, by working along the lodes. As a general rule, European populations favored the reduction of ore close to the extraction site in order to avoid the various problems related to long distance transport.

[16] In the 1950s, while building a forestry railway, at the entrance of the Tâmpu Valley, the remains of furnaces as well as three unusually large iron blooms were discovered. Unfortunately, as no archaeologist was present on site, no drawings, photographs or descriptions have been made; only one of the three artifacts was salvaged (currently kept in the storage rooms of the National History Museum of Transylvania).

[17] M. Rusu, *Începuturile metalurgiei fierului în Transilvania*, in H. Daicoviciu (ed.), In memoriam Constantini Daicoviciu, Cluj-Napoca 1974, p. 349-360; A. László, *Începuturile metalurgiei fierului pe teritoriul României*, SCIVA, 26, 1, 1975, p. 22; E. Iaroslavschi, Tehnica la daci, Cluj-Napoca 1997, p. 19-20.

[18] E. Iaroslavschi, *Siderurgia dacică în cadrul metalurgiei europene*, in S. Nemeti, F. Fodorean, E. Nemeth, S. Cociș, I. Nemeti, M. Pîslaru (eds.), Dacia Felix. Studia Michaeli Bărbulescu oblata, Cluj-Napoca 2007, p. 53-66.

The forges where iron objects were made or repaired at the clients' request and where recycling took place, were located in populous areas, close to the consumer. Meanwhile the place where the iron ore was obtained was located at a significant distance away from the sites investigated by archaeologists.

Iron and wood, the raw material for obtaining charcoal could be found almost everywhere. This does not mean however that iron metallurgy was equally spread throughout the Dacian territory. Due to the abundance of ore lodes located close to the surface, allowing for easy exploitation, the mining and processing of iron developed in two main areas identified and investigated by archaeologists.

One of these two areas was named "zona siderurgică"[19] ("the ironworks area") by P. János and D. Kovács. The area, quite extensive, is located in the Eastern Carpathian Mountains and contains large quantities of iron slag - sometimes in pieces weighing over 40 kg - and having a rather spongy aspect. It is not by chance that several thriving Dacian communities were located here. The powerful fortresses and the rich settlements prove that the inhabitants knew how to take advantage of the natural resources of the area[20].

The second such area, rich in iron ore, has a quadrilateral shape with Cugir, Vârful lui Pătru, Federi and Boşorod at its four angles. Traces of iron mining and processing have been identified in the area. In fact, this is where the largest metallurgical workshops from Dacia were found as well as easily accessible ore lodes[21], such as those from Bătrâna, Tâmpu, Cugir, Sibişel and so on. The iron blooms discussed in the present article were found in the same perimeter (Pl. XI/ 18).

Iron ore resources were discovered in other Dacian settlements[22] as well, some of them quite small and rather poor[23]. The next step should consist of analyzing the iron blooms, the iron slag and the iron artifacts from the entire Dacian area with the purpose of obtaining certain information regarding the use of these resources, the type of the furnaces as well as the commercial routes the products used to take.

As mentioned previously, the ore lodes closest to the surface were preferred. The term "Dacian mining", used rather frequently, is an exaggeration. The so-called miners resembled gatherers who sometimes used mason or blacksmith tools in order to crush the ore. Such tools can be found in large numbers around Sarmizegetusa[24].

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[19] P. János, D. Kovács, *Periegheză arheologică în bazinul Ciucului*, Studii şi materiale II, Târgu Mureş 1967, p. 43-53; E. Iaroslavschi, *Siderurgia dacică în Carpaţii Orientali*, Angustia 9, Sfântu Gheorghe 2005, p. 155-158.

[20] V. Crişan, Dacii din estul Transilvaniei, Sfântu Gheorghe 2000, p. 147-151.

[21] See the list of the most important ferriferous deposit in Şt. Ferenczi, *Premisele naturale ale metalurgiei fierului în Munţii Orăştiei*, Studii şi comunicări de etnografie-istorie III, Caransebeş 1977, p. 299-309.

[22] E. Iaroslavschi, *Les fourneaux de reduction du minerai du fer chez les Daces*, in M. Feugère, M. Gustin (eds.), Iron, Blacksmith and Tools. Ancient European Crafts, Monographies Instrumentum 12, Montagnac 2000, p. 97-102.

[23] Even the ferruginous deposits found in some river beds could be used. For example at the furnace in Bragadiru, on the outskirts of Bucharest, a low quality ore was used. The ore was obtained from the river bed of the Sabar River (M. Turcu, *Cuptorul pentru redus minereul de fier descoperit la Bragadiru (sec. II-I î.e.n)*, in H. Daicoviciu (ed.), In memoriam Constantini Daicoviciu, Cluj-Napoca 1974, p. 389-393).

[24] I. Glodariu, E. Iaroslavschi, op. cit., p. 104-108; I. Glodariu, *Cariere şi exploatarea pietrei în Dacia preromană,* ActaMN XXII-XXIII, 1985-1986, p. 91-103.

Iron was obtained in small furnaces where ore, charcoal and certain additives meant to facilitate the process were mixed. In order to obtain more iron of higher purity the ore had to be treated. The ore was subjected to mechanical operations such as breaking, grinding, griddling, repeated washing and roasting[25]. The same procedure was applied to non-ferrous ores.

Roasting was a very important thermal procedure, resulting in the elimination of water and, due to chemical reactions, of earthen compounds. In the ancient Europe we find it in Etruscan[26], Celtic[27] and Germanic[28] regions. In Dacia, though surely practiced in other places as well, it is certified in Cireşu[29], Oltenia and Herculian[30], in the Eastern Carpathian Mountains.

At Cireşu, 14 pieces of ore roasting equipment have been discovered. They can be divided in two categories. The first type is represented by an oval hearth, 5 meters in diameter, bordered by a rim consisting of burnt earth, impregnated with slag. The hearth, set upon a slope, had two superposed layers of clay at ground level and a protrusion in the middle, also covered in a layer of clay. A large amount of slag as well as parts of burnt rough cast were found in the hearth. The second type was discovered nearby and it is somewhat similar. The hearth was almost round, surrounded by two rows of raw bricks and presented several grooves that started from the central firing chamber and were disposed in the shape of a fan. The central part was deeper as compared to the rest of the hearth and had bricks on its margins, all of them placed in an upright position with small intervals between them. A clay tube went all the way inside the hearth, through the bricks. L. Roşu and E. Bujor who conducted the research, believed them to be "early types of reduction furnaces". The process was similar to heap roasting: iron ore and charcoal were stacked inside, then everything was covered with a layer of soft earth (its role was to prevent the air from leaking out of the installation). The combustion took place in the center of the hearth, the so-called firing chamber. It was maintained because of the air circulation inside the furnace created by an opening at the lower-end of the slope and by an alleged "chimney" at the upper part.

In 1979, when "Civilizaţia fierului la daci" was first published, theories such as this one began to be explored. The considerable size of the device meant that a large quantity of ore was used each time. The problem is that a lot more air was needed than could be provided by a system such as the one described above. Even if the clay tube, mistakenly believed to have been used for the evacuation of iron from the equipment,

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[25] J. Ramin, *La technique miniere et metallurgique des Anciennes*, Latomus 153, 1977, p. 166; E. Iaroslavschi, Tehnica la daci, Cluj-Napoca 1997, p. 161, pl. IX.

[26] G. D'Archiardi, *L'industria mineraria e metalurgica in Toscana al tempo degli Etruschi*, Studi Etruschi I, Firenze 1927, p. 411-420; R. J. Forbes, *Studies in Ancient Technology*, vol. IX, Leiden 1964, p. 181.

[27] Ch. Daremberg, E. Saglio (eds.), Dictionnaire des Antiquités Grecques et Romaines, s.v. *Ferrum*; R. Pleiner, Iron in Archaeology. The European Bloomery Smelters, Prague 2000, p. 106-113.

[28] S. Dušek, *Eisenschmelzöfen einer germanischen Siedlung bei Gera-Tinz*, Alt-Thüringen IX, Weimar 1967, p. 95-183.

[29] L. Roşu, E. Bujor, *Cuptoarele de redus minereul de fier din epocă geto-dacică descoperite la Cireşu*, RevMuz V, 4, 1968, p. 307-309.

[30] Z. Székely, *Contribuţie la studiul prelucrării fierului la dacii din sud-estul Transilvaniei*, Aluta. Revista Muzeului Naţional Secuiesc 12-13, Sfântu Gheorghe 1981, p. 31-34.

had been connected to bellows, the air flow still wouldn't have sufficed. Furthermore, the walls, shaped like a broken cap would have been unable to withstand a temperature as high as was needed to initiate the reduction process. In other words, the components of the furnace could not have offered structural resistance to the building and would have prevented proper ore reduction due to their size and composition[31]. For all these reasons the device from Cireşu was redefined as an ore roasting furnace, used in the preparatory phase of the reduction[32]. Their very large size as well as their construction features makes them significantly different from the ones used by contemporary European peoples.

Their brief description does not allow us to understand what the output looked like after roasting; apparently it was not homogeneous and did not have a compact mass. The temperature, not nearly high enough, allowed nonetheless for some light slag to form at the base of the furnace (all furnaces were located on gentle slopes) as well as for small lumps of ore, much richer in iron. Despite their iron content these lumps of ore cannot be considered "iron blooms" though this term may refer, throughout the European world, to various products having different shapes and sizes.

Most likely, the enriched ore was once again crushed, mixed with charcoal and then inserted into the reducing furnace.

The ore, whether or not roasted, contains iron alongside other elements. In order for the iron to form, these crystalline structures need to be broken and the oxygen atoms (as well as other atoms) need to be removed. Such a reaction requires heat and a reducing agent (a chemical agent with a higher capacity to produce oxides than the metal *per se*). In chemistry this is known as *a reduction process*.

In ferrous metallurgy this reducing chemical is carbon. At temperatures above 700°C, carbon and carbon monoxide extract oxygen from iron dioxide, FeO. This reaction produces carbon dioxide and iron. At higher temperatures this reaction is easily obtained[33].

$$FeO + CO = Fe + CO_2; 2FeO + C = 2Fe + CO_2$$

Another possible chemical reaction is this[34]:

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2 \qquad FeO + CO \rightarrow Fe + CO_2$$

In other words, charcoal (a fuel with great heat efficiency) combustion in a furnace will produce heat on the one hand and the reducing carbon monoxide on the other:

$$O_2 + C \rightarrow CO_2$$
$$CO_2 + C \rightarrow 2CO$$

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31 I. Glodariu, E. Iaroslavschi, op. cit., p. 31.

32 E. Iaroslavschi, op. cit., p. 114.

33 V. Serneels, *La chaîne opératoire de la sidérurgie ancienne*, in Groupe de travail Suisse d'Archéologie du Fer. Minerai, scoris, fer - Erze, Schlacken, Eisen: Technique des fouille-minerai, scories, fer. Cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie, Basel 1997, p. 9-12.

34 Idem, in M. Feugère, V. Serneels (éds.), Recherches sur l'économie du fer en Méditerranée nord-occidentale, Monographies Instrumentum 4, Montagnac 1998, p. 13.

At 700°C iron is not even close to its melting point. It remains solid, as do other compounds of the ore. At 1,100°-1,200°C the gangue reaches its melting point and liquefies while the metallic iron remains solid (more precisely it turns into a viscous paste). The liquid slag is separated from the iron. This is the direct method of iron reduction. It was spread throughout Europe (and beyond) and was used for a long time, until improvements allowed for higher temperatures to be attained and thus for other forms of reduction to be devised.

Recently, while trying to determine the place held by the Dacian ferrous metallurgy within ancient metallurgy[35], the methods of obtaining iron in Europe, at different times and in different places have been revised and Dacian devices have been compared to other similar devices whether older, contemporary or newer. In what follows, we shall present the main ideas of that (this study so as to better understand why the end products of such different devices in terms of form, technology as well as time frame can all be referred to as *iron bloom.*

Another method of obtaining iron was only discovered when it became possible for the furnaces to generate more heat for a longer period of time. This method allowed carbon to spread through the iron and generate pig-iron that has a lower melting point than iron. Two liquids resulted inside the furnace. On account of their different densities they could be separated and allowed to drain one after the other. This is the indirect method of iron reduction[36].The first blast furnace to produce pig-iron in Europe dates back to the 12th century but the method becomes widespread starting from the 16th century. We shall not insist on this particular method since the Dacians, like other contemporary civilizations, only used the direct reduction method that has to be seen as specific to the ancient period, though it was widely used in Europe until the 18th century and is used traditionally even today.

Various remains of Dacian furnaces have been found on a very extensive area but, unfortunately, their poor state of conservation did not allow a very accurate reconstruction. For instance no standing wall has yet been found; consequently, the actual height of the furnace walls had to be approximated. Most remains have been discovered inside the Carpathian arc: within or near the settlement of Grădiștea de Munte, the ancient *Sarmizegetusa Regia* (Valea Tâmpului, Sub Cununi, Vârtoape, Ohaba Ponor, Federi, Ponorici), Șercaia, Craiva, Teliuc, Cinciș, Cristian, Hărman, Copăcel, Doboșeni, Herculian, Sândominic, Pădureni, Biborțeni, Augustin, Tomești, Cârța, Mădăraș, Delnița, Cosmeni, Cașinu Nou, Bezid. Among noteworthy areas outside the Carpathian arc are the following: Bragadiru, Șirna, Teiu, Ulmetum and so on[37]. As a rule, the furnaces are found together with slag, both on the inside and on the outside but without the iron bloom. This makes sense as the removal of the bloom involves tearing down the walls

[35] E. Iaroslavschi, *Siderurgia dacică în cadrul metalurgiei europene,* in S. Nemeti, F. Fodorean, E. Nemeth, S. Cociș, I. Nemeti, M. Pîslaru (eds.), Dacia Felix. Studia Michaeli Bărbulescu Oblata, Cluj-Napoca 2007, p. 53-66.

[36] V. Serneels, op. cit., p. 13.

[37] Details and bibliography in E. Iaroslavschi, *Le fourneaux de reduction du minerai de fer chez les Daces,* in M. Feugère, M. Guštin (eds.), Iron, Blacksmith and Tools, Ancient European Crafts, Monographies Instrumentum 12, Montagnac 2000, p. 97-102.

of the furnace. There are a few exceptions to this rule: broken furnaces with the bloom still in place or located nearby, such as the ones found in Craiva[38], Șercaia[39], Teliuc[40], Copăcel[41], Sândominic[42] etc. However, because of their brief description and the lack of any photographs or drawings the only thing we know about them is the fact that they had a "round" shape. In all probability they are lost in museum storage rooms or perhaps in other places as we were unable to identify them. From the discussions that we had with their finders we found out that none of these iron blooms presented the typical cut of those discovered in the Orăștie Mountains.

In what furnaces are concerned, experts put forth different timelines, evolution patterns, radiation patterns that seem to present numerous similarities. They all agree, for instance, on the differences that exist between the furnaces (the type in which the ore is mixed with the fuel) whose walls are smaller than the diameter, *low furnaces,* and the furnaces whose walls are higher than the diameter, *blast furnaces*[43].

The Dacians used two types of furnaces: the first produced a single batch of iron and was subsequently abandoned; the other produced several batches.

The first category includes the furnace discovered at Șercaia[44] that we were able to reconstitute (Pl. XI/19, 2). The lower part presents a protrusion, a sort of tank, approximately 30 cm deep and 55 cm in diameter. Above ground the walls seem to have had an almost squared shape, rounded during the building process so that their final shape was that of a truncated cone. Local clay was used for their construction; about a third of their original height was preserved (~25 cm). The hearth was full of slag that still had a round iron bloom on top of it with the diameters 38 × 27 cm. On the inside, the walls presented burn marks 2-3 cm deep. As for the furnace from Copăcel, the author of the discovery[45] mentions, without providing any further details, that the remains as well as the iron bloom are similar to those discovered at Șercaia.

This type of furnace, 50-60 cm high and no more than 1 m in diameter, produced a single batch of material. As a result of the required physical and chemical reactions, an iron bloom was obtained; it could be removed only by dismantlement, be it only partial, of the walls. A new operation meant that a new installation had to be built.

The second type of furnace can be reconstituted based only on the discoveries from Doboșeni[46], in the lowlands of the Eastern Carpathians. Two furnaces were partially investigated there, they were found on a hillside and they had a circular section and a flat bottom. The diameter of the bottom was of about 80-90 cm while the height of the standing portion of the walls varied from 60 to 100 cm. In front of the furnaces

[38] V. Wollmann, *Valoarea cercetărilor metalografice pentru studierea unor descoperiri arheologice*, Apulum IX, 1971, p. 283-292.

[39] I. Glodariu, E. Iaroslavschi, op. cit., p. 23.

[40] O. Floca, M. Valea, *Villa rustica și necropola daco-romană de la Cinciș*, ActaMN II, 1965, p. 165-166.

[41] Fl. Costea, *Așezarea dacică de la Copăcel*, ActaMP V, 1981, p. 171-173.

[42] L. Barabași, *Din istoria metalurgiei pe teritoriul jud. Harghita*, SympThrac 5, 1987, p. 14-15.

[43] J. Ramin, *La technique minière et métallurgique des Anciens*, Latomus 153, 1977, p. 120-122.

[44] I. Glodariu, E. Iaroslavschi, op. cit., p. 23.

[45] Fl. Costea, op. cit., p. 171-173.

[46] Z. Székely, *Raport preliminar asupra sondajelor efectuate de Muzeul Regional din Sf. Gheorghe în anul 1956*, MCA V, 1959, p. 231-233.

and close by wall fragments and two panes were discovered, the latter were made of burnt clay and they were shaped as a half-disc with an opening in the middle; this is where a tube (also made of burnt clay) used to be inserted in order to blow air inside. A lot of slag, chalkstone (probably used as flux), iron ore as well as Dacian ceramics were discovered around this area[47]. This type of furnace had a flat bottom, 80-90 cm in diameter; part of the wall was made by sparing the hillside slope while the front side was built of local earth. The furnace narrows towards the top, the inside resembling a truncated cone. It was 1 m tall, reaching the natural hillside slope (and went beyond it in some cases). In the front there was an opening shaped like a half-disk where a "door" used to go (the burnt clay pieces previously described) (Pl. XI/19, 1). It was through this opening that the air pipe was inserted. When the reduction process was complete the iron was removed by simply dismantling the "door", the device remaining intact. The inside of the furnace was cleaned and could then be reused, the door was set in its place and the process resumed. It is hard to estimate how many times this operation could be repeated: the furnace still degraded with every use so that it would eventually be abandoned.

This is the furnace that could produce several batches of material. Judging by its size (it was larger than the first type) it had a higher productivity and was thus of a superior kind. Unfortunately the iron resulting from the reduction process was not found. The author of the discovery stated that both furnaces had a flat bottom, without mentioning whether it went any deeper (and if yes, how much so) than the half-disc opening - "the door". Thus, we do not know if the tank was large enough to collect all the slag on top of which the iron bloom would emerge. If the distance between the bottom and the lower end of the "door" was insufficient, the slag might not have gathered properly preventing the formation of the iron bloom (on top of the slag and thus, a little lower than the half-disc opening).

According to available data it is likely for the resulting iron blooms to be quite different from the hundreds discovered in the area of Sarmizegetusa Regia (obtained in single batch furnaces). The poor conservation state of the artifacts from Doboşeni did not allow archaeologists to see where the disc was placed. In 1979, when "Civilizaţia fierului la daci" was published, a reconstitution placed the disc a bit higher than the bottom of the furnace; as a result, the air hole was placed even higher. However, had the "door" been placed at the bottom of the furnace the end product as well as the shape of the "iron bloom" would have been quite different.

In other areas of Europe, in furnaces with slag evacuation systems, the end-product was a spongy iron accompanied by large quantities of residual material, i.e. slag. This had to be further processed, in order to obtain the desired quality [48].

We also tried to use some rather sketchy information according to which, in the lowlands of the Eastern Carpathians, in Sândominic (Harghita County) the remains

[47] V. Crişan, op. cit., p. 40.

[48] V. Serneels, op. cit., p. 10-11; see also L. Eschenlohr, *La méthode directe de reduction du minerais de fer en bas fourneau*, in Groupe de travail Suisse d'Archéologie du Fer. Minerai, scoris, fer - Erze, Schlacken, Eisen: Technique des fouille-minerai, scories, fer. Cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie, Basel 1997, p. 17-28.

of a furnace consisting of "ceramic panes for the mouth that supported the air tube for the bellows" and an "iron bloom" were found. Unfortunately, the discovery was not published and its brief mention in an abstract is not enlightening[49]. It would have been interesting to see if the iron bloom was or not similar to those found around the Dacian capital. Furthermore the large, spongy lumps, weighing tens of kilograms[50], frequently discovered in the metallurgical area of Ciuc, have to be investigated.

Until further data is gathered as to the furnaces used in eastern Transylvania, we can only assume, based on the few construction details that we know as well as on the size and shape of the lumps, that the device was similar to those used in western Europe (that allowed the evacuation of slag and produced a rather impure "iron sponge").

The situation is not out of the ordinary, it merely completes a long series of discoveries pertaining to nations contemporary with the Dacians. Just as in our case, metallurgical centers are found mostly in mountainous areas: the Carpathians, the Alps or the Pyrenees mountains[51]. Some of them were in use before the Latène period though most developed especially during the second Iron Age and went as far as the Roman and post-Roman ages. They all began by exploiting the ore found on the surface; some resources were exploited in depth and for a long period of time. Roasting remains abound in these areas, the resulting piles of slag being reused as raw material in modern furnaces.

The study of metallurgical areas, with hundreds of furnaces, has been useful in establishing typologies - slightly different at times but mostly complementary, facilitating further research. The experts distinguish several types and versions, perhaps not always acceptable, but understandable taking into consideration the fact that the excavations has been carried out over different periods of time and in different manners and given as the area of expertise of the researcher-in-chief. Modern efforts strive to implement shared excavation techniques, a unity of language as well as simplified exchange of information between specialists. This will surely lead to a development of what is already considered to be "the archaeology of iron"[52].

In accordance with widely used criteria, a first classification of ancient furnaces involves a first category of furnaces that do not posses a slag elimination system and a second type that do. In order to include a furnace into a category or the other, remains of the walls, the "door", the tubes, the slag-bell (shaped or discharged), the iron blooms and the "sponges" are closely analyzed.

As a rule, the earth used for building the walls came from the close vicinity of the chosen spot. It is believed that the shape of the furnace was more important than the material in the roasting process. The typological variety of the equipment is also remarkable - though the state of conservation does not always allow for a detailed reconstitution.

[49] L. Barabași, op. cit., p. 14-15.

[50] P. Iános, D. Kovács, op. cit., p. 43-53.

[51] For a vast bibliography use C. Dunikowski, S. Cabboi, La sidérurgie chez les Sénons: les ateliers celtiques et gallo-romains des Clérimois (Yonne), Documents d'Archéologie Française 51, Paris 1995, p. 178-180.

[52] E. Iaroslavschi, Tehnica la daci, Cluj-Napoca, 1997, p. 8.

In general, furnaces with exterior slag elimination systems were used several times: this is proven by the reconditioning of the walls and their small number as compared to the huge quantity of slag that was found. As for the furnaces with slag discharged on the interior, at the base of the tank, they were used only once. Most of the slag can still be found in the scooped part of the furnace. In order to obtain a certain quantity of iron, several furnaces were used[53]. Perhaps the best example of a place harboring a real "furnace field" (hundreds of them) can be found in Poland - in the Swietokrzyskie Mountains. In these furnaces the slag would take the shape of the tank, becoming almost cylindrical, such as a cask or a cap. Often, when the air intake hole was low, part of the liquid slag occupied the end of the draft tube or canal reason for which the bulk would present a beak-like growth [54].

Records mention in Europe: natural air-flow furnaces with drained slag, furnaces with bellows and drained slag, natural air-flow furnaces or furnaces with bellows and interior or exterior slag draining systems, furnaces with bellows and slag pit furnaces - especially in Northern and Eastern Europe[55]. Other types, spread over a smaller area, are the Catalan furnaces (in the North-Western Mediterranean area) and the Evenstad furnaces (in Norway and Sweden)[56]; they belong to a later age and so will not be discussed in the present study.

Air has a very important role in initiating and maintaining the reduction process; more precisely, the oxygen intake allows reaching high enough temperatures and facilitates the production of chemical reactions. There is still the question of whether the induced draught was an accidental discovery or whether there were several stages in its development. The use of an artificial ventilation system was noticed on several occasions, this was performed by the means of blowpipes attached to bellows or simply by the means of bellows, without any ceramic tubes. The orientation of the holes in the furnace walls proves that, although the rule was for oxygenated air to be directed diagonally towards the bottom of the furnace, where it was meant to reach the maximum temperature, there were cases in which the air flow was performed from the top or from the bottom through one or more horizontal openings - the arrangement of the tubes being bifid or even trifid.

At a certain point, natural draught was thought to be the main feature of archaic metallurgy. We now know that it coexisted for several centuries with induced draught. Natural air-flow furnaces (with one or more side openings and/or several openings in the "door") seemed to be taller than their bellow-using counterparts. But since the furnaces whose original height is known are very scarce this is more of a hypothesis than a proven fact. Artificial ventilation was achieved with the help of several blowpipes inserted into an opening in the wall or in a mobile perforated piece (usually this was placed at the front of the furnace, at different heights,

[53] L. Eschenlohr, op. cit., p. 20.

[54] K. Bielenin, Starozytne hutnictwo Swietokrzyskie, Warszawa 1969, passim; idem, *Dla Kogo produkowana zeleza w Gorach Swietokrzyskich*, Otchlani Wiekow XXXIV, Warszawa 1968, passim; R. Pleiner, op. cit., p. 71, fig. 18.

[55] R. Pleiner, op. cit., p. 259-261, fig. 68-69.

[56] L. Eschenlohr, op. cit., p. 20.

oriented toward the base). With the passage of time the size of the mobile clay components as well as that of the transversal tubes - known in the German and French literatures as *"Düse"* and *"tuyère"* respectively - changed[57]. Made out of clay, they present a large variety of sizes. Generally speaking, their thickness corresponds to that of the furnace walls and the main identified shapes are right-angled or trapezoidal. The tubes inserted into the nozzles or directly into the wall of the furnace also come in different sizes; they are often cylindrical, with the end pointing to the furnace slightly contracted, like a truncated cone or a funnel[58]. The inside diameter of those found in Dacia is only a few centimeters large, while the walls are ~1 cm thick. Funnel-shaped tubes dating back to the Roman age have also been discovered on the Dacian territory alongside cylindrical ones. Such items have been discovered at Şoşdea[59], Fizeş[60] while others have been identified over a larger area through surface investigations[61].

The existence of two types of ventilation for the two main categories of furnaces is not always easy to identify. There are furnaces with the slag gathered at the bottom, with evidence of bellow usage, as well as furnaces without such particularities; this led to the assumption that they used a natural draught. But this is not a phenomenon that evolves in time or space. Any clue might prove valuable and a lot of interest was shown lately in collecting and garnering all possible details, in the hope of obtaining a full picture. Still, all available data must be carefully examined because of the insufficient number of discoveries. The absence of tubes is not sufficient to proclaim the general use of a natural draught.

Explaining the plan of a Latène furnace, L. Eschenlohr speaks about an installation that presents two nozzles: one in the front, the other one in the rear as well as two more orifices on the sides[62], meaning that air was introduced from four sides. The same author presents a simplified layout of furnaces (Pl. XII/20). The furnaces in the second group (called "furnaces with vertical slag separation") are very similar to the ones used by the Dacians. The furnaces in pictures 2.1 and 2.2 (Pl. XII/20) belong to the 1st type of Dacian reduction devices (Pl. XI/19) while the one in picture 2.3 (Pl. XII/20) discovered on the Czech territory[63] is identical to those from Doboşeni (that could produce several batches).

The same pictures may be found in the study of V. Serneels; according to the Swiss researcher, both types are typical of Northern and Eastern Europe[64].

[57] Idem, op. cit., p. 19.

[58] Modifications tend to happen during usage, coming into contact with the large temperatures inside the furnace they tend to vitrify and change shape; see R. Pleiner, op. cit., p. 204-211, fig. 55-57.

[59] E. Iaroslavschi, *Cuptoarele de redus minereul de fier de la Şoşdea, jud. Caraş-Severin*, ActaMN XIII, 1976, p. 231-237.

[60] E. Iaroslavschi, R. Petrovszky, *Cuptoarele pentru redus minereul de fier de la Fizeş, jud. Caraş-Severin*, Tibiscus III, Timişoara 1974, p. 147-155.

[61] E. Iaroslavshi, G. Lazarovici, *Vestigii arheologice în bazinul Caraşului*, ActaMN XVI, 1979, p. 447-464.

[62] L. Eschenlohr, op. cit., p. 17, fig. 4.

[63] K. Motykova, R. Pleiner, *Die römerzeitliche Siedlung mit Eisenhütten in Ořech bei Prag*, Památky Arch. 78, 1987, p. 371-448.

[64] V. Serneels, op. cit., p. 16, fig. 10.

As to the Dacian furnaces, discoveries so far would suggest that a single type of air inducing equipment was used, a hypothesis also sustained by the shape of the iron blooms specific to this area. We of course hope that new discoveries in the Eastern Carpathians will shed more light on the shape of the end product from furnaces that produced more than one batch.

But let us have a closer look at the reduction process in a Dacian furnace. As previously mentioned the iron ore, enriched, roasted and crushed, was introduced in the furnace through its upper part and was placed in layers alternated by charcoal. Charcoal is a fuel with high caloric efficiency, obtained through the dry distillation of wood, in the absence of air, in pits with the upper side covered so as to moderate the burning process. Unfortunately such pits are not clearly signaled by Romanian archaeologists. This is understandable given the fact that before being found in large numbers in settlements from Poland, Germany, former Czechoslovakia[65] and other countries, their function was unknown; powdered coal found on the bottom was not enough to explain it[66].

Along with charcoal[67] and ore other rocks acting as fluxes were introduced. They were meant to speed up the process by lowering the reduction temperature and allowing the slag to form more easily[68].

The burning once initiated in the lower part of the furnace, filled with charcoal and a little dried wood, was maintained and amplified by the use of bellows. The blowpipes were inclined against the wall of the furnace, as proven by the deposits of slag on one end (noticed at Şercaia). This arrangement of the tubes was identical in all western European furnaces; this way, a maximum temperature was reached at the bottom and a lower one towards the top.

Metallographic analyses conducted in several laboratories from around the world proved that it was possible to attain high temperatures in the furnaces (1,300-1,450°C), not high enough to melt iron but sufficient to initiate and maintain the reduction process. In the first stage the ore is aggregated, the second stage corresponds to the beginning of the gradual reduction process (small grains appear in the ore), another stage is that of an advanced reduction while in the last stage the drops and the viscous metallic iron grains bind together, producing the iron bloom. At this stage, the melting of the earthen compounds also ends; along with a significant quantity of iron they will descend in the tank thus forming the slag[69].

The round/oval iron bloom can be found on top of this slag. Being heavier than the slag, the lower side of the bloom will sink slightly into the slag and acquire a

[65] R. Pleiner, Základy slovanskeho zeleárského v ceskych zemich, Prague 1958, p. 62-70.

[66] Idem, Iron in Archaeology. The European Bloomery Smelters, Prague 2008, p. 118-126, fig. 29-32.

[67] It is highly possible that part of the charcoal was obtained by using pile mounds covered by thin layers of earth. An attempt to recreate the method allowed us to recreate such a pile mound at Sarmizegetusa Regia so that in only two days a charcoal batch of excellent quality was obtained. See D. Sima, *Combustibili în antichitate. Obţinerea mangalului între arheologie experimentală şi etnografie*, in C. Gaiu, H. Bodale (eds.), Centru şi periferie, Lucrările colocviului naţional, Bistriţa 23-25 aprilie 2004, Cluj-Napoca 2004, p. 35-44.

[68] For fluxes used in Dacia and elsewhere see E. Iaroslavschi, Tehnica la daci, Cluj-Napoca 1997, p. 55.

[69] V. Wollmann, op. cit., p. 287-288.

smooth appearance. The upper side however is concave and has a rougher texture because of the air-flow injected by the bellows. This same air flow lead impurities in the region corresponding to the end of the clay tube. In order to eliminate them, right after the bloom's removal from the furnace, that portion was cropped out; this is why the Dacian iron blooms are similar to a round piece of cheese with a triangle cut out (Pl. IV/6; V/7; VI/8; VII/9).

Since all Dacian iron blooms present an only cropping we may safely assume that an induced draught, generated by a single bellow, was the method of choice every time. The cut was made with the help of massive, well tempered tools, with a wide drilling edge. Though most iron blooms were not cleaned of rust and properly preserved, one can easily see that after the removal of the triangle, the edges are smooth, straight, as if made by a skilled metal smith with one mighty hammer blow.

Within the large array of Dacian iron blacksmith tools we noticed a specialization for the most diverse operations. We believe that some of these tools could be successfully used to grab, handle and crop out the unwanted portion of the massive iron bloom[70].

No such removed triangle has ever been found. This is understandable as the operation was performed right after the removal of the iron blooms from the furnaces; moreover the iron blooms discussed in the present article were all discovered in the settlements and fortresses from the Orăştie Mountains. We believe those triangles were not thrown away, but kept, and then added to a new batch after previous crushing.

The purity of the iron blooms is exceptional; the iron concentration in some cases is above 99%. Such an iron is soft[71] and has to be treated in order to be used: by beating, carburetion and tempering the iron modifies its chemical properties and becomes steel[72]. The process would take place in forges, in devices such as those from "Căprăreaţa" [73] or in furnaces with deep tanks, like the on from Piatra Craivii[74].

Unfortunately we cannot say much about the iron obtained in multi-batch furnaces (from Doboşeni and nearby areas). However there are many similarities between these furnaces and the ones with nozzles or ventilation bricks from the northern Alps. The "door" or "gate" mentioned previously has a rounded upper part; it's taller, wider and less thick than the walls of the furnace[75]. We may safely say that Dacian installa-

[70] See for example the tongs from I. Glodariu, E. Iaroslavschi, op. cit., fig. 13/1-9, the sledgehammers in fig. 10/1-7; the axes in fig. 12/1-4; the chisels in fig. 18/4-5 and so on.

[71] Idem, op. cit., p. 33, tab. II, no. 1.

[72] E. Iaroslavschi, op. cit., p. 88-95.

[73] I. Glodariu, *Un atelier de făurărie la Sarmizegetusa dacică*, ActaMN XII, 1975, p. 107-134.

[74] V. Wollmann, believes this is "a reheating hearth for iron beating" and that the batch of iron inside it, 20 cm in diameter, is a semi finished product that had already undergone the desired transformation. "Considering the carbon (1.94%) as well as the iron content as a classification criterion, it becomes clear that we are dealing with steel" cf. V. Wollmann, op. cit., p. 288.

[75] This type of furnace, with an identical door but belonging to a later age was found in Somogyfajsz (Hungary) and in Nemeskér. Its replica can be seen at the Sopron Museum; see J. Gömöri, *The Bloomery Museum at Somogyfajsz (Hungary) and some Archaeo-metallurgical Sites in Pannonia from the Avar and Early Hungarian Period*, Journal of Metallurgy. Association of Metallurgical Engineers in Serbia AME, Beograd 2006, p. 183-196.

tions were similar to their Roman, Celtic or Germanic counterparts, the high quality iron proving their comparable efficiency.

All iron blooms discovered in the Sarmizegetusa Regia region belong to the same period: end of 1st century-beginning of 2nd century AD. Both, the iron blooms discovered in underground deposits and the ones recovered from workshops, burnt down in 106 AD were meant to be transformed in order to meet the needs for the final confrontation with Rome. We are certain about this timeline mainly because all blooms come from an enclosed area, where the only certified civilization is that the Dacians', whose evolution abruptly ends as a result of the Daco-Roman wars.

In what follows we shall have a look at how Dacian iron blooms from around the capital compared to other contemporary European blooms.

We noticed that numerous studies use the name "iron bloom" to designate various lumps of iron that differ not only in shape, in size but also as regards their production technique.

In most parts of Central and Western Europe, where furnaces that produced "iron sponges" were numerous the end product referred to as "iron bloom" are the "iron sponges" refined in a low furnace. In fact this is a lump of refined metal, be it iron or steel. The bloom has already been hammer-wrought, and may have been shaped so as to facilitate further transformation (such as rectangular-section bars)[76]. The German historians, known for their careful choice of terminology, call the blooms resulted from direct reduction in furnaces with outside slag discharge "*Schmiedeluppe*", differentiating them from those obtained indirectly called "*Luppe*" equivalent of the French "*renard*" (a result of pig iron refining)[77]. The opinion according to which it is possible for the product resulted from sponge refining to have regular shapes, including quadrilateral sections, such as ingots, may give rise to confusions. Usually ingots are thought to be the result of raw iron modeling whereas when made from nonferrous, fusible metals they were obtained by casting.

In general terms, ingots are defined as pieces of molded metal, coming in different shapes and sizes and meant to be stored, transported and traded. We believe these items cannot be defined as iron blooms and that such confusions ought to be avoided[78].

Sometimes iron sponges themselves were called "blooms". In a recent paper about European metalworking industry[79] R. Pleiner observes that "some iron blooms discovered on archaeological dig sites were left unwrought, while others had been subjected to certain operations, at least in the preliminary phases of forging".

Iron sponges obtained in western furnaces are often impure, containing slag. After the reduction process, the resulting product had to be refined. The "sponge" was refined as a whole or in several smaller pieces. If the bloom was hammer-wrought out

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[76] See V. Serneels et alii, *Vocabulaire raisonné de la sidérurgie ancienne*, in Techique des fouilles - minerai, scories, fer. Cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie, Basel 1997, p. 79.

[77] Idem, op. cit., p. 79-80.

[78] The subject is worthy of further research, so that we mean to dedicate a future study to the various categories of Dacian ingots.

[79] R. Pleiner, op. cit., p. 230.

of the furnace, the same operation was also important in order to consolidate the slag that contained numerous alveoli. The quality of the iron also changes after being hammer-wrought, the quantity of impurities decreases and the iron becomes harder due to carbon and phosphorous assimilation. Carbon has the property of hardening iron while also lowering its melting point; similarly, phosphorous also slightly increases hardness but its main function is to facilitate welding and protect against corrosion. Too much phosphorous however could make the iron brittle.

Though carbon, phosphorous and slag were unevenly spread within the iron sponge, a skilled blacksmith could nonetheless obtain a homogenous content after the required refining processes: the desired elements (carbon and phosphorous) were retained, while the slag was removed.

Unlike the iron obtained from iron sponges, the one obtained from blooms produced in one batch furnaces, with slag evacuated at the bottom, has a higher purity, it is more malleable, contains very low amounts of carbon and because of this it had to be carburized before it could be tempered.

The names given to the metal products resulted from direct reduction, irrespectively of the furnace type, are numerous, according to the country they were discovered in. The English term is "bloom", from the old English where "bloma" meant iron lump. In other languages, the term derives from local words ("Stuck", "kus", "kos") and from the Latin *"massa"/"massa ferri"* hence terms like "masella", "mass", meaning piece, lump[80]. R. Pleiner believes terms such as "Luppe", "loupe de fer", "lupa", "lupka", "vlk" derive from the Latin: *lupus* - wolf. It is our belief that the root word bears no connection to the animal but rather to the optical instrument to which its shape resembles: the magnifying glass. Indeed, the way in which the metal cools down and solidifies forming small deposits in the earth, leads to the formation of round or oval lumps, with a plan-convex profile that resembles that of optical lenses. The apparatus used to enlarge pictures, the magnifying glass (in French *"loupe"*, in German *"Luppe"*) can thus be found at the origin the name. A very similar comparison led to the Romanian term *"turte"*, another word used to designate blooms.

The Czech term "vlk" meaning "bloom" is quite probably a consequence of translating the word *"loupe/luppe"* by "wolf". There are other terms derived from Germanic languages such as "Deul", "dejl", "plik", the Russian "kritsa", the Hungarian "buca" and the Irish "caer"[81].

One of the oldest iron blooms ever found, belonging to the Kyjatice culture (HaB3 - 8th century BC) was discovered in a pit in Šafárikovo (Southern Slovakia - 12 × 10.5 × 6 cm; 2.43 kg). Given the scarcity of iron at that time this quantity of metal is remarkable: it could be processed into 3 long swords, 6-8 axe heads or several hundred small knives[82]. Other early blooms are mentioned at Krásna Hôrka (2 kg), Jasov-Fajka (1.5 kg), Berezan, near Olbia, at Nový Smokovec (13 pieces) and Radovesice (North-Western Bohemia), Magdalensburg (Carinthia). All the loca-

[80] Ibidem.
[81] Ibidem.
[82] Idem, op. cit., p. 231.

tions[83] mentioned above produced blooms similar to those we previously discussed, albeit smaller and without the specific cropping.

In Romania, ironworking traditions date back a very long time. Apart from having a long tradition, the metallurgy of non-ferrous metals as well as that of bronze was also very well developed: items produced in Transylvania reached places located at considerable distances away, both to the north-west and to the east[84]. The so called metal-foundry deposits, comprising thousands of pieces, contain alongside broken tools and weapons, numerous iron blooms, the result of recycling such artifacts. The bronze blooms from Uioara have a similar shape, a plan-convex profile, a height over 5 cm and diameters of 15 to 25 cm.

They all contain a certain amount of iron that betrays its presence by appearing in the form of rusty crusts on the greenish patina. All of them date back to the HaA, and are similar to others found in nearby areas (dated in Bronze A): for example the iron bloom from Palatca, 26.5 cm in diameter, 5.2 cm in height, with 3,07% Fe[85].

No iron bloom dating back to the Romanian Hallstatt period has been so far discovered[86], though other metal objects dating back to the said period have been found. The terms referring to blooms of different sizes, shapes, ranging from Prehistory to the Modern Ages are very numerous; the round blooms, with a typical "V" cut, discovered in small numbers on the European territory, are referred to as "split blooms", regardless of their time frame[87].

We believe this name to be improper - as previously explained the blooms are not merely *split* but rather *cut* as the part containing impurities brought in by the bellows was *clipped out*. Indeed, the author of naming himself writes that the clipping was performed while the bloom was hot, by the means of strong axes[88]. In our opinion, other tools were used in the process as well with the purpose of ensuring a greater homogeneity to the entire surface of the bloom. Thus we think it is better to refer to these artifacts as "*clipped blooms*".

In the area of the Dacian capital, Sarmizegetusa Regia, special circumstances allow archaeologists to precisely date artifacts to the 1st century AD-beginning of the 2nd century AD in other areas, the chronology is not as easily established. They are generally believed to belong to the early or even to the high middle Ages[89]. An exception from these European timelines might be the Hungarian clipped blooms, weighing up to 60 kg and dated back to the Roman period by some experts, though others believe them to be much more recent[90].

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83 Idem, op. cit., p. 231-233.

84 M. Petrescu-Dâmbovița, Depozitele de bronzuri din România, București 1977; T. Soroceanu, Vasele de metal prescitice de pe actualul teritoriu al României, Bistrița - Cluj-Napoca 2008.

85 Thanks to information from M. Rotea, M. Wittenberger.

86 I. Glodariu, E. Iaroslavschi, op. cit., p. 12; M. Rusu, *Începuturile metalurgiei fierului în Transilvania*, in H. Daicoviciu (ed.), In memoriam Constantini Daicoviciu, Cluj-Napoca 1974, p. 349-360.

87 R. Pleiner, op. cit., p. 238.

88 Ibidem.

89 Idem, op. cit., p. 240.

90 See J. Gömöri, op. cit., p. 85; Z. Hegedüs, *Loupes de fer dans les musées hongrois*, Revue d'Histoire de la Sidérurgie III, Nancy 1962-1963, p. 197-208.

Many opinions were put forth as to the reasons why blacksmiths made these clippings. Some of them are rather amusing and can't be taken seriously so we shall leave them aside on this occasion. The following theory is partly correct and is worth mentioning: "A careful examination clearly shows these bloom were split while still hot, with a single blow from an axe. The reason is obvious: a deep cut allowed workers to observe whether the iron was suitably hardened and thus to appreciate its quality while also allowing for the bloom to be split in half for future processing or trading"[91].

We do agree that the cut was performed while the iron was still hot and that examining the internal aspect of the section allowed buyers to determine the quality of the bloom, both while it was still hot as well as after cooling. In case the buyer was interested in a quality check, he had a benchmark on which to negotiate the price.

But this was not the main reasoning behind the clipping. We believe the blacksmiths noticed the homogenous structure of the bloom and its constant purity. The exception was the part close to the end mouth of the bellows, where induced air deformed the shape of the bloom and inserted impurities (slag, grit). These parts, less pure, were clipped out which left a homogenous purity level on the entire surface of the bloom; the price could thus be established by simply measuring the bloom's weight. This is why certain blooms have two or even three clippings, depending how many air-inducing devices were used[92] - one clipping would have been enough for quality control purposes.

The clipped blooms discovered so far, though not very numerous, are spread from the Middle East to Western Europe (up the Spanish coastline and Ireland) while on the North-South axis they range from Scandinavia to Bulgaria[93] (Pl. XIII/21). Nowhere were they found in such great numbers, dating back to such early times and on such a small area.

Regardless of the geographical area where clipped blooms were produced, experts agree that the process took place near the furnace, while the bloom was still hot. A solid support was needed for this: it could a big rock or an anvil. Unfortunately, in our country, mountain archaeology is not sufficiently advanced so that areas believed to contain remains of furnaces have not been investigated[94].

Thousands of iron blooms from single use furnaces have been found and attributed to the Dacian period. This means thousands of furnace remains are still to be identified - let us hope - in the not so distant future. We believe their remains to be located not very far away from the blooms; otherwise the treasure hunters would have surely stumbled upon them. We remind the reader that most of these blooms were found by treasure hunter. If metal detectors had identified slag filled furnaces, they

[91] R. Pleiner, op. cit., p. 238.

[92] Idem, op cit., p. 239, fig. 64/8-9 - blooms with three clippings, at p. 232, fig. 62/8, a bloom that seems to have the part close to the mouth of the bellows.

[93] Almost all are dated in the Middle Ages however; R. Pleiner, op. cit., p. 241-243.

[94] St. Ferenczi, *Premisele naturale ale metalurgiei fierului în Munții Orăștiei*, Studii și Comunicări II, Caransebeş 1977, p. 299-309; H. Daicoviciu, St. Ferenczi, I. Glodariu, Cetăți și așezări dacice în sud-vestul Transilvaniei, București 1989, p. 50.

would have signaled their presence and treasure hunters would have very probably unearthed them. At our turn, we would have identified the corresponding excavation sites together with their inventory.

We believe that a careful reexamination of the so-called "metallurgical quadrilateral" will shed some light on the places where the ore was collected or extracted, enriched, reduced, as well as on the intensity of such activities.

The identification of large metallurgical centers dating back to Ancient times is facilitated by the large quantities of slag that were left behind, raw material for modern furnaces. Etruscans[95], Celts[96] and other people[97], left tons of slag behind, proof of their intense metallurgical activities; nonetheless the number of iron blooms, ingots, tools or weapons discovered is rather small.

In contrast, the quantity of iron blooms, ingots, tools, weapons as well as other commodities and construction materials found around the Dacian capital is huge, despite the fact that the number of identified furnaces (as well as the quantity of slag) is rather small. We are not aware of such a large array of tools and in such great numbers being found in any another place in Europe. Moreover, the variety of these tools increases year after year. In 1979, when "Civilizația fierului la daci"[98] was published, a large number of items were illustrated - nowadays that number has increased exponentially[99]. Assuming that an anvil suggests a workshop nearby, this means that the 27 massive anvils (some over 50 kg) discovered alongside slag and other metal items at Sarmizegetusa Regia, prove the existence of an exceptional metallurgical centre in this area both in terms of size and output during the golden age of the Dacian civilization.

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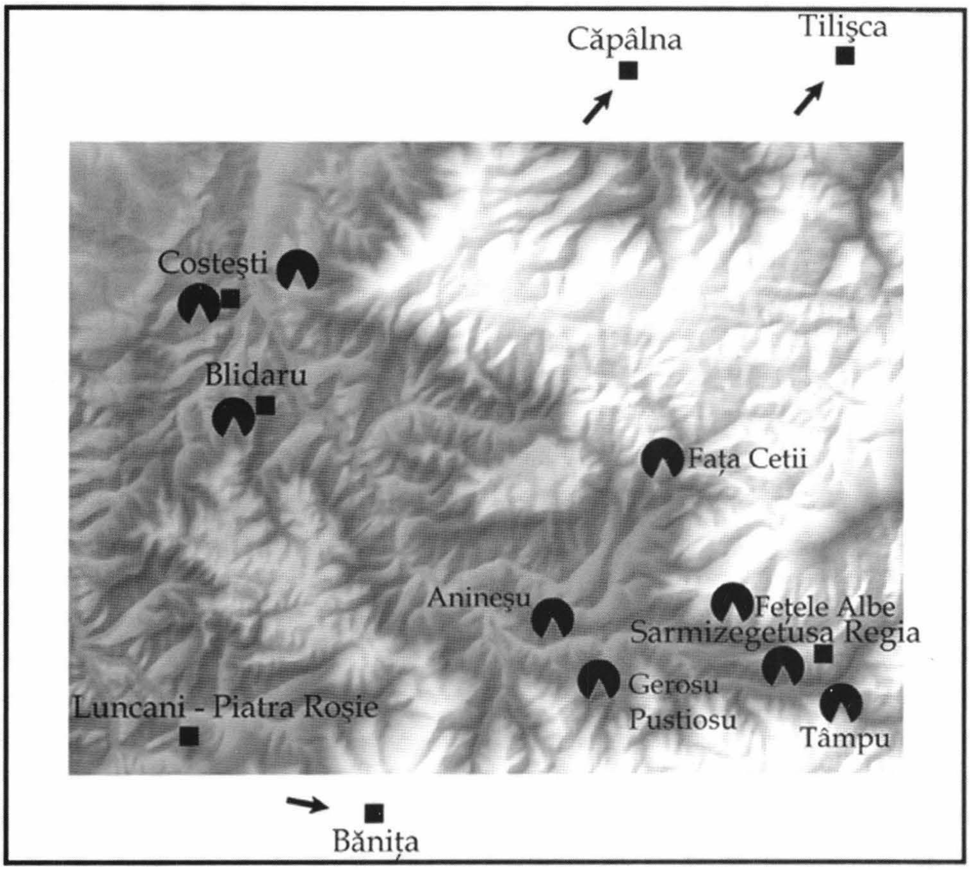
[95] R. Bloch, Etruscii, București 1966, p. 111.
[96] Ch. Danikovski, S. Cabboi, La sidérurgie chez les Senons; les ateliers celtiques et gallo-romains des Clerimois (Yonne), Documents d'Archéologie Française 51, Paris 1995.
[97] S. Dušek, op. cit., p. 95-183; R. Pleiner, op.cit., p. 36-46.
[98] I. Glodariu, E. Iaroslavschi, op. cit., fig. 6-73.
[99] The researchers already work on monographs referring to the fortresses, settlements and artifacts; one of them is dedicated to iron working.



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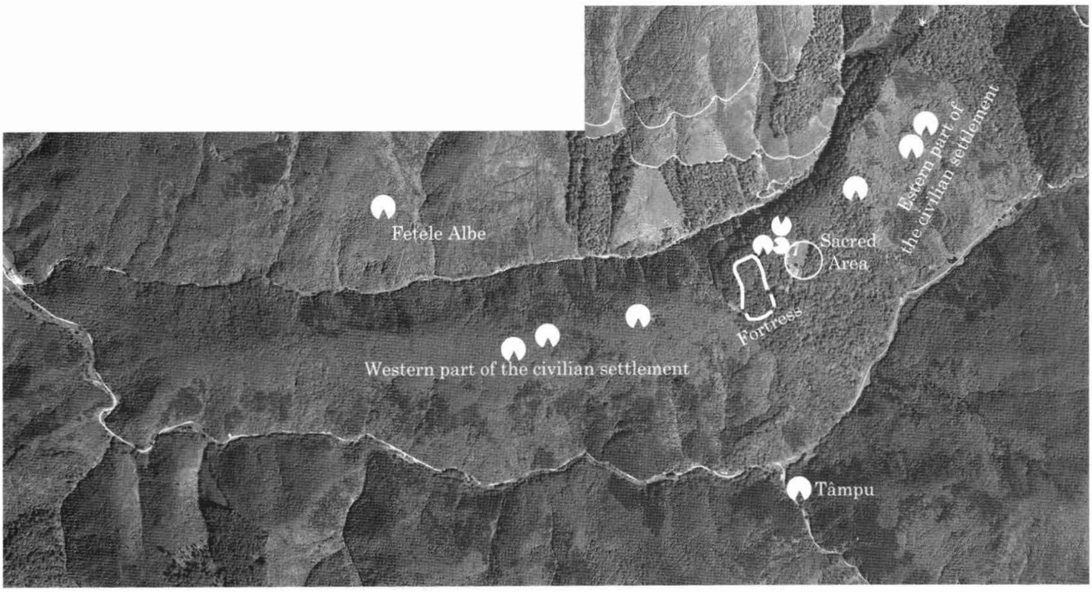

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Pl. I. 1. Orăştie Mountains. Map of the main areas presenting clipped iron bloom deposits; **2.** Sarmizegetusa Regia. Map of the main areas presenting clipped iron bloom deposits.

a

b

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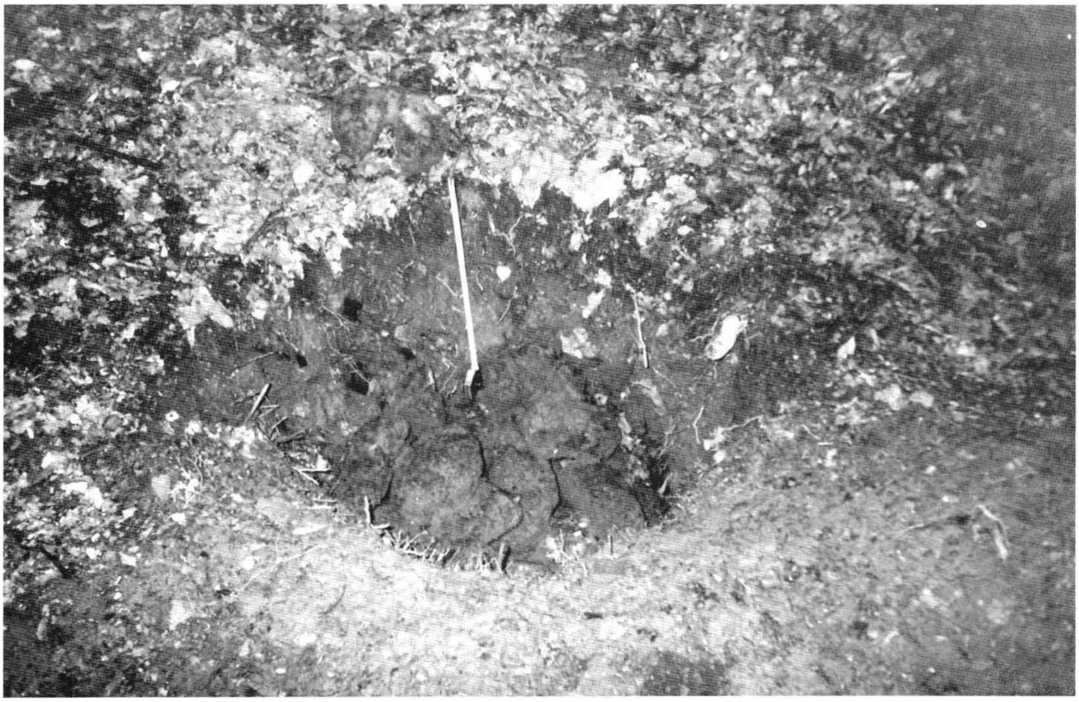
Pl. II. 3. Treasure hunters' hole, full of iron blooms (photos of the authors).



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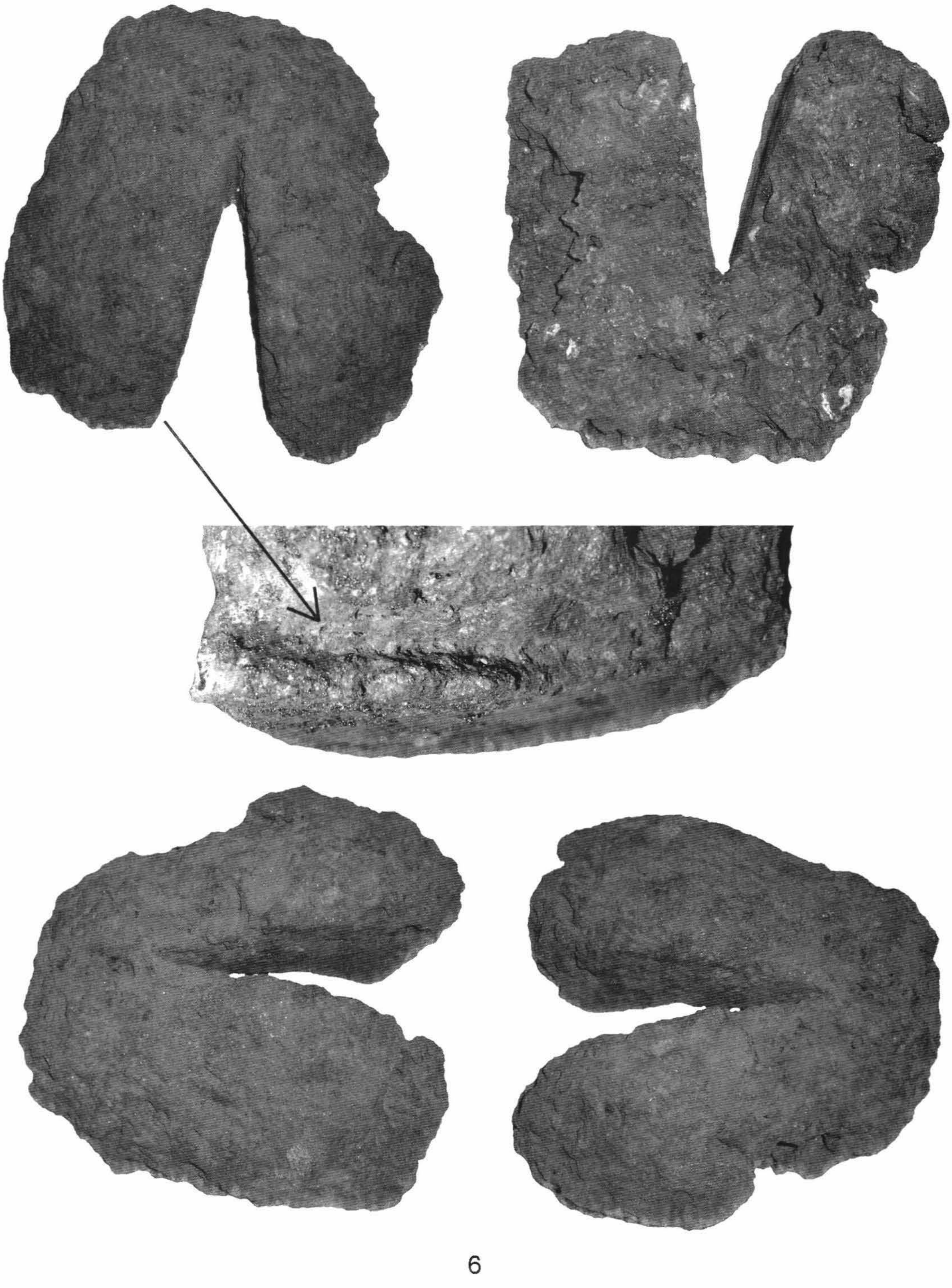
Pl. III. 4. Treasure hunters' hole, full of iron blooms; **5.** Clipped iron bloom deposit found at Sarmizegetusa Regia (photos of the authors).



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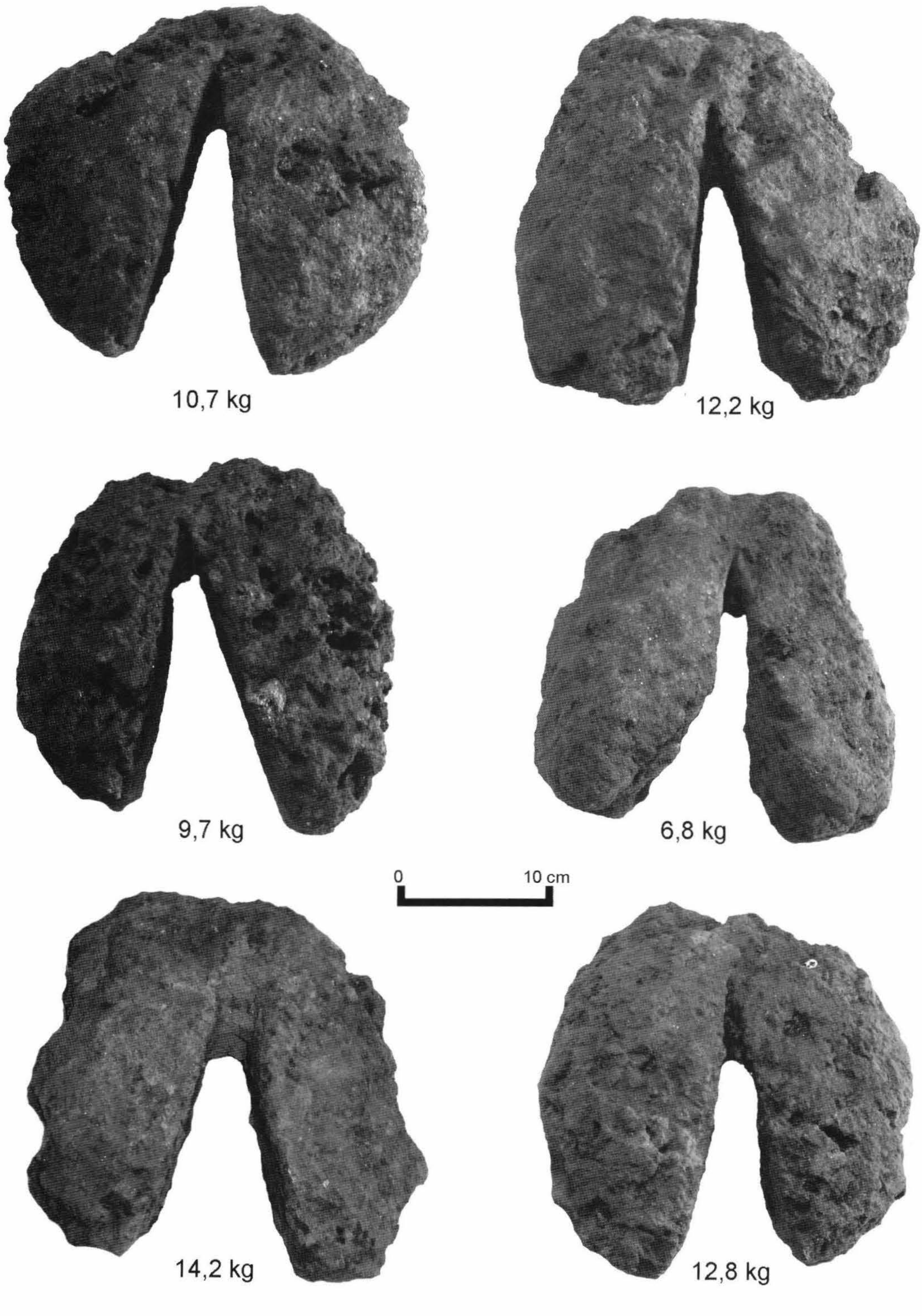
Pl. IV. 6. Clipped iron bloom whose clipping was obtained through several blows from a broad drilling blade tool (photos of the authors).



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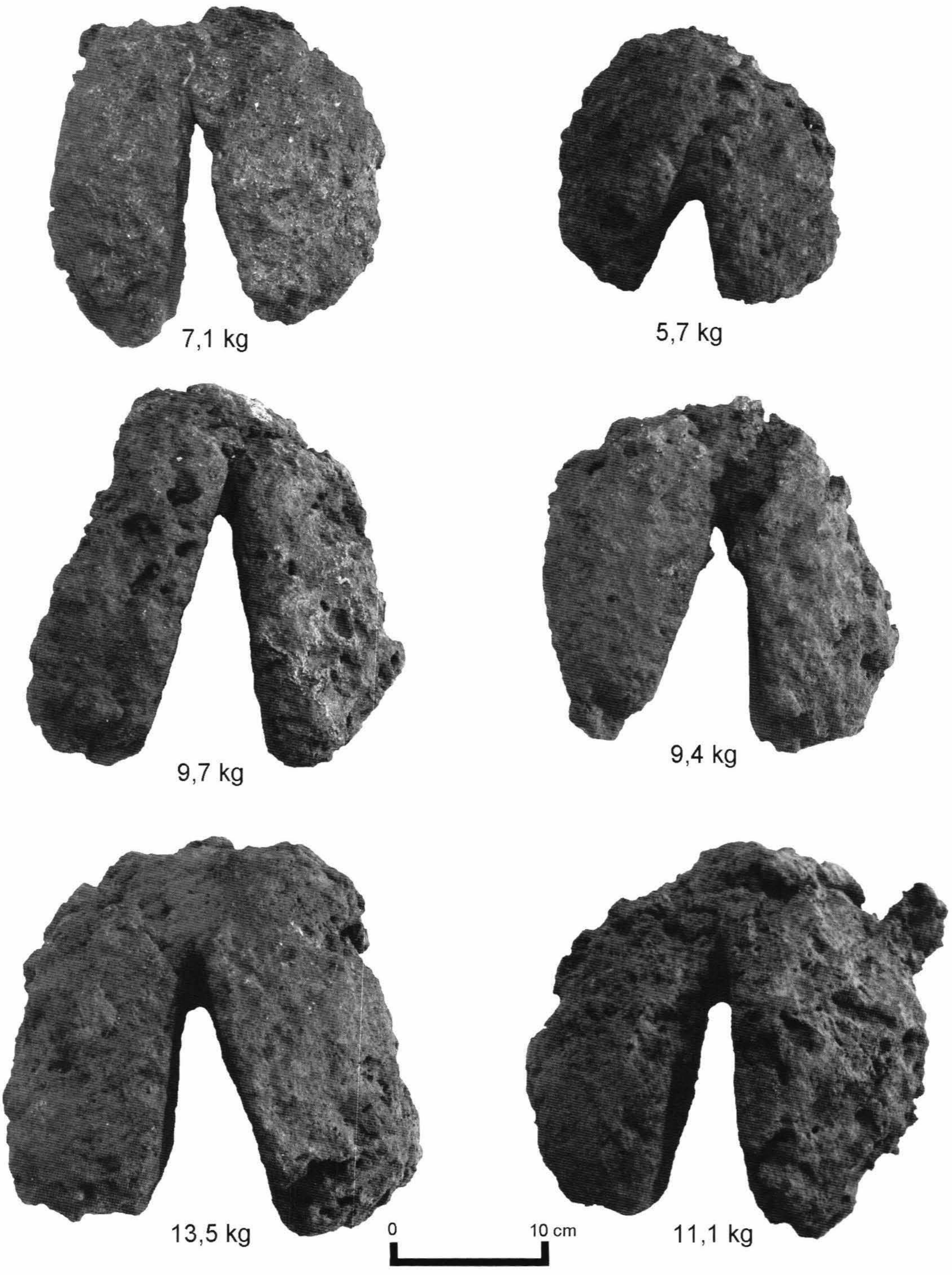
Pl. V. 7. Clipped iron blooms from the lot currently in the keeping of the National History Museum of Transylvania, Cluj-Napoca (photos of the authors).



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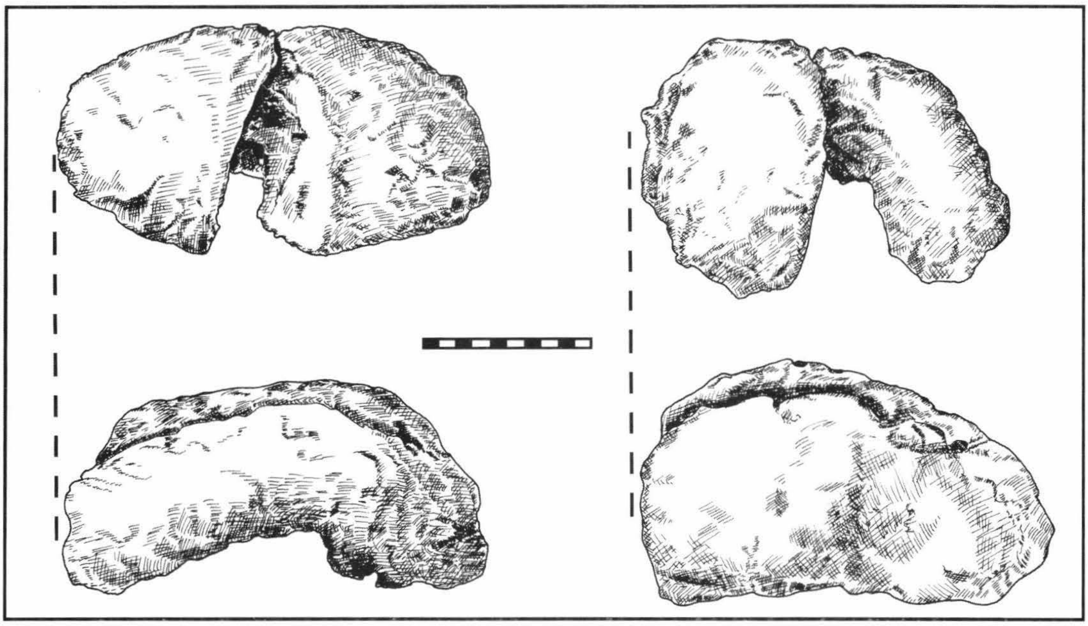
Pl. VI. 8. Clipped iron blooms from the lot currently in the keeping of the National History Museum of Transylvania, Cluj-Napoca (photos of the authors).



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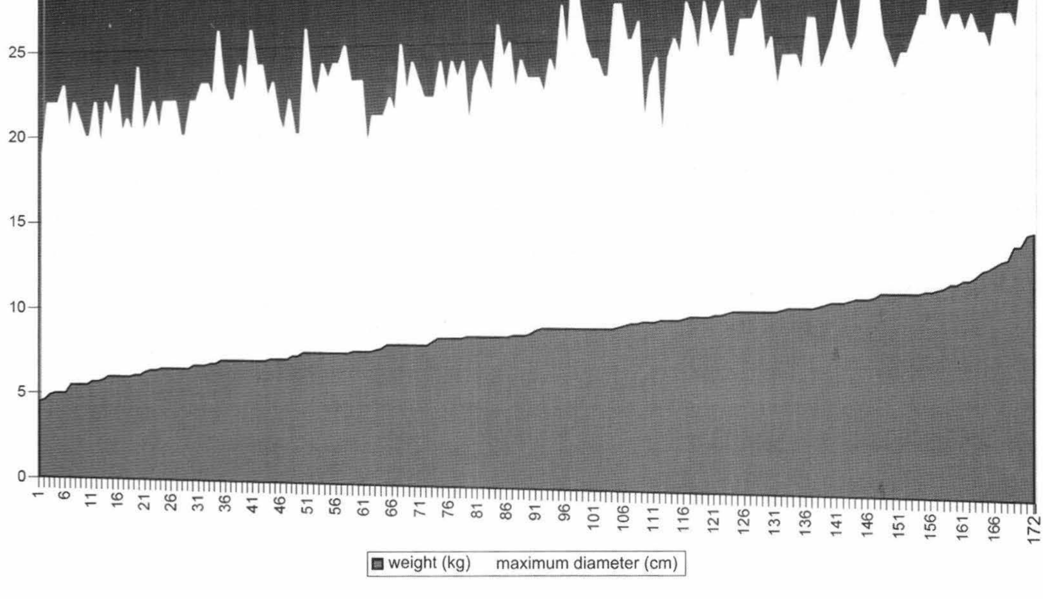

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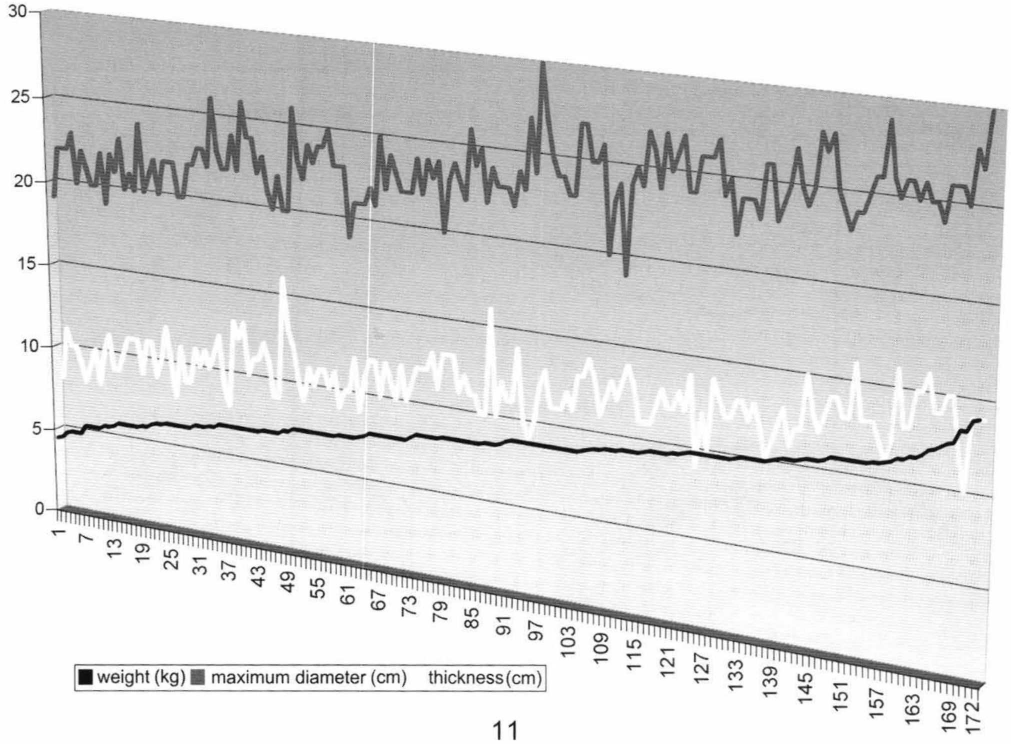
Pl. VII. 9. Dacian blooms (graphical representation); **10.** The evolution of the maximum diameter in relation to the blooms' weight.



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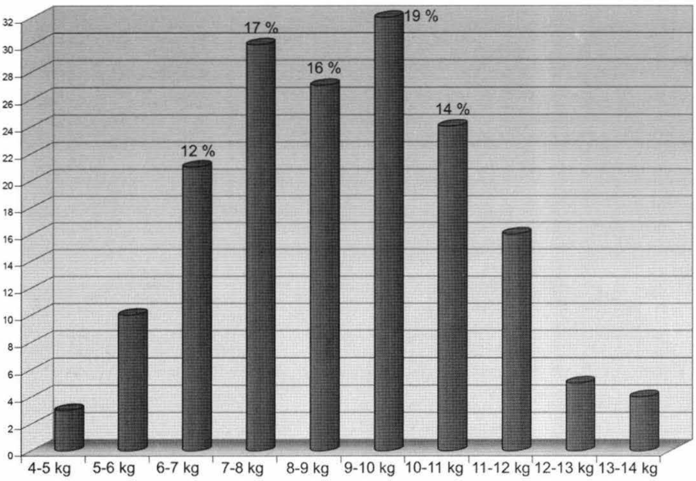
Pl. VIII. 11. The evolution of the maximum diameter and height in relation to the blooms' weight; **12.** Clipped iron blooms from the Cluj lot, currently in restoration (photos of the authors).

WHOLE IRON BLOOMS		
Deva weight number of artifacts	Cluj-Napoca weight number of artifacts	„Căprăreața” weight number of artifacts
4 → 5 kg.................1	4 → 5 kg.................2	6 → 7 kg..............4
5 → 6 kg................ 7	5 → 6 kg.................3	7 → 8 kg..............6
6 → 7 kg...............10	6 → 7 kg.................7	8 → 9 kg..............6
7 → 8 kg...............17	7 → 8 kg.................7	9 → 10 kg............8
8 → 9 kg...............13	8 → 9 kg.................8	10 → 11 kg..........8
9 → 10 kg.............15	9 → 10 kg...............9	11 → 12 kg..........2
10 → 11 kg.............9	10 → 11 kg.............7	**302 kg 34**
11 → 12 kg.............4	11 → 12 kg...........10	
13 → 14 kg 1	12→ 13 kg..............5	
620 kg 77	13 → 14 kg 3	
	568 kg 61	
172 blooms ....1490 kg		

13



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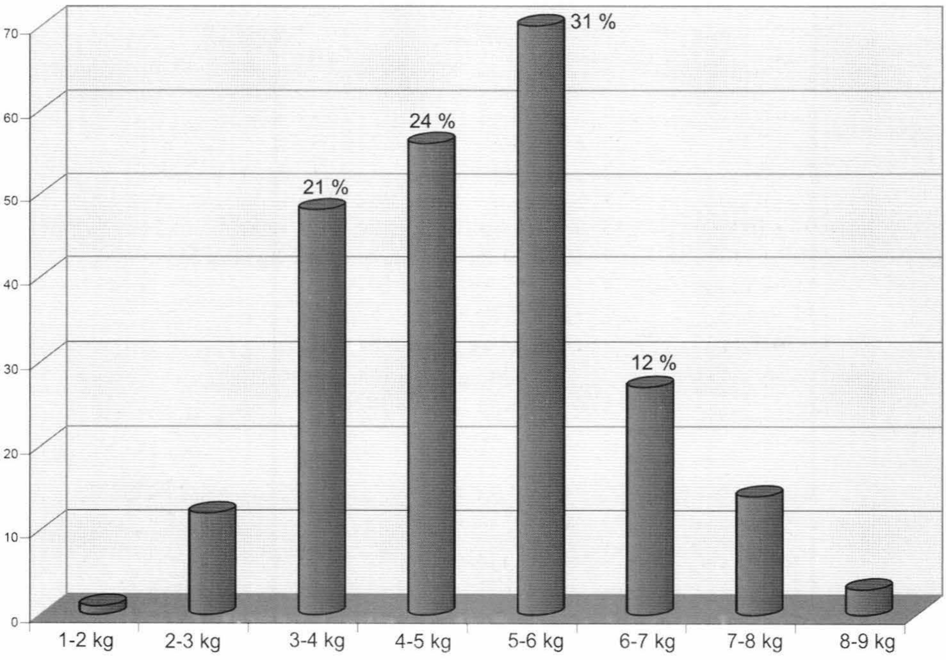
BLOOM HALVES		
DEVA weight number of artifacts	CLUJ-NAPOCA weight number of artifacts	"CĂPRĂREAȚA" weight number of artifacts
2 → 3 kg 2	2 → 3 kg 7	1 → 2 kg 1
3→ 4 kg 21	3→ 4 kg 9	2 → 3 kg 3
4 → 5 kg 26	4 → 5 kg 5	3→ 4 kg 18
5 → 6 kg 14	5 → 6 kg 12	4 → 5 kg 25
6 → 7 kg 5	6 → 7 kg 4	5 → 6 kg 44
7 → 8 kg 5	7 → 8 kg 3	6 → 7 kg 18
73 ....315 kg	8 → 9 kg 2	7 → 8 kg 6
	42 ....192 kg	8 → 9 kg 1
		116 .... 556 kg
231 bloom halves ....1063 kg		

15

Pl. IX. 13. General statistics of the distribution in weight groups of the whole blooms; **14.** Graph of the distribution in weight groups of the whole blooms; **15.** General statistics of the distribution in weight groups of the bloom halves.



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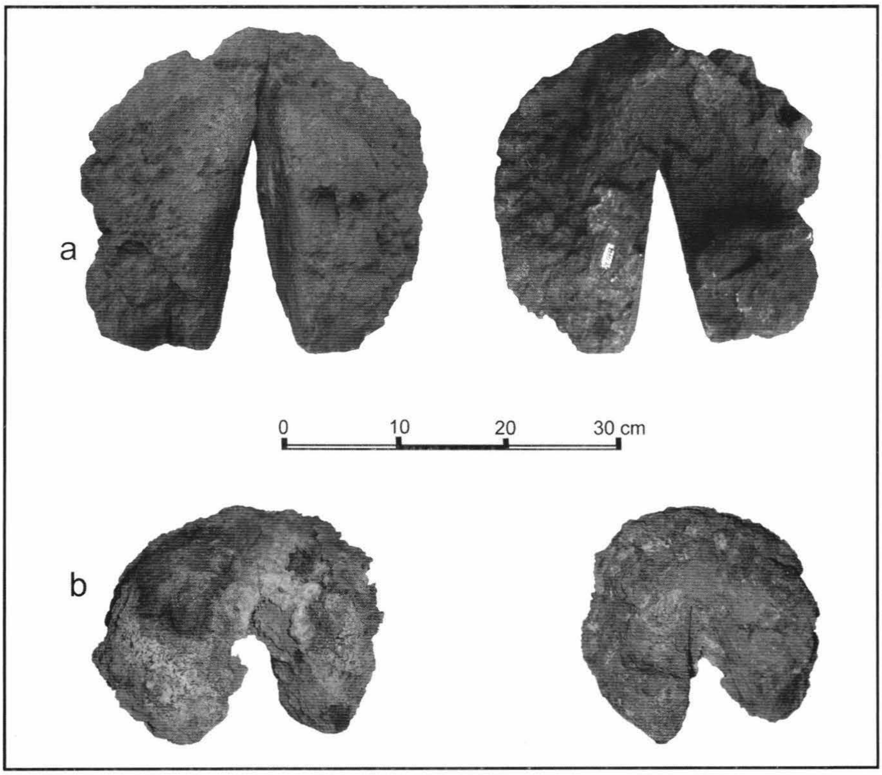

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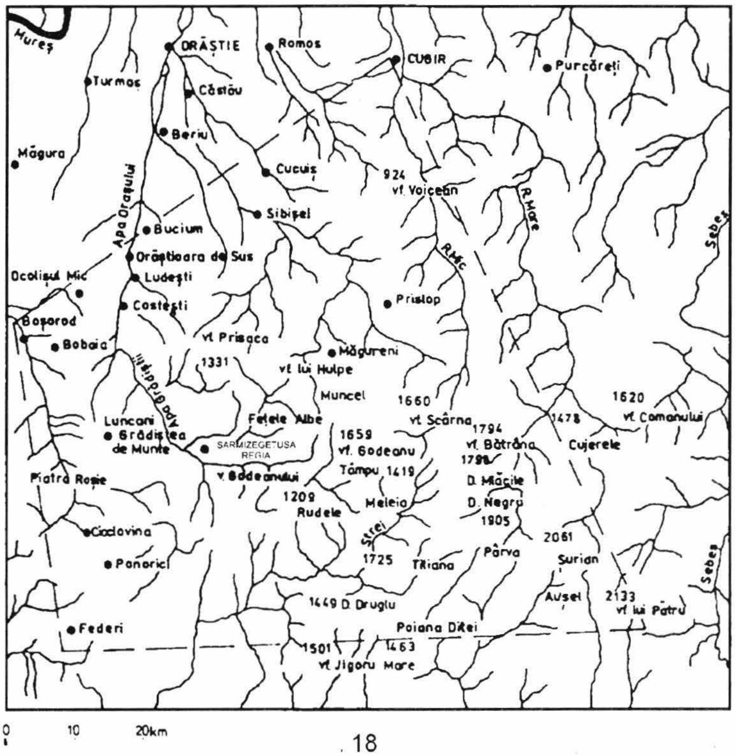
Pl. X. 16. Graph of the distribution in weight groups of the bloom halves; **17.** Unusual clipped iron bloom: **a.** bloom weighing approx. 46.7 k; **b.** the items preserves part of the slag on top of which it formed (photos of the authors).



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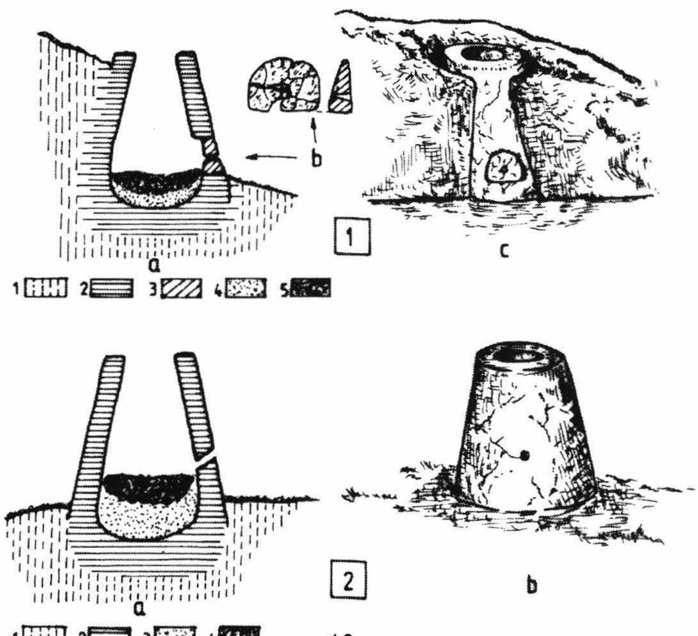

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Pl. XI. 18. The "metallurgical quadrilateral" from the Sarmizegetusa Regia area (after E. Iaroslavschi, *Siderurgia dacică în cadrul metalurgiei europene*, in S. Nemeti et alii (eds.), Dacia Felix: Studia Michaeli Bărbulescu oblata, Cluj-Napoca 2007, p. 62, fig. 1); **19.** Dacian iron ore reduction furnaces: 1. multiple charge (Doboșeni); 2. single use (Șercaia) (after I. Glodariu, E. Iaroslavschi, Civilizația fierului la daci (sec. II î. e. n - I e. n), Cluj-Napoca 1979, p. 199, fig. 5).

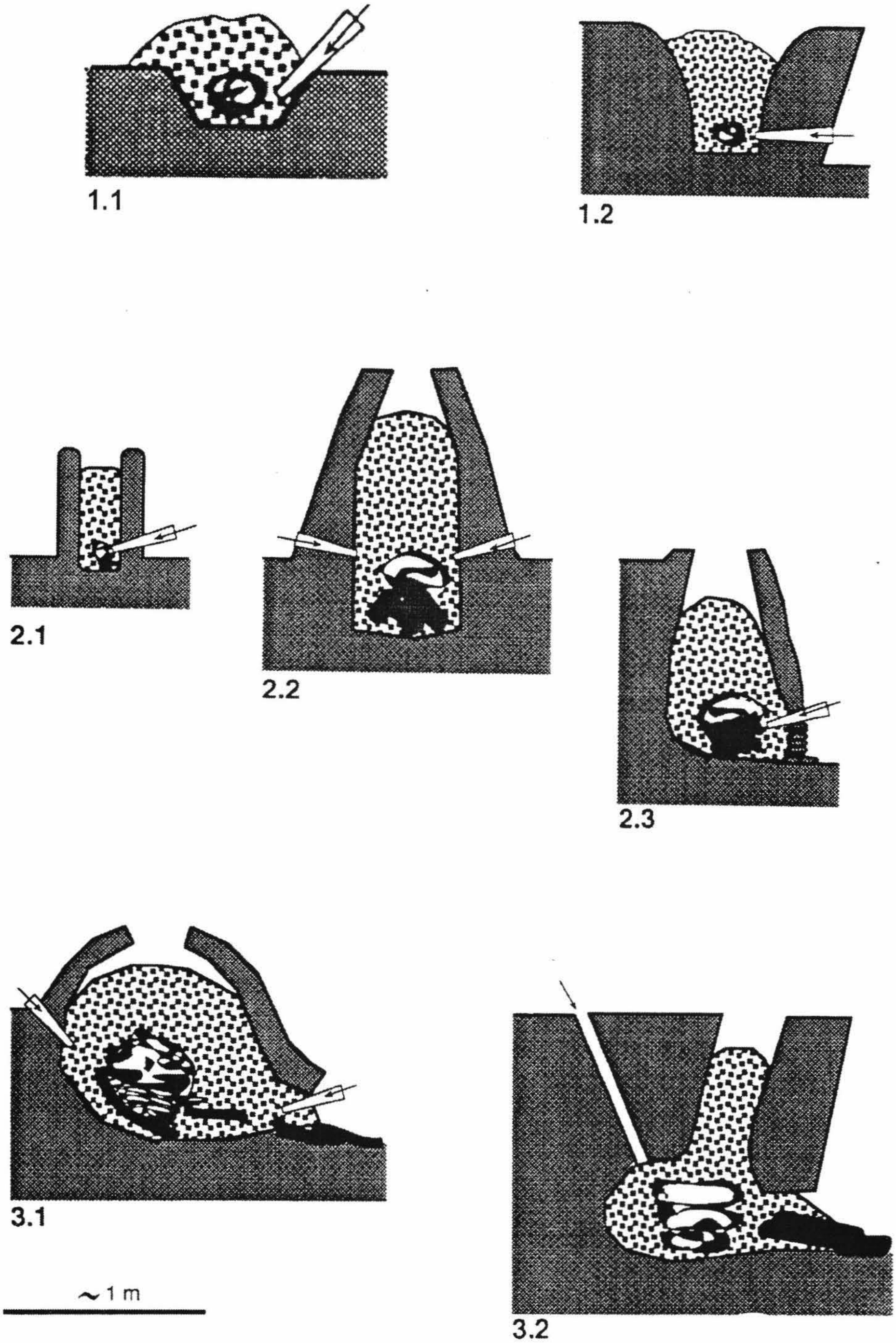

Fig. 20

Pl. XII. 20. The classification of low furnaces based on the model of iron-slag separation (after L. Eschenlohr, *La méthode directe de reduction du minerais de fer en bas fourneau*, in Minerai, scoris, fer. Technique des fouille-minerai, scories, fer. Cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie, Basel 1997, p. 21, fig. 5).

21

Pl. XIII. 21. Clipped iron blooms from northern Europe- 1, 3, 5-6. Norway; 2, 4. Sweden (9^{th} century AD) (after R. Pleiner, Iron in Archaeology. The European Bloomery Smelters, Prague 2000, p. 239, fig. 64).