

THE DISMANTLING OF A SMELTING FURNACE AFTER EXPERIMENTAL SMELTING OF IRON ORE

Tajana Sekelj Ivančan

In 2017, members of the TransFER project team participated in the ninth workshop of techniques of smelting iron ore held in Stará huť at Adamov near Brno in the Czech Republic. In the first part of the workshop, the focus was on education about all the stages of obtaining iron from ore and on active participation in the entire process of smelting in the furnace. In the second part, on the initiative of members of the TransFER project the smelting furnace in which the smelting experiments had previously been carried out was disassembled. In the investigations, which simulated archeological excavation, the aim was to define and recognize all the layers of its construction and repairs, and to compare the obtained results with situations at archaeological sites in Podravina, Croatia.

Key Words: experimental archaeology – smelting iron ore – dismantling a furnace

ROZEBRÁNÍ EXPERIMENTÁLNÍ ŽELEZÁŘSKÉ KUSOVÉ PECE

V roce 2017 se členové týmu projektu TransFER zúčastnili devátého workshopu starého železářství ve Staré huti u Adamova. První částí workshopu byl zaměřen na představení všech fází procesu získávání železa z rud a na aktivní účast na tavně v železářské kusové peci. Ve druhé části byla z iniciativy členů projektu TransFER pec, v níž byly prováděny experimentální tavně, rozebrána. Cílem aktivity simulující archeologický výzkum, bylo definovat a rozpoznat fáze stavby pece a jejích oprav a porovnat výsledky se situacemi získanými na archeologických lokalitách v Podravíně v Chorvatsku.

Klíčová slova: experimentální archeologie – tavně železné rudy – rozebrání pece

As a part of the scientific research project TransFER – **The Production of Iron along the Drava River in the Roman and Medieval periods: the Creation and Transfer of Knowledge, Technology, and Goods** (<http://transfer.iarh.hr/index.php/hr/>),¹ members of the project team (T. S. Ivančan and I. M. Hrovatin) participated in the ninth workshop of techniques of smelting iron ore in May 2017 held at Stará huť in Adamov near Brno in the Czech Republic (9. workshop starého železářství / 9th workshop of ancient ironmongery), organized by the Technical Museum in Brno (*Technické muzeum v Brně*). In the first part of the workshop the focus was on education and active participation of team members in the entire process of smelting in a free-standing bloomery furnace. The objective was better understanding of aspects in the production of iron and the most precise possible interpretation of finds excavated to the present related to the smelting of iron ore in various archaeological periods in the

Podravina (Croatian Drava River basin) region (Sekelj Ivančan 2010; 2014), the subject of the TransFER project.

As the workshop has been held for several years at the same place, it was found that the smelting furnaces utilized in earlier years needed repairs. Throughout the years, the furnaces were not under any protective covering and were directly exposed to various atmospheric influences. These were two types of smelting furnaces, on one side four of them in a row, located so that they were dug into the slope of a nearby hill, and on the other side one free-standing furnace. The four furnaces in a row were the same type, the so-called Hungarian furnace of the 10th and 11th centuries, with an opening for a “door” on the front (type 4 according to Gömöri 2000: 242, kép. 157: 4), while the second type of furnace was a free-standing surface, also with an opening in the front (type 2 according to Gömöri 2000: 242, kép. 157: 2). During the experimental smelting in four furnaces several

¹ The TransFER project is financed by the Croatian Science Foundation, and is carried out by the Institute of Archaeology in Zagreb, Republic of Croatia.

* Editor's note: The model of the experimental furnaces is one of the types of bloomery furnaces used in the Moravian Karst area. According to R. Pleiner, it is an embanked furnace with thin front wall and workshops in which this type was found in the Moravian Karst are dated to the 9th century.

different types of iron ore were utilized (magnetite, siderite, goethite), and the conclusion from all the performed was that the best result was acquired in the furnaces where the ore Goethite was utilized, from nearby Olomučany in the Blansko region (Czech Republic).

Special attention was paid to the smelting process that took place in the free standing furnace, because it was the closest in form to the archaeologically excavated furnaces in Podravina. During two days, several smelting processes were carried out in the free standing furnace, and goethite/limonite ore from Olomučany was placed in the furnace. At the very end of the second procedure during smelting, the temperature of the outer walls of the furnace was measured,² as well as the upper opening of the funnel-shaped part of the furnace, by the door, and in the interior of the hearth after opening the door, as well as the temperature of the molten slag after discharge from the hearth itself.

The last smelting was carried out in the free standing furnace after additional repairs to the hearth and walls of the furnace that cracked during earlier procedures. First, the furnace itself and the surrounding area were cleaned well and photographed. The cracks in the funnel-shaped walls were filled with clay-rich brown soil mixed with water that proved to be the best mixture for filling the exterior cracks created during earlier firings. As the furnace was already considerably damaged, it was necessary to additionally coat it in the lower section of the shaft where the greatest temperature is achieved. This coating extended approximately to halfway up the funnel-shaped walls, while in the upper section the same mixture was used to fill all the earlier cracks on the surface of the furnace, which was considered sufficient as in the upper funnel-shaped sections the hearth does not reach such high temperatures. After that, a fire was lit at the bottom of the hearth so that the added coating of the lower part of the shaft would dry well, followed by drying of the furnace opening as well as the upper part of the walls. After some time, when the coating of the opening had dried sufficiently, the opening, the so-called "door" of the furnace with the nozzle/tuyere in the center, was filled in with clay. Filling the furnace followed, first only with charcoal, and then with a mixture of coal and iron ore in a proportion of half a kilogram of coal and three-quarters of a kilogram of ore, in total 10 kg of ore and 7 kg of charcoal. Before and during opening of the furnace, the temperature was measured in several places, through the nozzle/tuyere in the still closed hearth, measuring around 1300°C; through the opening after removal of the "door", measuring around 1100°C; while the slag that was tapped through the drain hole had a temperature of 800°C. The result of the process was a *bloom* weighing ca. 2 kg and 150 g. As the free standing furnace was fired several times and repaired each time, as well as the fact that it was constructed at a site where in previous years some other furnace had been built, on the initiative of members of the TransFER project, a process of disassembling the furnace used for smelting was undertaken. The main objective was the definition and recognition of all the strata of its con-

struction and repairs, and the comparison of the results obtained with those from situations at archaeological sites in Podravina. The investigation was undertaken through gradual demolition of the furnace and documentation of all layers and procedures. Stones and brick served as the foundation for the dismantled furnace, irregularly placed and leveled with yellow clay (-2). This foundation lay on a stratum of reddish clay (-3). These remains are part of the activities that were carried out at the workshop over the course of earlier years. This same spot in fact was used from 2003 for various procedures related to the preparation or smelting of ore, but also for some other different types of furnaces. The position of the dismantled free standing smelting furnace was occupied from 2007 to 2010 by a brick bread oven, whose remains can in fact be recognized in the re-laid brick and stone leveled with yellow clay.³ The occasional preserved stone, particularly those in front and below the entrance to the dismantled furnace, can be related to earlier smelting furnaces that had a rectangular hearth in the lower section and that were built here in 2003, 2004, and most probably also in 2006.

During construction of the baking oven, the earlier formed rectangular hearth was filled and blocked with larger stones and this served as a compact foundation for the future baking oven. On this first noted stratum that could be related to the construction of the bread oven (-2) lay a layer of loose earth, dark gray to black, mixed with baked powder (-1). This dark grey – black layer extended along the entire surface where the baking oven was set, and it can be connected to its dismantling after 2010 and the cleaning and preparation of this area for some other structure. On the layer of loose mixed soil (-1) lay a layer of clay that had an organic (?) admixture (0). This fired clay with organic additions, representing the remains of some old oven/furnace, extended in only one smaller section, from the large stone to the middle of the hearth. According to the vertical stratigraphy, the fired walls of the oven into which organic (?) material was incorporated should have been built later than the period of the existence and removal of the bread oven, meaning that layer 0 could be connected at the earliest to the furnace built in 2011. That smaller furnace, in whose walls it was possible to recognize certain additions, lacked a door and simulated a La Tène smelting furnace.

Activities from 2013 were not identified, while for 2014, it seems that there was nothing at that position. The original fired furnace walls found at the site in 2017 (1) were of a compact pale clay with some sand. Around the middle of the furnace hearth, within the thick walls, was the exceptionally strongly fired bowl-shaped base of the hearth, the so-called "bowl" (1.1), which lay on greyish highly fired soil (1.2). As the exterior surface of the furnace walls descends at a slant in one part towards the stone, it seems that these remains can be related to the furnace with an anthropomorphic figure built in 2016, when on the exterior surface an oblique wall made of similar material as the entire furnace was placed in contact with the walking surface. However, the walls of the furnace themselves (1) can be connected to the furnace built in 2015, which according to

² Somewhat higher temperatures than 538°C and 780°C were measured at the cracks in the walls of the furnace.

³ For data and photographs, I would like to thank the organizer of the workshop, Ondřej Merta, MA, from the Technical Museum in Brno (Technické muzeum v Brně). The photographs are from 1995, and from 2003 to 2017. Photographs: Martin Barak. I am also grateful for access to the photographs sent by Jan Lokajíček, a smith who is a multiyear active participant in the workshops.

the noted strata cannot be established with certainty. Above all of this, in the interior of the hearth, a clay coating of the furnace was noted (3), i.e. the last repair. One more repair was visible on the exterior of furnace (2). This furnace was built on the original fired wall (1) noted upon arrival in the field in 2017, and in it during the first two days of the workshop, several experimental smeltings were carried out before the last repair and final smelting, followed by the dismantling of the furnace.

In the investigations that simulated archaeological excavations, the original furnace found upon arrival could be recognized (1). It was repaired into a so-called bloom furnace (2) in which two smelting processes were carried out (1.1). After that, the walls of the furnace were again repaired (3), or rather a new layer of fired clay was noted in the interior of the hearth, a layer that covered the so-called "bowl" formed in the earlier smelting (or smeltings). The layers below the dismantled furnace (0, -1, -2, -3) represent earlier activities that can only be hypothesized as related to individual furnaces, but it seems that the foundation built for the bread oven could be clearly recognized, and it is possible that at some point this site also served for certain other activities, such as roasting ore.

CONCLUSION

The objective of participation of members of the TransFER project team in the workshop for smelting iron ore in the Czech Republic, in addition to education and active experience of smelting iron ore in furnaces, was also the comparison of the varied results acquired. This included the measurement of temperatures in the interior of the smelting furnaces during two different smelting processes. While opening the "door" immediately prior to removal of the sponge-like iron (*bloom*), the temperature of the second smelting in two measurements was around 1100°C (first measurement: 1100°C; second measurement: 1125°C), as at the same spot in the third smelting: 1100°C. The molten slag, that discharged from the hearth at the moment the furnace was opened, had a temperature of 926°C next to the opening, and 870°C somewhat further along the channel, while the temperature of the molten slag in the third smelting, further along the channel, was 800°C. The comparison of the temperatures indicates approximately similar values while in the third smelting, the temperature was measured through the nozzle/tuyere, where it was ca. 1300°C. Although measurements are lacking for the closed inner part of the hearth of the furnace



Fig. 1: Earlier built elements at the site of the free standing bloomery furnace: a) furnaces with a rectangular hearth from 2006; b) construction of the baking oven; c) baking oven (-2); d) construction of the so-called La Tène furnace in 2011(0); e) smelting in the furnace built in 2015 and the latter's appearance after several months (f) (Archives of the Technical Museum in Brno)

in the second firing, it seems that temperature was the same or somewhat more. During dismantling of the free standing furnace, below the last layer of repairs (3) a highly fired bowl-shaped base to the hearth of the furnace was noted, the so-called "bowl" (1.1). The "bowl" was certainly the result of smelting in repaired furnace (2), as it was a composite part of the walls. This element on the one hand might indicate high temperatures achieved in the hearth of the repaired furnace, because of which the base in which the blazing spongy iron "swam" was strongly fired. On the other hand, it is possible that this was the result of the very process of smelting, or rather the process of smelting in a closed furnace after placement of the mixture of ore and coal could have been prolonged, and could even have reached approximately the same temperature but with firing continuing throughout a longer period of time, because of which the base could also have become fired. At the base of the hearth of the last repair (3), there were no such elements, as in that case the entire process of smelting was speeded up, and either a sufficiently high temperature was not achieved or the smelting itself did not last long enough for the base to be fired. It should be noted that in the last smelting 1300°C was measured inside the hearth, while there was no "bowl", meaning that if we go for the first possibility, the

temperature in the repaired furnace should be greater than the latter. If we choose the other hypothesis, it should be emphasized that the process itself in the last smelting was shortened, and as a result the product was a spongy iron still containing considerable slag, which could not be shaped subsequently. Although both possibilities remain open as to how the "bowl" could have been created, what further supplements our knowledge is that identical fired bowl-shaped bases, the so-called "bowls", were also found at archaeological sites in the Podravina region, at Volarski breg in Virje and Velike Hlebine in Hlebine (Sekelj Ivančan 2009: 66–67; Sekelj Ivančan, Valent 2017: 74–75). And even the layout discovered after the dismantling of the remains of the freestanding furnace and cleaning of the excavated surface displayed certain similarities to the furnaces in the Podravina region. The most noticeable was the fired earth in a width of ca. 20 to 25 cm that extended around the exterior surface of the furnace hearth. In addition, a surface with a distinctly black color was noted, which extended in a width of up to 40 cm around the fired earth on the rear side of the furnace, which would be related to the place from which charcoal was placed in the furnace. An almost identical situation was noted at the archaeologically excavated smelting furnaces at both sites in the Podravina district cited above.



Fig. 2: Free-standing smelting furnaces: a) furnace with an anthropomorphic figure built in 2016 (Archives of the Technical Museum in Brno); b) the walls of the furnace as found in 2017 (1); c) repairs to the above furnace; d) renovated furnace (2); e) last repairs with a visible new layer of clay on the base of the hearth (3); f) cross-section of the dismantled smelting furnace with visible layers (1, 2, 3); g) plan of the base of the hearth with visible layers (1, 2, 3) (b-g: photo: T. Sekelj Ivančan)

Participation in the workshop at Adamov offered excellent results in the framework of the scientific research TransFER project, both in the sense of education as well as active smelting in a free-standing pit-type furnace. Very good results were also obtained in simulation of archaeological excavations performed at the free standing furnace after completion of the entire process of smelting. All these activities considerably contributed to the better understanding of the procedures related to the processing of iron ore in general, and particularly the results obtained during dismantling of the utilized furnace as related to the archaeological sites in the Podravina region.

Translation: Barbara Smith Demo

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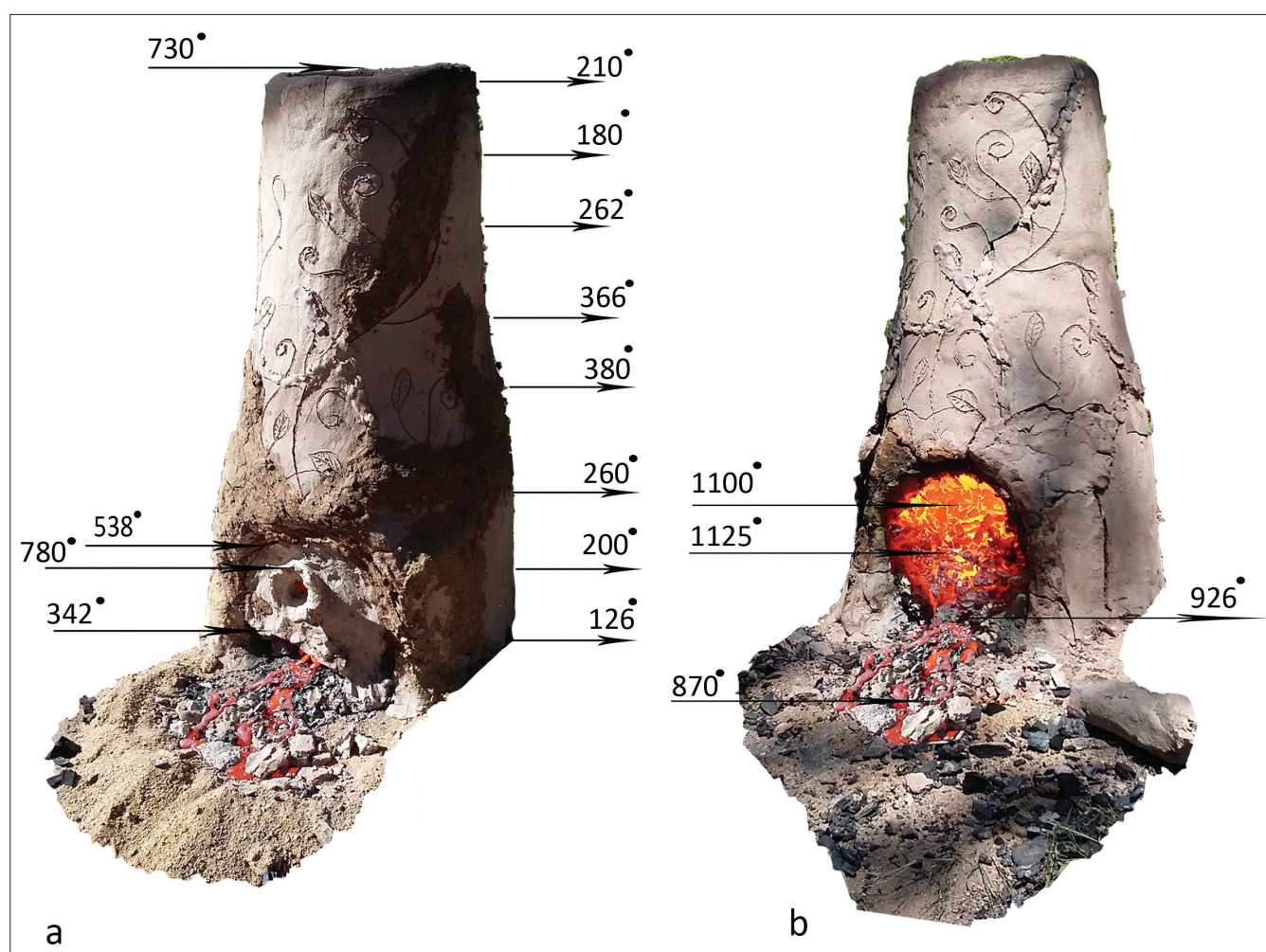


Fig. 3: Measured temperatures of the exterior side of the walls of the furnace during experimental smelting (photo and measurements: T. Sekelj Ivančan; prepared for press: K. Turkalj)

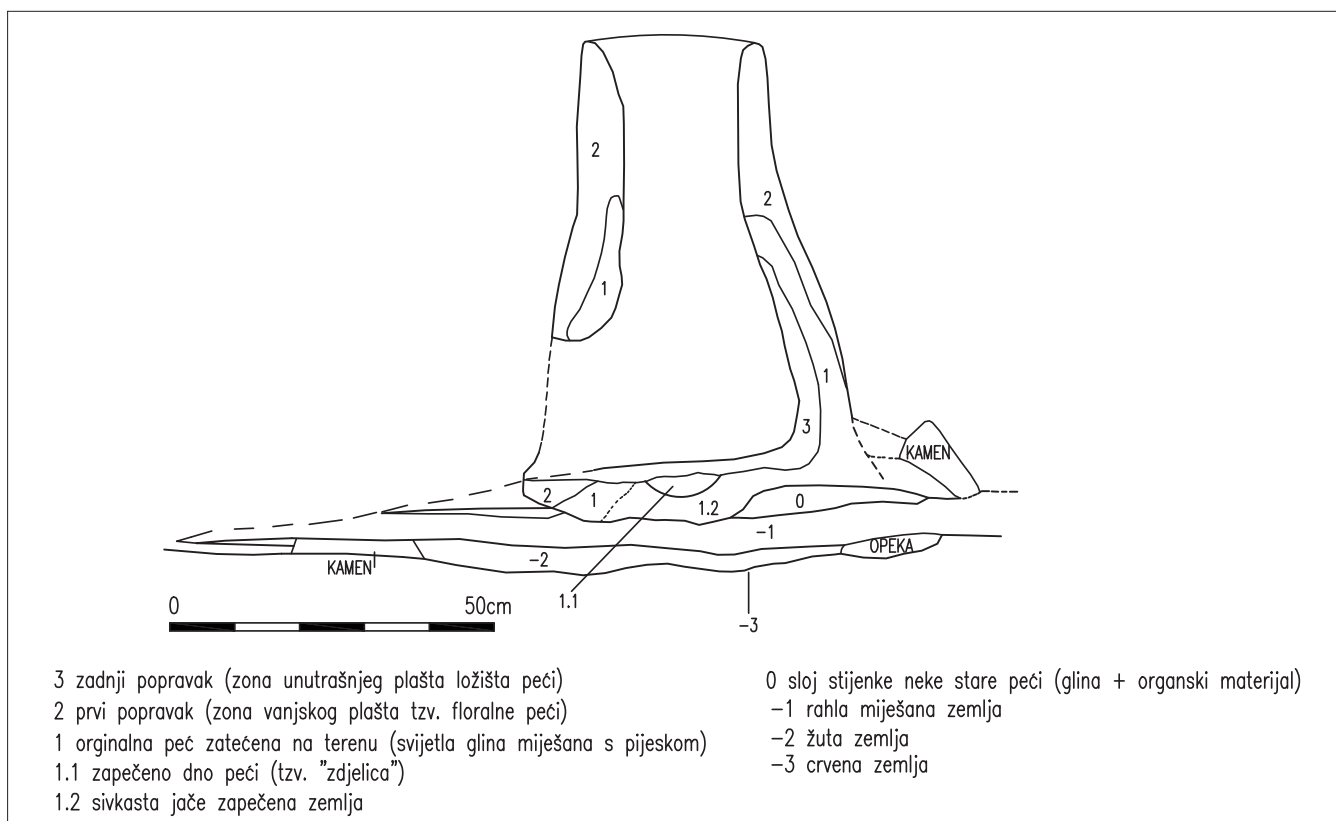


Fig. 4: Sketch of the cross-section of the laters of the free standing smelting furnaces during dismantling (drawing: I. M. Hrovatin; prepared for press: K. Turkalj)

- 3 – last repair (zone of the inner surface of the hearth of the furnace)
- 2 – first repair (zone of the exterior surface of the renovated furnace)
- 1 – original furnace found upon arrival (pale clay mixed with sand)
 - 1.1. – highly fired base of the furnace (so-called "bowl")
 - 1.2. – greyish highly fired earth
- 0 – layer of walls from some earlier furnace (clay + organic material)
- 1 – loose mixed soil
- 2 – yellow soil
- 3 – red clay



Fig. 5: Strata observed during dismantling of the stand-alone smelting furnace (photo: T. Sekelj Ivančan)



Fig. 6: Highly fired bowl-shaped base of the furnace hearth, the so-called "bowl" (photo: T. Sekelj Ivančan)

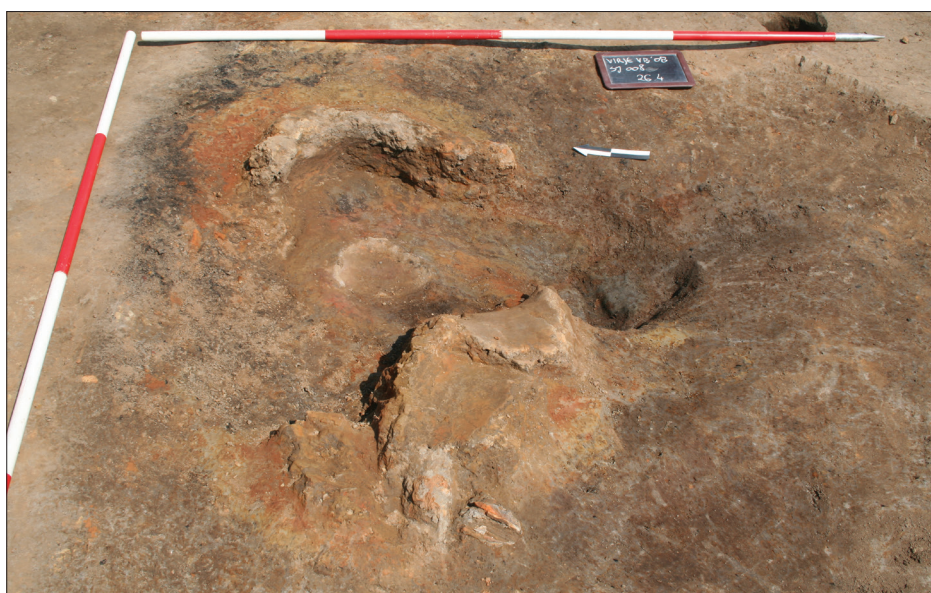


Fig. 7: The site of Virje-Volarski breg: hearth of smelting furnace SJ 008, with a highly fired base in the center at the bottom, the so-called "bowl", with a semicircular black layer beyond the exterior surface of the furnace (photo: T. Sekelj Ivančan)



Fig. 8: The site of Virje-Volarski breg: remains of smelting furnace SJ 056 with a visible highly fired bowl-shaped base, the so-called "bowl" in the center of the hearth (photo T. Sekelj Ivančan)