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THE BLOOMERY MUSEUM AT SOMOGYFAJSZ (HUNGARY) AND SOME ARCHAEOMETALLURGICAL SITES IN PANNONIA FROM THE AVAR - AND EARLY HUNGARIAN PERIOD

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ABSTRACT

The excavations of iron-smelting sites in Pannonia, especially in the counties Győr-Sopron, Vas and Somogy prove that iron-smelting was carried out intensively in these districts from the Age of the Avars up to the reign of the Hungarian Árpád-dynasty (between the 7th and 12th centuries). Similarly to the iron-smelting sites of county Győr-Sopron, in county Somogy the ferrous metallurgical sites from the Avar and the early Árpád period are highly distinctive.

The Working Group on Industrial Archaeology recorded in county Somogy remains of 25 iron production workshops which are recorded in the Pre-Industrial Site-register of Hungary by the archaeologists of the county. The workshop in Somogyfajsz excavated by the author is reported in greater details.

Key words: Bog ore, Ore roasting pits, Iron bloom, Early Medieval iron making, Bloomery workshop

1. INTRODUCTION

After the significant iron-production of the Celts [1] (Fig. 1, H) the Romans, who occupied Pannonia around the year 15 B. C., carried on iron-smelting on industrial level only in the vicinity of iron ore mines in Illyria (near to the border of Southern Pannonia and Dalmatia (Fig. 1, VII.)[2], in Noricum (Karinthia)[3] and after the beginning of the 2nd century in Dacia (Transylvania)[4]. North to the province Pannonia, beside the river Vág, iron was produced by the Celtic tribe of the *Cotini* [5], who were taxpayers of the Quads and Sarmatians. In one of the late Roman fortresses of Pannonia (*Valcum*- Keszthely Fenékpuszta), and in the vicinity of an important NS Roman military road (Szalacska, Hévíz, *Scarbantia*- Sopron) some large split iron blooms [6] (with a weight of about 50-60 kg) have been found. These ones were produced possibly near to the Roman mines of Northern Dalmatia.

The limonite occurrences of the Carpathian Basin were exploited again by the eastern tribes, the Onogurs, who settled down here in the Avar period, in the 7th century A.D. This sites from the 7th-9th c. A.D. can be considered as part of the NW-Hungarian region of iron-production, and are connected to the find-complexes from the counties Győr-Sopron (Tarjánpuszata [8], Dénesfa, Iván, Zsira, Nemeskér) (Fig. 2) and Vas (Tömörd) as well as from the present Burgenland (Dörfl, Draßmarkt). These were all part of an early medieval iron-smelting region based on neogene limonite ores from the Pannon age, situated in the eastern foreground of the Alps and the Western parts of the Small Hungarian Plain [8] (Fig. 1).

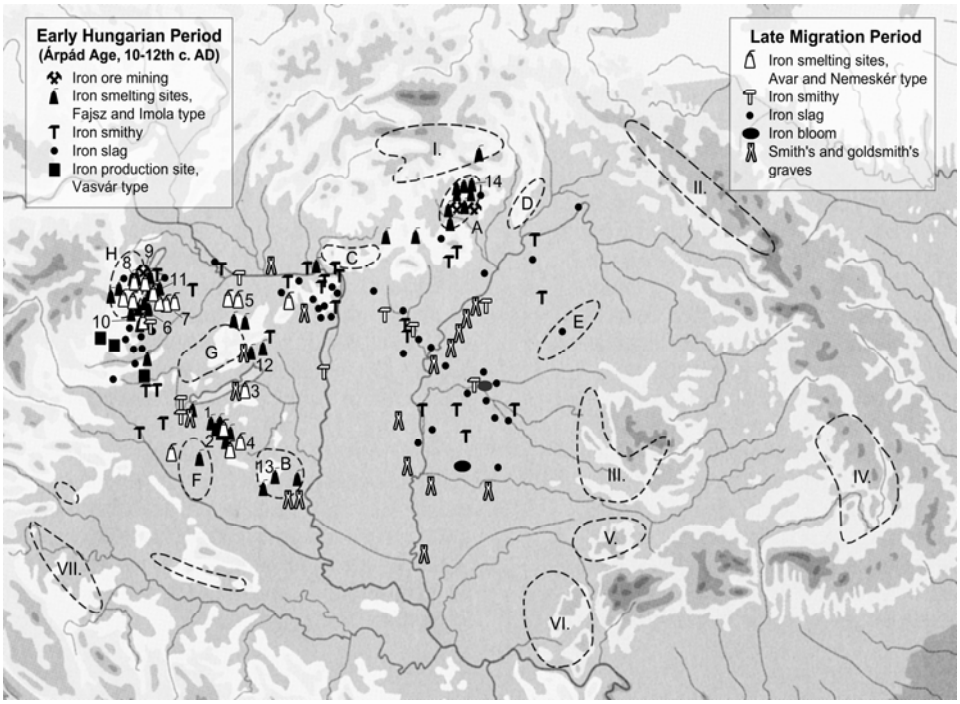

Fig. 1 - The excavated iron smelting furnaces from the Late Migration Period (Nr. 1.-7.) and from the early Hungarian Period (Nr. 8.-14.) in Hungary and in the surrounding countries, with numbering the sites mentioned in this paper: 1. Somogyfajsz, 2. Bodrog-Alsóbű, 3. Zamárdi, 4. Magyaratád, 5. Ravazd and Tarjánpuszta, 6. Nemeskér, 7. Iván and Dénesfa, 8. Sopron, 9. Kópháza, 10. Szakony, 11. Röjtökmuzsaj, 12. Veszprém, 13. Pécs-Vasas, 14. Imola and Trizs. The main iron ore regions in the area of the Carpathian Basin: I.-VII: used mostly in the Roman and Medieval Period. A.-H and IV: neogene (H), or bog ore deposits used partly in the Late Iron Age, but mostly in the Avar, Early Slav and Early Hungarian Periods.

Fig. 2 - One of the typical free standing iron smelting furnace (with twyer-panel) from Nemeskér (8th-9th century A.D.) reconstructed from original fragments of the furnace Nr. 3. Soproni Múzeum, permanent archeological exhibition

2. EXCAVATIONS OF AVAR IRON PRODUCTION SITES IN THE COUNTY SOMOGY (ZAMÁRDI AND MAGYARATÁD)

In the 1980-1990-s the systematic investigation of the remains of early iron-production was carried out which was unknown so far. There were only some scattered and uncertain data about destroyed iron-smelting furnaces [9] which came to light earlier from the South-Western part of Hungary, from county Somogy.

The first professional excavation was carried out at the village **Zamárdi**, close to the southern shore of Lake Balaton in 1986-87 which resulted in the discovery of an iron-smelting settlement from the late Avar period. The research group from Sopron which investigated the site excavated remains of two furnaces and 11 roasting pits or basins of charcoal-burning pits on the side of the Kútvölgyi brook [10]. The square ore roasting pits with rounded corners are typical. The considerable number of them shows an intensive iron metallurgical activity in this site. Ore roasting hearth similar to these in form and size were found only at the furnaces of Sopron, Potzman dülő (10^{th} century) and in Répcevis, Görbeárok (11^{th} century).

On the basis of these finds it could be verified that the same type of Avar furnace already known from Tarjánpuszta (near Pannonhalma) [11] was in use at Zamárdi in the $7\text{-}8^{th}$ centuries as well. Thick rough twyers were used in these workshops. The craftsmen's unit was situated in a distance, but not too far away

from the wooden buildings, yurts and small houses dug into the earth of a large Avar centre [12].

On the basis of the typology of the furnaces, the site of Zamárdi is supposed to be from the middle or late Avar period. This opinion is also supported by stratigraphic observation: as some furnaces are dug into Roman pits, in which there was no iron slag at all. According to the C14 method: the site is from between 734 and 770 AD. (Ede Hertelendi, Debrecen ATOMKI). Archaeomagnetic study put it between 734 and 770 and 580 and 850 AD. (Péter Márton, ELTE, Budapest)

At **Magyaratád** (1999) a longish slag site reminds us to the iron smelting site of the Avar period [13]. On the southern edge of the slag site, the remains of a house of 280 x 350 centimetres basic area with a stone oven was excavated. It is similar to one of the dug-in houses of the Avar iron production workshops of Tarjánpuszta.

The oven on the north-western edge was sometime re-built totally for a furnace-size oven, but there was not iron smelted in it as it is not burnt to grey. So the house is of the same age as the first phase of the bloomery.

Northwards the second of the surface slag piles was excavated. Among the irregularly shaped pits we found the remains of a furnace in a depth of 20 centimetres under the today surface. Its highest intact wall is 25 centimetres high, but it is dug into the ground. The furnaces of this site are of the Avar-type, similarly those in Tarjánpuszta and Zamárdi, which were built partly into the earth. They were practically free-standing furnaces as they were not cut into the wall of the working pit. Similarly as in Magyaratád, there was a shallow slag tapping pit in front of them, whith a diameter between 50 and 105 centimetres. Characteristics of this site were the numerous breast walls which also reminds to the above mentioned furnace-type. The pits full of iron slag were bordered by double ditch sloping towards the brook. The filling of the ditches contained lots of iron slag.

Age determination: The iron smelting of Magyaratád can be dated to the Avar- Onogur period only on the basis of furnace-typology. That means that the furnace existed in the second half of the Avar period, but possibly not later than in the 8th century. Absolute chronology of the first furnace: C14: 625-657, 586-673 AD**;** seventh pit (Avar, hand-made ceramics): 579 - 659, 458 - 497, 513 - **687** AD (Zsuzsa Szánó, Debrecen, ATOMKI). Archaeomagnetic: before 850 AD (Péter Márton, ELTE).

3. EXCAVATIONS OF THE 10^{th-} CENTURY BLOOMERY WORKSHOP (1988, 1995) AT SOMOGYFAJSZ AND BODROG-ALSÓBŰ

In spring, 1988, during earthworks in the forest around the Spawning lake (Ivató tó) at Somogyfajsz, iron slags were found. After the registration of the finds, the Industrial Archaeology Working Group of the Veszprém Regional

Committee of the Hungarian Academy of Sciences carried out here trial-excavations.

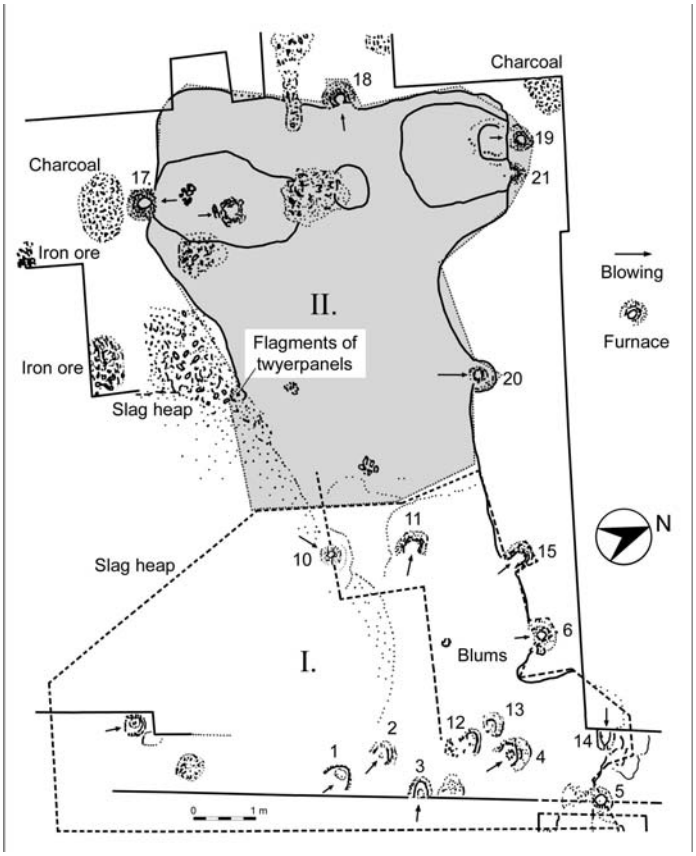

Fig. 3 - Somogyfajsz. Ground plan of the bloomery workshops Nr. I and Nr. II. End of the 10th century A.D. Workshop Nr. II is visible in situ in the „Őskohó Múzeum" (Bloomery Museum)

In the work pit of 16 metres diameter, 21 iron-smelting furnaces were dug out (fig. 3).The diameter of the hearth of the furnaces built into the side of the workshop are 35-40 centimetres in average. Their inner areas are pear-shaped, and their inner height could be about 70 centimetres. The clay furnaces are similar to the Imola-type iron smelting furnaces in their size and form (fig. 4) [14] At Somogyfajsz, however, unlike other Imola-type furnaces excavated earlier, breast-walls were applied as well. The one-time iron smelters piled up the broken remains of these breast-walls, containing one twyer each, on the top of the slag-heaps.

Two main periods of use can be observed at the iron smelting place.

The work pit no. 1 (I.) was built in a dip on a 6 x 8 meters area. The entry of the pit opened to the brook. From the same direction were blown, the furnaces sunk into the wall of the workshop. After wearing out the furnaces of the old

workshop, it was enlarged by an other pit of the same size. At the same time, the middle of the work pit no. I. was gradually filled up by the by-products of iron smelting furnaces built later.

Fig. 4 - Somogyfajsz. The „built in" furnaces Nr. 19 and 21 in the workshop Nr. II.

Only the hearths remained from the furnaces, demolished at the enlargement of work pit Nr. 1 (I.) (furnaces Nr. 1-13) During the use of work pit Nr... 2 (II...), the northern part of work pit I. was also enlarged by building new furnaces (furnaces Nr... 5-6, 10-11, 14-15)... In this pit, furnace Nr. 6 was used at last. Next to and in front of it, four blooms weighing 1,6 to 3,6 kilograms were found.

Work pit Nr... 2 (II.) shown in its original form in the Museum of ancient furnaces (Őskohó Múzeum) forms a round-cornered square with 6 meter long sides. Its entry is on the east from the work pit Nr... 1 (I.). The furnaces (Nr. 17-21) stood along the southern, western and northern walls, 3 metres from each other. Thus blowing with bellows was possible at the three furnaces at the same time. The supply of charcoal and the was possible through the mouth. The black charcoal spots and the red spots with granular ore of 100 cm diameter, shows the place of the piles of the raw material and fuel at the edge of the work pit.

Smelting [15] was carried out by two workers: one of them was working outside the pit, on its upper edge, while the other one operated the bellows inside the pit. This division of labour indicates that the workshop did not have any side walls, only perhaps a temporary roof, but no post-holes belonging to such a structure survived. One of the iron smelters worked outside the work pit, at the edge of the pit, his mate blew with the bellows (fig. 5).

During the excavation, the raw material used for the smelting: limonite blocks of the size of a human head were identified in the flood area of the Koroknai brook, within a distance of 2-3 km from the smelting site.

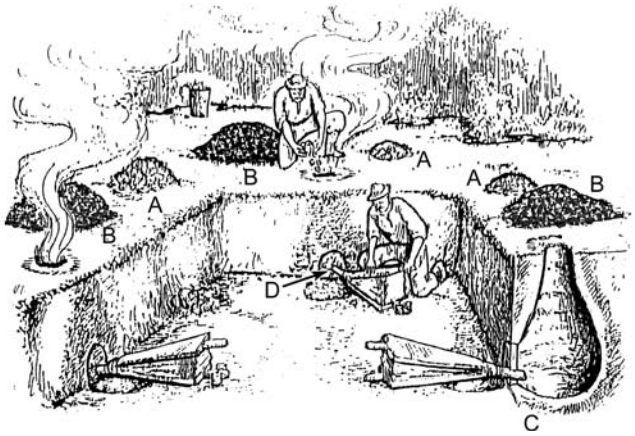

Fig. 5 - Reconstruction of the workshop Nr. II. at Somogyfajsz. A: heaps of roasted iron ore B: heaps of charcoal, C: one of the furnaces in section, D: twyer- panel made of clay.

The components of the bog ores found on the original place of occurrence and beside the furnaces, respectively, are the following [16].

Somogyfajsz	SiO_2	Al_2O_3	MgO	Na_2O	P_2O_5	CaO	MnO	K_2O	öFe	C	S
iron ore 88/6	11,40	1,84	0,38	1,03	2,87	1,79	3,65	-	46,68	0,36	0,006
iron ore 95/10	15,60	1,84	0,49	1,05	2,96	18,40	1,72	-	31,15	1,70	0,019
iron ore	23,5	2,34	0,66	0,95	4,08	13,4	3,52	-	35,15	0,88	0,038
red ore	10,9	1,92	0,45	0,78	2,32	1,65	0,87	-	49,77	0,56	0,010

Iron blooms from Somogyfajsz (SW-Hungary) and Jósvafő (NE-Hungary)

Site	C	Si	Mn	S	Cr	P	Ni	D (cm), Shape	Weight kg.
Somogyfajsz	0,03	0,77	0,16	0,03	0,003	0,62	0	14 ❍	2,7
Somogyfajsz	0,74	0,98	0,06	0,01	0,01	1,22	0	12 ❍	2,45
Somogyfajsz	0,16	0,72	0,71	0,06	0,008	0,40	0	17 ❍	3,2
Somogyfajsz	0,4	0,48	0,92	0,008	0,009	0,94	0	ca.10 ❍	1,72
Jósvafő- Szelcepuszta	--	--	--	--	--	--	--	❍	2,75

Age determination of the Somogyfajsz workshop: The sudden leave of the iron-smelting site was proved by the round iron blooms around the furnace no. 6. and the erected but never used smelting furnaces. It is supposed that the iron smelters left the workshop after 997, i. e. after the revolt of Koppány dux, i. e. the possibly owner of the workshop, - against Vajk Grand duke (later king Stephan the first). On the basis of the decoration of the pottery, the iron smelting furnaces of Somogyfajsz are dated to the end of the 10^{th} century.

Furnace no. 2. C14: 882 - 982 (888-966), 796 - 1006 AD, furnace no. 3 .: C14: 898 - 916 (900-910), 947 - 1016, 878 - 1038 , 1104 - 1108 AD, furnace no.4: C14: (900- 910), 947 - 1016, (954 - 1016) AD [17]; Archaeomagnetic: the beginning of the 11^{th} century AD [18].

Fig. 6 - The building of the Bloomery Museum in the forest next to Somogyfajsz

At **Bodrog-Alsóbű** (1999) next to Pogány (Pagan)-brook a large iron production workshop was excavated by the author and Kálmán Magyar. The size of the working pit found there is 24 x 16 metres. It contains at least three-four workshops („A"-„D"), with 15-20 enlarging periods. Altogether 43 iron-smelting furnaces and two baking ovens were found in the site, but not all worked at the same time. In a smelting season, two or three new iron-smelting furnaces were built. The baking ovens were also part of the workshops. An other paper reports in details the methods of preparing and using the inscripted clay twyer (fig. 7) found in the iron smelting workshop at Bodrog-Alsóbű [19].

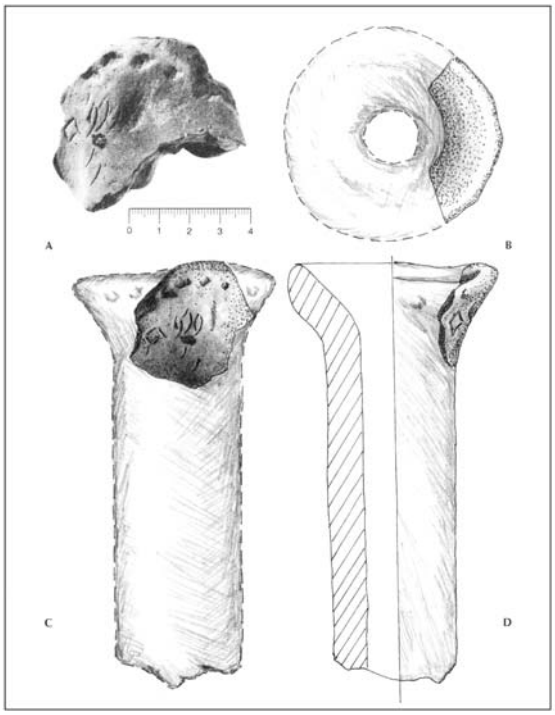

Fig. 7 - Fragment of a twyer made of clay with a Szekel runiform script from the iron smelting workshop at Bodrog-Alsóbű... (reconstruction of the twyer after the author). The reading of the inscription after Gábor Vékony is : funak, which means: „I would like to blow"... This one is in connection with the stimulating work-magic. (The Hungarian name of the twyer is fuvó, or fuvóka). 10th century A.D

The furnaces of Bodrog-Alsóbű can be connected to the Imola-type furnaces excavated in county Sopron (in Sopron- Bánfalvi út, Répcevis, Szakony, Röjtökmuzsaj and North-east Hungary). Their shape and size is the same, the only difference is in their working, in their method of blowing. The furnaces of Bodrog-Bű have breast walls. So have the furnaces of Somogyfajsz and Somogyvámos. They can be dated between the beginning of the 10th century and the turning of the 10th and 11th century AD.

C14 chronology: above the furnace No. 10: 717 - 728, 752 - 879, 682 - 922, 927-951 AD; baking oven no. 15: C14: 713 - 846, 673 - 905 AD. (Zsuzsa Szántó and Éva Svingor, ATOMKI Debrecen). Archaeomagnetic: the beginning of 10th century AD. (Péter Márton, ELTE, Budapest).

4. RESULTS AND DISCUSSION

The amount of iron produced in the Somogyfajsz workshop. Beside the 21 excavated furnaces, some more can be expected on parts of the workshop which could not be investigated yet. The 500 twyers found on the site indicate at least 500 smeltings. If, according to the table below, we suppose that about 2.5 kg of iron (or steel) was produced by each smelting process, some 1250 kg, i. e. one and a quarter metric tons of iron were produced in this workshop. Supposing about 500 smeltings for the workshop altogether, about 20 iron blooms were produced in each furnace which made altogether about 50 kg of iron. It would have been impossible to accomplish such an amount of smeltings in twenty two furnaces, but the number of furnaces was, as I mentioned above, probably somewhat higher. Therefore this calculation seems statistically acceptable.

The number of furnaces cannot be told exactly, further 3 or 4 of them may be situated under the surface which has not been excavated.

The exhibition of the "Őskohó Múzeum". 1995 the Dunaferr Ironworks provided a substantial grant, from which the excavation of the iron-smelting workshop could be completed, and a protecting building was erected over the workshop (fig. 6). The exhibition presents the better preserved part of the workshop, with the equipments and tools reconstructed on the basis of the original finds. Beside the detailed presentation of the workshop at Somogyfajsz, the finds and documents placed in the showcases and on the tables give the visitors a survey of the earliest stage of iron-production in Hungary, about the bloomeries prior to the implementation of blowing driven with water-wheels, with special regard to the 10th century.

5. CONCLUSION

The metallurgical finds of the two areas of Pannonia are more homogeneous in the Avar period than in the 10th century. The Avar furnaces stood alone, were partly dug into the earth, and there was a slag-tapping pit in front of them. Around them there were ore roasting pits or a settlement with houses, pits and ditches. In the early Árpád era, North to the Lake Balaton, there were many small pit workshops next to each other including one or two furnaces. South to Lake Balaton, the 10th century iron smelting sites with large workshops of the county Somogy situated in the forests, far from settlements. They were continuously enlarged, building new furnaces into the sides of the work pits.

This difference shows a variance in the work organization [20]. The Somogyfajsz type with large work pits is supposed to be the earlier. On the basis of the runic find in Bodrog-Alsóbű, it is presumed that in these workshops mostly Hungarian (Székely?) metalworkers worked. It is indicated also by the place-name Vasas near Somogyvár. After linguistic evidences the influence of the Slav iron-workers was very important in this period (see: Ruda, Zseliz, kovács etc.) The furnace-type used by the early Hungarians in Pannonia could be originated from the Central-European Celtic tradition, but it also could arrive from the East with the Onugors of the Avar period or with some of the seven conquering tribes of the Magyars.

The size of the furnaces was mainly similar in both periods: the diameter of the hearth was 35-40 centimetres, the diameter of the throat was 15-20 centimetres, their height was 70-80 centimetres. The lengthened pear-shaped inner place and the use of breast wall for fastening the twyer were also common features of the furnaces of the two periods.

According to the present stage of research, it is difficult to determine the origin of the furnace-type used at Somogyfajsz [21]. Although these furnaces have parallels in Moravia as well [22], they differ significantly from the typical Moravian furnaces of the Želehovice type [23]. The built-in furnaces from the 8-9th century discovered in the northern border region of "Levédia", beside the rivers Donec and Oskol, the territory between Kharkov and Voronezh which the Magyars might have observed before they moved to their new quarters named "Etelköz", were also operated with a different technology, with a different blowing system. These iron-smelting sites discovered in the neighbourhood of the one-time dwellings of the Hungarians (e.g... near the town Voltchansk) which belonged to the Saltovo culture of the border-region of the Khazar Empire, are connected by Russian and Ukrainian scholars with the bequest of the Bulgarian-Alan tribes [24]. The same type of furnaces can be observed around the SE-Carpathians as well [25]. It can be assumed that like contemporary pit-houses dug half into the soil, this type of iron-smelting workshops was also a common feature widespread around the iron-ore occurrences of Eastern and Central Europe. Nevertheless, further, more distant parallels are known from west, from France [26], and from east, from the Tuva Autonom Region [27], from the old homeland of the Avars beside the river Jenisey. In Central-Europe, the furnace-finds from Bohemia [28] prove that smaller pit-workshops were already in use as early as Celtic and Roman times with built-in furnaces of similar size. The workshops and equipment used for iron-smelting served only practical purposes in the 10th century - as well as in our times, so, independently from the ethnic origin of the metalworkers, they were very similar in broader regions. The smelters were interested in implementing the most productive procedures and in choosing the shape and equipment of the workshop and the structure of the furnaces on the basis of expedience, in order to produce iron with the least possible efforts. This is why it is so difficult to connect the different types of furnaces with different ethnic groups. We must take into consideration that the five types of furnaces known from Transdanubia so far [29] can all be dated within a period of 100-150 years, i. e. between the late Avar period and the Árpád-age[30]. This period of 3-4 generations comprised the process of disintegration and establishment of three subsequent

empires, full of shocking changes in politics and power which resulted in the fleeing, moving, or transmigration of vast numbers of people. Iron-smelting had to be reorganized several times too, with the employment of further groups of metalworkers. Some workshop-traditions, however, could be preserved in spite of all the changes. On the other hand, in more peaceful decades the increasing demand for iron posed by the society and economy of Central -Europe in transition created the basis of a series of "micro-innovations". Several professional excavations will be needed in order to take a closer look at the minor innovations in the process of bloom-smelting from this point of view which, of course, cannot be compared to the implementation of water-power in iron-production, or to the introduction of the direct process in metallurgy [31]. The question of defining the place of the workshop discovered at Somogyfajsz in the range of these innovations can be answered with the following sentence: The workshop at (Somogy)Fajsz - as far as the organization of work is concerned - represents that phase of development, when the ironworkers from different workshops were concentrated under princely power [32], thus bringing iron-production "under state management", to be distributed later (within the system of princely and royal serving villages) to manor courts and castle estates, to provide this way the basis of organized iron-production.

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[5] HECKENAST G. -NOVÁKI Gy. -VASTAGH G. -ZOLTAY E.: A magyarországi vaskohászat története a korai középkorban. Budapest 1968. p. 131: *Tacitus*: *Germania* 43,2, *Ptolemaios*: *Geographia* II. 11,11; PIASKOWSKI, J.: Zur Lokaliesierung der antiken Kotiner. AFD Beiheft 16, Beitrage zur Ur- und Frühgeschihte I. Berlin 1981. p. 675- 686.

[6] HEGEDŰS Z.: A diósgyőri Központi Kohászati Múzeumban és a soproni Liszt Ferenc Múzeum vasbucáinak kohászattörténeti vonatkozásai. (Concerning the age determination of the iron blooms found near Sopron, the Late Medieval period has been stated) Történelmi Szemle, Budapest 1 (1961), Kohászattörténeti Bizottság. Közleményei 9.; HEGEDŰS, Z.: Loupes de fer dans les musées Hongrois (1), Revue de' Histoire de la Sidérurgie, Tome III. Nancy 1962-63. Juillet-Septembre, p. 197- 208.; The same dating was taken over by TYLECOTE, R. F.: The early history of metallurgy in Europe. p. 250-251.; and as undated findings were mentioned by PLEINER, R.: The technology of iron making in the bloomery period. A brief survey of the archaeological evidence. in: Arheologia delle attivitá estrattive e metallurgiche (a cura di R. Francovich), Quaderni del Dipartimento di Acheologia e Storia delle Arti Sezione Archeologica - Universitá di Siena 1991.; On the basis of the archaeological evidences these blooms were produced in the late Roman period: SÁGI K.: A fenékpusztai V. századi vasbucák történeti háttere. (The historical background of the Keszthely-Fenékpuszta /Valcum/ iron blooms from the 5th century A. D.) Arrabona 21 (1979) p. 113- 115.; GÖMÖRI J.: A korai középkori vasolvasztó kemencék és az ékelt vasbucák kérdése. On the problem of early Medieval iron smelting furnaces and split iron blooms. in: Industrial Archaeology I.- Iparrégészet I. Veszprém 1981. p. 109 -121.; GÖMÖRI J.: Jelentés a nyugat-magyarországi vasvidék régészeti kutatásáról. II. Meldung über die Forschungen der Fundorte des West-Ungarischen Eisenerzgebietes im Komitate Győr-Sopron. II. Die Ausgrabung in Kányaszurdok und die Frage der gespaltenen Eisenluppen aus Sopron. II. Arrabona 21 (1979) p. 59-86.; ROZSNOKI ZS.: Nyugat- magyarországi vasbucák fémtani vizsgálata. (The metallographical investigations of the West Hungarian iron blooms). Arrabona 21(1979) p. 87- 106. The blooms have revealed high carbon content. Some peaces containing ledeburit structure were not suitable for smithing, therefore may have handled as waste. One of the iron masses was well forgeable and used as an anvil weighing 82 kg.

[7] An iron-smelting site of the Avars or Onogurs was found at Ravazd, between Tarjánpuszta and Pannonhalma in September 1997. Here bloomery workshops from the Avar period were excavated beside an earlier Roman settlement. The well of the earlier Roman village was filled up with the by-products of iron-production, slags, twyers and the fragments of the clay walls of the furnaces. The type of the workshops including size and shape of the furnaces was

similar to that used in the 7th 10th centuries. The furnace bottom showed a basin diametre of 35 cms.

[8] GÖMÖRI J.: The Hungarian Bloomeries. in: Archaeometallurgy of Iron 1967-1987. (R. Pleiner ed.) Symposium Liblice 1987, Prague 1989. p. 125-138.

[9] MAGYAR K.: A középkori vasművesség emlékei és forrásai Somogyban. Sources and relics of medieval ironworking in County Somogy /Part I/. Iparrégészet II- Industrial Archaeology. Veszprém 1984. p. 217-226.

[10] GÖMÖRI J.: Jelentés az 1986. évi zamárdi vaskohóásatásról. BKL., Kohászat 120 (1987), Nr. 5. p. 256-257.

[11] GÖMÖRI J.: Frühmittelalterliche Eisenschmelzöfen von Tarjánpuszta und Nemeskér, Acta Arch Hung. 32 (1980) p. 317-345.; Idem, Jelentés a nyugat-magyarországi vasvidék régészeti kutatásáról. I. (Report of archaeological research of the W-Hungarian iron ore region I.) Arrabona 19-20 (1977-78) 109-158.

[12] The proximity of this economical and administrative centre - *ordu* - situated probably at the Szántód ferry site is indicated by the Avar cemetery of some 2300 graves excavated by Edit Bárdos in the Réti földek (Meadow fields) balk. BÁRDOS Edit.: RégFüz. 41 /1988/ p. 59.; RégFüz. 44 /1992/ 55.; Somogy Megyei Múzeumok Igazgatósága Múzeumi Tájékoztató 1996/1. p. 33-35...; In the year 2005 a large part of this iron smelting settlement in Zamárdi was excavated by Zsolt GALLINA, when between the houses of the Avar village more then 20 bloomery furnaces and smithies were uncovered. Lecture, 26. 05.2006 in the Hung. Nat. Museum, Budapest. Session of the Work Group on Industrial Archaeology and Archaeomtery.

[13] GÖMÖRI J.: Az avar kori és X-XI. századi vaskohászat régészeti emlékei Somogy megyében. The archaeometallurgical sites of county Somogy in the Avar and early Árpád-period. Somogyi Múzeumok Közleményei, (Kaposvár) 14. (2000) p. 163-218.

[14] HECKENAST G. -NOVÁKI Gy. -VASTAGH G. -ZOLTAY E.: A magyarországi vaskohászat története a korai középkorban. Budapest. 1968. p. 21-35.; GÖMÖRI J., A vaskohászati maradványok régészeti kutatásáról. A szakonyi vasolvasztó telep. (On the archaeological research of the remains of iron smelting. The Szakony bloomery site). Bányászati Kohászati Lapok. Kohászat 116 (1983) p. 97-103.

[15] production of iron blooms with a weight of about 2-3 kg.

[16] Investigated by Dunaferr Qualitest Kft., Division of Material Testing, OLÁH Istvánné and ÁGH József. 23. 04. 1996. ÁGH József- GÖMÖRI János, Investigation of materials from the Somogyfajsz workshop. In: Traditions and Innovations in the Early Medieval Iron Production. Hagyományok és újítások a korai középkori vaskohászatban. (Ed. Gömöri János) Duanferr, Sopron-Somogyfajsz 1999. p. 192-198.

[17] Age determination of the charcoal pieces was carried out by Dr. Ede Hertelendi (Nuclear Research Institute of the Hung. Acad. of Sci., Debrecen): Charcoal samples from the furnace Nr. 2: 888-966 A. D., from the furnace Nr. 4: 900-910 A. D. and 950-1016 A. D. Charcoal fragments from the furnace Nr 5: 728.732, and 770-878 A. D., GÖMÖRI J. - MÁRTON P. - HERTELENDI E. - BENKŐ L.: Dating of iron smelting furnaces using physical methods. In: Traditions and Innovations in the Early Medieval Iron Production. Hagyományok és újítások a korai középkori vaskohászatban. (Ed. J. Gömöri) Dunaferr, Sopron-Somogyfajsz 1999. p. 142-148.

[18] MÁRTON P.: Archaeomagnetic directional data from Hungary: Some new results. Archeometry '90. p. 573. „Somogyfajsz two iron smelting furnaces 1000 +-100 A. D." as result of a 18 samples determination. Samples Nr. 1-10. are from the latest furnace 16; Samples Nr. 11-18 are from the earliest furnace 2.

[19] GÖMÖRI J.: The archaeometallurgical sites of county Somogy in the Avar and early Árpád-period. Somogyi Múzeumok Közleményei, (Kaposvár) 14. (2000) p. 197. fig. 5.

[20] GÖMÖRI J.: Az avar kori és Árpád-kori vaskohászat régészeti emlékei Pannoniában. Magyarország iparrégészeti lelőhelykatasztere I. Vasművesség. The Archaeometallurgical

Sites in Pannonia from the Avar and Early Árpád Period. Register of industrial archaeological sites in Hungary I. Ironworking. Sopron 2000.

[21] GÖMÖRI J.: Iron smelting. In: The Ancient Hungarians. Exhibition Catalogue. Hungarian National Museum. Budapest 1996. p. 63-64.

[22] SOUCHOPOVÁ,V.: Hutnictví železa v 8-11. století na západní Moravì. Praha. 1986. Tab. V.

[23] PLEINER, R.: Základy slovanského železárského hutnictví v Èeských zemích. Praha 1958. pp. 208-224., Fig. 55-58., PLEINER, R.: Iron in Archaeology. The European Ironsmelters. Praha 2000, p. 191, fig. 52.

[24] AFANASZ'YEV, G.E.- NIKOLAYENKO, A.G.: O saltovskom tipe syrodutnogo gorna. Sov. Ach. 1982. Nr. 2. 168- 175., SHRAMKO, B.A. - MIKHEYEV, V.K.: Do pitaniya pro vyrobnictvo zaliza u bolgaro- alanskih plemen saltivskoy kul'tury. Visnyk Kharkivskovo Universitetu, Istor. Ser. Nr 35 (1969) V. 3. 74- 81.

[25] TRIP^{a}A, Josif (red..): Din istoria metallurgiei Române^{o}ti. Bucureti. 1981. p. 33. Fig. 2. a. (Doboseni, Hargita megye (= Dobolló).

[26] LEROY, M.- FORRIERES, C.- PLOQUIN, A.: Un site de production sidérurgique du haut Moyen Age en Lorraine. Archeologie Medievale, Editions du CNRS. Tome XX. 1990. p. 141- 179.

[27] SUNCHUGASEV, Ya..I.: Gornoye delo i vyplavka metallov v drevnyey Tuve. Moszkva. 1969. furnace from the site Turlug: fig. 54. and an ore roasting pit similar to the Pannonian ones from the Avar Period: fig. 61.

[28] ZAVREL, J.: Die Eisenverhüttungsanlagen der älteren römischen Kaiserzeit in Rièany, Bez. Prag- Ost. in: Arhaeometallurgy of Iron. Prag 1989. p. 109- 124. Fig. 3.

[29] GÖMÖRI J.: 9-10. századi vaskohászat. in: Honfoglalás és régészet . Budapest. 1995. p. 259-269.

[30] From the decline of the Avar Empire (803) through the one hundred year long Carolingian supremacy (with strong Bawarian and Slavic influences) till the Hungarian conquest (896-900) with a social and economical reorganisation beginning with the second half the tenth century.

[31] HECKENAS G.: A vaskohászati innovációk lehetőségei és akadályai Magyarország történetében a középkortól a 18. század közepéig. in: Műszaki innovációk sorsa Magyarországon (Ed. Endrei Walter). Budapest. 1995. 141.

[32] Historical background of the Somogyfajsz Workshop*:* The village (Puszta)kovácsi (*Kovácsi* meaning "smith") in the neighbourhood belonged to an early estate-centre. The finds described above enabled us to investigate a complex iron-production site where the different stages of work, i.e. ore-collecting, smelting and processing of iron were carried out close to each other, but not exactly on the same site. The distribution of working sites was similar around Sopron as well, the iron-smelting site was located by the one-time (now desolated) village Kovácsi, in the Potzmann balk, the iron ore was mined beside the village Kópháza while the centre of the estate was probably located in the fortress of Sopron. Iron blooms at Somogyfajsz found near furnace no. 6, together with furnaces which were built ready, but had never been used prove that the smelting site was abandoned suddenly. Therefore we may suppose, that the workshops at Somogyfajsz were given up first in the 950-s, in the course of reorganization after the defeat at Augsburg and changes of the princely rule. When Fajsz lost his power, the rule over the territory and people South to Lake Balaton got into the hands of Koppány *dux* and his family who established the fortification at Somogyvár which later functioned as county seat. One of the other possibilities that the workshop was deserted after the victory of the later King István the first, and Koppány's defeat at the end of the 10th century.