DEMİRKÖY-SAMAKOCUK IRON FOUNDRY: AN INDUSTRIAL ARCHAEOLOGY PROJECT AT AN OTTOMAN METAL WORK-SHOP COMPLEX IN THRACE

DEMİRKÖY-SAMAKOCUK DEMİR DÖKÜMHANESİ: TRAKYA'DA OSMANLI DEMİR İŞLİK BÖLGESİNDEKİ ENDÜSTRİYEL ARKEOLOJİ PROJESİ

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Keywords: Iron Smelting Furnace, Ottoman Foundry, Industrial Production of Iron, Waterwheel Systems, Iron Ingots and Slag analysis, Archival Documents.
Anahtar Kelimeler: Demir Ergitme Fırını, Osmanlı Dökümhanesi, Demirin Endüstriyel Üretimi, Su Çark Sistemleri, Demir Külçeleri ve Cüruf Analizleri, Arşiv Belgeleri

2002 yılında başlatılan disiplinler arası Demirköy Endüstri Arkeolojisi projesi kapsamında yapılan çalışmalar Büyük Dökümhane Kompleksi ve bunun 250 m kadar batısında bulunan küçük işlikte gerçekleştirilmiştir. Geç Osmanlı Dönemine tarihlenen bu dökümhane Kırklareli Demirköy İlçesinde yer almaktadır. Arşiv çalışmaları ile desteklenmekte olan kazıların ana amacı burada gerçekleştirilmiş olan demir üretim teknolojisinin sosyo-ekonomik boyutlarını belirlemektir. Makalede sözü geçen işliğin endüstriyel işlevlerini, demir üretiminin nasıl ve ne koşullarda gerçekleştiğini ve işlikte ne türlü aktivitelerin yer aldığını saptamaya yönelik çalışmalar özetlenmektedir. Kazılarda ele geçen veriler ve bu verilere bağlı çark, körük ve çekiç sistemlerinin rekonstrüksiyonu verildikten sonra yapılan arkeometallurjik araştırmaların ilk sonuçları sunulmaktadır. Son olarak, ele geçen buluntular ve bunların işliği tarihlendirebilme açısından önemi vurgulanmakta ve ileriki yıllarda planlanan çalışmalara değinilmektedir.

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BACKGROUND TO THE PROJECT

A multi-disciplinary and multi-institutional industrial archaeology project was initiated in May 2002 at Demirköy-Samakocuk, an Ottoman Period metal working site. The foundry is located in the northeastern part of Turkish Thrace, situated in the province of Kırklareli about 20 km east of the Bulgarian border and approximately 25 km south of İğneada, the westernmost port-city of Turkey on the Black Sea coast. Under the auspices of the Society for Turkish History of Science and the direction of the Museum of Kırklareli, the first season of salvage excavations were started during the summer season of 2003 at the deserted site of an iron foundry located around 4 km from the southeast of the town center of Demirköy. Excavations continued through the summer of 2006. This research was supplemented by industrial archaeological surface surveys conducted in the thickly forested area around the vicinity of this site.

Traditionally called "*Fatih's* (or The Conqueror's) Foundry" by the local inhabitants, indicating a probable connection with the reign of the Ottoman Sultan Mehmed II, who is known to have cast some of his powerful bronze *shahee cannons* that he used during the siege of Constantinople in 1453 somewhere within the Liva (or Governate) of Edirne, this large foundry was originally identified and recorded in 1991 as a monument of historic interest by the then newly established Directorate of Kırklareli Museum, and subsequently registered as an archaeological conservation site by the Council for Preservation of Cultural Assets at Edirne. In June 2001 the Museum Directorate, with the financial assistance provided by the Turkish Ministry of Culture, carried out a preliminary salvage operation involving the surface cleaning of the foundry site from the thick growth of bushes and trees, and the construction of a perimeter fence of barb-wire around approximately 9,400 m^2 of the designated conservation area. The preliminary operation has revealed a fortified rectangular residential area with polygonal corner towers in the form of a terraced settlement with a lower level foundry workshop immediately to the south of this upper terrace. In addition to stone built walls preserved to a few meters in height, surface cleaning also revealed underground vaulted canals bringing water for the operation of the foundry machinery from a pooled reservoir behind a dike constructed over the Dolapdere stream located about 500 meters to the west of the site.

The geography of the Kırklareli Province in Eastern Thrace, defined by the Black Sea and the Yıldız (Istranca) Mountains, had strategic importance from a metallurgical point of view throughout all periods of its history. Particularly after the discovery of iron working, the region attained special attention due to its easily obtainable ores of iron. Consequently, Demirköy developed as a major industrial center in parallel with the growing importance of the manufacture of iron for the Ottoman Empire and its army and navy.

During surface surveys of 2003 and 2004, remains of many iron furnaces and heaps of slag and charcoal were identified within the thickly forested area in the vicinity of the foundry. Many water structures such as dams, dikes and remnants of stone and earthen water canals were revealed along numerous stream valleys. To supplement the field work, a separate team of historians of science have started to research Ottoman archival documents, particularly on the main foundry site with upper strata dating to Sultan Mahmud II's reign (1808-1839).

The Museum salvage excavations, which started at the upper residential terrace level of the foundry in 2003, have been organized adjacent to the North precinct wall, on either side of the main gate. During the subsequent seasons, trenches measuring 10 meters wide were opened along the western and eastern precinct walls, as well as the whole length of the North side, revealing barrack-like single story structures together with the remains of a masjid, a bath house and further rooms whose functions have yet to be identified. This research has also made it clear that the entire central area of the fortified settlement was an open courtyard, which most probably served as a military exercise and parade ground for the small contingent stationed here during the reign of Sultan Mahmud II in order to provide security for the foundry workers.

INTRODUCTION TO THE INDUSTRIAL ARCHAEOLOGICAL RESEARCH

Demirköy is located in the metalliferrous zone of the Istranca Mountains in the northeastern part of Turkish Thrace, in the province of Kırklareli. The region has ample supplies of the three main ingredients for iron production: extensive woodlands for charcoal production, perennial rivers to operate waterwheels, which in turn power bellows and forging hammers necessary for the industrial production, and good-quality iron ore in the form of local siliceous hematite and magnetite sands (Ryan 1960). In addition to iron, the copper ore deposits around the Dereköy-Şükrüpaşa and Demirköy-İkiztepe regions are known to have been crucial since prehistory. Archaeological research has shown that copper metallurgy in Bulgaria began in the fifth millennium BC (Todorova 1999). Producing beads from malachite was also widely practiced by the inhabitants of sixth and fifth millennium settlement of Aşağıpınar (Özdoğan, Parzinger 2000). Magnetite and siliceous hematite mineralization around Demirköy was probably what initiated the iron metallurgy in the region, probably as early as the Hellenistic-Roman Periods (Wagner, Öztunalı 2000). The research project described here deals with the metal production activities that took place at the Main Foundry and an adjacent small workshop in the Late Ottoman Period. Although excavations at both locales yielded little archaeological evidence that predates the nineteenth century,[2] written documents suggest that the facilities in the area may already have been in use centuries before this date.[3]

Two different types of iron were produced in the Ottoman Empire during the eighteenth and nineteenth centuries: cast iron and wrought iron (Aydüz 2006, Agoston 2005). Wrought iron was produced by the reduction of iron in solid state in bloomery furnaces. After consolidation of the slag incrusted spongy bloom by forging, wrought iron, used mainly for domestic or farming purposes including objects like horseshoes and nails, was obtained. Cast iron, however, was produced in much more efficient blast furnaces requing somewhat more sophisticated technical skills, and major capital investments, as was the case in the Main Foundry complex in Demirköy. Cast iron was the raw material for military use, especially in the manufacture of cannon balls. In fact, the late seventeenth century archival documents referencing the Demirköy (Samakov) foundry describe the site as a place where cannon balls were cast for the Ottoman artillery. The term "helon," which appears often in the archival documents refers to the cast (pig) iron that was produced together with wrought iron around Samakov. Among the documents that clarify the term "helon" we find one (C.BH., 191/8966, Nov. 12, 1719) that mentions the delivery of cast "helon" to Samakov, Nevrekob and other foundries via the shipyard. Another document (C.BH., 462/19295, March 10, 1818) contains information about a sunken ship sailing from İğneada, the seaport of Samakov and Torliye, which contained 228 pieces of "helon". A third document (C.BH., 83/3989) Sept. 30, 1818) contains instructions that the "helon" sent to the shipyard from Samakov and Torilye should be cast in three sizes, while a final document (C.AS., 944/40967, Nov. 20, 1815) states that the "helon" that came from Samakov was broken into pieces at the Hasköy foundry. The documents verify that "helon" was used to cast cannon balls or chain shots whereas wrought iron was used to manufacture ship anchors by forging. In addition to iron production, copper smelting was also actively practiced in the area between Demirköy and Balaban.

The interdisciplinary nature of the project recognizes that a full comprehension of the processes of manufacture at the workshops requires explicit investigations in the full array of archaeometallurgical materials present including ores, slags, furnace fragments, ingots, finished products as well as the types of furnaces. With an industrial archaeological focus in mind, the Demirköy Project aims to understand not only the technologies utilized in the mines and metal workshops but also the set-up of waterwheels and other power generating components that drove the system. This data is being combined with information on the social, economic and political background acquired from textual sources.

Both the archival documentation and the archaeological studies showed that magnetite sand was one of the main ores used. Several highly purified magnetite sand storage areas were discovered during excavations. Magnetite sand is still visibly available in the river sediments and can be easily enriched from the siliceous gang by simple washing in a sluice, which was also the enrichment method used since antiquity. The magnetite ores found in storage pits were highly pure with over 70% iron content.

The industrial archaeology research at Demirköy began in 2002. Initially, to understand the extent and the nature of metallurgical activity at Demirköy, intensive surface surveys were conducted in the vicinity of the Main Foundry. This research yielded more than seven smaller workshops within a ten km range (fig. 1). The research also discovered over twenty intact or partially destroyed furnaces known as "vigne" or "bekne" at these peripheral workshops and large numbers of slags, furnace fragments, ingots and ore samples were collected for analyses (Danışman, Tanyeli 2006). Surveys also made clear that water in this entire area was channeled through a network of artificial canals (some of which were underground) constructed along the natural contours of the adjacent hillsides. At the workshops, this water was fed into waterwheels, to generate the hydraulic power necessary to drive the forging hammers and bellow-systems. These natural resources coupled with a thickly forested landscape, from which fuel was supplied for the furnaces, made this an ideal locale for the workshops.

SMALL WORKSHOP EXCAVATIONS

In the summers of 2005 and 2006 two seasons of excavation took place at Kabakçının Tarlası, one of the metal production workshops associated with the Main Foundry. Investigations at Kabakçının Tarlası or the Small Workshop, located about 250 meters northwest of the main facilities of the Demirköy Foundry revealed a copper and an iron smelting furnace as well as the necessary infrastructure for metal production. Located along a steep hillslope, less than 50 meters from the Dolapdere stream, the Small Workshop foundry was designed to make maximum use of the water sources of the area.

Based on walls and furnace ruins that were partially visible before the start of the excavations, as well as the research done to date, it seems that the area was partitioned into several units, designated here as Area 1 through Area 6 (fig. 2). The total enclosed area at this location measures nearly 60 x 20 meters. Our excavations have succeeded in reconstructing the basic setup of the Small Workshop facilities associated with two large furnaces: Furnace F1 and F2, located respectively in Areas 1 and 4B. This article continues to describe the archaeological evidence that allows us to make a reliable assessment of the way in which the facility was designed, engineered and perhaps most importantly, how it was used. When combined with archaeometallurgical analyses conducted on the ore, the slag, and the manufactured tools (see below), we are able to gain important insights on the scale and system of the industrial production here. Provided below is a summary of the work that has been done in the different areas over the past two seasons and the preliminary interpretations that can be drawn regarding the function of the finds recovered.

AREAS 1 & 5

Area 1 forms a rough square (approximately 22 x 20 meters), and is enclosed by heavy stone walls on all four sides. Excavations and clearing conducted in this area indicate the presence of an entrance from the south. This is in line with our expectation that there was a road along the south side of the complex. This would allow the goods manufactured in the workshop to be loaded on transportation vehicles.

The northern wall of Area 1 functions as a retaining wall against the hill-slope and is preserved to a height of over 3.5 meters. All walls in this part of the workshop were made of undressed stones and held together with lime cement and a framework of longitudinal and transversal wooden beams, none of which are now preserved. This stone construction encloses furnace F1 and the surrounding features.

Excavations in Area 1 conducted in 2005 by a team from Eskişehir Anatolia University under the direction of Instructor A. Deveci focused on clearing the immediate surroundings of the furnace and removing the large amounts of rubble and fallen debris that had accumulated. One of the great challenges here was freeing the furnace and deposits from thickly intertwined tree roots. Even though this circumstance hindered the complete excavation of the furnace and surrounding areas, work conducted in the northern area allowed reconstructing the way in which the furnace system must have functioned (Danışman et al. 2007).

Water tapped from a canal running above the northern retaining wall was directed into a small channel and fed into a waterwheel. The small feeder channel, located in an area designated as Area 5, was cleared in 2006 over the full distance between the main canal and the retaining wall to establish its slope, size and width. Although somewhat insubstantially constructed, this canal must undoubtedly have sufficed in carrying the water necessary to set the waterwheel in motion and ultimately to power the bellows. It is possible that the water was delivered through an enclosed wooden chute as was not uncommon in Turkey (Cresswell 1993:201-202; Danışman 1977; Donners et al. 2002). The actual wheel would have been placed in a sunken trough set into the floor of the main chamber of Area 1 immediately northeast of the furnace F1. The preserved height of the retaining wall, at nearly four meters, may roughly correspond with the height of the no-longer preserved waterwheel. Overshot waterwheels, indicated here by the fact that water was fed from above, operate well even with a limited water supply because the weight of the water sets the wheel in motion, making this design one of the most efficient methods to power a mill (Denny 2004; Howard 1983:27; Reynolds 1983:106). Based on historical archives of similar furnace constructions, this mill probably powered a double bellow system which would have been located immediately west of the waterwheel and north of the furnace (fig. 3). Factors of preservation made it unfeasible to recover bellows.

Although only partially excavated, the results of the excavation in Area 1 and a carefully placed sounding in the northeastern corner indicate the presence of a canal, which began at the sunken trough into which the wheel was set, and probably extended beneath the floor towards the south of the building. Excavations exposed the beginning of the canal and much effort was devoted to clearing the accumulated fill to define the walls of this construction. Again, tree roots had damaged parts of the canal considerably, complicating the task of further exposing it.

Excavations and laboratory research (see below) indicate that the Furnace F1 in Area 1 functioned as a copper furnace. Even though it was not possible to study the furnace in detail due its very fragile state of preservation, numerous copper slag and metal fragments were recovered when the shaft of the furnace was cleared. We have evidence that copper production was of importance based on data from other parts of the site. During excavations at the Main Foundry, for example, one section of a two-piece copper mold for casting small solid lead cannon balls was recovered. Copper production at Demirköy was probably for local consumption. Copper, however, was also a strategic metal for the Ottomans since they preferred more expensive bronze cannons. To produce bronze, however, Ottomans had to import tin, which at times was difficult to achieve.

AREAS 2, 3, 4A

No excavation has yet been conducted to clarify the function of Areas 2 and 3. Similarly, Area 4A also awaits systematic excavations, as to date only some clearing work of the western wall and removal of shrubs has been done. This established that, like Area 1, this is also enclosed by stone walls, of which the northern one acts as the retaining wall against the hill-slope. Excavations in 2005 and 2006 focused on clearing the large bloom iron furnace in Area 4B and understanding how the surrounding workshop was used (fig. 5). Research conducted in 2006 indicates that Area 4A and 4B were originally built as one single enclosure. The two parts, 4A and 4B, were later separated by a much narrower wall, yet a wide (1.80 meter) doorway permitted passage between these two areas. As our excavations yielded no other entrance to Area 4B, all the fuel, ore, bloom and iron would have had to pass through this doorway, elucidating its industrial-sized width. The less substantial thickness of this partition wall (indicated on plan as Locus 55) and the fact that it has been constructed at an angle that is not exactly perpendicular to the walls it connects to suggests that the separation between Areas 4A and 4B was not part of the original building plan but was a decision which was made in a later use-phase of the structure. This is confirmed by the fact that Locus 55 abuts -and is not bonded to- the walls it is constructed between (i.e. Locus 53 and Locus 57). Constructed much less carefully than exterior walls, Locus 55 lacks the framework of wooden beams.

Preliminary clearing work in Area 4A yielded no indications for furnaces in this area. Whether there were other iron-working installations can only be established through future excavation. Surface cleaning in Area 4A yielded the presence of a red-bricky deposit, presumably remnants of roof-tiles, indicating that this large area had been roofed. The sandy ground surface across this area contains patches with high concentrations of magnetite. At present it is uncertain whether these patches are remnants of in situ deposits or they represent accumulations resulting from slope-wash. If the former holds, this would mean that Area 4A was a locale where the iron ore, to be used in the nearby furnaces, was stored.

AREA 4B & AREA 6

The most intensive excavations in the Kabakçının Tarlası workshop facility were in Area 4B, located in the easternmost section of the complex where a bloom iron furnace (F2) was investigated. The enclosed section of Area 4B measures 17.5 by 7 meters and, as mentioned above, would have been reached from the doorway through Area 4A. Excavations have not yet been concluded, but have reached a point where the main layout is clear; we now understand not only the furnace, the canals and the waterwheel systems but also some of the basic activities that took place within this workshop complex. The furnace in Area 4B, and presumably other areas in the workshop complex, had multiple use phases (see the phasing section below). Undoubtedly, use-phases that our excavations were unable to reach lie beneath.

The furnace was set close to the eastern enclosure wall, roughly in the middle between the north and south walls. The narrow space between furnace and enclosure wall was filled in and covered with flagstones that created two sets of steps, leading up to the top of the furnace both from the south and the north. From the top, the iron ore and charcoal would have been charged into the furnace.

The top and exterior of the exceptionally well-preserved furnace have been cleared, but the interior remains to be excavated. We are thus unable to comment on its inner features at this time. The furnace at its base (i.e. the level to which it is currently excavated) measures ca. 3 by 4 meters. The overall dimensions and style of this furnace resemble that of a "Stückofen" style bloomery furnace (Tylecote 1987, Tomas 1999). It is built of undressed rocks, covered on top by flat (slate-like) stones. The top is not completely preserved, but these cover stones indicate that the furnace did not reach much higher originally. This is one indication that this was a bloomery furnace and not a high blast furnace. Several slag samples from the tap hole of the furnace and various places in area 4B were analyzed as well as fragments obtained from the bloom iron ingots recovered from the area. A total of six of these ingots were found to date, each weighing between 61 -71 kg.

Research indicates that the furnace complex in Area 4B was powered by a dual waterwheel system. The waterwheels were located in a canal called Area 6, immediately east of Area 4B (fig. 4). Water would have been channeled into the canal from the artificial waterways that followed the hillslopes north of the workshop. The location of the water canal outside the eastern enclosure 4B is notable as it contrasts with the western workshop of Area 1, where the waterwheel(s) were located inside the workshop. The canal was excavated from the point near the northeastern corner of Area 4B where there was a vertical drop of at least 2.10 meters, until the southeastern corner of the workshop complex, after which the sides of the canal could no longer be detected. The exterior of the eastern enclosure wall of Area 4B (Locus 52) formed one of the sides of the canal. Preserved in places on the exterior of the stone wall was a layer of plaster, presumably remnants of the waterproofing material to prevent the water from seeping into the workshop compounds of Area 4B. Located about one meter to the east, paralleling this wall, was either a freestanding or a low retaining wall. This latter construction was also reinforced with timber beams placed in horizontal slots. The base of the sand and stone-filled canal in Area 6 has not yet been reached.

Our claim that the canal contained waterwheels is supported by several lines of evidence. The data available for the northern waterwheel, which would have been located close to the vertical drop in the canal, are perhaps most convincing. Here our excavations discovered a U-shaped iron strip or brace with regularly spaced nails which would presumably have held the wooden segments of the waterwheel together. Its span of at least 42 cm provides some insights into the width of the waterwheel. The presence of this waterwheel is also supported by the discovery of a break or hole in the eastern exterior wall of Area 4A (Locus 52), close to where the metal wheel brace was found. This would have been the orifice through which the axle of the waterwheel entered the workshop. A final piece of evidence is the discovery of a pedestal or platform (Locus 67) north of the furnace on to which this axle must have been secured (fig. 6).

No remains have been found so far of a possible second waterwheel, but its location can be reconstructed from a similar support feature south of the furnace (Locus 21). The pedestal to anchor the axle of the southern water wheel lies at approximately the same distance from the eastern wall as Locus 67. The feature lines up with two vertical slits, one in each of the two sides of the canal. These may have held posts that would have supported the waterwheel. Several meters after the second waterwheel, the water may have flowed the final 50 meters or so to the small Dolapdere stream in the valley bottom in a channel without built sides.

Although part of the same system, the two waterwheels would have powered very different facets of the furnace complex. The axle of the northern water wheel was connected to a dual bellow system which would have directed air into the furnace to achieve the temperatures necessary for the smelt. The bellows themselves were, unsurprisingly, not preserved, but a ca. 40 cm long iron tuyere, or nozzle portion of the bellow that was inserted into the furnace, was found near the entrance (fig. 7). The bellows were worked by a rotating axle with cams connected to the first waterwheel. The abovementioned stone-built platform directly opposite the hole in the enclosure wall (see above), probably served as a support for the end of the rotating shaft. Our excavations also discovered an opening at the back of the furnace in the north into which the tuyere would have been placed.

The southern waterwheel would have driven a forging hammer powered by a rotating shaft. Two rock-lined postholes and a stone-built platform in front of the tap hole of the furnace can best be understood as the supports for this forging hammer system (fig. 9). The tap hole at the southern side of the furnace would have served to allow slag to flow out of the furnace. The mechanically powered hammer was necessary in the iron making process to consolidate the iron in the bloom and drive out slag, charcoal and other impurities.

The hammer head would have been of iron, and probably weighed 50-200 kilos. It is not impossible that the pit that was found in the immediate vicinity of the postholes (of which the fill was quite loose, suggesting that the pit was of recent date) was dug to search for and possibly even to illegally retrieve the hammer head.

The postholes were dug from a level approximately 80 cm above the base of the furnace, into a compacted clay fill which contains very few finds (in contrast to the soil matrix elsewhere in the workshop which contains high concentrations of roof-tile fragments, charcoal and ash). This appears to be an artificial platform, roughly square, set in the southeastern corner of the workshop. The western edge of this platform was observed in the excavations, but its exact northern extent was not recognized, probably because it was first exposed in a narrow test trench dug in 2005. The surface of the platform, covered with possible debris from forging, appears to have been lined with flagstones of the same type as covered the top of the furnace. Many of these were found, disturbed but lying flat, in a layer at the level of the highest stones of the stone-lined posthole. This same layer yielded a rectangular iron slab with extensions protruding from the short ends (fig. 8). Its function is unknown, but one possibility is that is was a counterweight for the forging hammer.

An oven or hearth located by the southwestern corner of the furnace would probably have been used to reheat the bloom while working it into a consolidated wrought iron bar. This suggests that the area south and southwest of the furnace was selected for the forging and shaping of the consolidated iron. Yet our evidence indicates that the main installations of Area 4B were for the primary stages of iron production, like the smelting of the iron ore in the furnace and the forging of the bloom to create wrought iron. The production and finishing of iron artifacts must have taken place elsewhere, perhaps in Areas 2 and 3 (which await excavation in future years) or further away, perhaps even in Istanbul.

PHASING

There are indications that the Small Workshop was built over a period of time and that facilities were added when necessary. Architectural observations suggest that Areas 1 and 4 were not built at the same time, even though they are connected through Areas 2 and 3; the walls of

Area 1 are bonded with lime cement, whereas those of Area 4 are dry-stone walls. Being more substantial in construction and thickness, one presumes that Area 1 was constructed initially but further research and stratigraphic observations are necessary to confirm this observation. The excavation of Areas 2 and 3 will also help clarify this question.

In addition to differences in the general phasing of the complex, there are a number of modifications within Area 4B that suggest that there were at least two phases of use in the workshop. First, there is evidence that the platform into which the postholes 63 and 64 were placed does not belong to the original phase. This is clear because a layer that is very rich in charcoal covers much of the southern side of the workshop; it runs against the furnace and under the platform. It appears in the sides of the robber's pit described above as a ca. 3 cm thick charcoal lens. There must therefore have been a use-phase of the workshop predating the platform, but further excavation is necessary to establish whether there was also an earlier forging hammer installation.

Moreover, although not completely elucidated by the excavations, there is evidence that the furnace was re-used following a collapse phase of the workshop roof. A layer of blackened charcoal-filled soil, indicative of furnace use, overlies a deposit of brick collapse across most of the extent of Area 4B. In line with the idea that the furnace was reused is the fact that the roof-tiles near the high traffic main doorway to the compound are relatively more compacted than those of other surrounding areas.

ARCHAEOMETALLURGICAL ANALYSES

Because slag samples directly reflect the nature of the technology utilized in a smelting furnace, our efforts have most extensively been directed towards understanding their elemental and mineral composition. A total of 26 slag samples were investigated by SEM-EDX and XRD to determine the microstructure, mineral content and composition of different phases. The distribution of the three main components of slags (namely SiO_2, Al_2O_3 and FeO) is shown as a ternary diagram in (fig. 10). The majority of the slags (15 samples) were of fayalithic type (represented by square marks) that form during bloomery furnace operations. Nine slag samples (represented by circular marks) were glassy in nature and are byproducts of blast furnaces where cast iron is produced. Finally, there were two (represented by triangular marks), which are tentatively classified as refining slag. Further study is being carried out for their positive identification. When the distribution of different types of slag samples is considered, it becomes apparent that most of the fayalithic slags come from the peripheral workshops as well as from around the excavated furnace (F2) of the small workshop area. It can be concluded that wrought iron production, mainly for domestic consumption, was an important component of iron production at Demirköy. The glassy slag samples, however, were collected in the workshop of the Main Foundry as well as from the slag heaps to the south of this area. It is clear that cast iron was produced in the two partially destroyed smelting furnaces in this area. Though no excavation has been carried out at the workshop of the Main Foundry, it is still possible to see the foundations of a complex infrastructure.

Excavations at the Small Workshop in 2005 and 2006 were fortunate to a recover cast iron ingot (merchant bar) as well as blooms from the bloomery furnace as these are direct products from the smelting furnace. This unrefined metal, straight from the furnace, can yield technical information about the furnace conditions and help us understand the smelting processes. The microstructure of the ingots as well as several cast and wrought iron objects were also studied by examining the polished and etched surfaces with SEM and optical microscope. The microstructure of this 38 kg somewhat rectangular (46 x 13 x 8 cm) ingot discovered in Area 1 is an excellent example of gray cast iron (fig. 11).

The sample has about 3% carbon with graphite flakes arranged in flower clusters. This is the iron type used in casting military ordinance in the form of cannon balls or projectiles.

The back-scattered electron image of one of the 60-70 kg blooms found in Area 4B -depicting the spongy structure characteristic of blooms- is shown in (fig. 12). The light gray areas represent the ferritic mass whereas the medium and dark gray areas are the extensive slag inclusions. The carbon content of this bloom is 0.23%, and it is heterogeneously distributed in the ferritic phase. The forging hammer that was located in front of the F2 furnace in Area 4B was probably used to consolidate such blooms to convert it to usable wrought iron. We took a small section of this bloom to be forged in a blacksmith shop. In the back-scattered electron image of the consolidated bloom (fig. 13) we see that it still contains considerable slag inclusions, especially along the polygonal grain boundaries. The sample has a mild steel character with the perlitic structure appearing towards the edge of the sample. This is due to higher levels of carbon that has diffused into the matrix during production and heating for forging. Nails from the excavation were the most abundant metal artifacts recovered during the excavations. The back-scattered electron image of one of the nail samples shows very similar microstructure to that of the consolidated bloom iron (fig. 14).

The archaeometallurgical studies at the Demirköy project are at a preliminary stage. Only a few metallurgical materials have been analyzed so far and the regional surveys are still incomplete. However, the textual, field and material analyses collectively indicate that both wrought iron and cast iron were produced at Demirköy. It is still not clear whether the cast iron produced was used only for casting objects or whether some of it was converted to wrought iron by decarburization in the finery.

The relationship between the main foundry and the peripheral workshops is also not very clear. The peripheral workshops do not have any visible architectural features except the furnaces. It appears that only smelting was performed at these small sites. They could have been privately owned by the local population and could have been operated seasonally or whenever there was a demand for iron. The iron produced by the peripheral workshops was probably sold to the centrally-located Main Foundry, which was controlled by the government authorities. The foundry must have been the place where skilled metal smiths performed the necessary refinement and actually supervised the casting of the requested artifacts.

FINDS

Excavations across the Small Workshop areas yielded few artifacts (apart from roof-tile fragments). Iron was by far the most common raw material, especially in Area 4B, and nails were the most prevalent find. In addition to the recovered tuyere piece, iron slab and waterwheel brace fragment (see, for example, figs. 7 and 9), as described above, among the most significant iron artifacts we can count a small hammer-head about 10 cm in size, a solid iron sphere with a diameter of ca. 5 cm, and a hook for clothes or other possessions. Some pottery and clay pipes providing general dating information were also recovered.

The ceramics and clay pipes from the 2006 season excavations at the Small Workshop were analyzed by Katie Johnson from the University of Chicago. Fragments of about 14 vessels -most of which were storage vessels or water jugs- were recovered. Given the fact that the vessels are representatives of forms that showed little change for centuries, it is impossible to pin them down chronologically to a single phase. Yet analyses conducted on the pipes by Johnson provided more definite results. Based on factors such as the shape of the bowl, size of the airhole and the presence of a producer's stamp, she was able to assign most to the end (or second half) of the nineteenth or the beginning of

the twentieth century.
This assignment is in line with dates of imported bricks yielded by the excavations. Stamped with the word COWEN on one side, numerous examples of a yellow-colored firebrick were recovered by the excavations in Area 4B (fig. 15). Research indicates that these bricks were produced by Joseph Cowen and Company, located in Blaydon-on-Tyne in the northeast of England between 1823-1904 (Gurcke 1987:71). Refractory firebricks withstand high temperatures without melting or "spalling" but also have low thermal conductivity that saves energy. In furnace F2 they appear to have been used to close the back and front of the furnace. Excavations indicate that these bricks would have been replaced occasionally. Their presence therefore need not provide a date for the construction of the furnace but at least a *terminus post quem* through which the furnace was in operation. Given that the span during which the bricks were in use covers a period of close to eighty years, our excavations are in search of more exact date sources such as coins or other specific finds.

ARCHIVAL RESEARCH

A large number of documents located at the Prime Ministry's Ottoman Archives and the Archives of the Topkapı Palace Museum were studied as part of the Demirköy-Samakocuk foundry excavations and research. This collaboration makes the Demirköy Project among the first excavation projects in Turkey that is supported by investigations in the Ottoman archives. Although these documents contain little detailed technical knowledge, they do, nonetheless, yield information on the administrative and operational systems of the foundry, the manner in which fuel and ores were obtained, as well as insights into the production processes and transportation methods. Many documents regarding the socio-economic conditions of the region, and the way in which the central authority approaches this industrial enterprise have been carefully examined. Research shows that the Royal Arsenal and the Royal Cannon Foundry required wrought and cast iron to supply the Ottoman armed forces particularly during times of war. Given its proximity to Istanbul Samakocuk played a crucial role in supplying the much needed iron.

We find documents dating to as early as the 16th century that refer to the mining activity in this region. The document mentioned by Dernschwan in which a mining region near the Black Sea is discussed likely refers to Samakocuk (Babinger, 1923). Another, dated 1586, also makes a reference to Samakocuk and states that the Aya Tudor village and the mines in its vicinity, previously property of Hanzade Sultan, "were subsequently annexed as Imperial property." Iron furnace locales were required to supply the Royal Arsenal with given amounts of iron annually, as a special tax. However, documents show that towards the end of the 17th century the region had begun to fall behind in meeting this requirement. This is followed by a document dated 4 March 1696 (Ibnulemin-Maadin, #152), which indicates that the State was erecting a cannon ball casting foundry. The document goes on to explain that until its completion the existing furnaces in the vicinity were required to process and transport 500 *kantars* (a unit weight of about 120 pounds or 60 kilos) of ore.

Between the late 16th and the 20th centuries, the State sustained regular production here. Most documents from this period discuss the transportation of iron to Istanbul for the Royal Arsenal and the Royal Cannon Foundry, yet to date only one document with information regarding the procurement of Samakocuk iron for construction purposes has been discovered. Found in the Topkapı Palace Museum Archive, this document describes the construction expenses for the Nuruosmaniye Mosque and mentions that "İğneada" iron was being used (TSMA, D. 9869, yp. 1a). With all probability the iron referred must have been produced at Samakocuk and Torliye (or Turulya-Hamdi Bey) and then transported through the İğneada harbor.

The archives contain detailed data on the development and the problems of the iron industry of Samakocuk during the 18th and 19th centuries. One document mentions the appointment of a certain Yusuf Agha, to rebuild the Samakocuk foundry in 1819 so that it could meet the requirements of the Royal Cannon Foundry, the Royal Bomb-shell Factory, and the defense castles (HAT or Imperial Decree, 1254/48494, 19 October 1819). Dating to 1820-21, we find a document requesting the construction of a new furnace among the existing three furnaces at the Samakocuk foundry and an additional three furnaces at another appropriate location (C.İKTS. or Cevdet Economics, 478, 14 June 1821). Yusuf Agha was instructed, at around this time, to protect the foundry (with 150 soldiers) against the Greek uprising (C.AS. or Cevdet Military, 506/21123, 1 June 1821). In addition to the production of wrought iron and cast iron the abovementioned reorganization marks the beginning of cannon ball casting in the region (HAT., 244/13742, 31 October 1822). These cannon balls, produced and cast at the Samakocuk foundry, were sent to the Royal Cannon Foundry, as well as to fortifications in the vicinity (C.AS., 563/23640, 24 August 1825).

There were many complaints about the management of Yusuf Agha, who had originally established the foundry and had run it for a decade. Consequently, in 1829 Vecihi Pasha was appointed in his place (HAT., 844/37922, 2 July 1829). Another document of the same date informs us that the cannon balls produced at the Samakocuk foundry were of inferior quality (HAT., 538/26483, 2 July 1829). In 1830, due to the destruction of the foundry by a fire, cast iron ingots and charcoal were sent to Beykoz for production. (HAT., 538/28759, 13 September 1830). It is understood that by 1831 there were again 18 furnaces at Samakocuk producing cast iron (C.AS., 675/28355, 22 January 1831).

Following the fire and during the reconstruction process, the Admiral of the Navy Vizier Mehmed Tahir Pasha commissioned the building of a masjid at Samakocuk and appointed the mosque's staff (C.BH. or Cevdet Admiralty, 295/15012, 21 March 1833). This masjid's minaret is still partially standing and its foundations were uncovered during recent excavations. A document mentions the rebuilding of the coal depot at Samakocuk which had burnt down in 1835-6. However, the foundry was still functioning and copper was requested from the Royal Mint in order to renew the molds to improve the cannon ball casting (HAT., 385/28771, 28 April 1835). Another document dated 1838-9 talks about the request for price increase by the non-muslim subjects in the region for each bushel of ore they were mining (HAT., 85/28779, Hicri 1254).

The knowledge of cast iron production, which was developed at Samakocuk by master craftsmen sent there earlier, diffused to other iron production centers through these experts. For example, new people were appointed to Pravişte foundry in 1711 to replace 4 Vigne furnace masters who had been employed there originally (C.AS., 115/5162, 17 December 1711). Approximately a century later two master craftsmen from Samakocuk were sent to Erzurum's Kiğı mines to reopen them for casting iron bars (C.AS., 573/24123, 28 March 1816). In order to follow new developments in iron production and to modernize the enterprise, experts were brought from abroad (C.AS., 69/3256, 10 April 1839), and one Samakocuk foundry worker was sent to England for training (C.NAF. or Cevdet Public Works, #6, 3 December 1838).

It is mentioned in the Yearbook for the Governate of Edirne that the Samakocuk foundry was very active in 1875 producing horse-shoes, sheet-iron and even machinery (H. Sadi, 1931). This can be viewed as an indication that a certain degree of technological development was achieved at this time. However, the iron production at Samakocuk must have seriously stalled during the Turco-Russian war of 1877-78.

It is also certain that the production here stopped permanently in 1916, during the First World War, when a concession for 99 years granted to an English firm in 1913 was annulled. The Republican administration ordered an investigation of the region in 1927, but no feasible ore reserves were discovered (H. Sadi, 1931).

CONCLUSION

It is intended that the future research at the Main Foundry will concentrate on the details of the lower terrace which has been postponed until the 8 meters high stone retaining wall can be secured, and the work started at the second small foundry located about 250 meters to the west of the original site, known as "Kabakçının Tarlası" by the locals, is concluded. Industrial archaeological research at Demirköy will be completed by 2010.

NOTES

1. The various duties and responsibilities of the above-mentione-members of the industrial archaeology team within the multi-disciplinary research Project at Demirköy-Samakocuk, which is under the overall responsibility of the Society for Turkish History of Science (whose President, Prof. Dr. Ekmelettin İhsanoğlu has had the sole responsibility for securing the necessary financial resources for the Project), may be defined as follows:
   - Management of Museum Salvage Excavations: Archaeologist Zülküf Yılmaz, M.A., Director of Kırklareli Museum;
   - Responsibility for History of Technology Research: Prof. Dr. H.H. Günhan Danışman, Dept. of History of the Faculty of Arts and Sciences of Boğaziçi University;
   - Responsibility for Archaeometric Research: Prof. Dr. Hadi Özbal, Director of Archaeometry Center and Dept. of Chemistry of the Faculty of Arts and Sciences of Boğaziçi University;
   - Advisor for Archaeo-metallurgical Research: Assoc. Prof. Dr. Ünsal Yalçın, Metallurgy Museum, Bochum, Germany;
   - Responsibility for Ottoman Archive Research: Assoc. Prof. Dr. Mustafa Kaçar, Dept. of History of Science of the Faculty of Letters of İstanbul University;
   - Responsibility for Geodesic Research and Architectural Recording: Asst. Prof. Dr. Gülsün Tanyeli, Dept. of Restoration of the Faculty of Architecture of İstanbul Technical University;
   - Responsibility of Small Workshop Field Archaeology Team: Dr. Rana Özbal, Dept. of History of Faculty of Arts and Sciences of Boğaziçi University; and,
   - Advisor for Small Workshop Field Archaeology Team: Dr. Fokke Gerritsen, The Netherlands

   In addition to these members of the industrial archaeology team, during the excavations of 2005 Dr. Guntram Gassman of the Tübingen University in Germany has offered his services as Advisor for industrial archaeology of iron furnaces, and a group of young faculty members and students under the direction of Inst. Aptullah Deveci from the Dept. of Art History of the Anatolian University in Eskişehir have worked in the field, while a group of graduate students at Boğaziçi University have worked as the field archaeology team during the summer of 2006. The geodesic research has been coordinated by Dr. Kani Kuzucular of İstanbul Technical University together with a team of five graduate students of the Restoration Department of the Faculty of Architecture, and Prof. Dr. Attila Bir of the Electricity and Electronics Faculty of İstanbul Technical University and Prof. Dr. Emre Dölen of the Pharmaceuticals Faculty of Marmara University have acted as the team's overall technical advisors.

   The Museum's salvage excavations at the fortified settlement between 2003-2006 have been directed by Zülküf Yılmaz of the Kırklareli Museum, while the field archaeology team was composed of members of faculty and students of the Dept. of Art History of the 18th March University at Çanakkale under the coordination of Prof. Dr. Ali Osman Uysal of the same University.

   The research at Demirköy-Samakocuk Project has been generously financed by a "Social Sciences" grant (No.SBB2012) from TÜBİTAK, by Project No. 04-B-904 of the Research Projects Center of Boğaziçi University, as well as grants received from DÖSİMM Fund of the Turkish Ministry of Culture and Tourism and the Public Relations (Tanıtım) Fund of the Turkish Prime Minister's Office.
2. Although the ceramics and other datable finds fall within the second half of the nineteeth century, excavations have uncovered an Ottoman coin dating to 1187 AH or AD 1773 as well as a coin of the Austrian Empire with a stamp dating it to 1816 (Yılmaz and Uysal 2006:61).
3. A document from 1170 AH or AD 1757 mentions the Demirköy foundry as a production center for Ottoman cannons (Tanyeli 1990).

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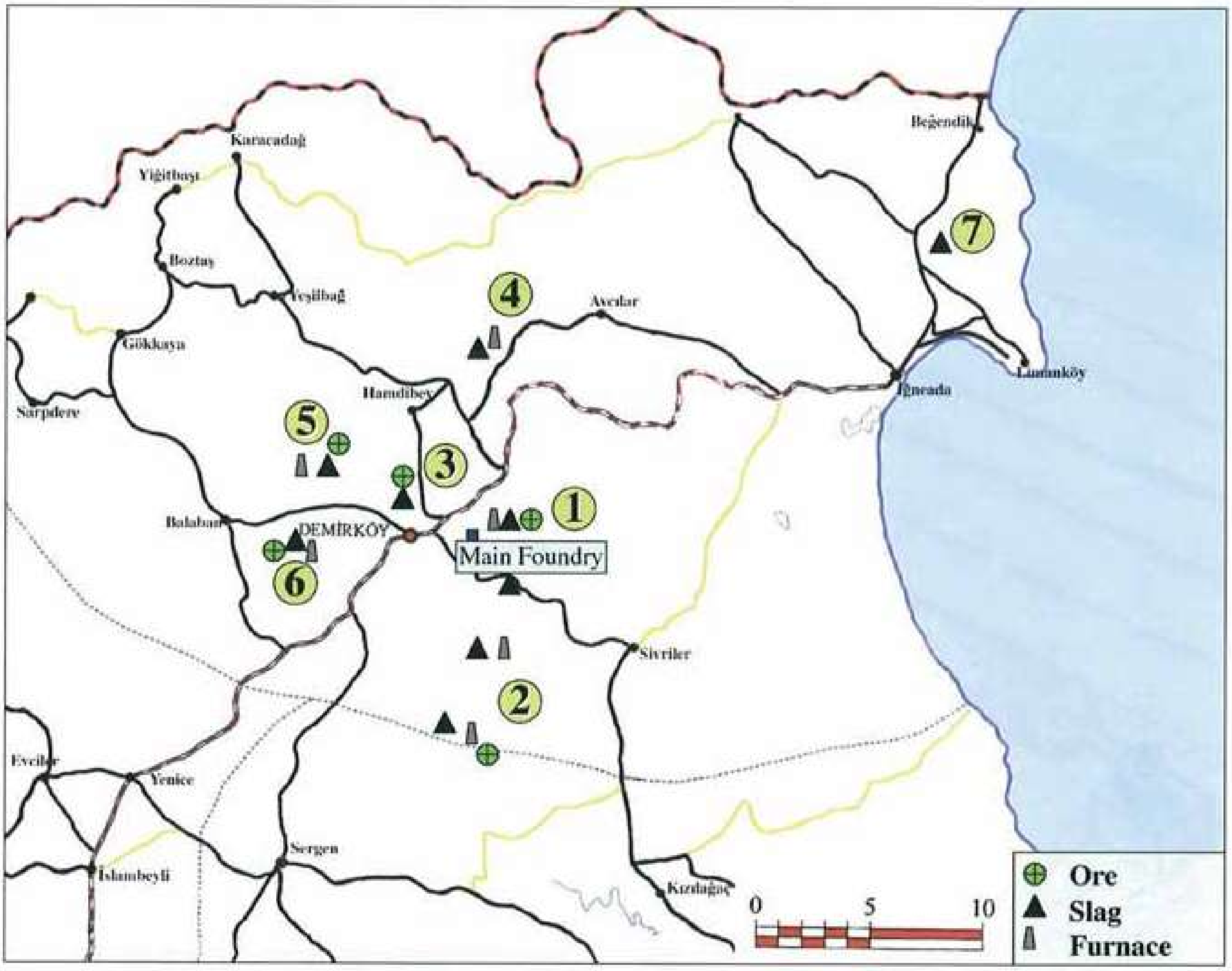

Fig. 1: Map of peripheral workshops around the Main Foundry as indicated by the finds of ore, slag and furnaces.

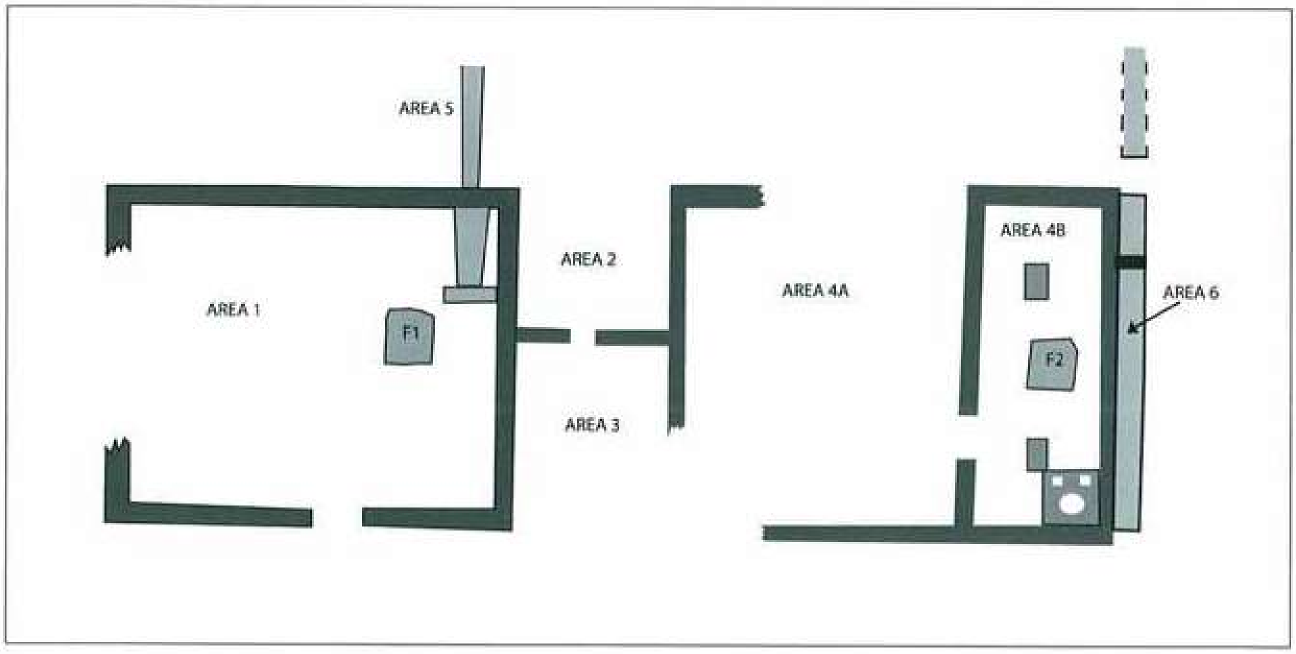

Fig. 2: Demirköy sketch plan showing the various areas in the Small Workshop (not to scale).

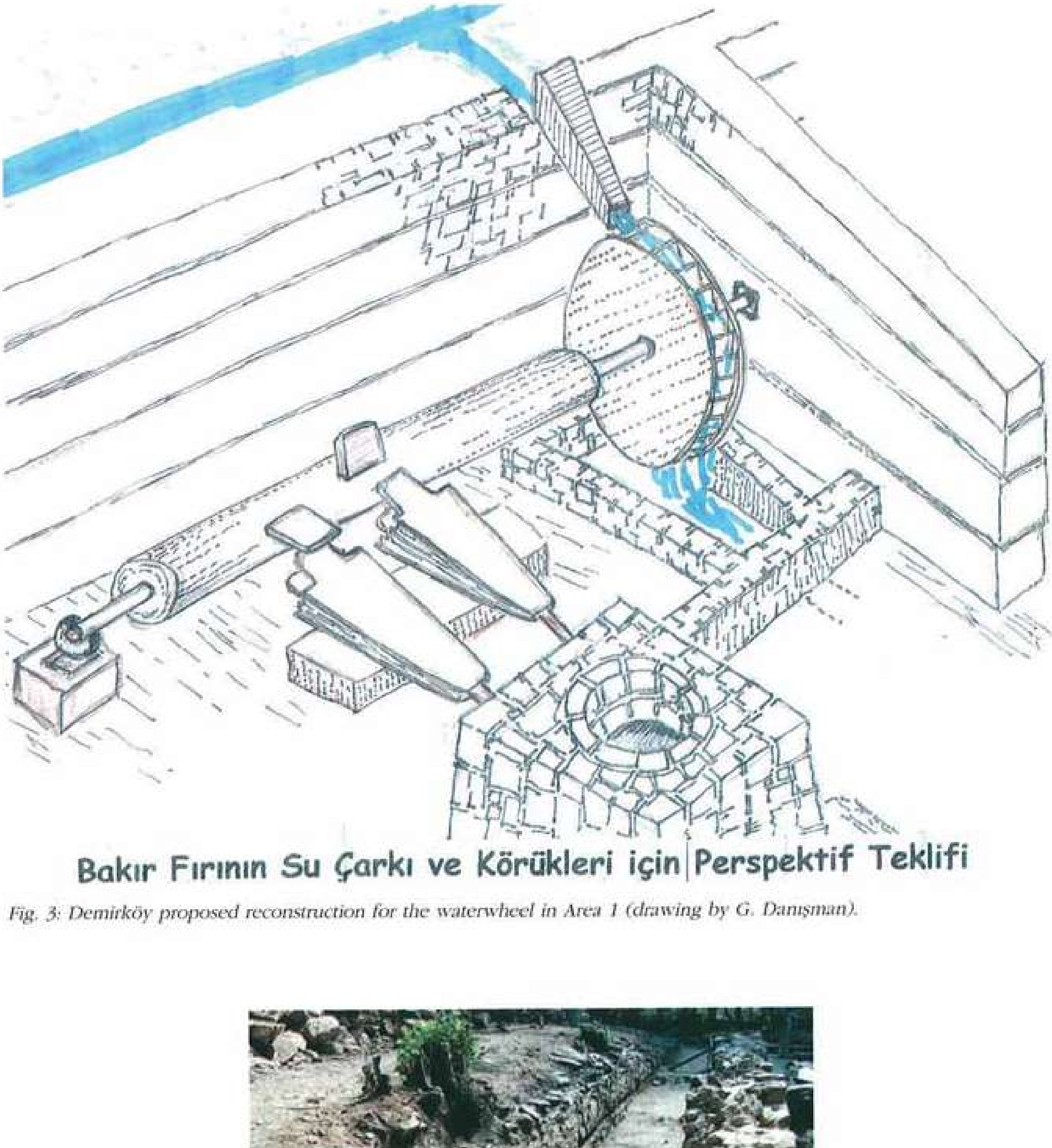

Fig. 3: Demirköy proposed reconstruction for the waterwheel in Area 1 (drawing by G. Danışman).

Fig. 4: Demirköy photo of canal in Area 6.

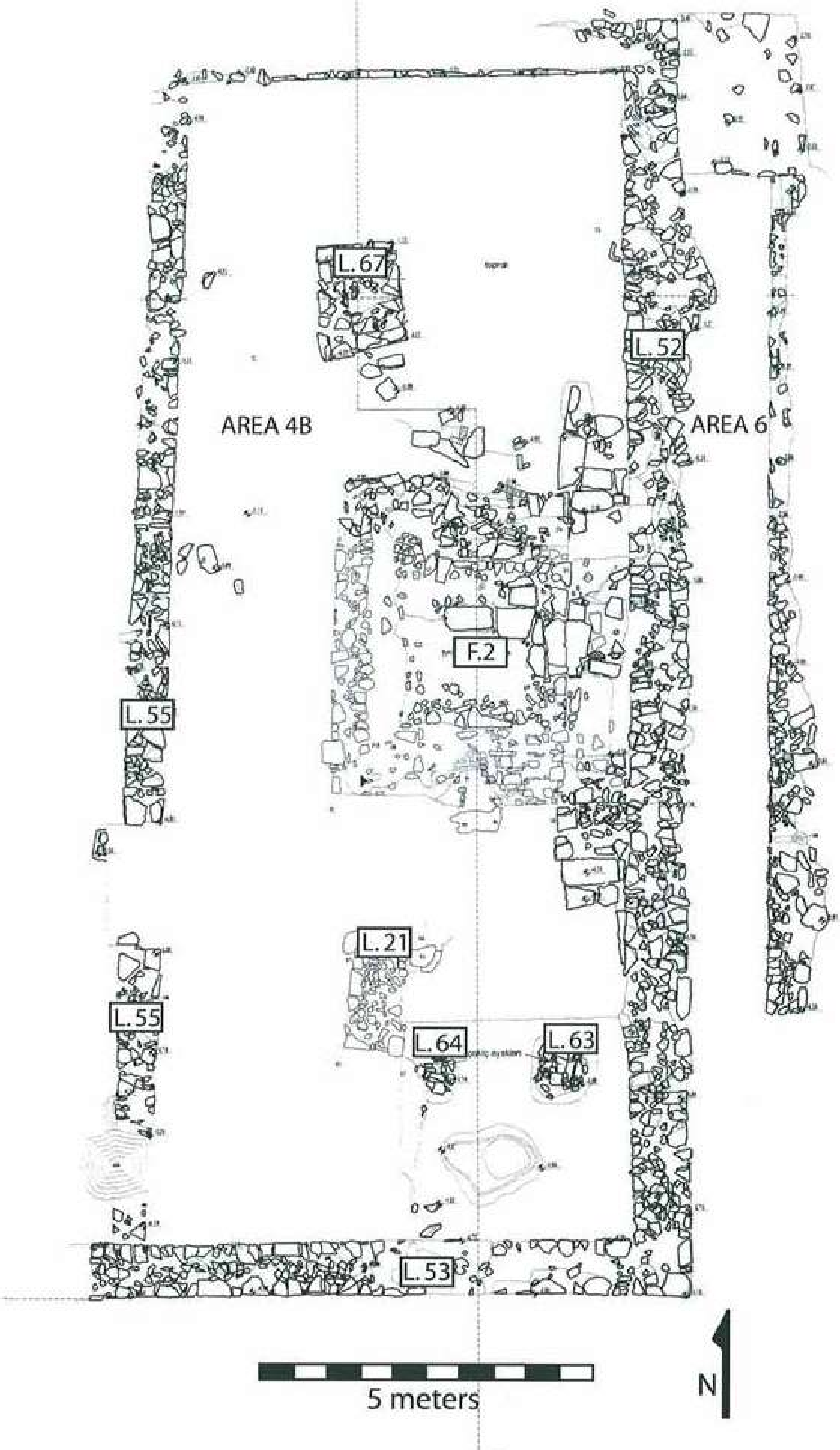

Fig. 5: Demirköy plan of Area 4B (drawing by E. Cambaz, O. Karahan and M. Alaboz).

Fig. 6: Demirköy platform 67 from east with a view of the indentation in wall 52.

Fig. 7: Demirköy tuyere fragment.

Fig. 8: Demirköy rectangular iron slab.

Fig. 9: Demirköy southern part of Area 4B with postholes 63 and 64 and the robber's pit in the foreground.

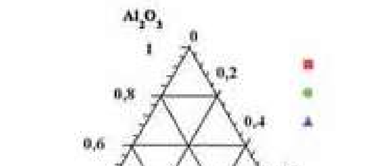

Fig. 10: Demirköy the distribution of the three main components of slags (namely SiO2, Al2O3 and FeO) shown in a ternary diagram.

Fig. 11: Demirköy the microstructure of an ingot discovered in Area 1 of the small workshop.

Fig. 12: Demirköy the back-scattered electron image of a bloom.

Fig. 13: Demirköy the back-scattered electron image of the consolidated bloom forged in a blacksmith shop.

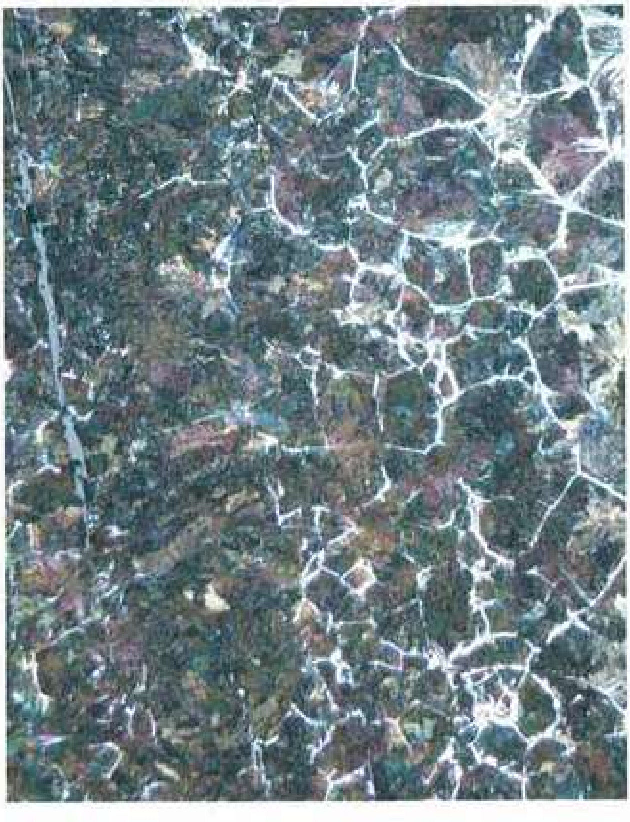

Fig. 14: Demirköy the back-scattered electron image a nail. Notice the similarity of the microstructure to that of the consolidated bloom iron.

Fig. 15: Demirköy a selection of COWEN bricks.