Mediterranean Archaeology and Archaeometry, Vol. 9, No. 2, pp. 71-85

PILLARS OF POWER: SILVER AND STEEL OF THE OTTOMAN EMPIRE

N. Nerantzis

University of Sheffield Department of Archaeology and Prehistory Northgate House West Street S1 4ET U.K.

Received: 7/4/2008
Accepted: 17/2/2009
Corresponding author: nnerantzis2001@yahoo.co.uk

ABSTRACT

The Ottoman Empire was forged over disintegrating Byzantium, stretching across Anatolia and the Balkans and ruled for almost five centuries. One crucial parameter that allowed for its quick expansion has been a combination of economic wealth and superiority of armed forces. The Ottomans succeeded in both sectors by promoting innovative technology in the field of silver and steel production for supplying their monetary system and weapons industry. Rich mines and smelting workshops provided increased output in metals, allowing for quick expansion and economic growth. Some of the major centres for silver and steel production are being discussed in this paper in conjunction with analytical data from smelting residues.

KEYWORDS: mining, smelting, corvée, samakov, foundry, slag, speiss

1. INTRODUCTION

In the early 14th century the Ottoman state was a small principality on the frontiers of the Islamic world, which gradually conquered and absorbed former Byzantine territories in Anatolia and the Balkans. Its rapid political growth was such that in the 16th century it formed a mature imperial structure with its traditions of statecraft, administration, financial policies, land systems and military organisation fully developed (Inalcik 1973; Faroqhi 1999). Ottoman administration based on bureaucratic traditions was implemented with the application of registration, and accounting systems aimed at increasing the Treasury revenue.

A crucial point in near eastern political theory was to protect the peasantry from illegal taxation as all revenue derived from among those same taxpayers, the *reâyâ*. It was these measures that dictated tax and population surveys for the better enforcement of laws, which usually did not abolish older customs and institutions of conquered territory, hoping to avoid social unrests (Inalcik 1973; Pamuk 2000). Accumulating revenue in the standards of the *mukataa* system was crucial for the running of Ottoman administration and the army, while available technologies revolved around implementing an infrastructure for the acquisition of wealth (Issawi 1980). Such conditions favoured an increase in production and consumption systems and caused a booming of metallurgical industries associated with the widespread use of hydraulic power in the smelting furnaces. Silver for the minting of coins and iron-steel for tools and weaponry were highly valued and systematically extracted from former Byzantine mining districts (Inalcik and Quataert 1994).

The transition from Byzantine to Ottoman administration in Thrace and eastern Macedonia has been the outcome of gradual change of the mid 14th century, predating the final collapse of central power at Constantinople for almost one hundred years (Vakalopoulos 1996). Peasant communities in rural Serres, the plains around Drama and Philippoi and the grazing fields of Pangaeon and Lekani became part of an integrated economic model fuelled by taxed agrarian surpluses that were paid as revenue to newly imposed local authorities. Other sectors such as mining, salt works and trade were under increasing state control since revenue was extracted out of any commodity or crafting profession. Inherent within this new regime of administration was an urge to control the means of production and encourage innovation that would contribute to increases in production.

The current paper is an attempt to approach issues of mining and extraction of metals from their ores, mainly silver and iron, during Ottoman times based on literary and archaeological evidence. A review of the relevant literature provides valuable information on labour organization, administrative structure and logistics in the mines and smelting workshops across the empire (figure 1). Within such documents we find a wealth of information concerning the actual production sites and the output in extracted metals which when seen in conjunction to surveys, archaeological and analytical data could lead to coherent conclusions on technology, economy and social orientations towards resource perception strategies. Chemical and mineralogical data have been acquired from metallurgical residues of Ottoman date deriving from extensive slag heaps at Makrychori in Macedonia and are presented here in an attempt to integrate historical information with solid evidence on the technology of iron and silver production.

Figure 1 Silver and steel production sites mentioned in the text

2.1 HISTORICAL DOCUMENTATION

Contemporary documents, such as fiscal records and cadastral registers represent a useful source of information concerning agricultural produce, craftwork and trade of finished products across several regions of the Empire. The *Tahrir defteri* were official cadastral registers compiled for most of the territories under Ottoman rule and there are several of them recording transactions relating to metals. *Tapu-Tahrir defteri* § 3 compiled in 1464-1465 includes registers for Serres, Sidirokastro, Zihne, Drama and Nevrokopi among others, while *Tapu-Tahrir defteri* § 7 compiled in 1478 includes sub-sections for Thessaloniki and eastern Macedonia (Lowry 1986, 24). Travelers' accounts also provide valuable information and basic descriptions of the technical processes being followed in various crafts.

Further information could be gained from fiscal documents recording the sources of revenue, which was fundamental for the Ottoman state economic policy. Laonikos Chalcocondyles, a Byzantine historian of the Palaeologan period, informs us that the total imperial revenue from European Ottoman provinces reached 900.000 staters in mid 15th century (*Laonici Chalcocondylae historiarum demonstrations I*, 1922). The same author describes various taxes such as the *harac* and taxation for herding and transporting of agrarian produce. In addition we find references to duties for hiring pack animals (horses and camels) reaching 300.000 staters, ferry duties around 200.000 staters and duties for rice transporting about 200.000 staters (Zografopoulos 2002). It is interesting to note that during the 16th century the duty paid for the transportation of metals reached 100.000 staters which is significantly lower than agricultural produce and animal hiring, which might suggest reduced costs for the shipping of valuable materials such as minerals or metals for reasons of efficiency in production.

2.2 MINE ADMINISTRATION AND DIVISION OF LABOUR

Mine administrators of the Ottoman state did not make any basic changes in the production methods or technology in the mines, which came under their control. Their policy on mines was simply a translation of the previous regulations in which the original German (Saxon) terminology was preserved (Inalcik and Quataert 1994, 59) but Jewish communities played an important role in financing and coordinating such undertakings (Rozen 1993). Tax registers from the regions being studied refer to miners either as *kureci* or simply as being tax-exempt persons, *muafs* (Faroqhi 1999). The organization of mineral exploitation from the 16th to the 18th century had a uniform character in most places of the Pontus region for which most records exist and that was also the case for most mining regions in Greece and the Balkans. The internal organization of the Chaldian metallurgists' class did not show considerable changes in any of the mining colonies outside the region of Chaldia. Georgios Th. Kandilaptis, a scholar from Chanes, provides detailed information concerning the division of labour, wages, working methods and names of the General Directors of mining regions (Kandilaptis 1929).

In charge of all mines was the Royal Commissioner for Mines (*Maden Emin*) assisted by a number of Greek chief-smelters (αρχιμεταλλουργός or μαντεντσίμπασης) who coordinated mining activity and ore transportation to Gumushane where the local commander had his seat (Kandilaptis 1929; Vakalopoulos 1973). The local commander, representative of the sultan had the right to strike silver coins, collected provincial taxes and safeguarded silver, copper and lead exportation to the imperial treasury at Constantinople. With the help of chief-smelters they investigated the possibilities for prospecting, initiating new shafts and appointing workers.

The basic pertinence of the chief-smelters, apart from directing mining operations, was the coordination of prospecting for new mineral veins and the expansion of activities to new areas. According to Ottoman legislation each one of them had the right, after receiving permission from the state, to undertake exploration. Whenever a new deposit was discovered the Royal Commissioner for Mines (*Maden Emin*) was called upon to declare the site as state property and name it after the closest village, stream or mountain name. Permission for exploitation was given to the chief-smelter while the initiation of workings started with a ceremony which often included a sacrifice. According to tradition a trampled mass of clay was left on a crack of rock for one night upon which it was believed the mine demon would leave the footprint of the animal which had to be sacrificed the next day (Kandilaptis 1929).

The labour force consisted of specialized units such as miners: μαντεντσίδες (*madentsides)*, workers who crushed the ore into thin powder: τσαουλτσίδες (*tsaoultsides)*, ore-washers: γαλτσίδες (*galtsides)*, smelters: παραστάτες or φούρναροι (*parastates* or *fournaroi)* and those responsible for providing timber for fuel and for the timbering of mining galleries: μπαλτατζίδες (*baltatzides)* (Vakalopoulos 1973, 109). The region of Chaldia was rich in timber and was a major source of supply for smelting activities. Its inhabitants formed a large unit of lumberjacks and those involved with charcoal preparation and both groups shared the same benefits of tax exemptions as the metalworkers. In general terms local authorities complemented specific regulations that protected most workers associated with mining and metallurgical activities and exempted them from paying taxes and levies mainly the *harac*. They were tied to the work and were not allowed to pursue a different profession, dug out various ore types under harsh conditions whilst facing high mortality rates within collapsing galleries (Chatzikyriakidis 1999).

Mining was undertaken by following the mineral veins and lighting was provided with torches and lamps. Breaking of the ore was conducted by hand pick, hammers and fuse levers and occasionally by the use of gunpowder or firesetting. The heating of exposed ore with bonfires followed by immediate cooling with water was common practice when all other methods failed. The extracted ore was carried in sacks and hand wagons and was handed over to those responsible for sorting and crushing. Washing and enrichment was the responsibility of a different group the *galtsides*. Flooding of the galleries was common and wooden ladders were used to reach deeper levels. Kandilaptis (1929) mentions that water from inside the flooded mines was somehow channelled through and pumped out to the surface where it was used for the washing of crushed ore.

3.1 CENTERS OF SILVER AND IRON PRODUCTION IN MACEDONIA, GREECE

Chalkidiki has been undoubtedly the wealthiest and most profitable mineral region in Ottoman Rumelia and thus industrial activity has been meticulously recorded in state documents of the time. The region's twelve villages, later known as Mademochoria, were a *hass* (Ottoman administrative division) since the time of their conquest and as mentioned in the *Tahrir defteri* for Thessaloniki, they belonged to the sultan (Dimitriadis 1986). The obligations and rights of the miners are clearly specified in a *ferman* of 1475-1476 including the main duty of providing the Imperial Treasury with a certain amount of silver each year and also a substitute to the sultan for the various taxes (Dimitriadis 1986, 44). Mining and smelting activity began to flourish in 1536 during the reign of sultan Süleyman the Magnificent when a group of Hungarian Jews, experts in metallurgy settled at Sidrekapsi, the old Byzantine metallurgical centre of Siderokapsia.

Various sources inform us that most state controlled enterprises were actually undertaken and managed by private contractors (Rozen 1993; Inalcik and Quataert 1994). It was these contractors that invested the capital needed for exploitation whilst the state collaborated through finding labour, protecting the profits and securing monopoly. For the case of Sidrekapsi Rozen (1993, 37) informs us that in order to ensure uninterrupted mining 'the rulers of the Empire imposed the obligation to operate them on the Jews of Thessaloniki, as a corvée for all intents and purposes, whenever they were unable to find an individual willing to risk his capital voluntarily'. The mine operator (*sarraf*) was a wealthy individual, recruited by the state, who was responsible for mining and payment of the poll tax in a way that often served his own interests. Even though the tax was imposed *per capita* or as a global payment the community often settled it through an internal assessment method by which the wealthy paid the poll tax for many of the poor (Rozen 1993). Such transactions were made possible by the imposition of the corvée which automatically exempted them from all other taxes to the government, but in the long run impoverished the wealthy and undermined the community's source of funds.

At the heyday of its output in the middle of the 16th century Sidrekapsi employed as many as 6.000 miners, owned numerous processing installations in the order of 500-600 furnaces and became the largest Macedonian industrial complex and most productive of the Balkan centres (Vakalopoulos 1996). According to official records the miners were obliged to send their annual output of around 220 *okas* (= 347 kg) of silver to the Treasury at Constantinople. Based on descriptions by the French traveller Piere Belón around 1553 it is suggested that co-smelting of pyrite and roasted galena was taking place in one furnace from which the slag and speiss were tapped out first and then the precious metals-rich Pb layer was recovered (Photos *et al* 1987). Archaeometric research by Wagner *et al* (1986) confirmed that such activity described in the sources has been shown to belong between the 16th and 18th centuries by radiocarbon and thermoluminescence dating on slag.

Sidrekapsi attracted a stream of workers from far and wide. In addition to the Greek labourers and Jewish *sarrafs*, there were workers of an astonishing variety of races: Bulgarians, Serbs, Turks, Albanians and Germans (Vakalopoulos 1973, 153). Apparently miners were also called 'safi', allegedly deriving from the word for Saxons, where the mining techniques came from but direct historical evidence for the presence of Germans in Ottoman mines is weak (Anhegger 1943).

Increased industrial activity of the 18th century called for a reorganisation of the operating system and laws for conduct in the mineral regions of Chalkidiki. By 1705 a sultan's *ferman* granted the residents with the renewed rights to exploiting silver from the mines of the region. All mining activities were assigned to a federation of twelve semi-autonomous villages known as Mademochoria responsible for providing the work force and administrative staff for the workings (Papaggelos 2003). These were Galatista, Vavdos, Plana, Stanos, Varvara, Liaringovi (Arnaia), Novoselo, Mahalas (Stagira), Isvoro, Chorouda, Ravenikia (M. Panagia) and Ierissos. At the same time, a state owned mint was established at Mahalas the Mademochorian administrative centre. Following these changes production increased to reach 30.000 ducats per month from which 1/3 was paid to the Sultan. Four Greek leaders, the *vekils* and a secretary undertook an administrative role and judicial power of the federation. The Maden Emin and 20 soldiers represented the Turkish authorities, virtually implementing and validating decisions of the *vekils* (Vakalopoulos 1996). As the output from mining gradually declined the Mademochorians continued sending the annual revenue of 220 *okas* (= 347 kg) of silver by melting down Spanish coinage.

Further evidence for precious metals extraction in Macedonia comes from Livadia south of Nikisiani on Mt. Pangaeon where a smelting furnace dated to around 1550's has been located (Koukouli-Chrysanhtaki 1990). The excavation revealed a double furnace of two hearths reminiscent of Buchard's furnace, widespread in the 16th century for lead smelting. An illustration of such an installation included in Tylecote's *History of Metallurgy* (1976, 99) shows a pair of blast furnaces about 2 m high operated by a set of four bellows. The arrangement of a double furnace is described by Georgius Agricola in his treatise *De Re Metallica* (1556) in reference to silver refining methods. Through such a process lumps of impure native silver are co-smelted with powdered litharge in the assay furnace and the alloy which settles at the bottom is carried to the cupellation furnace (Hoover and Hoover 1950, 400). Such practice would leave behind remains similar to those found at Livadia and residues such as litharge or speiss and could be thus argued that silver extraction was taking place on site in the mid 16th century.

Centres of bloomery and cast iron production were established at Demirhisar (Sidirokastro), Maden Kara in Palaea Kavala and Eleutheroupolis mentioned as Pravi or Pravista in Ottoman sources. According to a Turkish *ferman* of 1583 and the descriptions of a traveller, Christoforo Vallier, extensive iron production is documented by the end of the 16th century at Pravista (Anhegger 1943; Murphey 1980). Intensification of production is evidenced with the establishment of a foundry in 1698 where specialised production of cannon balls and iron for construction material was taking place (Photos 1987). Further the earliest evidence for the production of cast iron comes from the site of Avli suggesting the operation of a blast furnace in the 17th century. The metallic prills in the slag found at Avli which was analysed by Photos (1987) were found to be grey cast iron including graphite flakes with silica, phosphorus and manganese. Such findings are clearly associated with certain steps of cast iron production from white to grey cast iron (Kostoglou and Navasaitis 2006).

Recent field surveys in eastern Macedonia have shown that some of the ancient and Byzantine mining-metallurgical centres close to highland villages yielded Ottoman surface pottery indicating the use of locations that were suitable for smelting in past periods (Nerantzis 2006). There is no evidence to suggest uninterrupted continuation under the new Ottoman administration rather a reuse strategy of sites that met all criteria for efficient iron smelting. Demirhisar (Sidirokastro), Faia Petra and Angistro were most probably the reused Byzantine production sites in Serres while the large slag heaps at Maden Kara and Maden Chiflik in Palaea Kavala probably resulted from attempts of re-smelting ancient slag. The nature of the evidence suggests an increase in output as production was funded by the state, coordinated by master smelters and undertaken by specialised groups of smelters who provided revenue (*mukataa*) to the Sultan. At sites in Serres iron sands have been a diachronic source for raw material, a tradition which was apparently reproduced through time as similar practices were common until the early 1930's. Smiths from Vrontou used the same iron sands in addition to marcasite from iron pyrites as raw material for their products until 1913 (Samsaris 1979). Chatzikyriakou writing in 1929 described 8 surviving foundries and water powered facilities for the production of iron nails and other utensils at the village of Vrontou (Samsaris 1979).

3.2 WORKSHOPS IN ANATOLIA AND THE BALKANS

Although the 16th and 17th centuries witnessed an increase in mining activity across former Byzantine territories such as Chalkidiki, Eleutheroupolis and the Pontic seaboard mainly Chalybia and Chaldia, by the 18th century a lack in reforming mining operations led to a recession of output. Various contemporary and later documents describe the life of mining communities and the ways by which labour was organized (Felekis 1907; Kandilaptis 1929). It is known for instance from official Ottoman records that vezir Köprülü Zade Hussein attempted a reformation of the old mining system in the metals rich Chaldian region at a time when exhaustion of the rich deposits of Gumushane (former Argyroupolis) was at a stake (Vakalopoulos 1973, 105). The privileges formerly granted to miners no longer existed and due to a lack of state interest in metallurgy numerous mines became private property or were abandoned. These conditions caused immigrations of the highland village dwellers and miners who left their homes in search for new working opportunities. The waves of immigration started in the middle of the 18th century and were continued well within the 19th by which time technical knowledge and oriental metallurgical traditions were transmitted to central and southern Asia Minor, Thrace and Macedonia (Vakalopoulos 1973).

Despite the exhaustion of some major deposits, the number of mines at Pontus listed by Cuinet in 1890 is astonishingly large (*Turquie d' Asie* I, 56-58, 68). In the *sancak* of Trebizond, which comprises the modern Trebizond, Giresun and Ordu districts there were 21 mines of argentiferous lead, 34 copper mines, 3 of copper and lead, 2 of manganese, 10 of iron and 2 of coal. In the *sancak* of Gumushane there were 37 mines of argentiferous lead and 6 copper mines while the *sancak* of Samsun had only 1 mine of argentiferous lead (Bryer and Winfield 1985, 3).

The miners of Pontus and especially those from Chaldian Argyroupolis who spread across Asia Minor and beyond became admirable prospectors. Those well-known miners searched for rich deposits beyond their homelands and established new metallurgical settlements (Bryer 1983). An example of their activity is described in a document dated 15 February 1774, according to which two Greek prospectors from Argyroupolis and Prousa discovered a silver bearing deposit on Bithynian Olympus at the site of Maden Deresi (Vakalopoulos 1973, 107). A continuation of this tradition is noted during the exchange of populations in 1923 when prospectors from Pontus discovered numerous metal bearing deposits in Macedonia.

Evlija Celebi, an Ottoman traveller who has visited most of the major towns in the southern Balkans, provides some information on the conditions of mining in the 17th century. An important trading-industrial centre was Skopje where the silver and lead mines procured abundant raw material for the growing of local industries. The mines at Kratovo, near Skopje prospered from the 14th to the middle of the 17th centuries but at the time when Evlija visited the town most of the deposits had been already exhausted (Dimitriadis 1973). According to the traveller's description a military corps located in the region of Skopje received each year their wages from the *maden emin* (mine director) of Kratovo who commanded silver and iron mines in other regions as well (Dimitriadis 1973).

3.3 THE TAURUS MINE IN CAPPADOCIA (BUGA MADEN)

The Taurus Mine (Buga Maden) has been one of the many metallurgical settlements in Asia Minor of the 19th century. The prosperity of this southernmost Cappadocian settlement, founded by metallurgists from Pontus has been highlighted by travellers such as H.H. Schweinitz and H. Grothe and represents one of the numerous mining communities in metal rich Anatolian regions such as Aq-Dag Maden, Denek Maden, Ergani, Keban and Bereketli (Chatzikyriakidis 1999).

According to Gustave de Pauliny, General Director of the Turkish Mines in 1836 all mines lacked modern technological infrastructure and smelting techniques were obsolete leading to a loss of 1/3 of overall production. The ore was smelted in small furnaces while their cooling was bellows generated since the use of water in such instances was unfamiliar. If reforms and upgrading had been conduced it is estimated that the silver output would have increased by 40% while lead and copper output would have doubled (Chatzikyriakidis 1999, 76). Despite the numerous shortcomings metallurgical operations were a major source of wealth for settlements such as Buga Maden.

The wider region of Cappadocia including the Taurus and Antitaurus range had rich mines which according to tradition were worked by the ancient Persian kings and later by Romans and the Byzantine Komnenoi of Trebizond. This is supported by Choutouriadis' testimony that the Genoese then the Arabs and lastly the Chaldians worked these mines as testified by dumped slag in large heaps at Gumus Alam and Kara Gumus (Bryer 1983). Therefore when the Chaldian miners settled in the region in the 1820s they found enough evidence to pursue an economic strategy for exploitation.

The first chief-smelter (*madentsibasis*) was Chatzi Leuteris Apostologlou from Koronixa, Argyroupolis who established mining installations and commenced extracting argentiferous lead which was refined to produce silver despite the obsolete means available. The Ottoman *ferman* which authorised the founding of the settlement and right to initiate mining activity was issued in 1826. As chief inspector of the mine Apostologlou represented all metalworkers to the Turkish authorities until his death in 1868 (Kandilaptis 1929; Chatzikyriakidis 1999, 77). In the first years of operation the miners constructed an extended road network reaching a radial extent of 400 km and opened a large number of galleries at their own expenditure.

After 1873 the status of legal prescription was raised by the Ottoman government which proceeded to auction the mine and for that reason called for European engineers to evaluate its output capacity. According to their reports the mine's annual profit reached 40.000-50.000 pounds despite the obsolete methods of exploitation. They also suggested that it appeared impossible to find a bidder through auction unless the affiliation of the local miners with the mine was terminated. The first attempt for concession was made in 1887 when Buga Maden was commissioned to the 'Koroniou and Azarian Company' but the rapid reaction of the locals for their unfair treatment reached the Sultan in Istanbul.

The resulting decree prescribed that the contract between the Company and the miners should consider the rights of exploitation to the locals but due to proposed extortionate compensations, the Company abdicated from its claims (Chatzikyriakidis 1999). The miner's privileges remained intact until the outbreak of the Balkan Wars, with only minor interruptions when the government claimed the whole annual output in 1905.

3.4 SAMAKOV IN EASTERN THRACE

Samakov of eastern Thrace lies west of the Black Sea at short distance northeast of Vizye close to the banks of Tholos River. Its modern Turkish name is Demirköy, literary meaning village of iron. According to Savvas Lakides in his *History of Vizye and Medeia* (1899) the settlement was founded in the 15th century and derived its name from the numerous *samakovia* i.e. foundries for casting and forging iron from the rich nearby iron sand deposits. Local traditions refer to Serbian prospectors who came in search for minerals, inhabited the village and collected the iron bearing sands of Tholos River across most of its length. In his book Lakides provides some of the local terms used for the iron industry which formed the basic subsistence for the locals up to the 19th century. Thus the mineral veins are described as βίγναι (*vignes)*, the furnaces as οδζάκια (*odzakia*), while the charge consisting of charcoal and iron sand was known as ποχωνιά (*pohonia*) which was approximately 80-100 *okas* (= c.130 kg). Collection of the surface sands was achieved by channeling the river water into large reservoirs of 500 tons in capacity. Through holes on the reservoir walls the collected water rushed into wooden channels. During this process the heavier iron particles formed sediments at the bottom of the channels while excess water was poured into the fields (Apostolidis 1944).

The smelters of Samakov enjoyed tax exemptions up to the early 19th century when Turkish authorities levied the forge owners with a quantity of cast iron per year for the state factories at a fixed price. The early furnaces of the 17th and 18th centuries were small, providing low output in iron and were situated at half an hour's distance from the village within ravines of the river valley. Under Chatzi Yusuf pasha, who was appointed commander in 1810, Samakov witnessed an increase in production as three major state foundries were established at its environs. 'Mavr Odza Karhane' was the state grand foundry for the casting of cannon balls while in the valley to the east 'Buyuk Odzak' and 'Dukyum Hane' produced cast iron in large quantities.

By 1830 the management of the foundries passed on to Tahir pasa who refurbished and improved the facilities. He directed four *samakovia* for the production of wrought iron with two furnaces in each. For one year's operation each *samakov* expended roughly 100.000-200.000 *okas* (= 158.000-316.000 kg) of charcoal and 1.000-2.000 kg of iron ore and paid the smelters 6-8 grosia per kg of ore in total of 80 *okas*, and 6-8 grosia per kg of charcoal in total of 100 *okas* (Apostolidis 1944). Based on official data it is estimated that each of the four foundries produced 40.000 *okas* (= 63.000 kg) of iron. The cannon ball foundry's needs in charcoal and iron ore was around 700.000-800.000 *okas*. The director hired all workers to be engaged with mining and smelting operations and excluded them from any agricultural work. Recent archaeological work at the site revealed a wealth of information on the furnaces and leat systems for water management at the smelting workshops and foundries (Danisman 2007). The organization of space with its labour division associations, ensuring efficient production, demonstrates how crucial steps and decision affected the smelting or forging process.

4. ANALYTICAL RESULTS ON SLAG FROM MAKRYCHORI, KAVALA

Compositional data on slag from Ottoman smelting sites is a rare occurrence as such 'technical' residues are generally neglected during survey and excavation at sites of the recent past. Large slag heaps which resulted from accumulation through long periods of metallurgical activity are often problematic as regards chronology. Typical Ottoman pottery found among metallurgical debris is currently coming to light in areas where ancient and Byzantine smelting has been confirmed (Chiotis *et al* 1996; Photos *et al* 1989; Koukouli-Chrysanthaki 1990). One such case is Makrychori located at the foothills of Lekani in Kavala, which shows a long history of metal extraction through Classical, Byzantine and Ottoman times and has also yielded finds belonging to 20th century industrial activity.

Chemical analysis conducted on slag from eastern Macedonian sites of the late Byzantine and Ottoman periods revealed the potential for discerning certain smelting conditions (Nerantzis 2007). The samples from Makrychori analysed by X-ray Fluorescence could be characterised as typically high temperature products deriving from proto-industrial smelting operations which unavoidably fall within Ottoman times as indicated by pottery sherds. The sampled site produced highly alkaline and siliceous slag with low FeO contents which have been interpreted as belonging to blast furnace operations for the production of cast iron. It is interesting to note that similar evidence comes from Avli in Pangaeon where grey cast iron production is confirmed by slag analysis (Photos 1987). The high melting points above 1300°C observed through ternary plots for slag from Makrychori are further proof that these are derivatives of an indirect reduction process. As shown in figure 2 the specimens form clusters away from the fayalitic region and close to where cristobalite is predominant indicative for high temperature blast furnace residues.

Researchers have argued that even small charcoal fired furnaces from which molten slag is drawn off have to operate at a high temperature in the

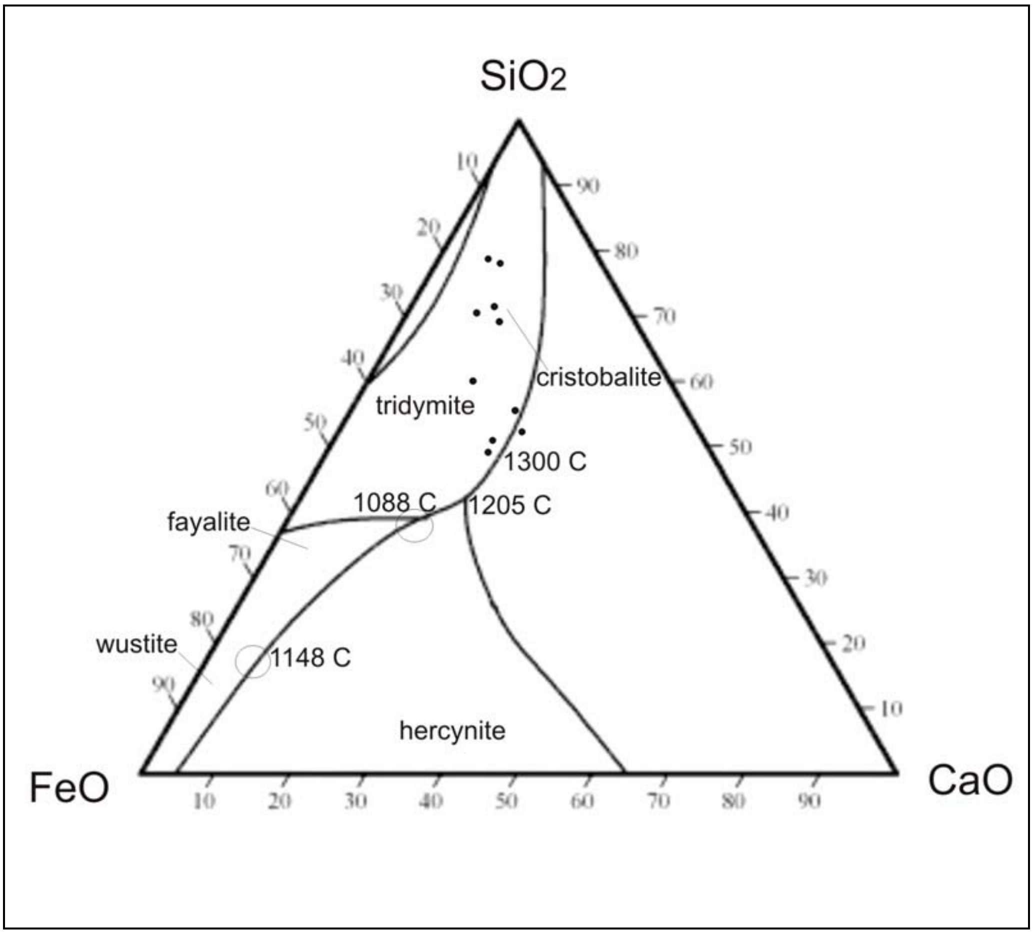

Figure 2 Ternary plot of the system FeO-CaO-SiO2. Slag samples from Makrychori (black dots) cluster in high temperature regions (high CaO-SiO2) away from typical bloomery slag compositions which fall within the wüstite-fayalite region of the diagram.

blast zone (Bjorkenstam 1985; Buchwald 2005; Rehren *et al* 2007).

It has been shown by experiments that in small blast furnaces higher siliceous contents were found in the iron formed above the blast zone while low silicon contents were observed in the produced iron. The reason for extremely low wüstite contents in blast furnace operations could be the silicon reduction of slag wüstite (Bjorkenstam 1985). The presence of alkalis is also important as such compounds accelerate the reduction of FeO and SiO_2. Clay from the refractory furnace material clearly contributes to the formation of iron. Both characteristics of blast furnace slag i.e. low wüstite contents and high contents of alkalis have been found in Makrychori slag and could be therefore characterised as such. Appreciable silver contents (up to 57.32 ppm) were noted within Pb-rich slag while the numerous speiss fragments retrieved from the field indicate some sort of silver refining being undertaken on the same site in addition to iron production.

5. CONCLUSION

An inherent centralisation of Ottoman administration and the far-reaching taxing system modified production and consumption strategies across the empire leaving producers preoccupied with the necessity to increase yield and hence metal output at all costs (Nerantzis 2006). It should be noted that instead of seeing devolved control we see more centralisation during the 16th century when production of foodstuffs, tools, weapons and commodities might have increased but only with the subjugation of the populous. At times when taxation intensified and agriculture or herding would not supply sufficient income, metal production increased but the reward to those engaged in the activity was often minimal (Rozen 1993; Murphey 1980).

Based on a synthesis of documentary information and the available analytical data on metallurgical residues it could be concluded that although metal workers experienced control from central authorities they were at the same time tax-exempt persons with certain valued specialised skills. With regard to socio-economic orientations such highly specialized communities would have been involved in mining and metallurgy full time for most of the year's duration. Being secluded from farming or herding, their basic subsistence needs were provided for through exchange with other groups or a coordinating central power such as the state.

Within this economic context based on generating revenue for the state, mining communities adopted a resiliency strategy which promoted innovative technology from experimentation to adapt to the given circumstances (Edmondson 1989; Palmer and Neaverson 1998). Thus the appearance of the blast furnace in the wider Kavala region at Pravista, Avli and Makrychori was an outcome of adaptation to minimise metallurgical costs and increase efficiency in production, at a time of constant demand for iron and steel in the guns and weapons industry (Photos 1987). The role of iron tools and weapons in the 1550s was important and demand was related to a pressure for making superior properties and thus provided a stimulus to technological innovation. Gun founding and ammunition production would have been a matter of priority at sites close to the frontier zone to facilitate immediate supply for the expansion of the Ottomans in the central Balkans. Further the high inflation throughout Europe caused by the influx of American silver led to redoubled efforts to maximize the output of precious metals from the Empire's own natural resources (Rozen 1993). The smelting evidence discussed testifies to highly innovative technology applied in both fields of iron and silver production in response to socio-political factors and orientation towards increased output in the productive sector across the Ottoman realm.

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr R.C.P. Doonan for supervising the project and Dr Y. Bassiakos for help in the laboratory. Special merit should be granted to Prof J. Stratis for the conduct of compositional analysis. I also thank Dr. Tsouris for indispensable help on fieldwork and sampling slag deposits.

REFERENCES

Anhegger R. (1943) *Beiträge zur Geschichte des Bergbaus im Osmanischen Reich*, Istanbul

Apostolidis K. (1944) To Samakovi kai ta metalleia tou, *Thrakika*, 19, 178-183

Belon P. (1588) *Les observations de plusiers singularitez choses memorables trouvées a la Grèce*, Paris

Bjorkenstam N. (1985) Prehistoric and Medieval Iron Production, Reaction processes in the production of iron ores in low shaft furnaces, *Journal of the Historical Metallurgy Society*, 19(2), 186-192

Bryer A.A.M. (1983) The question of Byzantine mines in the Pontos: Chalybian iron, Chaldian silver, Koloneian alum and the mummy of Cheriana, *Anatolian Studies* 32, 133-150

Bryer A.A.M. and Winfield D. (1985) *The Byzantine Monuments and Topography of the Pontos*, Vol 1, Dumbarton Oaks Research Library and Collection, Washington D.C.

Buchwald V. F. (2005) *Iron and Steel in Ancient Times*, Copenhagen, Det Kongelige: Danske Videnskabernes Selskab

Chatzikyriakidis K. (1999) *To Metalleio Taurou (Buga Maden) 1826-1924*, Ekdotikos Oikos Adelfon Kyriakidi

Chiotis E., Koukouzas C. and Papadimitriou G. (1996) Old mining and metallurgical activities in Angistron-Serres-Macedonia, *Proceedings of the 2nd Symposium of the Hellenic Archaeometric Society*, Thessaloniki, 77-89

Danisman H.H.G (2007) Ottoman mining and metalworking in the Balkans: Its impact on fire-arms technology of southeast Europe (15th-17th centuries), *Foundation for Science Technology and Civilisation*

Dimitriadis V. (1973) *I kentriki kai dytiki Makedonia kata ton Evlija Celebi*, Makedoniki Bibliotheki 39, Thessaloniki

Dimitriadis V. (1986) Ottoman Chalkidiki: An area in transition, In Bryer A. and Lowry H. (eds.) *Continuity and Change in Late Byzantine and Early Ottoman Society*, Papers given at a Symposium at Dumbarton Oaks, May 1982, 39-50

Edmondson J.C. (1989) Mining in the Later Roman Empire and Beyond: Continuity or Disruption, *The Journal of Roman Studies*, 79, 84-102

Faroqhi S. (1999) *Approaching Ottoman History, an introduction to the sources*, Cambridge University Press

Felekis C. (1907) Topographia metalleiou Bulgar tis eparchias Chaldias, *Xenophanes* 4, 346-351

Inalcik H. (1973) The Ottoman Empire, The Classical Age 1300-1600, Phoenix

Inalcik H. and Quataert D. 1994 *An Economic and Social History of the Ottoman Empire 1300-1914*, Vol. I, Cambridge University Press

Issawi C. (1980) *The Economic History of Turkey 1800-1914*, Chicago and London

Kandilaptis G. (1929) *Oi archimetallourgoi tou Pontou kai to ethnikon ergon auton*, Alexandroupolis

Kostoglou M. and Navasaitis J. (2006) Cast iron in ancient Greece: myth or fact? *Journal of Mediterranean Archaeology and Archaeometry* 6, 2, 53-56

Koukouli-Chrysanthaki C. (1990) Ta "metalla" tis Thasiakis Peraias, *Mnimi D. Lazaridi: Polis kai Chora stin archaia Makedonia kai Thraki*, Praktika Archaeologikou Synedriou, Kavala 1986, Ellinogallikes Ereunes I, Thessaloniki, 493-514

Lakides S. (1899) *Historia Vizyes kai Medeias*, Istanbul

Lowry H. (1986) Changes in fifteenth-century Ottoman peasant taxation: The case study of Radilofo, In Bryer A. and Lowry H. (eds.) *Continuity and Change in Late Byzantine and Early Ottoman Society*, Papers given at a Symposium at Dumbarton Oaks, May 1982, 23-37

Murphey R. (1980) Silver Production in Rumelia according to an official Ottoman Report circa 1600, *Sudost-Forschungen* 33, 75-104

Nerantzis N. (2006) Metal production towards the end of Byzantine rule in Eastern Macedonia, *Journal of Mediterranean Archaeology and Archaeometry*, Vol. 6, No 2, 57-63

Nerantzis N. (2007) H Byzantini metalleytiki kai metallourgia stin anatoliki Makedonia, *Archaeologia kai Technes* 103, 70-76

Palmer M. and Neaverson P. (1998) *Industrial Archaeology, Principles and Practice*, Routledge, London and New York

Pamuk S. (2000) *A Monetary History of the Ottoman Empire*, Cambridge University Press

Papaggelos I. A. 2003 I Othomaniki Kyriarchia, *Kathimerini, Epta Imeres*, 1st June 2003, 20-21

Photos E. (1987) *Early Extractive Iron Metallurgy in N. Greece: A Unified Approach to Regional Archaeometallurgy*, PhD Dissertation, University of London

Photos E., Koukouli-Chrysanthaki C., Tylecote R.F. and Gialoglou G. (1989) Precious Metals Extraction in Palaia Kavala, NE Greece, An Archaeometallurgical Attempt to Locate Skapte Hyle, *International Old World Archaeometallurgy Conference*, Max Plank Institut fur Kern Physik, Heidelberg, 179-190

Rehren T., Charlton M., Chrikure S., Hamphris J., Ige A. and Veldhuijzen A.H. (2007) Decisions set in slag-the human factor in African iron smelting, In S. LaNiece, D. Hook and P. Craddock (eds.) *Metals and Mines - Studies in Archaeometallurgy*, Archetype, London, 211-218

Rozen M. (1993) The corvée of operating the mines in Siderokapisi and its effects on the Jewish community of Thessaloniki in the 16th century, *Balkan Studies* 34, 29-47

Vakalopoulos K. (1973) *History of Macedonia, 1354-1833*, Institute for Balkan Studies, Thessaloniki

Vakalopoulos K. (1996) *Istoria tou Boriou Ellinismou, Makedonia*, Thessaloniki

Wagner G. A., Pernicka E., Vavelidis M., Baranyl I. and Bassiakos I. (1986) Archaeometallurgische Untersuchungen auf Chalkidiki, *Der Anschnitt* 38, 5-6

Zografopoulos K. (2002) *O Laonikos Chalcocondylis kai oi apopseis toy gia tous Tourkous*, Ekdoseis Spanidi, Xanthi