**Byzantine and Ottoman Mineral Exploration and Smelting in Eastern Macedonia, Greece and their Implications for Regional Economies**

## Volume 1

Nerantzis X. Nerantzis

A Thesis Submitted for the degree of
Doctor of Philosophy

**Department of Archaeology and Prehistory**
**University of Sheffield**

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# TABLE OF CONTENTS



## Volume 1

# Volume 2

# LIST OF FIGURES

# ABSTRACT

The study outlined here is an investigation of mining and smelting evidence across eastern Macedonia in northern Greece particularly through the Byzantine (AD 324-1453) and Ottoman (AD 1453-1912) periods. Diverse evidence for mineral exploration and metallurgical extraction in the ancient and medieval past exists throughout this region bounded by the Strymon and Nestos river valleys. Through an integrated approach to survey, site characterization and scientific analysis of metallurgical debris it has been intended to approach issues of interrelatedness between subsistence and production sectors, and address questions relating to Byzantine economy and technological complexity.

Documentary evidence from antiquity, late Byzantine Mount Athos charters and Ottoman cadastral registers refer to local, large-scale iron production in the region. Although at present there exists no clear understanding of the chronology for the various production sites, surveys and analytical studies carried out elsewhere have been proven enlightening towards that end. Further, the actual practices represented at these sites remains to be established. Although the mainstay of the metallurgical traditions seems to be iron metallurgy, analyses of slag from sites across Macedonia, particularly high arsenic concentrations, and the occurrence of speiss among the debris, suggested that precious metal extraction could have been an important but peripheral activity. This coupled with documentary evidence allows for the potential of eastern Macedonia to be a minor but significant source of precious metals in the Byzantine world.

The current study focuses on the survey and sampling of four smelting sites in the region and scientific analysis by various instrumental techniques undertaken in view to characterizing the metallurgical processes represented in each case. The production sites are characterized by spatial and scalar variation reflecting distinct modes of organizing labour and fluctuations in specialization, intensity and time-length of operations. Analytical data provide an overview of the technical parameters which in turn represent human capacities and choices deeply rooted in social and cultural information. Eventually the dynamics of practice and technical choices for organizing seasonal smelting ventures are being perceived as identity forging incidents among the medieval rural communities of the region.

# ACKNOWLEDGMENTS

I would like to personally thank my supervisor Dr. Roger C. P. Doonan for offering indispensable guidance, support and inspiration throughout this long period of research. I am truly grateful to Dr. Yannis Bassiakos from NCSR 'Demokritos' and Dr. Evangelia Kyriatzi from the Fitch Lab, BSA for their valuable help and guidance in the conduct of laboratory research. I should also extend my gratitude to Prof Yannis Stratis for compositional and mineralogical analyses conducted at the Department of Chemistry, Aristotle University of Thessaloniki and Dr. Leon Black for help in microscopic examination. Special thanks should be granted to the 12th Ephoria of Byzantine Antiquities, Kavala and especially Dr. Konstantinos Tsouris for supporting the application to sampling permission and also the Hellenic Ministry of Culture for granting the sampling permit. I would also like to thank Mr. Epitropou, Mr. Dimadis and Mr. Gialoglou from IGME in Xanthi for all the geological information they kindly provided. This study was partly funded by the Friends of the British School at Athens studentship and I should like to thank the Director Dr. James Whitley and Assistant Director Dr. Eleni Hatzaki for their assistance during my residency at the BSA. For the fruitful and inspiring discussions or simply exchange of ideas I thank Prof Paul Halstead, Dr. Peter Day, Dr. Ian Whitbread, Dr. Michael Boyd, Dr. Michalis Catapotis, Dr. Myrto Georgakopoulou, Dr. Elizabeth Potter, Matthew Haysom, Heinrich Hall, Jill Hilditch, Clare Pickersgill, Harriet White and Vasko Démou. I would finally like to express my thanks and gratitude to my parents Xanthos and Aikaterini Nerantzi, my brother Yannis and Roula Xanthopoulou for their constant support, encouragement and tolerance. Special thanks to the kind people from numerous villages across Serres, Drama and Kavala who guided me to most of the sites discussed in this thesis.

## *CHAPTER 1*

# *Metals technology in Byzantine rural Macedonia*

### 1.1 Introduction

The issue of metallurgy across provinces of the Eastern Roman Empire is generally regarded as a neglected area of study while the spread and fusion of eastern and western technologies in Byzantine lands, during Ottoman expansion, is in fact an ill-understood subject (Harvey 1989; Lefort 1993; Laiou 2002; Cameron 2007). Highly valued commodities such as silk textiles, glassware and precious metalwork deriving from Byzantine workshops were traded as diplomatic gifts far and wide across Anglo-Saxon, Frankish and Persian lands for centuries (Haldon 1990; Laiou *et al* 2002; Harris 2003). In this context long distance trade and macro-scale agency associated with central government initiatives has been over emphasized in regards to the metals 'industry' when at the same time the dynamics of numerous micro-regional Byzantine territories have often been ignored.

Historical information provided by Byzantine scholars describes an imperial bureaucratic structure that exercised profound control over resources, the economy and the productive sectors which generated revenue (Beck 1977; Hunger 1978; Kazhdan 1999). Although control of precious metals for striking coins and safeguarding the imperial state treasury supply would seem imperative such presumptions are primarily based on literary accounts (Ahrweiler 2000). Archaeological findings from various contexts testify to a more complex situation where control over resources is negotiated among rural communities, rich landowning individuals and officials of the state demonstrating regional variation across the imperial provinces (Cameron 2007; Herrin 2008).

What is notable is that throughout its turbulent history the Byzantine gold solidus, used as the major coin for most transactions, was never debased until the 11th century. It seems therefore that the Byzantine economy was underpinned by a stable and reliable supply of gold that lasted for over six hundred years. Some scholars (Vryonis 1962, Bryer 1983) have suggested that this was made possible by the creation of a huge treasury during periods of expansion which invariably included some of the richest deposits of gold in the Balkans i.e. Romania, Serbia and Bulgaria, the Taurus range in Anatolia and the Black Sea coasts of modern day Turkey. Others have argued that a key source of gold was to be found within the bounds of the contracted empire most likely in Thrace and Macedonia (Edmondson 1989; Matschke 2002). The question of the source of gold remains an important and so far unanswered question in Byzantine studies.

This thesis aims to investigate diverse evidence for Byzantine (AD 324-1453) and Ottoman (AD 1453-1912) mineral exploration and smelting in eastern Macedonia, Greece through survey and scientific analysis of the findings in conjunction with research on relevant literary information. This current undertaking is proposed as a means to explore the role of such activities in regional economies and how they impact on the social identity of individuals engaged in them. By employing an integrated approach to survey, site characterization, and material culture studies it is intended that questions relating to Byzantine economy and technology can be addressed. Further the structuring of certain relationships among communities of producers with other groups and a negotiation of local resources for sustaining their subsistence are being examined. Eventually results from this study can be used to argue whether such metalworking sites from Thrace and Macedonia were involved in the production of gold during the Byzantine period (4th-15th centuries).

Adopting a regional focus towards production sites allows a history to be written which is directly rooted in evidence rather than a technological history which appeals to macro-scale abstract processes. At such regional scales investigation of raw materials, workspaces, manufacturing debris and choices of the labour force could be examined with a good degree of accuracy, compared to large mining-smelting districts that are difficult to interpret archaeologically (Budd *et al* 1994; Craddock 1995; Knapp *et al* 1998). It is for such reasons that a clearly defined area of northern Greece has been chosen for thorough examination in order to approach questions of technical nature and test hypotheses of social formation. The area upon which the study is focused is bound between the Strymon and Nestos river valleys, stretching across the prefectures of Serres, Drama and Kavala. The actual archaeological sites investigated, are situated in Kato Nevrokopi, the Vrontou range, Mounts Angistro and Pangaeon, and the Lekani range (Figure 1).

This study area has been selected for a number of reasons, which could be summarized into the following; the geological-mineralogical diversity characterizing eastern Macedonia and Thasos Island, the long histories of mineral exploration, and the important socio-cultural role of this region due to its location between Constantinople and Thessaloniki, the empire's second largest city. Additionally previous archaeometallurgical work focused on this region has concentrated on tangible evidence of the Classical and Roman past leaving medieval material evidence largely unexplored. In the following chapters such long histories of mineral exploration are being investigated in order to discriminate between different periods of activity that would help towards characterizing the later phases of mineral processing and production of metals.

Recent material culture studies have worked within a paradigm, which emphasizes small scale contextual approaches to technological remains in order to elucidate issues of regional technologies and expression of identities through craft production. In most cases prehistoric and ancient cultures attracted attention as candidate cases upon which socio-economic models of human behaviour were constructed (Branigan 1974; Catling and Jones 1977; Chapman and Tylecote 1983; Craddock 1976; 1995; de Jesus 1980; Evely 1995; Gale *et al* 1990; Koukouli-Chrysanthaki 1990; 1992; Knapp 2000; Northover 1984; Northover and Evely 1995; Renfrew 1978; 1986; Whitbread 1995). For instance the emergence of metallurgy in centres of the Balkans and Aegean region has attracted the attention of scholars since the large-scale excavation projects of the 60s and 70s (Branigan 1974; Chernych 1978; Jovanović 1979; 1980; Renfrew 1972). Findings from the field and laboratory research constituted a solid body of evidence as much as providing theoretical legitimacy for a discourse on early technological stimuli responsible for cultural achievements. Specialists investigating trade in metals over large interaction zones and production technologies meticulously structured the research agenda for the last twenty or thirty years influencing in such a way our perception about economic patterns of the prehistoric past (Gale and Stos-Gale 1981; Gale *et al* 1990).

One such characteristic case has been the emphasis drawn upon provenance studies on tracing the raw materials that fuelled the booming of metallurgical activity during the Late Bronze Age. Locating the ore deposits from which extracted metals were used for certain artefacts of various eastern Mediterranean cultures has been an alluring task for both archaeologists and material scientists for most of the 80s (Gale *et al* 1985; McGeehan-Liritzis 1983; Gale *et al* 1990). However the complex processes behind metal production including recycling or mixing of various ores were responsible for significant bias on the results of such studies designed to determine the mechanisms driving mobilization of exotic raw materials.

In more recent material culture studies sophisticated modern analytical tools are increasingly being employed for the investigation of manufacturing stages, production sequences or provenance of raw materials and artefacts made out of almost any material accessible to ancient populations (Bimson and Freestone 1987; Rice 1987; Wilson and Day 1994; Pollard and Heron 1996; Henderson 2000; Liritzis *et al* 2006). However analytical studies have rarely focused on more recent archaeological periods for which historical documents have traditionally been a major source of information. Some of the few laboratory-based research projects on medieval material culture from Eastern Europe were often biased towards reflecting social meaning due to certain conditions of research methodology applied to findings from this part of the world (Lazzarini *et al* 1980; Calogero and Lazzarini 1983; Maguire 1997; Wisseman *et al* 1997). Since the spread of standard technological modes across the globe rendered uniqueness in crafts almost impossible, many argued that material culture of proto-industrial nature from the recent past is not loaded with elements of local identity.

It is becoming increasingly acknowledged that new theoretical and methodological approaches are needed to account for processes embedded within broader cultural arenas. Artefacts could no longer be seen as products of technological systems acting as potential cultural signifiers (Bourdieu 1977; Lemonnier 1992; Dobres 2000). According to Nakou (1995, 3) "the conclusion that technology is culturally and historically constructed implies that any broad characterization relating to the mute objects of the archaeological record masks essential differences". Such differences in technical expression that could potentially reflect regionalism should be realized in the context of artefact production. Expanding the study of artefacts toward technological action defined by gestures and choices within operative chains is in fact more crucial for an understanding of the interrelatedness of technology and society (Cowan 1996; Dobres and Hoffman 1994; Phaffenberger 1992; 1996). For reasons of enhancing accuracy in interpretation, context specific techniques in defined regional production centres of the Byzantine and Ottoman periods which remain largely unexplored form the core of this current thesis.

### 1.2 Aims and Thesis outline

This research has been structured in view to defining the resource potential of eastern Macedonia and how communities had been organized in response to the exploitation of such resources. On a second level important issues are being addressed concerning how basic subsistence needs were met by communities specializing on mining and metallurgy either through local strategies or exchange with other groups. Having outlined these important considerations the broad aims of this thesis would be to critically question how we have conceptualised Byzantine technology as a subsystem of a static, immutable society, impervious to change. By drawing attention to the Byzantines themselves with their distinctive behavioural patterns we will be in a better position to understand the dynamic social processes as they have materialised in technological remains. The major objectives could be summarised as follows:

- Define the region upon which to address certain questions on technological action
- Evaluate relevant archaeological and literary information on the socio-technical constitution of metals production

- Characterise production sites through field survey
- Sample, analyse and discuss the potential of results at elucidating social meaning and choices for action
- Address questions on resources perception, organization of production, social identities of the labour force
- Characterise communities and understand the entanglement of various *chaînes opératoires* and subsistence strategies through an holistic approach: farming, herding, mining, smelting

### 1.3 Byzantine technology in context

Traditionally Byzantine studies have focused on historical texts, ecclesiastic architecture, and the investigation of settlements and cemeteries (Angold 1975; 1984; 2001; Bakirtzis 1977; 1979; Guillou 1994; Mango 1980; Ostrogorsky 1968; Runciman 1951-1953; 1977). The key focus for material culture studies has been for understandable reasons, ceramics and coinage. Although Byzantine economics have recently attracted better attention with the role of production in understanding economy being increasingly acknowledged (i.e Laiou *et al* 2002), technological studies, or more broadly, material culture studies relating to innovation and production have not been well represented in the study of this period. In part this is due to wider issues concerning erroneous attitudes many scholars hold towards the role of technology within society but also relate specifically to enduring attitudes to Byzantine technology. Cyril Mango (1980) summarizes this well where technological change is seen to parallel changes more broadly in art and literature "...Byzantine art, like Byzantine literature, was undeniably very conservative. Since it evolved at a slow pace, the dating of its oeuvre is seldom an easy matter..." (Mango 1980, 256).

Often technology in the Byzantine world is depicted in stark contrast to the Roman and Classical worlds. It is seen as devolving or stagnating, hence it has tended to neither attract the attention of Byzantine scholars or indeed historians of technology who are particularly focused on documenting instances that support ideas of endless technological progression. Among eleven of the most important works on the history of Byzantium spanning almost fifty years of research only five pages collectively are dedicated to technology (Angold 1984; Browning 1980; Guillou 1994; Haldon 1990; Jenkins 1966; Mango 1980; 1984; Ostrogorsky 1968; Savidis 1995; Vasiliev 1952; Vryonis 1967). Likewise in general textbooks on the history of technology, engineering and mechanical operations (Forbes 1950; Finch 1951; Craddock 1995; Kirby *et al* 1990; Tylecote 1976; Usher 1959) there are only scarce references to technical examples such as clocks, navigational devices or military equipment from the Byzantine world all too often isolated from their socio-cultural context.

And yet even though no comprehensive treatment of technical issues exists either in terms of archaeology or history, arbitrary arguments have been made in the past. Norman Cantor's (1963) book on Medieval History emphasises the idea of backwardness when Byzantium is compared with the preceding Greco-Roman world: "the history of Byzantium is a study in disappointment. The empire centering on Constantinople had begun with all the advantages obtained from the inheritance of the political, economic, and intellectual life of the 4$^{th}$ century Roman Empire... Byzantium added scarcely anything to this superb foundation. The Eastern Roman empire of the Middle Ages made no important contributions to philosophy, theology, science or literature. Its political institutions remained fundamentally unchanged from those which existed ... at the end of the 4$^{th}$ century..." (Cantor 1963, 248-9).

As Turner (1997) has stressed ''Cantor suggests a continuity between Late Antiquity and the empire of New Rome. But his is the static and sterile continuity of an outer shell, not of substance''. This line of argument followed by Cantor betrays some of the Western tradition's contexts of continuity involving notions of 'innovation', 'progress', and 'the individual', notions on which western historical tradition is based (Baldwin 1971; Le Goff 1985; Rossi 1997). The supposedly static nature of Byzantine culture and society which was the impression transmitted by much of the popularising historiography about the empire until not too long ago has been shown to be a serious misconception (Haldon 2000, 196-170). Clearly Byzantine culture and all of its sectors including technology should be studied in separation from western thought systems and traditional lines of reasoning that have been employed in the recent past (Grabmann 1957; Gabriel 1961).

Such attitudes to Byzantine technology as described above are exaggerated in the study of the period after the fragmentation of the Byzantine Empire following the events of the thirteenth century (Laiou 2002, 6). Prior to this the pivotal political role of metal procurement is widely accepted but virtually no studies have been undertaken to better understand this area. Work proposed here intends to readdress this imbalance. For instance it is argued by some scholars that the rich gold deposits in the border regions of Armenia were "...so important to the early Byzantine state that the conflicts with the Persians/Sassanids, which dominated political events from the fifth to the seventh century, at times took on the character of economic wars" (Matschke 2002, 116).

Clearly the study of technological activities, their organisation and change cannot be disarticulated from concurrent political and social issues. This is not a minor point as it illustrates that the study of technology is more than simply documenting technical processes but in fact acts as a window to diverse social practices. This realisation has meant that technological studies have been reappraised in light of the increased awareness of the anthropological basis of technology. Technology can no longer be considered "arid, boring or scientifically sterile...." (Malinowski 1945) nor simply reduced to "an extra-somatic means of adaptation" (Binford 1962; 1964; 1989), rather it must be considered a socially embedded set of human behaviours which are culturally contingent, at the heart of which is located choice. From this anthropological perspective technological activities are central to social practice and become an important means by which to explore wider societal issues such as the organization of labour, identity, the articulation of power and resource perception (Hayden 1998). It is a central theme in the work proposed here that traditional approaches to Byzantine technology have tended to treat the Byzantine world as a homogenous whole (Healy 1978) viewed through a particular westernizing lens with a disregard for the benefits of a focused regional study such as this proposed here.

Another intriguing aspect of the study of Byzantine technology is how it is depicted as existing in a state of stasis. This is an intriguing sociological phenomenon which itself is worthy of study as it contrasts with western notions of progress and innovation (Murray 1978) and can provide insight into the social organization and ideologies dominant in Byzantine society as well as revealing contemporary attitudes to it. It is through such an anthropological approach to technology that insights into Byzantine economy and the social identity of miners and metalworkers can be gained.

Although there are several good studies of various aspects of Byzantine economy, there remains no single synthetic work that would provide a global view of the subject (Laiou 2002, 7). In part this is understandable since the Byzantine world is characterised by regional variation and difference, something which has not been reflected in accounts of technology (see for instance Matschke 2002). However there now exists a need for a work where the economy can be understood as a whole but such an understanding can only come from a synthesis based on focused regional studies, something that is lacking in many approaches to innovation and production in the Byzantine world. For instance, again Laiou (2002) has proposed the following as a key question to be addressed in Byzantine economics: how productive were its various sectors? Much is known about some aspects i.e. agrarian economies or pottery but only in certain regions whilst mining and metallurgy within Greece remains scarcely understood at all (c.f. Edmondson 1989; Nakou 1995; Pernicka and Wagner 1991; but see also Weisgerber and Wagner 1988; Werner 1985).

One issue that is essential to address in the understanding of mining and metallurgy in the Byzantine world is to gain a clear understanding of organisation of labour and how changes in the ownership of land impacted on rights of exploitation and the willingness of communities to be involved in such activities (McClellan and Rautman 1994). According to many scholars it is proposed that the tendency toward simpler organizational forms, already evident in the early Byzantine period, intensified further and that mining was once again more closely linked to landownership and frequently was an activity that peasants pursued on the side. However, such assertions are usually made from a general perspective and are rarely tied to specific case studies. It is this issue of organisation and change and how it is realised at the local level, which will remain a key focus of the study outlined here.

In the following chapters the evidence for mining and smelting in northern Greece will be presented and reviewed in order to arrive at an understanding of metallurgical traditions through the centuries when the so-called *banausic* arts left no trace in the historical literary record. The second chapter provides an environmental and geological background to the region under study. The anthropological dimensions of mining and social attitudes towards labour are being discussed in chapter three where medieval settlement and economy are equally investigated in an attempt to search for socially constructed views on technical operations such as the smelting of ores. The fourth chapter concentrates on a review of mineral exploitation in northern Greece and the surrounding regions starting from prehistoric times and ending to the beginnings of the last century. In this way the diachronic persistence of minerals in the economic palette of choices for the inhabitants is evaluated. Special focus is given on the archaeological and historical evidence for mining and metallurgy and their place in economy through the Byzantine and Ottoman years in Greece, the Balkans and Asia Minor. What follows in the fifth chapter is an account of the field survey methodology, a description of all sites encountered, a detailed report on the four sampled sites' topography and presentation of the finds. The sixth chapter provides an outline of the analytical methodology and the techniques which were applied, a report of all laboratory work and the results from microscopic examination and chemical characterisation of chosen samples. The seventh chapter provides the synthesis and evaluation of the various social, economic and technical issues encountered through the discussion of results. It also contains concluding remarks and a critical appraisal of the questions being raised through the conduct of research.

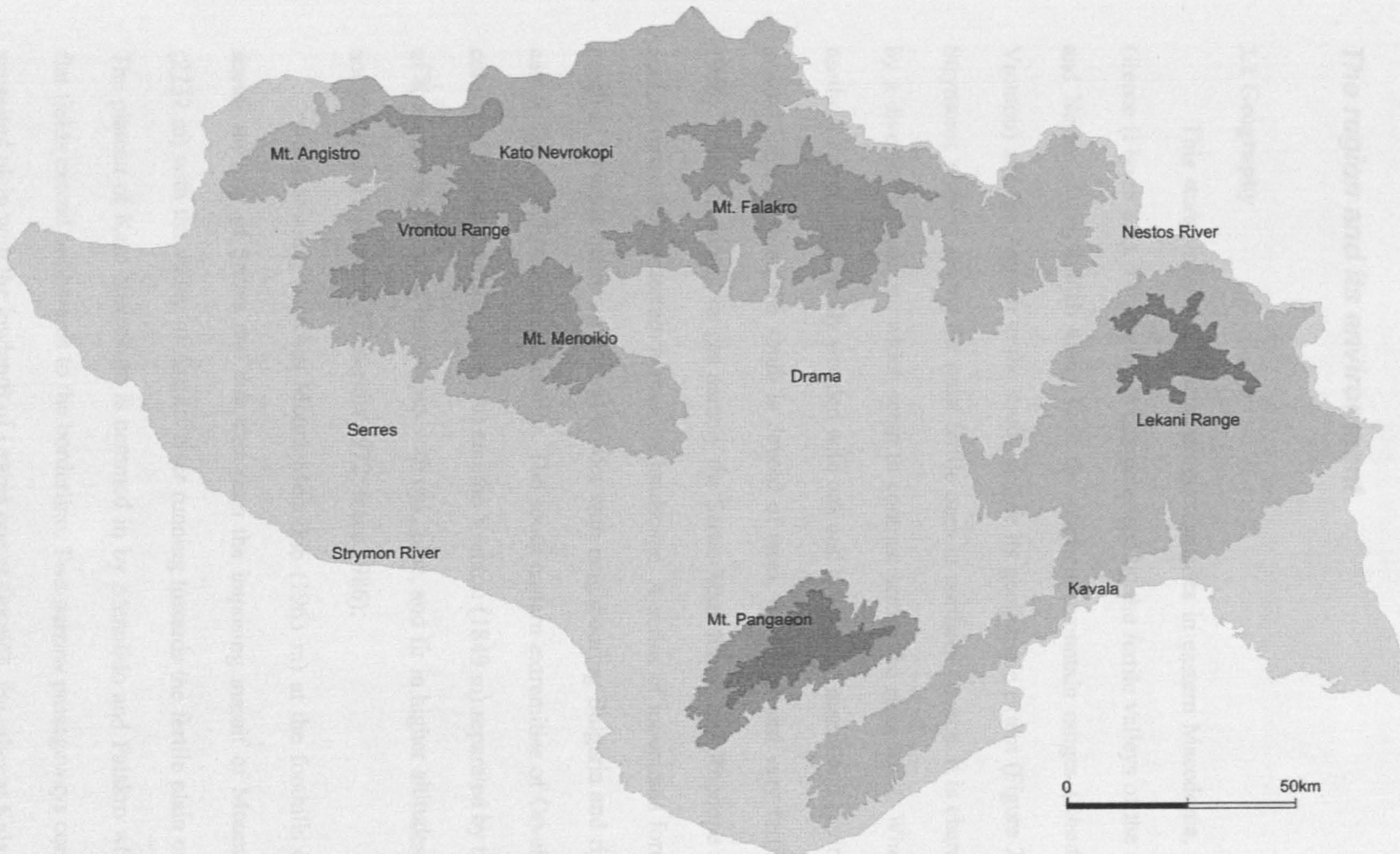



Figure 1.1 Map of the region under study

## *CHAPTER 2*

# *The region and its environment*

### 2.1 Geography

This study focuses on metal production sites in eastern Macedonia, northern Greece (Figure 2.1). The region is characterised by the fertile valleys of the Strymon and Nestos rivers, which along with the northern mountain ranges (Rhodope and Vrontou) and the Aegean to the south, define its geographic extent (Figure 2.2). The Strymonic plain is among the most fertile ones in northern Greece. It is characterised by a diversity of habitats which seem to contrast across the river itself. Whereas the northern riverside is thickly wooded with oak and beech with marshland environments around Lake Kerkini, the south is devoid of trees, quite flat and very fertile (Isaac 1986). Two substantial ranges namely the Serbo-Macedonian and Rhodope form the core of mountainous terrain across the landscape. A series of mountains forming the range of Orvelos defines a natural border with neighbouring Bulgaria and rise in the east to form the Rhodope Mountains. The south eastern extremities of Orvelos range consist of Mount Angistro (1294 m) and the Vrontou (1849 m) separated by the gorge of Krousovitis. Wooded landscapes with oak, pine, and fir in higher altitudes, ravines and streams are common (Lazaridis 1972; Isaac 1986).

Further south stretches Mount Menoikio (1963 m) at the foothills of which stands the city of Serres and due east rises the imposing massif of Mount Falakro (2232 m) with the valley of Angitis river running towards the fertile plain of Drama. The plateau of Kato Nevrokopi is hemmed in by Menoikio and Falakro whereas its flat fields extend northwards to the borderline. Two narrow passageways connect this separated plain with the lowlands of Drama one at Granitis, the other at Kalapoti. The city of Drama situated by the foothills of Falakro overlooks the well watered plain which resulted by the draining of extended marshlands and swamps. Mount Pangaeon (1956 m) dominates the southern extent of the plain and further south Mount Symvolo (694 m) overlooks the Aegean. North of the city of Kavala the mountainous expanse of Lekani extends towards Nestos river with its narrow northern ravines and the wide estuary on the fertile plain of Chrysoupolis (Isaac 1986). The coastal environment has undergone several transformations with multiple episodes of alluviation and salt bed formations. The coastal zone is characterised by a variety of capes, gulfs, coves and lagoons which together form a complex and varied environment which affords diverse activities ranging from sheltered harbouring to exploitation of particular rocks which may be exposed.

## 2.2 Environment

Throughout the extent of this broad, segmented region there are small ravines, gorges, valleys and plains which have been subject to diverse cultivation strategies. The plains are alluvial formed by river action and the hilly stretches are tertiary neogene formations of red earth deposited on conglomerate soils (Lazaridis 1972). Soil quality varies spatially from poor to very good and is a mixture of sand, clay, loam, dunes, gravel and continental deposits. Natural springs with hot, mineral-rich waters are located at Angistro in Serres and Eleutheres in Kavala. Lakes, lagoons, marshlands and above all the two river estuaries contribute substantially to the region's fertility. The flora of uncultivated land includes chestnut trees, willows, hazel and walnut trees, poplars and a variety of wild flowers and aromatic plants (Lazaridis 1972).

The climate of the northern zone and the plain of Philippoi around Pangaeon is markedly different from that of the coastal area. It resembles a central European climate with hot summers and cold winters. The winter can be severely cold as the plains are exposed to north winds. Snow falls regularly on mountaintop and lowlands as well, while the Strymon can be covered with ice. In the past it has been more humid than today with large parts of the lakes having been reclaimed. Quite differently the coastal zone has a Mediterranean climate with mild winters and pleasant but dry and cool summers (Isaac 1986). Some of the main crops cultivated in the plains are corn, cereals and tobacco while the coastal area is suitable for olive trees, vineyards, cereals, melons, various fruit trees, rice and vegetables (Lazaridis 1972). The major crops that were cultivated throughout the Byzantine period on the fertile alluvial lowlands of the Strymon and Nestos river systems were wheat and rye along with vine and olive while barley and oats were cultivated in highland semi-arid settings. Since conditions in the uplands (i.e. poor soils, severely cold winters) were not favorable for extensive farming, subsistence was dominated by stock-raising. Populations in the uplands had been diachronically sustained by semi-nomadic pastoralism while surpluses in oats and barley provided an ideal animal fodder. Seasonal mining and trading of processed ores has been reported as an additional activity of those highland communities (Vakalopoulos 1973).

Although environmental conditions have generally remained stable in the recent past throughout Greece the climate during Ottoman times might have been slightly different than it is today. Since climatic conditions in Europe are known to have shifted towards colder winters that drove what has become known as the Little Ice Age ($16^{th}$-$19^{th}$ centuries) such change might have affected southern regions. It is highly possible that cultivated land was reclaimed by forests due to possible failing of crops. Such physical regeneration of forests would appear favourable for charcoal preparation, which is crucial for fuel acquisition in any 'industrial' activity. Further the introduction of new crops during the same period that provided high yields might have rearranged subsistence strategies. New industrial crops such as cotton and tobacco adaptable to colder conditions that became widespread from the 1800's onwards brought about increased yields across the fertile plains. The prospect of greater returns from upgraded agricultural practice would have affected alternative, highly demanding pursuits of income such as specialised production and exchange. Through a gradual infiltration of such resistant crops to the highland pastures mining and smelting eventually declined as unfavourable, laborious and obsolete practices compared to innovative and profitable cultivations.

Recent palaeoenvironmental investigations undertaken along the lower Strymon valley and the island of Thasos have provided a record of soil erosion and alluvial aggradation along the rivers Xeropotamos, Angithis and Strymon (Van Andel *et al* 1990; Lespez 2003). Such regional scale studies have contributed to our knowledge on the part of human activities and climatic oscillations or events in the environmental changes and helped towards an understanding of links between the different scales within the environmental system (Lespez *et al* 2000). Along the main river, the two phases of alluvial aggradation identified are historical and belong to Antiquity and the Early Byzantine period (3$^{rd}$ c. BC to 7$^{th}$ c. AD) and more significantly fall within the Ottoman period through the Little Ice Age (15$^{th}$-19$^{th}$ c. AD). During this latest period, the rate of accumulation has been three to five times that during the Late Holocene (Lespez *et al* 2004). These two phases of accelerated alluviation in historical times are clearly linked to land use changes, particularly associates with the upstream progression of cropping and grazing (Lespez *et al* 2004).

## 2.3 Geology and mineral wealth

The region's geology is characterised by the presence of acidic and intermediary igneous rocks which geotechtonically belong to the Rhodope massif. The major rocks found are gneiss, amphibolites, schist and marbles (Figure 2.3). Higgins and Higgins (1996) provide a concise review on geological formations across Greece which should be considered in this context. The following summary referring to eastern Macedonia comes from their work: "The core of the Rhodope Mountains is made up of the Rhodope massif, a series of sedimentary and igneous rocks formed during the Mesozoic or Palaeozoic periods and metamorphosed at high temperatures into amphibolites, gneisses and marbles. They are divided from the essentially similar rocks of the Serbo-Macedonian massif to the west by the Strymon thrust fault, which runs along the eastern side of the Strymon basin. The age of the initial metamorphism is not clear, but it certainly took place well before the Alpine compressions. The isopic zones of the Hellenides, which now make up the Greek peninsula (e.g. Pelagonian, Vardar, etc.) originally lay to the south-west of the massifs as a series of low islands, ridges and ocean floor. The Alpine compressions forced these blocks against the Rhodope massif and Serbo-Macedonian zone, which were a more rigid block. Metamorphosed sedimentary and igneous rocks of the Circum-Rhodope zone extend from east of the Serbo-Macedonian massif southwards to the islands of Samothrace and Lemnos, and then north-eastwards to the eastern part of Greek Thrace" (Higgins and Higgins 1996).

The three major mineralised zones of the Rhodope/Serbo-Macedonian geotectonic system have been identified and thoroughly surveyed during IGME explorations (Anastopoulos *et al* 1976; Maratos and Andronopoulos 1966; Gialoglou and Drymonitis 1983). The first one concentrates in the Lekani range in form of iron-manganese deposits in the wider region of Palaea Kavala. The second one is composed of the granodiorite of Vrontou range and its associated mixed sulphide mineralization of Mount Angistro and the third consists of the arsenopyritic, Ag-Au mineral deposits of Mount Pangaeon (Figure 2.4 and table 2.1). The complex mineralization of Thasos Island has been a constant focus of exploitation from ancient times and comprises limonite related to smithsonite that contains barite, hematite, copper carbonates such as malachite and azurite as well as gold and silver (Wagner *et al* 1981).

The region of Palaea Kavala is rich in iron deposits of hydrothermal origin occurring in association with manganese and occasional presence of other metals such as Pb, Zn, As, Ag and Au. An extensive study of the mineralization undertaken by Spathi *et al* (1982) has shown that metallic minerals occur at the contact of marbles and mica schists and the mineralization extends across two zones, one of NE and a second of NW direction quite distinct in chemical terms. In the NE the Fe-Mn ores are associated with Pb, Zn, As and Ag while the NW one is associated with Cu, As and Au and occasionally Bi. The iron oxides reported are goethite, limonite and the manganese minerals nsutite ($\gamma$-$MnO_2$) and cryptomelane ($\alpha$-$MnO_2$).

The granites of the Vrontou range through natural enrichment in stream beds formed substantial surface deposits of Ti-rich magnetite sands. As Photos (1987, 82) has proposed it is probable that ore beneficiation with the use of water channels must have taken place by local miners in addition to natural dressing in a way similar to that observed through ethnographic work in Japan. Analytical data from the Vrontou granodiorite revealed the presence of magnetite grains dispersed in the granitic matrix. Chemical analysis showed 2-3% $Fe_2O_3$ in the granite but with proper beneficiation through a combination of desliming and magnetic separation the iron content could be enhanced up to 73% $Fe_2O_3$ (Karamatzani and Kaklamani 1983). An examination of the microstructure revealed a light phase, hematite and a dark phase, magnetite suggesting the partial weathering of the magnetite. Apart from magnetite the Vrontou sands also contain ilmenite and are considerably radioactive due to the presence of uranium with zirconium and thorium compounds (Stavropodis 1983). Increased levels of radioactivity were found in slag from Katafyto, A. Vronotou, Faia Petra and Domatia in Pangaeon suggesting their formation from radioactive ores. In the region of Angistro the mixed sulfide mineralization is of hydrothermal origin and consists of galena, pyrite, chalcopyrite and sphalerite (Chiotis *et al* 1996).

The earliest dated mining and smelting sites are concentrated in marginal upland locations similar in location and topography to Lavrion, Attica and Scories on Kythnos (Conophagos 1980; Gale and Stos-Gale 1981). On the other hand the majority of settled areas of Bronze Age Aegean could be found in coastal regions chosen for facilitating agriculture and maritime trade. For such reasons safeguarding of a steady supply of metals demanded long distance exchange networks which had been established since the beginnings of metallurgy in the Late Neolithic. In ancient and medieval times more complex and deeper deposits were progressively being reached and a greater variety of minerals became available for extraction (Palmer and Neaverson 1998; Tylecote 1987). Some of the main sources of minerals were either surface scatters of crystalline ores or weathered ore veins, clearly recognizable due to characteristic bright colours caused by oxidation. The majority of copper and iron ores shows a concentration in mainland Greece and is generally found in metamorphic rocks, comprising gneiss, schist, marbles and phyllites (Anastopoulos *et al* 1976; Vavelidis *et al* 1996). Among these the most abundant copper deposits are to be found in Phthiotis, Chalkidiki and Rhodope. McGeehan-Liritzis (1983) reported numerous slag heaps which are known to occur in the above regions, but most of them lack accurate dating due to restricted studies concentrating on such material evidence.

There are many deposits of gold in the rocks of the Rhodope massif, but most of these are too small, or too low grade to be worth mining. However, some gold ore has been eroded and transported, and the gold concentrated by the action of streams and rivers to produce placer deposits. Most of the rivers of northern Greece once had placer gold, but these deposits were easy to extract and were worked out at an early date (Mack 1983; Vavelidis 1994).

Mount Pangaeon is part of the Rhodope massif, and the block has been isolated from the rest of the massif by Neogene faulting, which produced the grabens of the Strymon and Angitis rivers (Higgins and Higgins 1996). It is a horst of marbles and gneisses, intruded by a series of granites, with the upper parts dominated by white marble. The gold and silver ores are in quartz veins, together with pyrite and arsenopyrite hosted in the gneiss (Vavelidis 2000). Hot water, probably associated with the metamorphism or the intrusion of the granites, circulated deep into the earth and extracted a number of minerals, including gold and silver, from the surrounding rocks. These minerals were re-deposited in veins as the waters cooled. Some gold was also extracted from placer deposits in the surrounding streams and rivers (Higgins and Higgins 1996).

### 2.4 Conclusion

The study region can be divided into two major zones, a northern highland and southern lowland. The mountainous northern zone has, it seems, been somewhat isolated for much of its history as it does not facilitate communication routes which have tended E-W along the coastal zone, especially between Constantinople and

Thessaloniki (Via Egnatia). It is via the coastal towns of the south, its mountain passages and rivers which have acted as conduits to the neighbouring northern provinces and the mineral rich zones therein. In addition to specific resources the importance of this zone lies on its geographical significance as a northern passage while at the same time constituting a naturally defended frontier from external threats (Ostrogorsky 1965). For such strategic reasons strongly defended fortresses were built on numerous highland locations on the Rhodope and Vrontou ranges to provide shelter for the agrarian populations at times of turmoil.

Throughout its history the northern zone was inhabited by herdsmen living in isolated small hamlets some of which became villages through processes of agglomeration. Sidirokastro and Kato Nevrokopi were the major Late Byzantine nucleated settlements with a farming base around which smaller farmsteads and herding stalls were scattered in the highland zone (Vakalopoulos 1996). Site names, traditional architecture and oral history point to a Greek ethnic stock that survived the long pressures from the north and desertions caused by war and pestilence. After the Ottoman conquest starting around 1383 the increasing incoming of Turkish settlers and the settling of Slavonic tribes changed the demographic makeup of those villages (Vakalopoulos 1973). Although there exists a small body of information on founding dates for various sites, Evlija Celebi in his travel account 'Sehajiat-Name' describes the ethnically mixed flourishing villages around Sidirokastro in northern Serres of 1668.

The southern zone of eastern Macedonia with the fertile plains and rich cities of Serres, Drama and Philippoi, the coastal towns of Amphipolis and Christoupolis became a flourishing agricultural and trading region in half distance between the the Byzantine Capital and its second largest city, Thessaloniki. A network of towns and rural farmsteads, some under the ownership of Athonite monasteries, coastal trading centres and the Via Egnatia safely connecting them, rendered the region a place of vibrant social interaction and economic efflorescence for most of the Byzantine period (Ostrogorsky 1963; Browning 1980). The agrarian economy organised by village communities and estate entrepreneurs was coupled by restricted craft production, trade and procurement of raw materials destined for the urban markets.

An integral part of this system of resource management and primary exploitation has been mining and metallurgy of iron, and small-scale silver and gold extraction. Numerous slag heaps and associated smelting debris mostly undated are scattered close to highland villages of Mt. Angistro and the Vrontou and Lekani ranges representing landscapes of 'industrial' use in the ancient and medieval past. Several putative mining sites were visited as part of this research and further details are given in chapter five. Some of the investigated sites are noted in Table 2.1 (indicated in red) which displays the occurrence of metallic minerals across the study area. The nature of the evidence suggests small scale, decentralized production that was coordinated and undertaken by small groups of smelters living with their families at villages in the vicinity. Crushed ore close to mineralised zones and some of the slag heaps and scatters that macroscopically relate to iron bloomery processes have been studied in the past across the region (Photos *et al* 1986; Koukouli-Chrysanthaki 1990; Chiotis *et al* 1996; Vavelidis *et al* 1997). Although the mainstay of the metallurgical traditions seems to be iron metallurgy, analyses of slag from these sites, particularly high arsenic concentrations, suggest that precious metal extraction could have been an important but peripheral activity.

**Table 2.1: METAL-BEARING DEPOSITS IN EASTERN MACEDONIA**
**(Distribution between Nestos and Strymon)***

| DRAMA | |
|---|---|
| Volakas | Mn |
| Granitis | Fe, Mn, Pyrites |
| Exochi | Cu, Fe, Mn |
| Kalithea | Fe, Mn |
| Kato Nevrokopi | Fe, Mn |
| Leukogia | Fe |
| Katafyto | Fe, Pyrites, Sulphidic |
| Delta | Mn |
| Dipotama | Sulphidic |
| Pagoneri | Fe, Mn |
| Perithorio | Mn, Pyrites |
| Pigadia | Fe |
| Potamaki | Mn, Mo |
| Sidironero | Mn |
| Skaloti | Mn |
| Paranesti | Fe, Mo, Pyrites |
| Kyria | Fe |

| KAVALA | |
|---|---|
| Agios Andreas | Fe |
| Amygdaleonas | Fe |
| Zygos | Fe |
| Leuki | Fe |
| Makrychori | Mn |
| Mesolakia | Mn, Cr, Pyrites, Sulphidic |
| Nea Komi | Fe |
| Nikissiani | Au, Pyrites |
| Palaeochori | Au, Pyrites |
| Paradisos | Fe |
| Petropigi | Fe |
| Palaea Kavala | Fe, Pyrites, Sulphidic |

| SERRES | |
|---|---|
| Angistro | Fe, Au, Sulphidic |
| Agriani | Cu |
| Anastasia | Sulphidic |
| Dafni | Fe |
| Em. Pappas | Fe |
| Therma | Mg |
| Kapnofyto | Pyrites |
| Kato Vrontou | Fe, Pyrites, Sulphidic |
| Lagadi | Cu |
| Orini | Fe, Mn |
| Chionochori | Mn |

*Based on field surveys, mapping and mineralogical analyses carried out by the Institute of Geological and Mineral Explorations in Greece (IGME): Maratos and Andronopoulos (1966); Papastamataki (1975)


Figure 2.1 Greece and the Aegean, satellite image with eastern Macedonia highlighted (source: www.greeklandscapes.com)


Figure 2.2 Eastern Macedonia, Greece, landscape features (source: Google Earth)

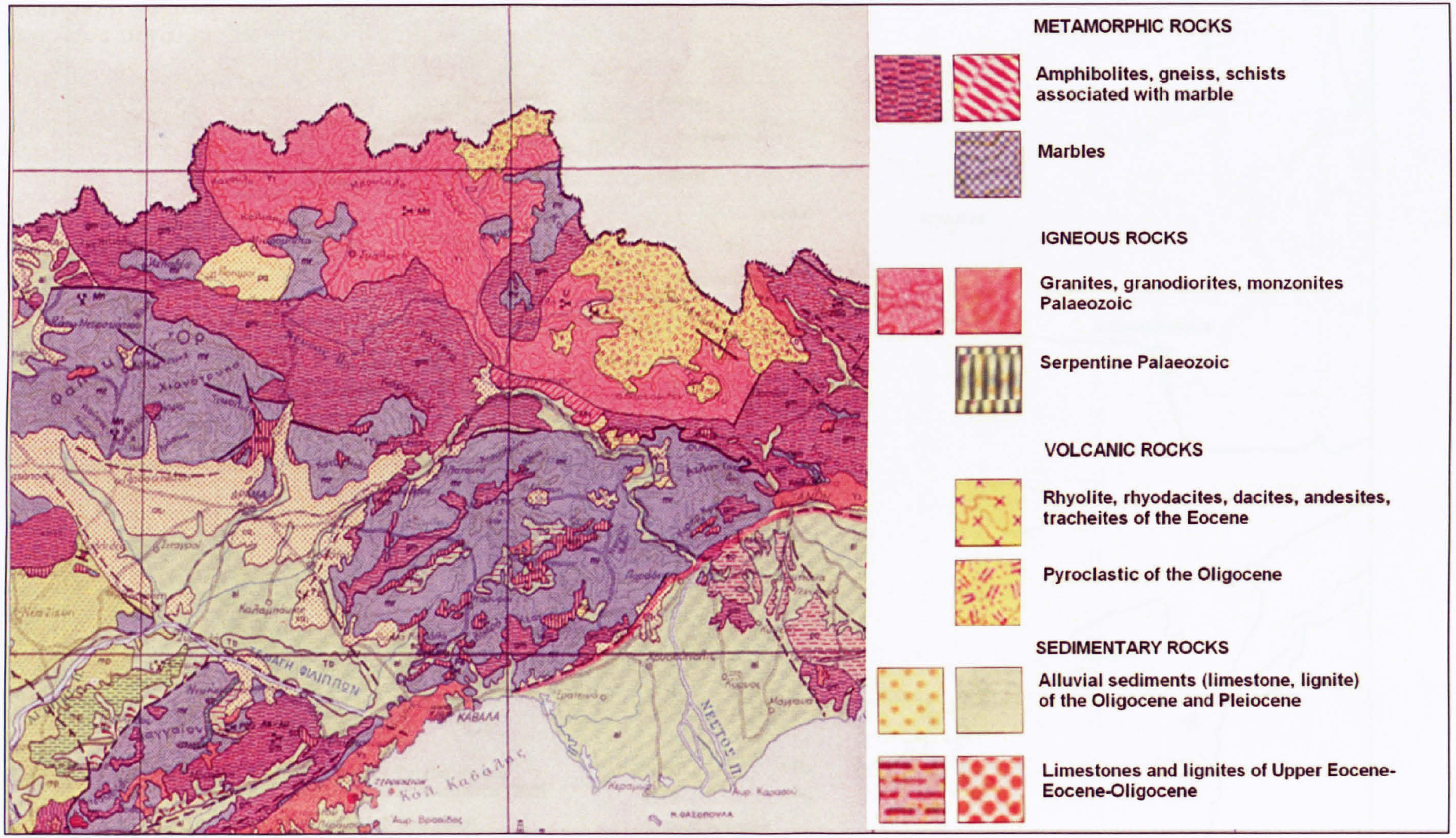



Figure 2.3 Eastern Macedonia, geological features (after Epitropou 2004)

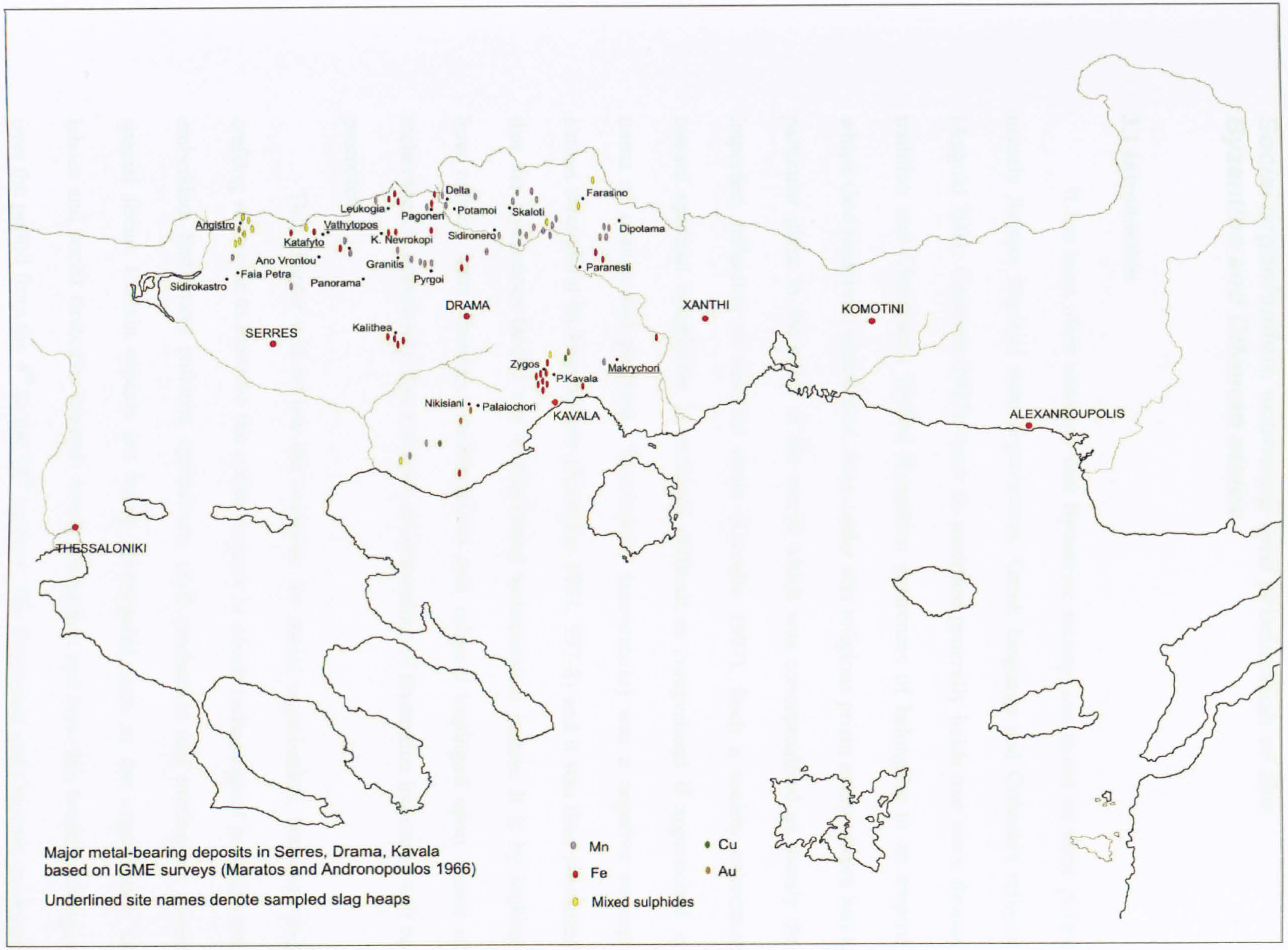



Figure 2.4 Mineral deposits in eastern Macedonia

## *CHAPTER 3*

# *Social organisation, economy and production of the Byzantine and Ottoman states*

### 3.1 Introduction

It has been often assumed that Byzantine society was based on three pillars namely Roman imperial state organization, Greek language and Orthodox religion (Angold 2001; Cameron 2007). Such an assertion generally holds true since Roman tradition and Christianity fuelled Byzantine awareness of belonging to an empire, which God preserved undefeated. Seen under this religious prism every citizen had a particular place in the order of the world which was conceptualised as merely the imperfect reflection of celestial order (Cavallo 1997). Such a society orientated toward spiritual completion is certainly difficult to comprehend if approached in terms of change and progress. 'Innovation' (*καινοτομία*) was a negative concept almost throughout its long history (Kazhdan 1991, 997-8) and it was thus presumed that the Byzantines lacked any sophisticated technological means. It is by looking how official state ideology, traditionalism and religion impinged upon issues of technological complexity that a deeper understanding of Byzantine industries will be promoted.

This chapter will review the evidence for social organisation, economy and crafting strategies to examine the social context in which technological practices are embedded. Settlement patterns, agriculture, craft production and mining are given special focus. Certain aspects are being investigated such as the organisation of labour and social strategies towards metal production and how this broadly changes over the period from the $4^{th}$ to the $18^{th}$ century. The Byzantine and Ottoman evidence for organization strategies is compared with a wide range of relevant examples from European contexts where extensive research has produced a wealth of information.

### 3.2 Byzantine social organisation

The fundamental elements of Byzantine state ideology could be epitomized in notions of eternity, unity, universality and ecumenical identity of the Empire (Cameron 1993; Turner 1998). When in AD 330 Constantine the Great founded the centre of a Christianised, Latin and later Greek speaking state on the ruins of ancient Byzantium he symbolically established an ecumenical empire in the grace of God destined to rule perpetually. The rhetoric of power negotiation was profoundly rooted in notions of supremacy springing from divine, fatherly providence and thus the new social structure was dominated by a crucial image of the father-state (Ahrweiler 2000). Such symbolic imagery underlines the state-church equation, forming a strong dyad of power which expressed political control under incontestable religious sanctification.

The new political scheme that soon engulfed vast territories of the Balkans and the Near East is often seen as an inheritor of a long tradition in economic practice, exchange systems and craft production, which developed within the eastern Mediterranean basin since Classical and Roman times (Angold 2001; Guillou 1994). However certain technical and ideological aspects apparent in literary tradition, crafting manuals and iconography clearly differentiate antique from medieval systems of manufacture and economic behaviour. Furthermore continuities of technical traditions have lately been considered with caution given the highly innovative nature in the daily performance of certain manufacturing processes. Tradition is continued every time an action is repeated but by definition each act is unique and hence changes that certain tradition (Lemonnier 1986; 1992; Dobres 2000). Interestingly the middle ages in western Europe heralded a break in Greco-Roman and oriental notions of harmony between human and nature through a process of assigning dignity and spiritual value to labour. Medieval monastic orders identified labour with worship, so lucidly summarised in the phrase '*laborare est orare*' (Oikonomaki-Papadopoulou 2005). And yet as the western European states promoted innovative technology from an integrated theoretical and practical stance the Byzantine east ostentatiously ignored changes and relied on traditionally established technical systems.

### 3.2.1 Political organisation, religion and approaches to crafting and labour

The most important concept in respect to non-economic behaviour apparent in Byzantine society owes a great deal to Christian thinking. As underlined by Laiou (2002, 1124) the Christian negotiation of worldly riches, which places a high value on behaviour that is irrational in economic terms but rational in spiritual terms and in the divine economy is a recurrent theme in Byzantine literature. The lack of treatises on purely economic practice could be explained by the marked difference between ideology and economic thought. Thus ideological posturing tended to be deliberately more conservative than practice, as derivative from positions regarding the material life. Saints lives and patristic writings underline the Orthodox position toward economic and productive activity, where agriculture is perceived as a safe activity so long as the poor peasant's labour is concerned. On the other hand the landowners who exploit the peasant and make profit are castigated. In a generalised system of thinking with the above elements all behaviour that seeks reward through material means appears risky; the major spiritual danger lurking as a temptation to commit the sins of *philargyria* and *pleonexia* (avarice and greed) (Laiou 2002, 1125).

The integration of Orthodox religion upon all aspects of every day Byzantine life heavily influenced the social perception of technology and that was reflected upon all strands of crafting either in isolation or under the guild system. As Yannaras (1984, 231) pointed out 'the ontological content of the eucharist– eucharistic communion as a mode of existence– assumes that the communal reality of life has a cosmological dimension: it presupposes matter and the use of matter, which is to say *art,* as the creative transformation of matter into a fact of relationship and communion.' In other words technical knowledge had predominantly been applied so as to serve the supreme goal of expressing communal religious sentiments. The worship of the Church is art: it is the work of a *communal* use of material reality, building and shaping the earth's material so as to render it capable of serving life, that existential fullness of life which is communion and relationship (Yannaras 1984, 231).

Although every day life and craft production is rarely depicted in Byzantine iconography there are some examples of ploughing, harvesting, working in vineyards as well as temple building and carpentry activities. The laborious process of metalworking has been emphasised in few instances mainly on Byzantine curved ivory boxes. There are two striking examples of late 10th to early 11th century ivory boxes depicting Adam and Eve involved in a forging operation (Papanikola-Bakirtzis 2002). Both depictions show Adam who holds an iron rod, using tongs, which he hammers on an anvil while Eve is operating the bellows to direct a blast of air into the hearth (figures 3.1 and 3.2).

Such depictions are part of a larger corpus of evidence such as wall paintings, icons, wood and ivory curved objects, which seem to emphasise the everyday struggles Adam and Eve had to endure such as ploughing, weaving or building. Given their first state of living in constant joy there appears to be a rather nostalgic element for the loss of paradise when at the same time common Byzantine activities are illustrated through the use of biblical figures. It seems that such imagery underlines the seriousness and moral weight of tasting the fruit of knowledge for which the first couple on earth had been condemned to hard labour. Metalworking is thus seen as part of undesirable, laborious activity, a 'necessary evil' or even a punishment for those who have faltered, while such depictions inform us on the socially constructed viewpoint for technical operations as well as the division of labour and the role of women in metalworking activities during the Byzantine period. Further the mining decrees included in the Codex Theodosianus clearly refer to work in the mines as a punishment for criminals and prisoners of war. As Vryonis (1962, 2) has stressed "to condemn someone to the mines, in *metallum damnare* or in Byzantine language, *μεταλλίζειν* was probably the worst punishment in Roman law next to that of death".

Drawing specific attention to the Byzantine worldview on matters of labour we can observe the socially-imposed identity of the craftsmen engaged in the productive sector. The scarcity of technical treatises in Byzantium overtly outnumbered by patristic writings and saint's lives serving indoctrination practices, springs out from a socially constructed stance that technology as a dehumanising force, radically materialistic is bound to corrupt the spiritualist and religious development of man (Norris-Clarke 1962) and seems to build on classical ideas of technology as bad for the body and soul.

Continuity of such ideas originating in classical antiquity has been emphasised by Turner (1997) who describes Byzantine culture resulting from a culminating process of the East Mediterranean Synthesis. The Roman citizens of the eastern part of the empire came from a Hellenic or Hellenised society blended with Semitic ideas whose enduring beliefs on labour were incorporated into Byzantine culture. Most classical writers emphasise their disrespect to craftsmen which are often described as *banausoi* whilst the general attitude to work and labour is one of mistrust and alienation. Hesiod's narrative is haunted by humanity's degrading status from a golden race of immortals to one of workers and labourers in his *Works and Days*, which revolves around the idea that labour is the universal lot of Man (Tandy and Neal 1996). Likewise Plutarch (AD 46-120) in his *Parallel Lives* refers to the simple minds of craftsmen incapable for any intellectual endeavours whilst Christian writer Procopius of Caesarea (AD 500-565) in his De Aedificiis describes the low status of masons (Duff 2002; Cameron 1985). Eventually the universal image of lame Hephaestus carried strong connotations about the corruptive nature of metalworking that was transmitted into Christian ideology.

It is important to note in that respect that parable, myth, folklore and partly religious scholarship have drawn attention to the contaminating effect of technology over the natural world which contributed at demonising mining and metallurgical practice in particular. According to Jakob Grimm: "our lord of the underworld rules under many names -Satan, Loki, Mammon, Mulciber, Hephaestus, etc.; and his workers are the gnomes, trolls, kobolds, the dwarfs and other grimy, hard-working creatures" (Nibley 1994). For the classical writers, Spain was his kingdom, with its blighted regions of mines, smelters and foundries- all worked by starving, driven slaves, converting the landscape into barren wastes of slag and stunted vegetation (Nibley 1994). The model is plainly taken from the vast mining regions of medieval Europe which left behind depleted forests, large volumes of debris and impoverished labourers.

A congruence of classical ideas on the low status of craftsmen and Christian thinking about potentially contaminating practice categorized technical knowledge to be identified with vulgar and profane activity, described as banausic arts (brutal) which should at all instances be reined in to accommodate sustaining goals (i.e. civil infrastructure). Such theological explanations on matters of pureness of the natural world and its transformation through contaminating technology had profound influence on the identity of Byzantine workers. Blacksmiths, miners or smelters were seen as members of inferior social groups or *fringe* communities often secluded from established value systems.

Non-economic behaviour and debasement of labour characterising Byzantine society stand in opposition to the enlightenment and the scientific discoveries accompanying that and the process of industrialisations. The reformist ideas of the humanists which paved the way for the scientific revolution of the $17^{th}$ century brought about a new understanding about nature albeit within a real process of fundamental change (Henry 1997). This western philosophical tradition based on notions of progress and economic expansion so greatly at odds with the thought-world of Byzantium constitutes an opposed field of understanding social identities. As Morris (1995) has stressed the apparent 'incompatibility' of approaches does not only involve a style of thought based upon an ontological and epistemological distinction between East and West but rather "a western style for dominating, restructuring and having authority over the Orient" as has been shown by Said (1979). Yet treating human myths and the irrational so profoundly present in socio-economics for any cultural context as essential parts of human history could contribute to a holistic understanding of status-induced social divisions and the structuring of identities.

### 3.3 Ottoman society

The Ottomans would come to represent the last great universal empire of the eastern Mediterranean. After the capturing of Constantinople in AD 1453 and the gradual consolidation of power the Sultan overlords considered themselves legitimate heirs to the Byzantine legacy. Social organisation of the Ottoman state followed near eastern Islamic prototypes linked to revenue generating economic strategies (Inalcik 1973). For an appraisal of how technology is deeply rooted in social action it is interesting to note the origin myth of the major Turkish tribes. According to tradition they were a people who were hemmed in by mountains and the only way they could escape, and colonise other areas was to 'mine' their way out of the mountains. In doing so they allege it was they who first discovered iron (Gibbons 1916; Wittek 1938). This mythical account underlines both their expansive nature and interest in exploiting natural resources but also underlines the nature of their collective identity. The strategy of military conquest against infidels was legitimised by Islamic religious concepts such as the ideal of Gazâ (Holy War) against Christianity. In the early 14$^{th}$ 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 16$^{th}$ century it formed a mature imperial structure with its traditions of statecraft, administration, financial policies, land systems and military organisation fully developed (Inalcik 1973).

#### 3.3.1 Political organisation, ideology and resource perception

Ottoman administration based on bureaucratic traditions was implemented with the application of registration, and accounting systems aimed at increasing the

Treasury revenue. Such political concepts were common in the Abbasid caliphate and the Turco-Mongol principalities where issues of justice by means of protection of the subjects were elaborated (Inalcik 1973). 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 laws, customs and institutions of conquered territory, hoping to avoid social unrests. 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 (Inalcik and Quataert 1994). Such conditions favoured an increase in production and consumption systems and caused a boom in the metallurgical industries associated with the widespread use of hydraulic power in the smelting furnaces and forges. 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).

### 3.4 Settlement patterns of the Byzantine and Ottoman periods

In order to understand the organization of production and its articulation through procurement, direct and indirect manufacturing sectors, central and peripheral units and consumption patterns through local or regional networks of trade it is essential to study the rural and urban contexts throughout the Byzantine and Ottoman periods and focus on any inherent interactions among them. Villages, estates, provincial towns and large cities, fortresses, castles and road networks compile a mosaic of the built environment or a landscape of social interaction, which should be considered.

### 3.4.1 Early Byzantine Period (4th-7th c.)

The *synekdemon* compiled by Hierokles at the dawn of the Slavic invasions recorded 935 cities excluding those in Italy and North Africa (Moutsopoulos 1997), while Mango (1980, 77) estimated a total of 1,500 Byzantine urban centres during the reign of Justinian I (527-565). In most cases elements of ancient cities such as public buildings, an agora, aqueducts, cisterns, public baths and storage facilities for grain produce reoccurred, though planning was not strictly geometric following the Roman prototypes. The turmoil that started in the late 6th and continued for most of the 7th century had profound consequences on the evolution of urban environments and economy of the Byzantine state.

Justinian I (527-565) launched a large scale programme of defensive building activity since the northern borders were under increasing pressure. The defensive architectural campaign included strengthening the existing walls with towers at intervals and strongly defended gateways as well as the creation of shelters (refugia) and defended villages (vici murati) (Moutsopoulos 1997). By AD 586 onwards as the devastating Slavic attacks were on the increase up to the early 7th century new types of defended settlements evolved such as castella and oppida. As Dagron (2002, 349) has summarized Byzantine towns were the result of large rural agglomerations, which had been fortified early in their history, and in which basic cottage industries developed.

### 3.4.2 Middle Byzantine Period (7th-13th c.)

During the 7th century Slavic tribes gradually captured the central Balkan territories while Persian invasions in Asia Minor triggered the counteroffensive by Herakleios (624-630) resulting in the collapse of the Persian Empire (Dagron 2002). The effect of constant warfare caused a dramatic demographic decline in Constantinople where population dropped from 500,000 to around 40,000-50,000. As outlined by Dagron (2002, 398) 'during this long crisis many cities disappeared; the geographic distribution of urban centres changed; towns became ruralized and their functions changed'.

The 8th and 9th centuries witnessed a large scale rebuilding activity following the raids and numerous old cities regained their former urban character. Smaller urban configurations in Macedonia such as Philippoi, Kitros, Serres, Zihna, Drama and Veroia became trading centres (Moutsopoulos 1997). The rebirth of cities led to a reawakening of trade in agricultural produce (grapes, wine, cereals) and Thessaloniki became an important centre with a vibrant market. The main crops cultivated were grapes, cereals, vegetables, flax, hemp and cotton. Silk and woollen textiles as well as raw materials for glassmaking and metalworking such as iron, copper, tin and lead were among the products of exchange. The field reconnaissance discussed in chapter five has been designed to characterise such activity by means of recording the scale and diversity of operations represented throughout eastern Macedonia in relation to corresponding subsistence strategies. In this way the mechanisms driving production, trading and consumption of metals and how the industry was sustained by other groups could be approached in their broader social and cultural dimensions.

### 3.4.3 Late Byzantine Period ($13^{th}$-$15^{th}$ c.)

For the period between 1204 and 1261 Frankish Rule was imposed upon most of the southern provinces on the Greek mainland and the Aegean and Ionian Islands. Genoese and Venetian merchants and entrepreneurs were increasingly coordinating trade whilst Constantinople lost its significance as a centre for transactions between east and west (Angold 1975; 1984; Browning 1980). Even after the restoration of Byzantine rule later in the $13^{th}$ century the turmoil did not cease, as new economic powers emerged in Western Europe. The Byzantine cottage industries were facing an endemic crisis while a 'feudal' system of administration was finally settled (Chrysostomides 1970; Harvey 1989). It should be noted here that feudalism is a term applicable only to western society and it is only used here to denote similar reciprocal and contractual relationships between rulers and subjects apparent in Late Byzantine society (Lefort 1993).

Old ideas of constant decline modelled a dramatic representation of Byzantine rural life explicitly along the lines of a feudal system. For instance it has been argued that the free rural communities that enforced the agrarian economy of the $7^{th}$ and $8^{th}$ centuries already in decline by the $11^{th}$ had become dependent on estate holders (Ostrogorsky 1968). Peasants lost their rights on land property and became serfs (*paroikoi*) through a process that lasted until the fall of the capital to the Ottomans. But as Lefort (1993) has aptly remarked, in Byzantium the term paroikoi comes in generalised use from the $11^{th}$ century to include both owners and tenants and has a different connotation than dependent serfs. The paroikoi were almost always owners of high-yield parcels (vineyards, gardens) and often tenants of their fields and the uncultivated area (Lefort 1993, 112).

The progressing economic turmoil of the 13th century had significant impact on transactions as well as the organisation of the administrative system. The rapid accumulation of land into the hands of entrepreneurs transformed Byzantine landscape into a highly fragmented patchwork of estates and counties. As Theocharidis (1954) has noted such changes were well under way by the time of the Komnenoi starting with Alexios I (1081-1118) and followed by his successors John II (1118-1114) and Manuel I (1114-1180). The large military-administrative divisions known as *themata* (θέματα) were further subdivided into smaller counties that became known as *katepanikia* (the word deriving from *kat' epano* denoting administrative authority).

The Byzantine administrative territory of Macedonia (figure 3.3) and in particular the *thema* of Thessaloniki and Serres, bounded by Axios and Nestos rivers, are thoroughly described in a large corpus of documents from the Mount Athos monastic archives (Theocharidis 1954; Lemerle *et al* 1979). Agriculture is listed as the economic basis supplemented by stock breeding in rural areas and craft production in urban centres. The *thema* of Serres was divided into five *katepanikia*, that of Zavaltia (or Parastrymono), Popolia, Zihna, Serres and Christoupolis which provided raw materials for the urban industries. The neighbouring *thema* of Zagoria to the north incorporated large regions of today's Serres and Drama prefectures where local iron industries were established at Angistro and the northern Vrontou uplands (figure 3.4).

In AD 1331 Stefan Dušan ascended to the Serbian throne whilst an internal crisis in Byzantium led to a dichotomy of power expressed by two rulers, Ioannis V Palaeologos and Ioannis VI Kantakouzenos whose progressing conflict took dimensions of civil warfare (Mango 1980; Moutsopoulos 1997). The two rulers in search for military allies turned to Serbs, Bulgarians and Turks, which instead captured large territories in Macedonia and subsequently Epirus and Thessaly. Stefan Dušan after capturing most of Macedonia and Epirus confiscated all ecclesiastical estates that were eventually given to Serbian military officials (Ostrogorsky 1965). This short-lived independent state started disintegrating after his death in AD 1355 but Slavic presence in Macedonia persisted in the Strymon region where mixed populations of Greeks and Serbs inhabited Serres, Zihna and Christoupolis (Kavala). Whilst the raids of Bulgarians and Serbs especially under Dušan and several peaceful immigrations created favourable conditions for Slavic settlement in Macedonia, the first Ottoman Turks invaded eastern Thrace in AD 1354.

Medieval Serres represents the most significant Byzantine urban settlement close to the production sites studied here. During the $12^{th}$ c. it was a flourishing provincial town with a vibrant workshop producing high quality glazed pottery and during the Palaeologan period it developed into a powerful economic and social centre, owing to the fertile plain on which it stood (Bakirtzis 1996). Serres survived the dynastic strife of the $14^{th}$ century, the period of Serbian rule between AD 1345 and AD 1371 and the Ottoman conquest of AD 1383. Archaeological evidence testifies to changes in production modes following centralized models after the arrival and spread of the Ottomans in the region.

The changes in the demographic makeup of populations in Macedonia brought about cultural interactions often characterized by strong elements of ethnic self-awareness (Vakalopoulos 1973; 1996). Opposition against language changes or religious conversions preserved the distinctiveness of the various ethnic backgrounds but numerous cultural traits were constantly being exchanged often at a subconscious level. Technical knowledge expressed as practical operations, sequential acts for the manufacture of artefacts, recipes, ideas were some of the cultural traits exchanged between natives and newcomers.

### 3.4.4 Ottoman Period (15$^{th}$- 19$^{th}$ c.)

Three major cities of the Ottoman Empire, namely Istanbul, Bursa and Edirne constituted significant cultural and trading centres with increased population and vibrant social activity. An essential part of the Ottoman urban environment was the *imâret*, a complex of institutions of charitable nature including a mosque, medrese, hospital and hostel, and institutions which provided revenue for their upkeep such as an inn, market, caravanserai, bath house, mill, dye-house and the like. The *bedestan*, a covered market for the sale of valuable goods was an important transactions centre serving also to protect the money and jewellery of the wealthy. Important trade centres grew up around *bedestans* in all major Ottoman towns in the Balkans such as Tatar Pazarjik, Plovdiv, Sarajevo, Sofia, Skopje, Monastir, Serres and Thessaloniki (Inalcik 1973; Faroquhi 1999). Greek Orthodox, Armenian and Jewish communities, present in most towns contributed to their economic life as guild members, craftsmen and merchants.

The empire's various production areas were linked to a single centre as in any integrated economy, a practice that sprung out from the need to provide food for the capital's thriving population (Inalcik and Quataert 1994). To support such a system an infrastructure of road networks and ports was developed to connect Istanbul with the Balkans through the ancient Via Egnatia, the military road through Belgrade, Sofia and Plovdiv and the road from the Danube region through the Tundza valley and Edirne. Establishment of caravanserais at strategic stations on the way of these routes facilitated transactions in addition to serving administrative functions as the seats of government viziers (Barkan 1956; Faroquhi 1999).

Following ancient near eastern prototypes, Ottoman society was stratified recognising farmers, merchants and craftsmen as the three productive classes. Further division between Muslim and non-Muslim populations was imposed as a classification scheme by the palace, but as Inalcik (1973, 151) noted it did not correspond to the real social and economic divisions in society. Craftsmen and merchants of either Christian or Muslim persuasion belonged to the same class and enjoyed the same rights (Baer 1970; Fine 1994). Relevant information on the privileges enjoyed by Greek miners and descriptions of their social status in Ottoman society has been included in contemporary document and the work of scholars in the 19th and 20th centuries. Such cases represent unique opportunities to approach the task of entangling the socio-technical dimensions of the metals industry in regions under study.

### 3.5 Agricultural production: foundations of economy (7th-15th centuries)

Through the 7th and for most of the 8th centuries Byzantium faced a full-blown demographic, political and economic crisis. The plague of the mid. 6th century caused dramatic effects on demography a fact which has been suggested as a competent reason for the military losses in the Balkan and Asia Minor frontiers (Harvey 1989). In regards to economy, the scarcity of labour in the countryside resulted in a decline in production, which in turn caused a disruption in exchange and a breakdown of communication networks. Laiou (2002) underlined three major points that summarise the features of Byzantine economy from the 7th through the early 9th centuries. The first is the significance of the state's administration and the measures taken to overcome the harsh economic conditions of the time. Towards this direction the shortage of labour was mitigated by the increased role of hereditary lease contracts. In this way part of the state's surplus was redistributed in form of salaries through a system facilitating monetization in the countryside (Oikonomides 2002). Such measures including the reintroduction of silver into coinage were signs of economic recovery and the simplification of the copper coinage in the following centuries afforded flexibility to the monetary system (Laiou 2002, 1146).

The second point regards the duality of administrative control which was not monopolised by the state, but was exercised by entrepreneurs as well. In regards to important commodities such as grain and silk some form of combined action from the state and individual entrepreneurship was common (Dagron 2002). The third point is a matter of scale. A diminishing in the size of cities and ports and a retraction of trade made all economic transactions, investments and profits of a small scale. The gradual revival of the cities, the reorganization of the fiscal system after AD 820 and the expansion of monetary circulation have proven that the restructuring of the economy was overall successful (Laiou 2002, 1147) at least in terms of diffusion of coinage across rural areas.

A substantial population increase and the associated expansion of cultivated areas, the revival of cities and rise in production are all determinant factors for the growing of Byzantine economy during the 9$^{th}$ and 10$^{th}$ centuries. As noted by Laiou (2002, 1148) the economic system had by that time acquired an outward aspect of equilibrium. Agriculture was in the hands of free peasants organised in villages while the state drew resources in form of taxation from the peasants. Under such conditions peasants were protected as the state prevented the expansion of large estates. The minting of gold and sustaining of its circulation through the payment of peasant taxes and salaries for the bureaucracy were crucial for keeping the economy in equilibrium (Morrisson 2002). The deterrence of rapid growth was only partially succeeded through legislation, aimed at preventing the accumulation of land in the hands of private individuals. Eventually such growth came in the 11th-12th c. for a number of reasons. Firstly the sales of land parcels to wealthy individuals helped accumulation of property. Secondly as growth continued and peasants obtained wealth, the whole agrarian system responded to conditions created by opportunities for profit. The general prosperity and opening of the western European markets created new conditions to which the Byzantine economy responded with great adaptability (Laiou 2002, 1150).

The 11th and 12th centuries witnessed a phase of population growth, greater urbanization, and increased production of items for a middle-level market as well as for mass consumption. The frequent appearance of the water mill and the development of new crops (i.e. cotton) supported expansion in previously uncultivated areas. Land improvement was practised by peasants and landlords of the estate sector which expanded rapidly. To follow these changes the fiscal system was adjusted from the previous taxation of village communities to taxing the wealth of individuals. Such a strategy fragmented community concerns and introduced a new set of relations amongst villagers. Estate owners, public officials and Italian merchants gained privileges, a fact that had negative results for the state in the long run, but in general the system facilitated the circulation of money (Oikonomides 2002). In regards to manufacturing an increase in demand led to commercialisation of production that was taking place in urban centres like Corinth, Thebes and Turnovo. At the same time trade revived, strengthened by ideological tendencies that gave positive value to profit. The activities of merchants and bankers until previously based in the Capital, extended into the provinces and international markets. However as trade influenced the pattern of production, it had sufficient impact on agriculture and hence diminishing returns to labour. In the later centuries of Byzantium it is plausible to hypothesise that livestock assumed a larger role and thus agriculture ceased to be a full time activity (Kazhdan 1997, 57). The great landowners produced grain, eggs, meat and hides for foreign markets.

The political fragmentation of the early 13th century (1204-1261) left a number of rival 'states' competing for succession through a process that caused severe economic disarticulation. In fact it is the period of emerging regional economies, which meant decentralisation of the monetary system, lack of unified fiscality and no market under the state's protection. The dominant role of foreign commercial powers such as Venice and Genoa led to a decline of Byzantine industries although pottery production expanded at Thessaloniki, Pergamon, Serres and Nicaea. As stressed by Laiou (2002, 1159) in terms of organization of production the large estate increasingly provides the framework, while the participation of merchants in long distance trade as partners of the Italians resulted in heavy export of bulk products. Although foreign merchants dominate, the Byzantine local trader serving the needs of local and regional markets plays an important role (Matschke 2002). Described under the framework of the core-periphery model of uneven development, the concentration of manufacturing at the Italian states left Byzantium to the agricultural periphery.

After the 1340s and for the last hundred years a combination of wars, the impoverishment of the peasantry and the Ottoman expansion had catastrophic effects on population, agriculture and the economy. It was a time when resources were concentrated in the hands of a few rich individuals and some monasteries. The accumulation of capital was increasingly invested in foreign institutions leaving the impoverished state unable to avoid the outcome of military and economic subjugation.

### 3.6 Byzantine craft production

Certain professional institutions generally known as guilds implemented organization of production among Byzantine urban centres. Craftsmen and traders organised in guilds were responsible for electing their representatives, regulating the standards of their profession, and encouraging social events. In such a way the state through its urban officials, exercised supervision of the craftsmen via the corporations into which they were organised (Guillou 1994; Vryonis 1967). Vryonis (1967, 97) argues that the guilds of Byzantium 'directly descended from the Greco-Roman world, had a limited membership and many of their members managed to accumulate considerable wealth and achieved social prominence'. By the later years of the Macedonian dynasty most guilds were playing a similar role as had circus factions (*venetoi, prasinoi*) in the political life of the Empire. The most famous craftworks were luxury goods, often intended for diplomatic gift exchange, that were produced by the imperial goldsmiths and silk weavers within the palatial workshops. According to Vryonis (1967) industry appears to have been significant not only in the Capital but across provinces as well, where the raw materials were conveniently at hand. The mines of the Chalkidiki, Euboea, Lavrion and Anatolia yielded the essential metals, stone and alum (Vryonis 1967, 97).

The agrarian economy supported by state regulations that also promoted exchange of goods in markets was supplemented by small scale production, limited trade and eventual consumption of daily use articles such as pottery, metal utensils or agricultural tools and implements. Such a system was quite different than the highly specialized urban guild system but represented the core of the agriculturally based economic structure of Byzantium. Economy in provincial territories was based mainly on agricultural produce and animal husbandry as well as the acquisition and trading of raw materials and up to the 7th century, craft production was restricted among rural communities (Laiou 2002). The study of surnames from Byzantine villages denotes the rare presence of craftsmen (carpenters, lumberjacks, blacksmiths) among peasants after the 7th century. During the following centuries more workshops were being established in rural contexts so that in the 12th century peasants with names of trades reached 8-10% of the total population in Macedonia (Lefort 2002, 309).

The organization of craft production largely depended on geographical distribution of raw materials, access to technical knowledge (family based concern-father to son), exchange networks and consumption patterns. Max Weber (1978) describes three major levels of artisanal activity for the middle Byzantine period. The basic level can be defined as the 'demiurgical' activity, a village concentrated, rarely specialized, household economy. An intermediate level includes the production of items for sale, which presupposed a certain degree of technical specialization and a local market. The third level even though not being of an industrial scale, exceeds local demand while products are forwarded by merchants rather than producers. Such an approach stresses that in rural areas most activity of craft production was oriented towards self-sufficiency, with no intent of creating markets.

Turning to archaeological evidence mainly in the form of representative material culture found in abundance such as pottery, various methodological issues have to be explored. As Vroom (2003) has summarised medieval and post-medieval pottery found in Greece has been scarcely studied, as until quite recently post-Roman ceramics were being removed quickly during excavations in view of getting to precious remains of the antique and prehistoric past. This imbalance in studies of pottery from the Greek past has started to be countered during the last two decades as recent field surveys and excavations (Sanders 1995; Bintliff *et al* 2008; Snodgrass 1992) have opened up this vast period as a legitimate field of study (Vroom 2003, 25).

Ceramic production of the Early Byzantine period exhibits a wide range of coarsewares such as cooking pots, bowls, domed or saucer-shaped lids, *mortaria*, jars, jugs, cups candlesticks, flasks, amphorae and others (Dark 2001). The fine wares of the 5$^{th}$ to 7$^{th}$ centuries consist of unglazed painted vessels and unglazed red-painted slipped wares. It appears possible that the standardised range of such wares could account for production patterns such as the model of a small number of large-scale industries as has been suggested (Sanders 1995; Dark 2001).

Through the Middle Byzantine period production is characterized by an increasing use of glazed pottery that was already in use from Late Roman times (Sanders 1995). The glazed pottery that became the standard fine-ware of the period was the whiteware (CWW) decorated with painted, incised or stamped designs and most was produced in or near Constantinople and traded to Thessaloniki, Thasos, Samothrace, Melos, Iznik (Nicaea) and Thrace (Dark 2001).

Pottery workshops of the late 12$^{th}$ and 13$^{th}$ centuries investigated at Thessaloniki, Serres and Mikro Pisto near Komotini seem to share a common practice of producing high quality sgrafitto and other types of glazed ceramics and follow a unique pottery tradition (Papanikola-Bakirtzis 1992; Armstrong *et al* 1997; Dark 2001). From the late 13$^{th}$ century a workshop producing glazed pottery operated in Thessaloniki. Its wares have been identified in other parts of Macedonia, and also in Bulgaria, Constantinople and Venice. The vessels from this workshop are mainly small bowls with sole decoration an incised bird pecking a leaf, under the characteristic yellow glaze. The pottery workshop located at Serres operated from the second half of the 13th century and produced vases for export (Papanikola-Bakirtzis 1992; 1994). The typical glazing at Serres and Mikro Pisto is creamy white with green and yellow glaze and decorative motifs consist of geometric patterns, animal-bird figures and occasional scenes depicting humans. The network of exchange of high quality pottery appears to have been active on the line of the Via Egnatia axis between Constantinople and Thessaloniki.

### 3.7 Ottoman crafts, trade and associated state regulations

From the perspective of manufacturing the period from c. 1600 to the collapse of the Ottoman Empire in 1914 roughly divides into three parts. The first beginning around 1600 and ending in 1826 is marked by dwindling export of Ottoman industrial products. Between 1826 and 1870 a significant shrinkage of manufacturing centres led to the gradual destruction of industries. The final period spanning 1870-1914 shows an expansion of manufacturing output relatively and absolutely for domestic and export markets (Faroquhi *et al* 1994; Inalcik 1973; Inalcik and Quataert 1994).

Ottoman manufactures until the 1760s appeared successful at participating in international trade but mercantilist policies dominant in the Habsburg domains around 1770 and the succeeding internal disorder of the late 18th century drastically changed that picture. Raw materials began to play an ever-increasing part in Ottoman exports meanwhile local crafts continued to use traditional methods and therefore became vulnerable to foreign wares (Faroquhi *et al* 1994).

Faroquhi *et al* (1994) provided useful information on the state-crafting relations across regions that came under Ottoman administration. For instance 'just as Ottoman governments favoured and supported concentration of production under craft association controls, by the same token they discouraged production outside older production centres' (Faroquhi *et al* 1994, 697). Penalties could reach 200% fine, unlike tax evasion, which involved a 100% fine. Confiscation or destruction of equipment was common for merchants involved in international trade a fact that raises questions concerning how the Ottoman economy could have kept up with contemporary technological innovations (Pamuk 2000).

It has been argued that in some regions such as Thrace, eastern Macedonia and parts of Bulgaria that were incorporated in the Ottoman Empire at an early date, there was a tendency of hiding produce to avoid taxation. In some remote villages there were occasional attempts to hide new workshops, so as to escape the controls of the state and some craft association (Faroquhi *et al* 1994, 697). Identifying such activity and locating some of the areas involved is problematic but at present we can point to villages near Serres (cotton), Samakov (iron) and Tokat (silk or copper-work) as examples. But the fact that we can name these areas indicates that these were all too well known to escape government control (Pamuk 2000). Non-recorded craft production in the mountainous regions of northern Serres (Sidirokastro, Faia Petra, Vrontou), Drama (Nevrokopi, Vathytopos) and southern Bulgaria (Samakov, Tokat) might complicate the picture for iron smelting activities, which were possibly taking place without any significant state control regulations and are therefore absent from official registers.

### 3.8 Mineral extraction from the Late Roman to the Ottoman period

Two distinct modes of production have been applicable since late Roman times concerning mining activity. These could be described as large-scale operations managed by the state and smaller-scale private ones managed by landowners or more rarely by villagers who owned a communal village territory. As Edmondson (1989, 98) has noted "mining, where it was organized as a state-run district was divorced from the local economy in that mines were administered independently of the local city, while labour might be brought from far outside the mining area". On the other hand mining on a small scale was more integrated with the local agriculturally based economic pattern of a region. Landowners had the capital investment to exploit mineral resources on their estates or the right to mine in imperially owned land under contracts and also possessed a ready source of labour in their agricultural workers. This mode of production required less centralized control and economic support from Rome and gave landowners economic power by pursuing income from diverse resources throughout the annual cycle. Evidence for the existence of both state and privately owned mines comes from law codes such as the *praestatio auraria, aeraria* and *ferraria* levied from owners of metalliferous land (Edmondson 1989). State-owned mines became scarcer as the 5th century progressed and the preferred situation involved private individuals in the running of the larger mining regions.

As summarized by Edmondson (1989) mining in the later Roman Empire did not cease entirely but there was a general decline of large mining districts attributed to three major factors, mainly technological, socio-economic and socio-political. Exhaustion of over exploited ore bodies, severe problems in drainage, flooding of mines and the lack of supplies due to deforestation rendered mining technically inefficient in many regions. The limited capital investment dispensable for such undertakings coupled with the shortage in labour supplies are representative of the general economic predicament of the period. A final reason that accelerated the generalized decline in mining operations was insecurity and the inherent difficulties of defending mines which were often located in remote areas, and became easy targets for barbarian raids.

Demand in metals continued with the establishment of barbarian kingdoms in the west that searched for a legitimization of authority as inheritors of the Romans and continued to mint gold coins (Harris 2003). Gold coinage in Byzantium was widely circulating uninterrupted after the transferring of power to Constantinople. Further the royal courts, various elites and the church stimulated production of luxury objects in form of silver plate, gold jewelry and bronze work. As far as base metals are concerned there was a constant need for iron and lead for building materials, iron for arms, military equipment and agricultural tools (Vryonis 1962, Matschke 2002).

A dynamic economic strategy to counter the problems of shortage in metals outlined above would dictate a centralization of production in one region where a single infrastructure would suffice for the same mechanisms, facilities and technical expertise of a coordinated mining community. Such a strategy could also enhance the social control sought for by Byzantine authorities towards the labour force. Transfer of manpower to a mining zone from a recently conquered land or the usual workforce formed of condemned criminals functioned as an instrument of social control encouraged by the central authorities of the Capital. Within conditions of close control by state officials, the problem of security was often countered by the use of military force to secure labour force and facilities as well as to help avoid disruptions in production.

One significant change in socio-economic life apparent from the middle Byzantine period is the fixing of professions and trades among urban and rural contexts as implied in the Book of the Eparch (Pharr 1952). It is possible that non-slave miners were also included in the new scheme. Official permits from the state encouraged private individuals to engage in mining, a practice that is recorded in the Basilica in an extract concerning the private ownership of mines (Vryonis 1962). Undoubtedly the Gothic attacks and invasions caused confusion and instability across the Balkan Peninsula and reduced the output of the mines. However unlike the attacks in the former western provinces where mining was dramatically affected, mines in the Balkans seem to have continued operating, albeit with a smaller output, up to medieval times.

Rights on the ownership of land were in constant change and negotiation between the official state and the rural, peasant populations which were tied to the land. A substantial population rise apparent during the middle Byzantine period became the key issue leading to agricultural surpluses and ultimately wealth in a predominantly rural economy devoid of technical innovation. As Harvey (1989) has pointed out the surpluses extracted from the peasant producer by the state or by private landlords served to fund their demand for non-essential commodities and services thus stimulating various forms of industrial production. Regional variations in Byzantine production have lately been evaluated through focused regional surveys (Lefort 2002). Thus coastal zones were favoured for cereal crops, vines and olive groves and the interior of the Balkans (including Macedonia) and Asia Minor concentrated on stock raising and timber (Hendy 1985).

Within this system the landless peasants were often being installed on the estates of landlords who obtained privileges such as exemptions from fiscal obligations. At the same time the state did not lose in terms of collecting revenue by installing rent-paying peasants on imperial estates. However this highly localised power structure emergent through the 13th century fragmentation and the rise of peripheral forces posed proliferation to the central government. Through certain political initiatives and indirect control over land ownership we are left with a diffusion of wealth which eventually undermined the imperial regime as a source of patronage, eroding its administrative competence and ability to collect revenues (Shepherd 1993). Although the provinces became lucrative regions with small producers, traders and estate owners in direct interaction with each other they also became more intractable for the state to keep under control.

During the late stages of Byzantine power state-run mining became divorced from the local economy as the mines were administered independently while labour and skilled personnel were often imported as was the case with the Late Roman empire (Edmondson 1989; Knapp *et al* 1998). Fiscal documents describe the small-scale mining practiced during late Byzantine times that was closely associated with an agriculturally based economy. Nevertheless results derived from the field survey have revealed a different picture than this described in contemporary documents. The mining regions where confirmed Byzantine activity has been noted show a diversity of communal endeavours towards subsistence including mixed farming and herding strategies which are being discussed in chapter seven. Landowning farmers and monastic institutions were often the only people with the resources available to exploit mineral deposits. Alternatively rich estate holders were able to lease contracts to operate mining shafts in imperially owned mining districts. In such political conditions a conservative strategy with no margins for experimentation would appear ideal for optimising production to benefit the estate holders.

One crucial parameter that allowed for the quick Ottoman expansion to the Balkans has been a combination of economic wealth and superiority of armed forces (Pamuk 2000). 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 across the conquered territory (Murphey 1980; Lowry 1986).

The progressing Ottoman occupation in the Balkans caused political instability and a disruption of economic power relations. Within this context mining communities probably adopted a resiliency strategy which promoted innovative technology from experimentation to adapt to the given circumstances. A certain degree of labour division amongst them ensured running of the industry by extended families working together. Thus the appearance of the blast furnace in the wider Pangaeon region at Pravista and Avli 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 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.

One significant aspect that should not be overlooked in this context of Ottoman industrial policies regards the interrelatedness of mining for minerals with salt production. Most sources inform us that most state controlled enterprises were actually undertaken and managed by private contractors (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. Interestingly within such regulations the various salt production units operated under financial autonomy having to meet all expenses from their receipts but due to severe difficulties in communication this type of financial decentralization was followed in all state enterprises (Inalcik and Quataert 1994; Pamuk 2000). Based on the paradigm of salt works, the whole infrastructure for mining, mineral and fuel transportation, smelting stations and further transit of articles were managed through a decentralised network monitored by the state at certain levels. In terms of social relations and the status of salt workers within their local communities, according to written sources they shared the same conditions as the peasants registered as miners or rice growers.

### 3.9 Iron technology: The European Context

The treatment of metals technology by historians and archaeologists has been considerably variable across Europe. In some areas i.e. Germany, Sweden, Hungary and Italy it has been the focus of studies mainly because iron production has served a prominent position in their own identity today (Gordon and Reynolds 1986; Jockenhövel and Willms 1997). For Greece such information is limited since industry has often been considered as a negative aspect of modern life and did not attract the attention of scholars. Comparison of the evidence for metals technology across Europe with the study area is being attempted in this section to provide an insight to the diversity of practices represented in the archaeological and historical record. Iron technology and the various logistics involved are given special focus since the mainstay of activity across the study area is associated with iron metallurgy as described in chapters five and six.

Ancient operations for extracting iron from its ores involved smelting in furnaces through a process known as bloomery that produced a spongy mass of iron. Much of what is known and supposed about traditional ironworking is mainly the result of laboratory and field experiments as well as actual archaeological findings. The various details about the technology of iron is based on reference books by Tylecote (1987), Rostoker and Bronson (1990), Craddock (1995), Pleiner (2000) and articles by Killick (1992; 2004), Killick and Gordon (1988), Crew (1991; 2004) and others. Further the most recent examples of iron production by the bloomery process have been recorded by ethnographers in various African locations where this tradition survived until the early 1900s (Miller *et al* 2001; Rehren *et al* 2007). Since bloomery smelting has been a widely used technique for producing metallic iron in most pre-industrial societies the rich ethnographic record from Africa has been valuable for approaching similar extant European processes by use of analogy. The basic operational characteristics of an African bloomery shaft furnace appears strikingly similar to most European pre-industrial examples that have been excavated and this model is used to interpret the scanty evidence found during the current field survey in Macedonia (see chapter 5).

A thorough assessment of the Haya process in Buhaya, northwestern Tanzania described by Schmidt (1997) provides a suitable analogy to counter the lack of tangible and substantive evidence for a furnace from the study area. This ancient technique for producing metallic iron has been well documented and recorded through full scale re-enactment and since its material remains resemble those encountered across the studied sites it appears as a fitting model worthy of consideration. The sintering of iron within the bloom was successful by raising the temperature in the order of 1150°C achieved through the use of bellows to direct blasts of airflow into the furnace. After building the furnace with stones and fire resistant clay and preheating its interior, charging of the ore and charcoal fuel followed. Addition of fuel accompanied by constant operation of the bellows led to the progressing separation of slag that was tapped out from an opening at the bottom. Once the bloom has formed the furnace was broken to reveal the bloom that was then hammered to separate metallic iron from slag entrapped within its matrix (figure 3.5). During the process described in simple terms, slag was tapped out or formed at the furnace bottom and was usually discarded to form piles of debris near the smelting site.

The size of the produced bloom in the Roman period has been estimated at around 8 kg and through the Middle Ages the average bloom size increased to reach 14 kg by 1340 in Britain and without the use of water power (Tylecote 1976). Based on various examples from western European furnaces two basic types can be distinguished: the horizontally developed bowl furnace inspired by Roman prototypes and the vertically developed bowl furnace. A review of furnace characteristics based on archaeological examples across Europe reveals a diversity of forms partly due to the different nature of ores being used, the technology available and the socially structured ideas on smelting within the various regions. Thus the Catalan hearth, widespread in the Pyrenees, resulted from early medieval types from which the bloom was extracted from the top. Simple bowl furnaces were used by the Slavs and Finno-Ugrian tribes while the shaft furnace of the Roman period passing through remarkable transformations was adopted at places across the North-Sea from Saxony and Jutland to eastern England (Craddock 1995). The final elaborate examples of tall shaft furnaces come from Styria in form of the Stückofen type, a precursor form of the blast furnace but there is a lack of transitional types to testify continuity between them (Tylecote 1976). Unfortunately there is no robust evidence for furnace technology from Greek smelting sites apart from fragmentary examples and thus the development of types and forms could not be easily followed through time. Thus a synthesis of available data from across Europe is being discussed in this section in order to position the Macedonian findings in their broader context.

### 3.9.1 Minerals, charcoal and water: raw materials and power

The very nature of iron production either by the direct (bloomery) and later the indirect (blast) process partly defines the use of space, management of the working force and strategies employed for the division of labour while other important factors include the role of central authorities and landowners in the decision making process and establishment of production centres. The organization of working space at smelting sites of the Middle Ages has been influenced by various factors of topographic nature while at the same time technical parameters were considered. Previous studies have often stressed the choice of smelters to establish their installations at certain wooded landscapes, close to mining shafts. Although such practice might be expected among similar groups the evidence encountered across the study area shows a more complex picture whereby smelting workshops are more commonly found within ravines and streams often at some distance from mines. Such issues underline considerations of transport constraints, availability or negotiation for accessible resources, and the progressing use of water power.

The acquisition of dependable raw materials for considerable time periods has been a major issue the smelters had to face, and given the large scale production noted in eastern Macedonian sites those agents involved (smelters, landowners) must have had direct access to all necessary materials. Choosing a location for establishing a workshop that meets all appropriate criteria for efficient production was a crucial step. Mining and associated ore preparation involved laborious work that produced heavy raw ore in large quantities. Usually the extracted ore was sorted and crushed in the immediate vicinity of mines due to the unmanageable weight of accumulated material (Palmer and Neaverson 1998). Transporting of large volumes was costly and therefore smelters had to compromise and locate their smelting furnaces at considerably short distance to mines. Ore beneficiation and washing was an important step which followed initial crushing. Sufficient roasting stages and thorough washing were necessary to separate heavier metal-rich ore fragments from lighter earthly minerals and improve the ore quality. During that process even low grade ores were enhanced by separation and led to more efficient metal extraction.

Fuel was undoubtedly a vital component of the smelting cycle equally determinative of the strategic steps during planning and organization. The main type of fuel used for all the pyrotechnologies of the middle ages was charcoal produced from carbonised wood. Charcoal was needed for various daily activities mainly food preparation, heating, and more specialised ones like glassmaking and metallurgy. Charcoal deriving from oak of the Macedonian mountains was produced by a specialised and trained workforce that prepared timber in stacks and fired it in large bonfires (Papaggelos 2003a). The tradition of charcoal preparation survives today at mountainous villages in Chalkidiki and Lesvos to meet the local needs for fuel and for small scale exportation to larger towns. Deforestation was never a serious threat in the highland regions of Macedonia which even today are covered with a variety of vegetation including mixed deciduous pine, oak and juniper forests.

As Lefort (2002) has noted in terms of Byzantine forest management, the demand for timber and for fuel, wood, charcoal and pitch, together with stock raising and the peasant's own needs built up links between town, cultivated countryside and *incultum*. Forests and grasslands belonged to the state, to the owners of estates and by the 7$^{th}$ century to villagers. Oak played a predominant role, principally as timber while all trees were a source for fuel and poorer specimens were presumably used to make charcoal (Dunn 1996). Forests were used only partially although they seem to have been more heavily exploited by the 12th century onwards. Rights of usage in state woods were sometimes free although in most cases their exploitation was subject to charges, albeit indirectly through the medium of entrepreneurs or woodcutters (Lefort 2002). Presumably a part of forest produce such as timber, fuel and charcoal was traded everywhere, as were derived industrial products.

Since the microenvironments effective for smelting occurred in close proximity to the mines and forests which were finite resources, variation through time may be expected. Thus when an ore body became exhausted or a forest substantially diminished by over-exploitation smelters would have to shift to more favourable settings. The moving nature of mining communities is evident to varying degrees in artefact morphology and settlement patterns (Knapp *et al* 1998). Additionally the search for metallic minerals was often haphazard giving rise to a diversity of practices among mining communities. Capital investment has generally been more limited and so old methods survived for longer, sometimes alongside newer ones (Palmer and Neaverson 1998).

The earliest forms of power utilised in the context of prehistoric technologies have been generated by human and animal muscle which remained the major forces for lifting, pounding, grinding and similar applications before the introduction of engineering devices that exploited alternative forms of power. The first complex classical Greek, Roman and Chinese mechanical devises appeared in developmental stages roughly around the 6th century BC and were transmitted through exchange or war across Asia and Europe (Munro 2002). By late medieval times hydraulic engineering was rapidly spreading across Europe often stimulated by the introduction of Asian technological knowledge or the application of local inventions in modes of production (Usher 1959). As Tylecote (1976, 64) has aptly remarked, metallurgical units were based on limited capital resources whilst the exploitation of water power required considerable capital and therefore its use in metallurgy had to compete with its use in corn grinding and fulling. Since the latter were greater consumers of power than blowing they were given greater priority in most European examples. Within this shortage of private investments it seems that only monastic or Episcopal bodies had sufficient capital to invest in the iron industry and that large scale units appeared in the context of religious institutions.

Around 1098 the Cistercian reform movement of western Europe carried on the Benedictine tradition of promoting technology by founding water powered grain mills, cloth-fulling mills, cable-twisting machinery, iron forges and furnaces (where the wheels powered the bellows, figure 3.6) winepresses, breweries and glassworks (Gies and Gies 1994). The major role in iron production, with the use of hydraulic energy, played by Cistercian abbeys in France, Spain, England and Sweden could not be ignored. By the late 11$^{th}$ century, water power was pounding, lifting, grinding and pressing in locations from Spain to central Europe. Important applications include wire drawing and water pumping in mines but the most momentous came in smelting iron ore in the new blast furnace (Munro 2002). According to Gies and Gies (1994, 200) the Chinese water powered blast furnace evidently migrated as far west as Persia, but how early is unknown and further transmission is undocumented.

The Byzantine provinces have not been considered as industrially complex to have employed similar structures as the ones reported in western sources. However the basic mechanics for the construction of such devices have been known in Eastern Mediterranean since the 2$^{nd}$ century BC (figure 3.7). During late antiquity engineering reached high levels of sophistication for constructing efficient machines used for purposes other than grinding agricultural produce. Water mills though infrequent during the proto-Byzantine period, were already numerous by the 12th century, possibly already by the 10th (Lefort 2002). Further the use of wind and water power has been attested by numerous references to windmills and watermills in Macedonian ecclesiastical estates from the 13th century onwards (Actes De Xeropotamou: Bompaire 1964; Actes De Lavra: Lemerle *et al* 1979).

Within Byzantine territories conservative attitudes towards technical practice resulted in a lack of emphasis on technological innovation and thus modes of progress remained low. Reynolds (1983, 5) summarizes this well by pointing out that: ''if there was a single key element distinguishing western European technology from the technologies of Islam, Byzantium, India, or even China after around 1200, it was the West's extensive commitment to and use of water power''. Progressively larger hydraulic systems emerged by late 14th century in the mining regions of Central and Western Europe as have been thoroughly described in technical treatises of the 16th century. Cardinal Bessarion, a Byzantine scholar, refers to such devices from Italy in his memorandum to Constantine Palaeologos, between 1443 and 1446, as follows: *in the smelting and separation of metals they have leather bellows which are distended and relaxed untouched by any hand, and separate the metal from the useless and earthy matter that may be present* (Keller 1955, 346). Eventually hydraulic power for the operation of bellows in Byzantine lands was applied in the following century during the reign of Suleiman the Magnificent initially at Sidirokapsia in Chalkidiki, some years before Belon's visit, between 1546 and 1549 (Oikonomaki-Papadopoulou 2006).

The transition from Byzantine to Ottoman administration in Thrace and eastern Macedonia has been the outcome of quick, abrupt change of the mid 14th century, predating the final collapse of central power at Constantinople for almost one hundred years. 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.

Innovative methods gradually replaced or modified the way traditional crafts were being exercised through slow transformations that could be partly observed in material culture. The introduction of water mill technology to the smelting workshop has found wide acceptance in western European and Balkan contexts. Ottoman expansion to the Balkans facilitated an acquaintance of soldiers with workshops generated by water-wheels. Such devices were widely used for wheat grinding, cloth-fulling and possibly for smelting and forging operations as well (Cortese and Francovich 1995) and became increasingly widespread in Ottoman territories during the 16th century. It is interesting to note that one of the smelting sites encountered during field reconnaissance appears to have developed around a waterwheel close to Vathytopos village. Considerable amounts of slag have been deposited around the tower of a horizontal waterwheel which is described in more detail in chapter five. The existence of such a device might reveal some dating clues (early Ottoman times) and certain technological information when seen in conjunction with the results from instrumental analysis of sampled residues reported in chapter six.

### 3.9.2 Technological change and social reorganisation in Europe

Given the highly technical nature of mining and extractive metallurgy certain devices and machinery have been employed in the process of ore digging, water-pumping in mines, ore washing, and extracting, refining and assaying metals. The evidence comes from archaeological material as well as contemporary documents. Water-wheels and mills have been in use across Europe from Roman times and their use intensified during the middle Ages mainly for flour processing or grinding materials for other purposes (figures 3.7 and 3.8). Cresswell (1993) provided a concise review of the evidence and identified certain types and their dates and distribution across the Mediterranean, Western Europe and the Middle East. There is a distributional pattern of horizontal water-wheels widespread across Mediterranean shores in Spain, Italy, Greece, Anatolia and northern Africa while vertical ones were common in northwestern Europe at Britain, Gaul, Germany, Denmark, Sweden and elsewhere (figure 3.9). The use of waterwheels for ore washing, water pumping systems in mines, smelting and mechanical hammering is attested in Agricola's major work *De Re Metallica* where various wheels used in certain cases are described and illustrated (Hoover and Hoover 1950).

The possible use of coal for fuel in industrial operations has been well argued by Dearne and Branigan (1995) who provided a review on archaeological evidence for coal from a wide range of Roman cities and settlements across Britain. The high concentration of finds close to Hadrian's Wall, western England and Wales coincides with numerous large coal deposits that were probably exploited since Roman times for fuelling in hearths and industrial furnaces (Dearne and Branigan 1995). No clear picture for coal or other deposits such as peat or lignite exploitation exists before 1700 though it remains a matter of possibility.

An important innovation that was introduced to Byzantium from the Far East roughly around the 12th century was gunpowder accompanied by the magnetic compass and the printing press. Gunpowder arrived in the West from China via Byzantium and the Arabic kingdoms directly from the Mongols, revolutionizing warfare and probably quarrying and mining (Kazhdan and Pingree 1991). The Mongols pioneered the use of lengths of bamboo packed with gunpowder as 'pipe bombs' to help blow open city gates, and they brought this technology with them during their ravages of Poland and Hungary in 1241. The first European mention of gunpowder occurs in 1268 in the writings of the Franciscan friar Roger Bacon. The so called 'black powder' discussed by Marcus Graecus in his '*Book of Fires for the Burning of Enemies*' was a mixture of saltpeter (sodium or potassium salt of nitric acid), sulphur and charcoal which became widespread across Europe from the beginning of the 14th century (Gies and Gies 1994). By 1326 there is a picture of the new European invention, the cannon. Since the Europeans had a thriving metal mining, smelting, and manufacturing industry, it was quickly converted to the improvement of the new weapon. According to Cowen (2000) there was no gunpowder left over for commercial purposes such as rock blasting in mining or canal building. Hard rock had to be excavated out by hand with hammers and picks and wedges, or it had to be fire-set.

### 3.9.3 Parallel traditions of iron technology across Europe

The evidence for metallurgical furnaces in Greece is highly fragmentary with only scarce remains having been investigated and published, and thus furnace shapes and sizes, operational characteristics and output in metals could not be estimated. It is for these reasons that a discussion of well-documented furnace technologies from the European Middle Ages has been included in the following section. An assessment of archaeological evidence from the 7$^{th}$ through the 16$^{th}$ century from various European contexts such as in Hungary, Sweden, Germany and Italy and the different models of smelting technology would clearly benefit the current study in a comparative way.

#### a. Hungarian metallurgy

Between the 7$^{th}$ and 10$^{th}$ centuries a characteristic type of bloomery furnace has been in operation in Hungary deriving from the Avar prototype. It is known as Nemesker named after the site where it was first investigated. The Nemesker type furnace was a free standing structure around 70-100 cm in height, in the shape of a truncated cone (figure 3.10). On its front side it featured a 40 x 40 cm opening which was covered during smelting by a clay breast-wall (tuyère panel) with a clay tuyère adjusted to a slot in its centre (Gömöri and Torok 2002). A shallow slag pit was formed in front of the furnace where slag was allowed to run freely across a tapping slot. Examples of the Nemesker type have been excavated at Tomord, Denesfa, Ivan and Harka (Gömöri and Torok 2002).

From the middle of the 10$^{th}$ century a transitional type between the Nemesker and the later examples, known as the 'Fajsz furnace' became widespread. In terms of structure it resembles the Nemesker type with the only difference that it was built in to the walls of sunken workshop pits. These sunken areas facilitated three to four furnaces operated by four pairs of workers half of which were working outside the pit, on its upper edge, while the others operated the bellows inside the pit (Gömöri 2006). Remains of that type have been found at Somogyfajsz and Sopron-Potzmann. The typical bloomery furnace coming in common use from the 11th century is the Imola type which structurally corresponds to the Fajsz furnace which preceded it (Gömöri and Torok 2002). It was a non slag tapping furnace and it operated with a partly open breast possibly being slightly less efficient. Imola type bloomeries can be found all over Hungary at workshops built next to each other, close to brooks. At Repcevis three workshops with Imola furnaces have been excavated dating around the 10th-12th centuries. As Gömöri and Torok (2002, 378) have indicated the construction of the bloomery and the separated workshops could be connected to the changing pattern of work organization, namely shifting from the collective service to the individual iron tax on the families of self-supplying iron workers.

These three types of furnaces described above share common characteristics such as hearth diameters about 35-40 cm, throat diameters 15-20 cm, and height around 70-80 cm. The lengthened pear-shaped interior and the use of breast wall for fastening the tuyère were also common features of the two periods. However a major difference is the presence of a slag pit which is common for the earliest Nemesker type but has been abandoned in later furnace examples (i.e. the Fajsz and Imola). This change in furnace design over time reflects a shifting model of organisation of production in these Hungarian smelting workshops. Changes in technology would produce low viscosity slag that was not tapped out and therefore slag pits became redundant features. Moreover by building clusters of three to four furnaces in large sunken pits allowed for easier bellows operation demanding fewer workers to maintain, and brought about a more efficient charging of the furnace from above (Gömöri 2006). Such innovative characteristics contributed to high temperature reductions (1200°C) whereby the iron bloom was recovered enveloped in slag after dismantling of the furnace.

At the same time such a centralized model encouraged increased production achieved through efficient management of the workforce. This shifting pattern emerged either due to changes in ore procurement or transformations in efficiency parameters during smelting or might have involved social strategies concerning labour organisation or shortages in manpower. Overall the smelters were interested in implementing the most productive procedures and in choosing the shape and equipment of the workshop and the structure of the furnaces on the basis of expedience, in order to produce iron with the least possible efforts. Among the sampled smelting sites (see chapters 5 and 6) substantial evidence of furnace slag found in greater proportions compared to tapped slag at Katafyto, reveal similarities in furnace technology with those 12$^{th}$ century Hungarian workshops.

**b. Swedish and German smelting technology**

Based on existing evidence, southern European workshops shifted from bloomery to cast iron production sometime in the 14$^{th}$ century at the latest, with some probability that the process started earlier in the 13$^{th}$. This change should not be understood as a complete replacement since both production methods co-existed for some time. For northern Europe however there is definite evidence for earlier cast iron production. In Sweden the furnace at Lapphyttan, dated around 1270, is the oldest blast furnace known in Europe (Gordon and Reynolds 1986).

Excavations at various sites have revealed that an active iron industry was growing in Sweden since the 12$^{th}$ century. Before 1050 iron was smelted in hand blown bloomeries most probably from bog ore. Subsequently population growth, colonization of new lands and iron manufacture begun in the Bergslagen through the indirect process i.e. the use of the blast furnace and associated fineries to produce wrought iron. Various explanations were given to establish the origins of Swedish wrought iron production such as independent invention, introduction from Germany or transfer from China along with other technical traits. According to Tylecote (1987) the Swedes were among the first Europeans to establish trade with China by the 7th century through a Russian route. Further the appearance of the waterwheel with a vertical shaft in medieval Scandinavia, similar to those widespread in China, could be attributed to the same transfer of technical knowledge (Creswell 1993).

Based on slag analyses from Lapphyttan it was determined that pieces of incompletely reduced ore, bits of charcoal and droplets of cast iron are embedded in the residues reflecting partly imperfect operation. Nevertheless the large quantity of slag shows that commercially useful technical competence was attained by local smelters. Operation of this smelting complex required both a skilled workforce and a social structure that would permit the assembly of raw materials and the sale of the finished wrought iron (Gordon and Reynolds 1986, 116). This model of production is characterised as communal since no one could own less than one eighth of a furnace according to King Magnus Eriksson's charter of the ironworkers (bergsmen). Hence the blast furnace may have been jointly owned and operated but the production of final products was undertaken by individual craftsmen in the eight associated fineries. In terms of technical expertise mastering the indirect reduction would have required superior ore quality, ingenuity in the blowing devices to reach temperatures above 1300 °C and effective division of labour.

Further examples of early blast furnaces and transitional types (13th-15th c.) come from Dürstel in Switzerland, the Märkische Sauerland in Germany and from Schwäbische Alb, Germany where slags have indicated the indirect process in the 12th century so far (Tylecote 1987). In the Märkische Sauerland besides a large number of bloomery furnaces more than 100 blast furnace sites have been discovered. Two blast furnaces were excavated in the basin of the Kerspe-Dam, radiocarbon-dated to 1205-1300 and 1290-1395 (Jockenhövel and Willms 1997). They were built of loam in the tradition of bloomery furnace construction and had an outer diameter of c. 3m and an inner diameter of c. 0.8m. Both furnaces were built with their backsides into the slope of the basin, so that the slope could be used as a natural charging platform. In the wall of the younger furnace the hole for the water-powered bellows was still intact. Further a mill race, a wheel pit, and depots for ore and charcoal, post-holes and stone-built drainage trenches were found (Jockenhövel and Willms 1997).

At a second site of Sauerland, on the Wipper Valley a blast furnace of a 'mature' type, mainly built of stones and measuring c. 3,5 x 3,5m on the outside and c. 1,25 x 1,25m on the inside was investigated. It was built into the slope so that it could be easily charged with ore and charcoal (Jockenhövel and Willms 1997). About 3.5m downhill a trench with wooden boards on the sides may have been the culvert of the water-wheel and/or the drainage. Near the blast furnace there was an older bloomery furnace whose slag heaps may have been used for recycling the old iron-rich slag in the new furnace (Kempa and Yalcin 1995). The new indirect iron technology modified the decision making process for establishing furnaces and fineries. Flowing water became a significant priority and thus river valleys and streams became ideal foci for the smelting and refining stages of iron metallurgy. Information on similar features from the surveyed region is mostly inconclusive but where waterpower has been applied i.e. the workshops at Vathytopos and Vrontou (see chapter 5) similar organisational parameters to those described for the Swedish and German workshops would have prevailed.

**c. Italian smelting technology**

A transfer of Oriental technology in medieval Europe has been a common theme which is once again underlined through metallurgy in Italian furnace types, bellows arrangements, smelting operations and manifested by metal products. Standard iron smelting practice in 15th century northern Italy is mentioned in a treatise by Antonio Filarete, a Florentine sculptor and architect who described a smelting workshop at Ferriere in the Apuan Alps and a forge with its attached hammer-mill at Grottaferrata near Rome (Spencer 1963; Singer *et al* 1956). As Spencer (1963, 202) outlined, the technique of iron smelting described by Filarete does not differ markedly from standard methods of extraction that were in use up to the 18th century. The ore was improved by roasting with lime and the resulting product was ground, sifted and prepared for the charge which consisted of layers of charcoal and an ore-lime mixture. The air flow in the furnace was provided by an ingenious arrangement, rare in a European context, where the bellows blow alternately through a single tuyère (Spencer 1963). Filarete emphasises that the bellows were installed vertically rather than horizontally, as would be the common practice in a smithy, and appear to have supplied a continuous blast of air through a common tuyère. He omits referring to the water power driving mechanism of the bellows presumably because such matters were well-known to his readers.

The uniqueness of such an innovative arrangement lies on its considerable size but most of all in the common pipe that allowed for a continual blast of air (Spencer 1963). Based on the drawings included in the treatise and especially Figure 2 as reproduced in Spencer's work, Needham (1964) was able to describe the driving mechanism in detail. He suggested that the central log was a bell crank rocking roller which resembles blowing-engines depicted in Chinese treatises from 1313 onwards.

Such a device would make sense in the Chinese context since the alternating reciprocatory motion required has been made possible through contemporary engineering. The bellows are considered to have been cubical made of wood and leather and connected to the horizontal water wheel with the set-up described by Needham. Based on the dimensions given in braccia by Filarete, the size estimates for the bellows hint to a large box approximately 132″x 88″ comparable to the 12-foot bellows reported by Biringuccio. Such large boxes would have been unnecessary if not unusual features for bloomery furnace arrangements. Further Filarete mentions that the stack received 20-25 charges in a 24-hour period and was tapped twice a day both of which facts indicate a continuous heat (Spencer 1963).

Clear reference to molten metal pouring from the furnace suggests wrought iron being produced by the indirect method. According to Smith (1964) the granulation of molten metals in water is an old method and was used in the making of rosette copper. Granulation of cast iron produced irregular fattened spheroids free from slag and such a method had probably been preferred than casting in pig form. As Smith (1964, 387) has noted 'since the blast furnace at the time must have given a variable product, granules would have an added advantage that material from different furnace runs could be mixed to obtain uniformity'. Based on the above Wertime (1964) classified this furnace as the *canneccio* type, which had to be rebuilt after not very long periods of constant functioning.

Information on the Grottaferrata fining mill generally seems to be more adequate. Filarete describes a forge sustained by water powered-bellows of the horizontal, smithy type and a hammer mill also generated by water power. Wrought iron was re-melted in the forge and then hammered on an anvil by means of the mechanism on which the hammer was attached. All the evidence discussed fall within a pattern of technical adaptation to new modes of production flourishing in Europe of the 14th and 15th centuries stimulated by Oriental prototypes. Chinese transmission as the cardinal influence on a European technology, in this case the making of cast iron from 1380 onwards has been clearly supported by substantial evidence (Needham 1964; Spencer 1963; Smith 1964).

The Italian examples characterise a model of entrepreneurial nature by which capital investment was prerequisite for any innovative applications in the field of iron production. New technological advances inspired by oriental prototypes made possible the reaching of raised temperatures necessary for indirect smelting. Production of iron through the indirect process involved a certain mode of ore procurement and pre-treatment, substantial volumes of charcoal and available manpower for the constant maintenance of a blast furnace and more efficient administrative management.

**d. Monastic and seigneurial administration of iron production: The cases of Maremma and Merse valley**

Information on the organization of bloomery and cast iron production is preserved in Italian medieval documents and archaeological deposits of smelting sites. A well documented case of evolution of the particular craft industry from its humble beginnings in the 9th century to its booming in the 14th provides an important example for comparison with the investigated case. Further the organization of production and entrusting of workforce for each of the operational stages is presented as a growing enterprise accomplished by seigneurial initiatives within a model apparently similar to the contemporary Byzantine (Cortese and Francovich 1995).

The island of Elba and the opposite Campigliese and the Maremma coast formed a technologically unified region, at least from the early Middle Ages, where abundant evidence shown interaction in terms of raw material exchange, uniformity of smelting techniques and administrative conditions. Waste from the working of iron from Elba has been identified in some castles of the Maremma area underlining the importance of Elba as a mining region supplying the opposite coast with surplus ore. Surface survey has in fact identified in the Maremma area three sites with the presence of slag and fragments of Elban hematite, associated with ceramic finds dateable to between the 9th and 10th century (Cortese and Francovich 1995). The ore extracted from the low grade iron-bearing deposits of Sienna was probably enriched with small quantities of mineral coming from Elba and smelted in open hearth furnaces as the one found at Montarrenti. In this early period iron products occur by means of a limited production in scattered ironworks designed to meet the local needs of communities based on an essentially agrarian economy.

The 12th century is marked by the spread of a massive civic initiative, aspiring towards the creation of a well-defended and controlled productive system, where extraction and the first phase of the metal-working are organized on a vast scale (Cortese and Francovich 1995). Even though no clear picture of the common furnace types exists they must have required manual operation of the bellows given their location attached to castle walls far from any water-courses. Such local industries of the castle sites involved a limited capital investment aimed at satisfying internal consumption. Around 1192 Pisa gained legal control over Elba and expanded its territory to Piombino, the diocese of Massa-Populonia, the mountains of the Alma district and Capalbio.

A well documented case of organized medieval iron production depicting a combination of monastic and seigneurial administration comes from Merse valley in southern Tuscany. Ironworking installations mentioned in written sources for the 13th to 15th centuries are 13 in total with the earliest report for the existence of a water powered iron-workshop to the year 1278 (Cortese 1997a). This earliest mention comes from the archives of St. Galgano Abbey which owned large tracts of land and invested tremendously on hydraulic technology. Therefore it was suggested that the introduction of iron mills to the Merse valley has been a monastic initiative. As Cortese (1997b, 361) has noted 'the data from written sources is much richer about lay proprietors of iron-workshops, and this makes us believe that the technological know-how largely circulated also within extra-monastic milieus'. As noted in the 1278 manuscript a woman who was member of a group of important landowners became proprietor of part of the foundry. Such a practice became common and started gaining momentum by the beginning of the 14th century. A direct outcome was a spontaneous appearance of a dozen of hydraulic workshops in the valley by lay entrepreneurs, who also owned substantial tracts of woodland. The archaeological finds indicated that at least two stages of the iron working process were taking place, starting with reduction of the ore by smelting and followed by the first stages of smithing which left behind tapping and porous slag respectively.

The Italian examples illustrate how societal factors such as the acquisition of large tracts of land from monastic circles redefined economic strategies and enhanced existing modes of production. Changing manners of organisation meant that the relationship between wider economic factors and production changed dramatically hence technology found wider applications in numerous occasions. Byzantium had undergone similar changes in terms of landownership as a growing class of aristocrats gained economic potential to challenge ecclesiastical claims on fertile and metal rich land parcels. Such a shift appears the more obvious after the political fragmentation of the early 13th century when Constantinople fell in the hands of the Frankish leaders of the fourth crusade. The rival 'states' of Epirus, Nicaea and Moreas at times engaged in martial conflict causing in this way severe economic disarticulation. Social reorganisation and reforms in the debased monetary system affected local markets while rural communities faced severe problems of dependency on the rich land aristocracy. Lay estate initiatives were the major driving force behind venturous attempts for profit and social award reflected in the historical record of Byzantine Macedonia.

### 3.10 Conclusion

Byzantine social organisation has played a dominant role in the formation of conservative technological traditions significantly dissimilar to western European ones. Such a dichotomy underlines the tension between technical acts and social organisation. In the west technical practices changed alongside social reorganisation and then understood as technological development, whilst in the Byzantine world social reorganisation never occurred in such a way. In an ecumenical empire there were no margins for social mobility but perpetual continuity whereas in western Europe major revisions, the thought systems springing from enlightenment ideas and the emergence of nation states fostered technological innovation in a completely different fashion (Anderson 1991).

Examples have illustrated how the family unit was involved in the organisation of labour for iron production in Hungary and also how Swedish and Italian smelters promoted innovation through exchange of technological information. A comparison of such models shows differences in raw materials, modes of organisation, labour constraints and obvious cultural differentiation which dictates certain codes of behaviour with regards to technical action. Along these lines broad differences become apparent with regards to conceptualisations of technology developing from socially determined parameters. Nevertheless any potential similarities could be evaluated in terms of positioning the production of metals in broader subsistence schemes which in most cases have been mixed farming strategies. Since mineral deposits tend to be concentrated on deficient soils unsuitable for agriculture, stock breeding represents the obvious subsistence alternative as illustrated in chapter 2. Any potential similarities in technological practice across Europe would spring out from resembling needs, choices and strategies determined by prevailing climatic and environmental conditions.

The study area is characterised by an agrarian economy of land-owner peasants and labourers and the presence of private contractors and entrepreneurs operating mines and workshops somewhat similar to those found in Italy. Clearly an investigation of metal production in one of the longest lived empires, an area where technology has been traditionally deemphasised, would benefit Byzantine studies which tend to ignore or not concentrate on such issues. This will help widen our understanding of Byzantine society but also serve to act as a contrasting model to other areas of Europe and demonstrate the diversity of social strategies to metal production.

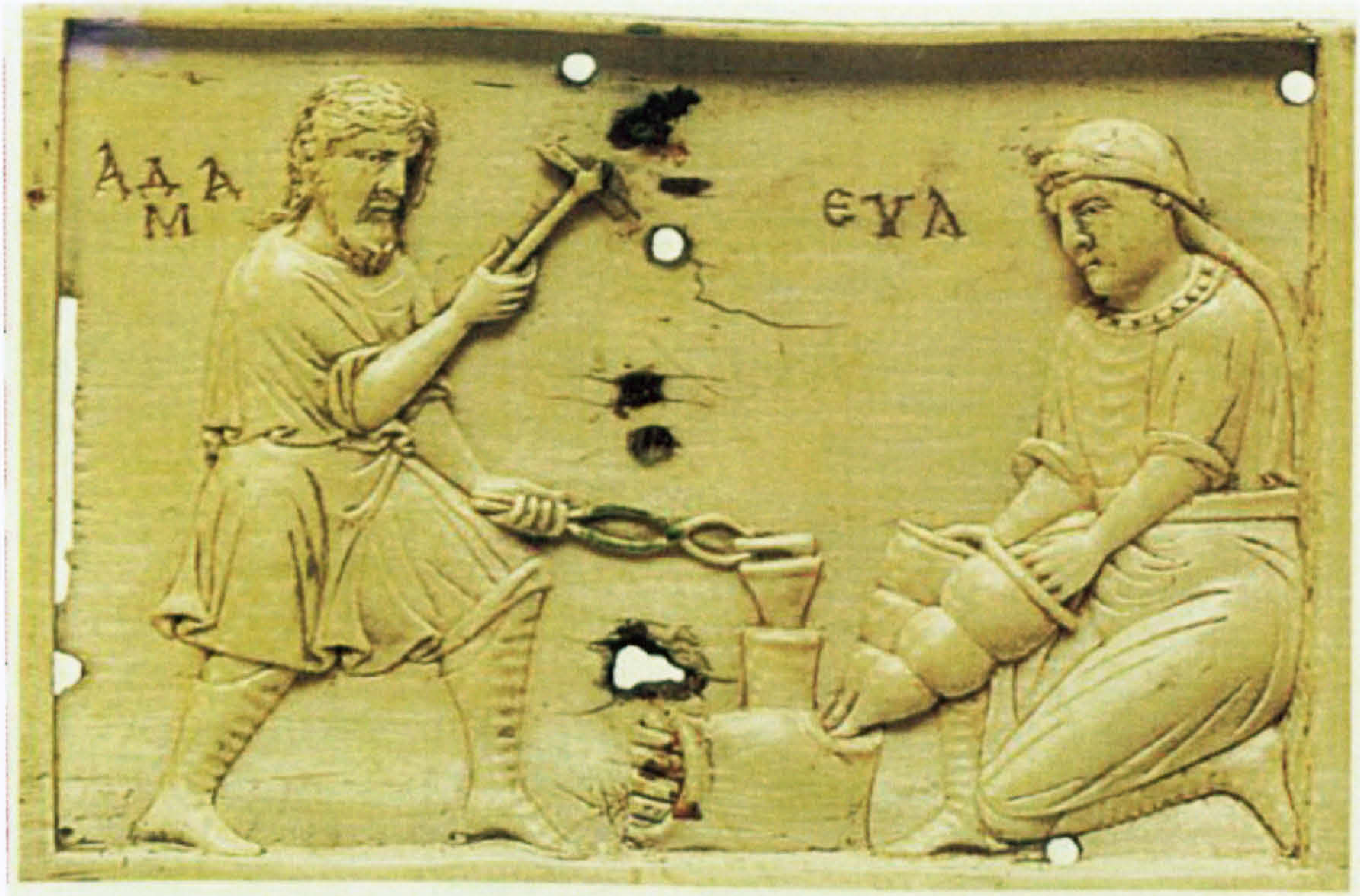



Figure 3.1 Byzantine curved ivory box 10th or 11th century depicting Adam and Eve whilst forging iron (after Papanikola-Bakirtzis 2002)

Figure 3.2 Byzantine curved ivory box 10th century (after Papanikola-Bakirtzis 2002)

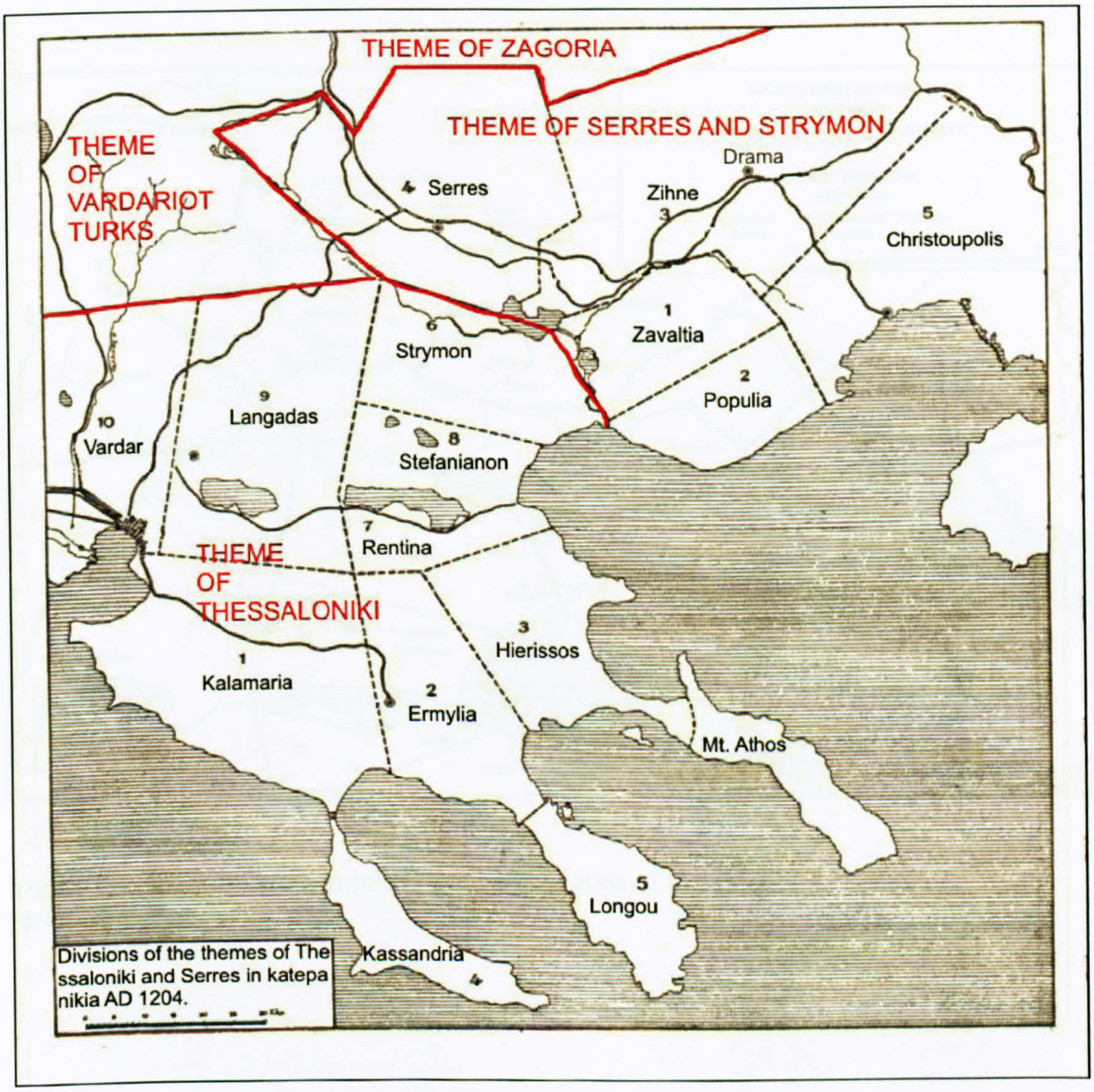



Figure 3.3 Large administrative divisions, *themes* in northern Greece, 13th century (after Theocharidis 1954)

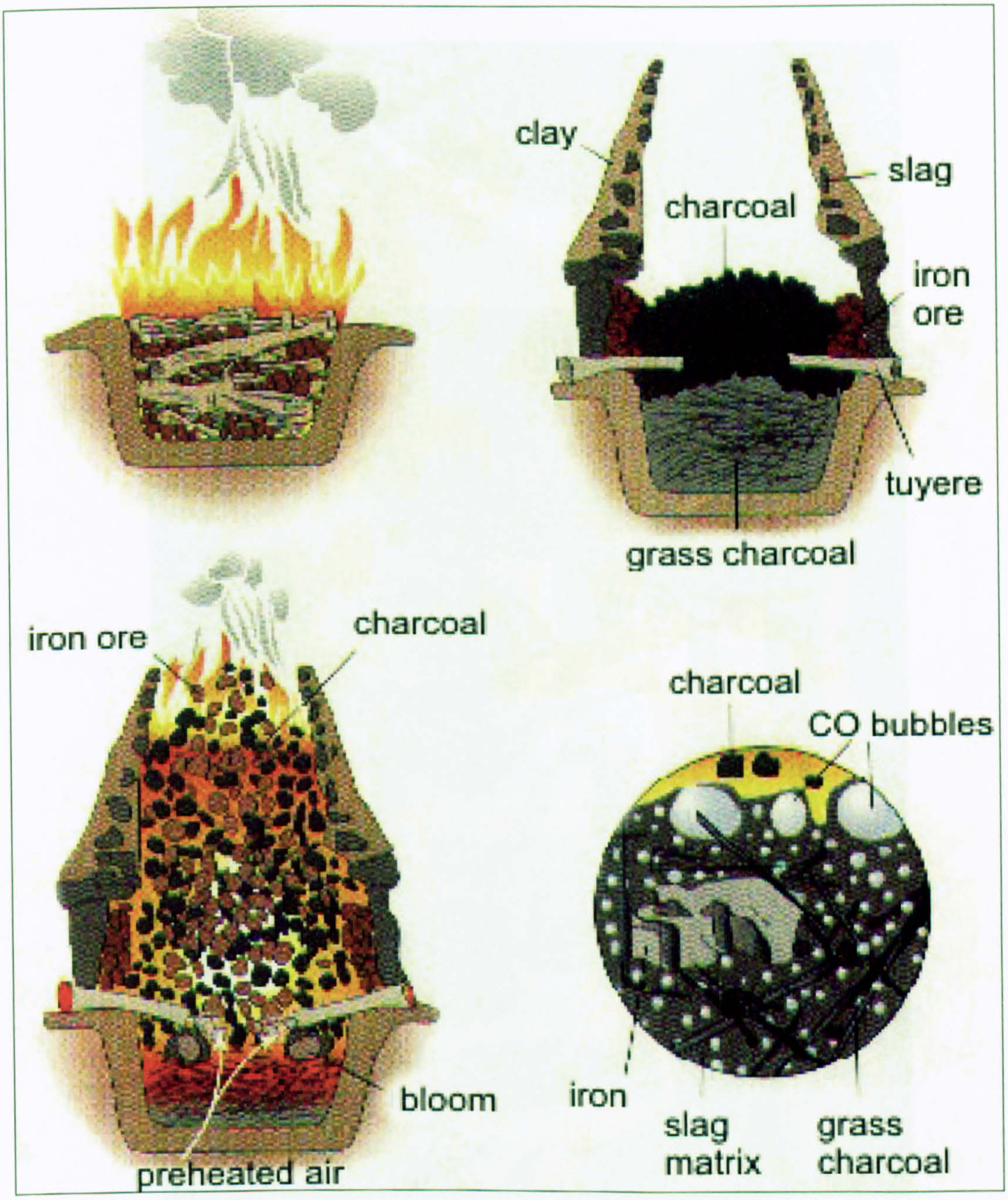



Figure 3.5 Schematic representation of the iron smelting process. Formation of the bloom and slag within the furnace (after Schmidt 1997)

Figure 3.6 Furnace with associated water-wheel for bellows operation. Detail from Slovak painting, 1513 (after Oikonomaki-Papadopoulou 2005)

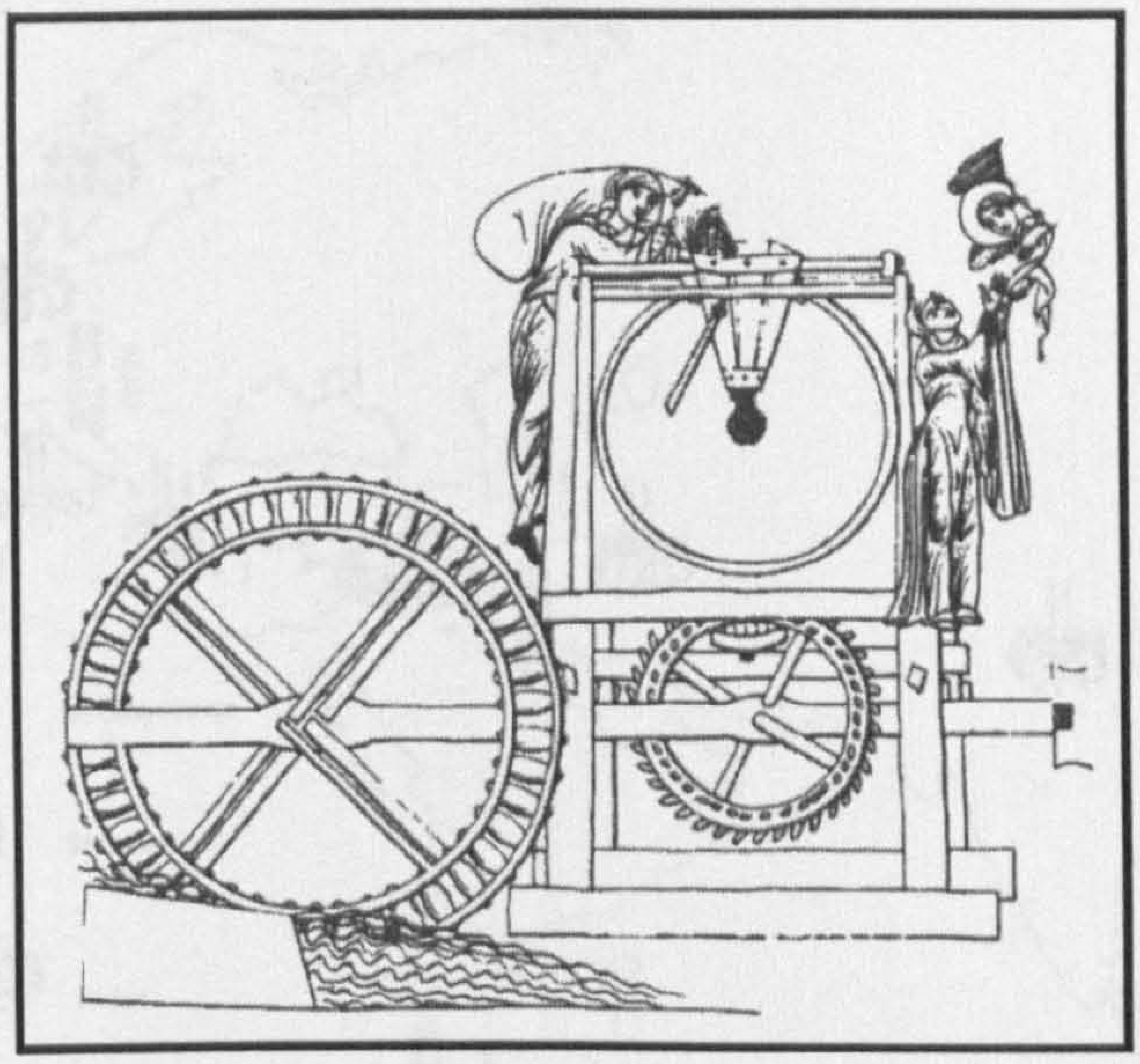


Figure 3.7 Byzantine drawing depicting the water wheel described by Vitruvius (after Drakopoulos 1985)

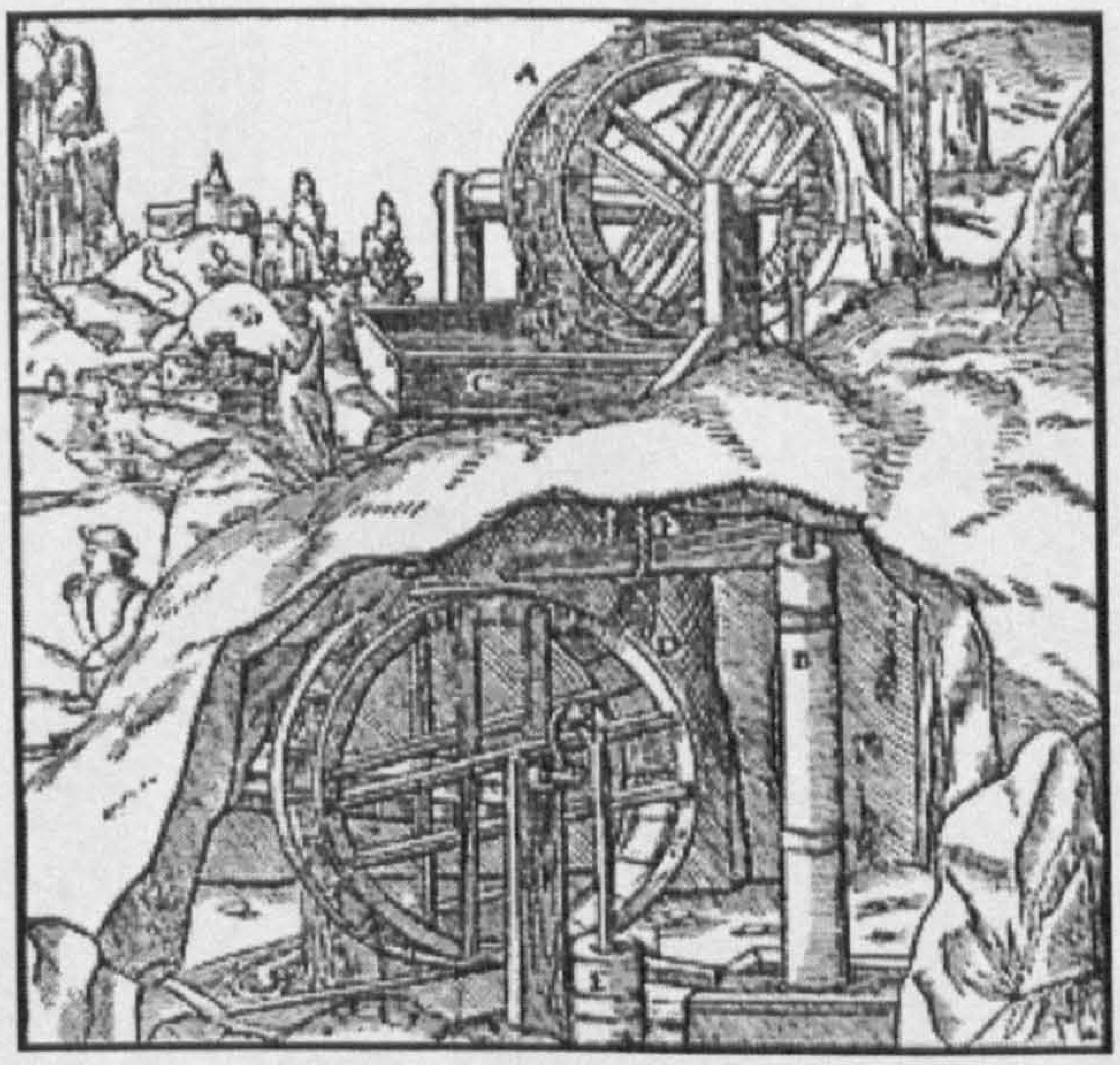


Figure 3.8 Water wheels used in mining described by Georgius Agricola (after Hoover and Hoover 1950)

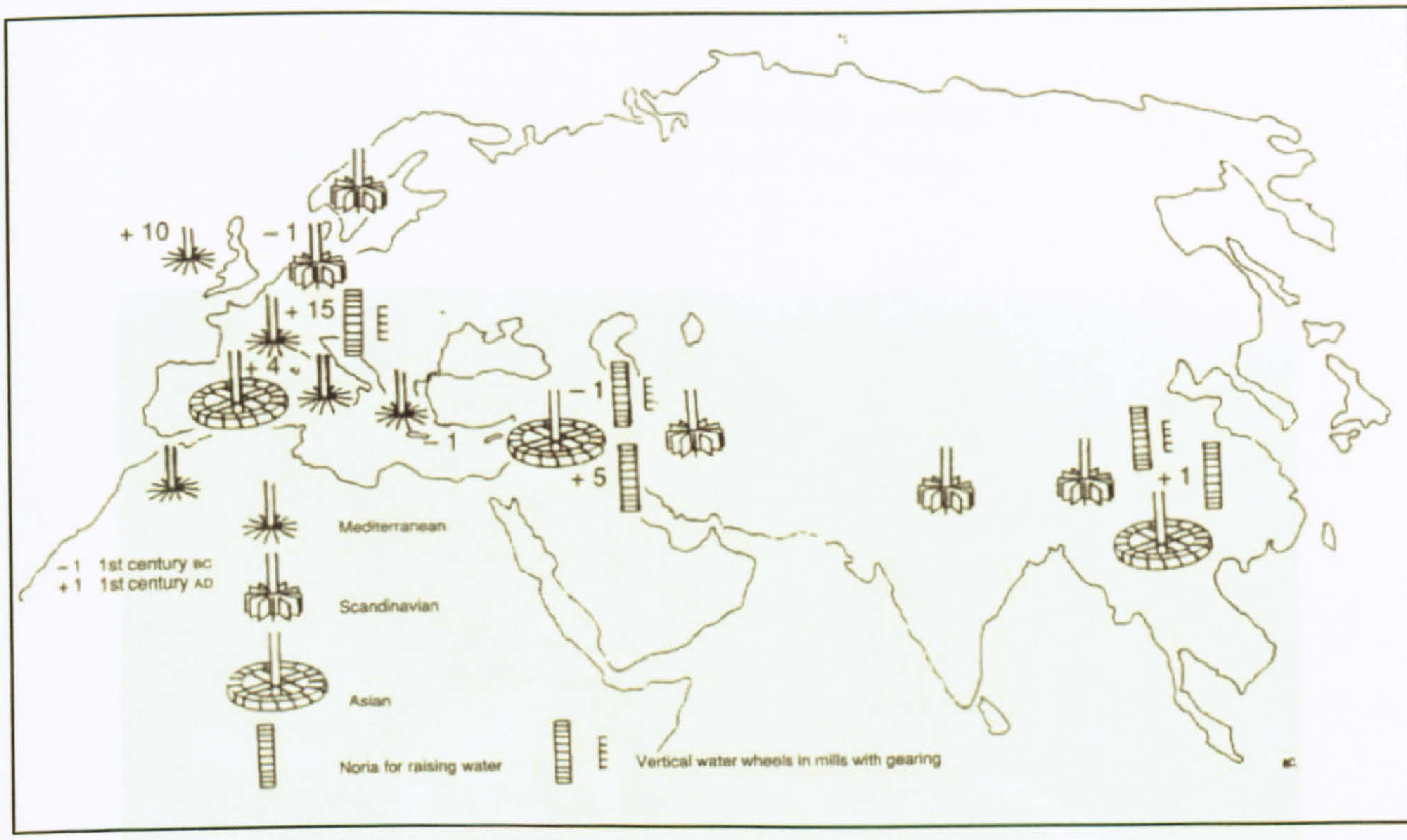



Figure 3.9 Geographic distribution of water wheels (after Cresswell 1993)

3.10 Hungarian furnace of Nemesker type with clay breast-wall and tuyères (partly reconstructed) (after Gomori and Torok 2002)

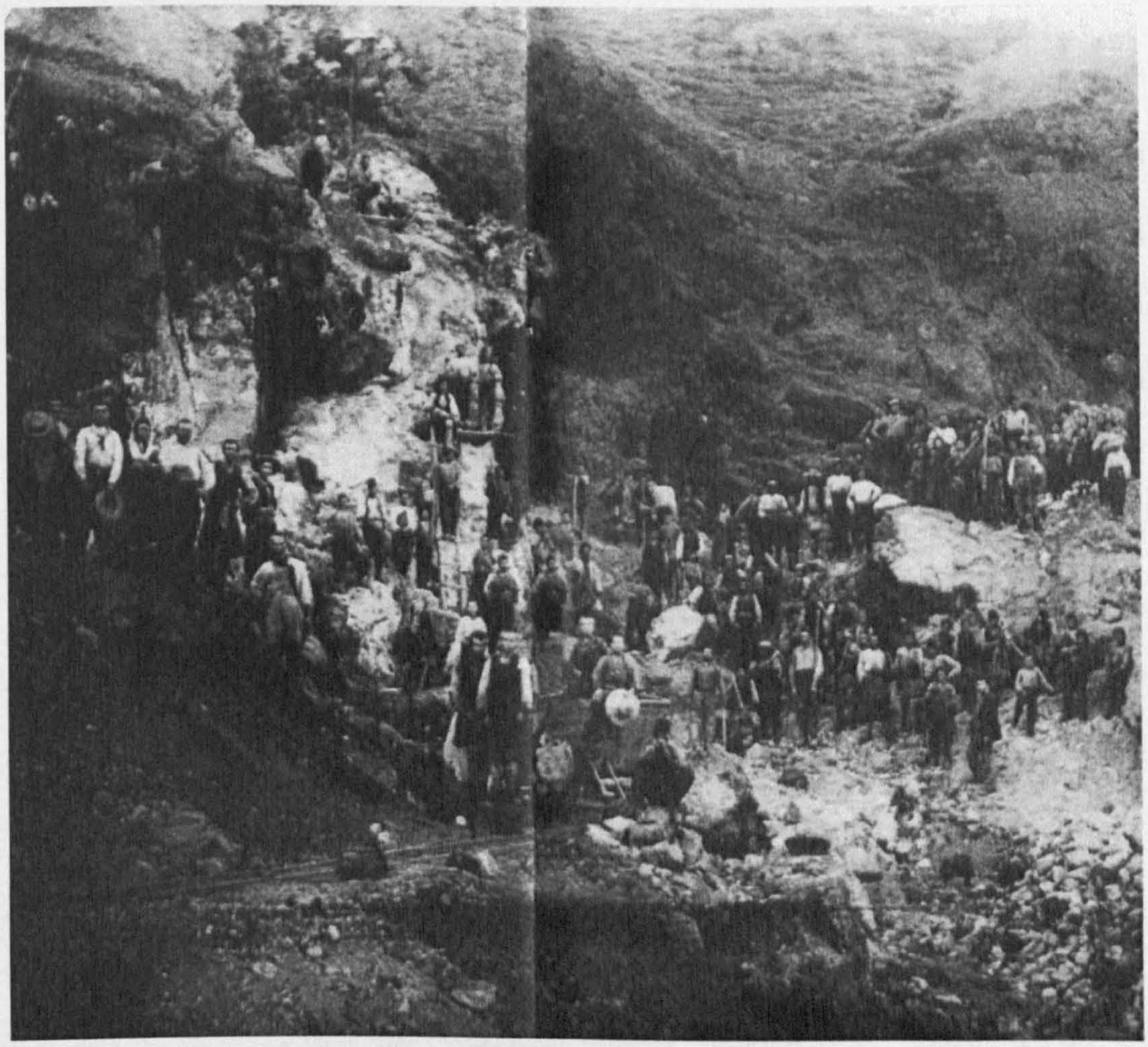


Figure 3.11 Mine entrance in Chalkidiki of the early 20th century. Miners of various ages with their tools (Mount Athos Photographic Archive) (after Papaggelos 2003)

*CHAPTER 4*

# *Mining and metal production in Greece and surrounding regions: archaeology and historical evidence*

## 4.1 Introduction

Although at present there exists no clear understanding of the chronology for various metal production sites across eastern Macedonia, archaeological excavations and analytical studies carried out elsewhere in Greece have been proved enlightening towards that end. The breadth of processes represented reflects a diversity which could be evaluated in light of available archaeological material and its interpretation through models of socio-economic organisation (Costin 1991; Doman 2002; Killick 2004). Further documentary evidence from antiquity, late Byzantine Mount Athos charters and Ottoman cadastral registers refer to large-scale iron production in the region whilst there is recurring reference to gold prospecting. Literary sources rarely refer to technical issues of the ancient past and where they do so they often provide inadequate or dubious accounts on crafting, and therefore their credibility is generally regarded questionable (Healy 1978; Koukouli-Chrysanthaki 1990).

A critical evaluation of archaeological data in contrast to literary accounts outlined in this chapter has revealed certain contradictions which should be considered with some caution. Two such characteristic examples with regards to the study region are the exaggerated figures for the output in precious metals provided by ancient authors and secondly that archaeological evidence for gold or silver extraction is somehow elusive whereas iron working abounds. This emphasis on precious metals in textual sources and the dominant evidence for iron mining and production reflected in the archaeological record accentuates this dichotomy with what has been written and what is present archeologically.

Mining and metallurgy due to their practice regime, which involves an unfolding of complex processes at specific contexts, over considerable periods of time, are inescapably rooted in deep histories. Since the resources necessary for any metallurgical activity are concentrated at certain locations, such places gradually become foci for exploration during lengthy periods (Palmer and Neaverson 1998). Often a prehistoric mine has been reused in antiquity, the middle ages and where conditions were favourable modern exploitation concentrated on re-melting of old slag. Any tradition in mining and smelting transmits cultural information through time and not necessarily following progressive steps towards greater efficiency (Knapp *et al* 1998). Assessing the technological means employed by certain past communities towards specific needs involves a diachronic study of their settings and resource perception through long periods, since such processes could not be disarticulated from preceding practices (Lemmonier 1992; Knapp *et al* 1998).

A unified, historically informed evaluation would dictate a review of the earliest steps in minerals exploitation of a certain area of study. Mining regions were valued resources in use over long periods and the strategies adopted for 'efficient' exploitation were socially constructed and highly varied through time. The long and complex nature of such undertakings could be appraised diachronically firstly by examining prehistoric innovations upon which later strategies had been formulated.

### 4.1.1 Archaeological evidence for metal production

The study area is characterised by mining regions and slag deposits formed over numerous incidents of deposition which span several hundreds of years. In order to approach issues of medieval smelting technology its historical ties with ancient practice, which itself builds on older traditions should not be overlooked. The origins of technological traditions are often obscured by reforms and changes through time but a detailed review of the evidence from humble beginnings towards greater organisation would promote a better understanding of how technologies transform. It is for such reasons that the unfolding of technological traditions built upon early mining and smelting operations over the larger area are being examined in this chapter.

Metallurgy was emphasised in the context of archaeological research in Greece since Renfrew saw a competition being focused towards metal goods within the prehistoric Aegean (Renfrew 1972) but elite goods always attracted scholars' attention. The exchange of raw materials which concentrated at specifically defined sources such as obsidian brought about societal change since the Neolithic. One significant change in that respect was connected to perception of resources, which modified social strategies towards the gaining of 'exotic' materials through exchange networks. The rise in the use of metallic ores emerged within such cultural conditions favouring certain groups at accumulating prestige items and hence enhancing their social ranking and status (Branigan 1974).

Evidence from excavated settlements such as pottery or metal tools and jewels has shown that Macedonia was in contact with Balkan centres (Todorova 1981), the Aegean (Zachos 2007) and western Anatolia from an early date (map 4.1). Initially being an active partner of what Chernych (1991, 387) termed as the Balkan-Carpathian Metallurgical Province and later as a significant gold, bronze and iron producing region helped create a legacy that made it a suitable area for industrial endeavour. This long history of metals technology in Macedonia is being assessed in this section based on representative archaeological findings.

### 4.1.2 Literary evidence on metals

The earliest surviving documents that refer exclusively to mining and smelting of ores generally draw back to Classical Greek and Roman times but are notoriously scarce and have been often considered as being misleading. Theophrastus, Aristotle's principal disciple, appears to have written at least two works on the matter: one 'On Stones' (*De Lapidibus*) and the other on metals, mining or metallurgy but the latter is not extant (Eichholz 1965). Strato of Lampsacus the successor of Theophrastus is referred to as the author of *De Machinis Metallicis* while Dioscurides' Book V is devoted to minerals and rocks (Osbaldeston 2000). In Pliny's *Naturalis Historia* out of the 37 Books in total, only the last 4 partially relate to extractive metallurgy (Hoover and Hoover 1950). An apparent dichotomy between theoretical and practical knowledge has been observed within the literature corpus of antiquity and the early middle ages which often triggered a bias on appreciation for the small number of technical treatises. Despite the scarcity of surviving documents, a considerable body of ancient Greek manuscripts on technical matters and philosophical, 'scientific' treatises were readily available to Byzantine scholars, in addition to purely theoretical works (Litsas 2008). Mount Athos charters recording land use and revenue paid to the monasteries also include remarks on the issue of metals production.

## 4.2 Prehistory

### 4.2.1 The beginnings in Later Neolithic

The idea of the early and autonomous development of metallurgy in southeast Europe is not new. Renfrew's (1971; 1978) early ideas on the autonomy of Eneolithic metallurgy in Bulgaria and former Yugoslavia found support by numerous scholars (Chernych 1978; Jovanović 1979; 1980; Todorova 1981) and increasing evidence that comes to light testifies to the importance of his argument. Early metalworking cultures such as Vinca (Jovanović and Ottaway 1976), Cucuteni-Tripolye (Greeves 1975) and Karanovo (Gale *et al* 1990) yielded some of Europe's earliest copper artefacts and posed questions on the emergence and nature of this technological innovation while Varna is an early example of conspicuous consumption of gold and copper in elite burials (Renfrew 1986). Two key sites for the study of early metallurgy where copper mining and processing is evidenced are Ai Bunar in Bulgaria and Rudna Glava in Serbia (Figure 4.1). The Later Neolithic use of metals in northern Greece and its probable associations with these established Balkan metallurgical traditions of the 5$^{th}$ millennium BC (Ai Bunar, Rudna Glava) appears timidly in form of small objects of display and has been characterised as trinket metallurgy (Renfrew and Slater 2003; Demoule and Perlès 1993; Zachos 2007).

The earliest copper finds in Northern Greece come from Sitagroi, Drama (Figure 4.1) from excavation phases II and III dated to 5200-4800 BC and earlier than 4700-3300 BC respectively (Renfrew and Slater 2003). Phase II yielded four copper objects, while phase III had eleven copper objects, one gold piece, one copper slag and a possible piece of copper ore (McGeehan-Liritzis 1983, 153). Further evidence for copper metallurgy comes from Promachon-Topolnica, Serres in conjunction with habitation phase II, securely dated to the first half of the 5$^{th}$ millennium BC that is culturally related to Sitagroi II (Koukouli-Chrysanthaki and Bassiakos 2002, 193). The existence of such finds in early contexts would suggest that minerals were conceived as part of a broad array of local resources potentially exploitable as would be stone, clay or timber. Since material transformation technologies available to Neolithic communities involved hardening knapped flint through heating or firing clay vessels the importance of minerals would have been realised in such a context.

### 4.2.2 The use of metals during the Bronze and Iron Ages

Regionalism has been a central theme in the study of Aegean Bronze Age that was traditionally seen as a mosaic of cultural groups, namely the Minoan, Cycladic, Mycenaean and north eastern Aegean-Troadic sharing common characteristics such as social organization and a certain degree of uniform technological complexity (Dickinson 1994; Korfmann 1995; Renfrew 1979; Treuil *et al* 1989). The earliest interpretations for cultural formation have followed migration and diffusionist models (Childe 1942) wherein the northern provinces have been regarded distant, alienated and backward peripheries compared to their central and southern Greek counterparts (Wardle 1994). Since the early excavation campaigns of the 1920s and 1930s, northern Greece, namely Macedonia and Thrace have been described as 'conservative' units of a Balkan cultural sphere (Casson 1926; Heurtley 1926). Through the course of the 20th century archaeological reasoning vested prehistoric Macedonia with a deficient role by comparison with the Aegean core provinces (but see Renfrew 1972; Theocharis 1973).

Systematic research, excavation and surveys generated substantial amounts of knowledge for the Cycladic, Minoan and Mycenaean south, whereas prehistoric northern Greece still remains largely under-represented archaeologically. Further the structuring of palatial economies of southern Greece was realised within extensive exchange systems expanding towards Egypt, the Middle East or western Mediterranean leaving aside a plausible expansion to the north Aegean (but see Matsas 1991). In this way Macedonia becomes a so-called periphery for which information on settlement, society and economy is significantly limited, and should therefore be interpreted as a scarcely attractive place for establishing socio-cultural explanatory models similar to those offered for the 'core' southern regions. Clearly such a picture is not only fragmentary due to limited archaeological evidence but also a misleading one since it deflects research focus from issues of cultural dynamics within inter-regional space and often leads to anticipated conclusions.

Nevertheless as Fotiadis (2001, 116) has argued, the disciplinary discourse on Macedonia's prehistory has developed on the premise of the province's alterity instead of assessing the region in its own terms. The persistence of metals so crucial for power relations among prehistoric communities of Macedonia should be seen in its regional context but understood within broader producing mechanisms and consuming networks extending from the southern Balkans to the Aegean islands and beyond.

The study of Bronze Age metallurgy in prehistoric Aegean and the surrounding regions has been addressed in numerous instances (Branigan 1974; Renfrew 1971; 1978; Weisgerber and Wagner 1988; Evely 1995) and the general pattern that currently started to emerge shows a diversification of craft production enacted in numerous regional centres within interacting cultural spheres (Day and Doonan 2007). The importance of the metals trade in Bronze Age Mediterranean has been emphasised in numerous occasions often associated with the negotiation of power and control over resources from rising elites (Branigan 1974; 1983; Gale *et al* 1990; Muhly 1988; 1999).

Organization of production was accommodated through primary smelting centres in mineral rich regions such as Cyprus and the Cyclades providing raw copper, and melting workshops in palatial and urban contexts where fabrication of artefacts was taking place. Primary treatment of ores i.e smelting was often exercised in remote places far from habitation sites. Copper-smelting sites in the Cyclades such as on Kea (Papastamataki 1998), Kythnos (Gale 1985; Gale and Stos-Gale 1981) and lead-silver smelting on Siphnos (Wagner and Weisgerber 1985), Lavrion and Seriphos often at marginal locations comprise the standard production-site type (figure 4.1).

The most thoroughly investigated examples are those of lead-silver smelting at Agios Sostis on Siphnos and copper smelting at Scories on Kythnos, and Chrysokamino on north-eastern Crete. The evidence from the latter site belongs to the Prepalatial period (EM III) and consists of fragments of a perforated furnace, pot bellows, tuyères and a small amount of slag (Betancourt 2006). The apparent organization of metals production in Bronze Age Aegean could be summarised as a southern arsenical copper tradition of the EBA and MBA centred at Crete, the Cyclades and southeastern Anatolia (Bassiakos and Doumas 1998; Gale and Stos-Gale 2002; Doonan *et al* 2004; Georgakopoulou 2004; Day and Doonan 2007) and a northern early arsenical and MBA-LBA bronze (an alloy of copper and tin) tradition centred at Troy, Poliochni, Koukonisi, Mikro Vouni and Thermi (Pernicka *et al* 1981; 1990; Korfmann 1995; Matsas 1991). The LBA is characterised by the widespread use of tin bronze and the gradual decline of arsenical coppers.

Metal finds and occasional melting slag from EBA Dikili Tash, EBA Limenaria on Thasos (Bassiakos 2003; Koukouli-Chrysanthaki *et al* 1996; Renfrew 1971) along with increasing evidence that has come to light during the last thirty years from settlements of the Bronze and Iron Ages at Vardaroftsa (Wardle and Wardle 1999), Kastanas (Hochstetter 1987), Assiros (Wardle 1989) and Kastri on Thasos (Koukouli-Chrysanthaki 1992) provided proof of an early and autonomous northern metallurgical tradition. Being part of a long-lived Balkan tradition and benefited by contacts with the south, prehistoric communities of Macedonia and Thrace forwarded craft production in a distinct manner often dissimilar to southern counterparts but rather inspired by Balkan production centres (Hoddinott 1981; Bailey 2000).

The transition to the Iron Age has been marked by crucial changes in the production, circulation and consumption of metals across the Eastern Mediterranean. Iron, the 'democratic' metal, as described by Snodgrass (1986) was known since the Bronze Age but came into general use around 1200-1050 BC and through the Geometric period largely replaced bronze in the use for utilitarian objects. Despite the collapse of Bronze Age trading networks which connected the Aegean with the Middle East and Egypt and the associated diminishing of output in production areas, metals continued to play a sustaining role in every day life. The concurrence of bronze with iron finds in Macedonia of the $11^{th}$ and $10^{th}$ centuries is indicative of access to both metals and production technologies while no shortage in raw materials is evident.

Various sites of the EIA in Macedonia such as Boubousti, Gynaikokastro and Vergina produced numerous iron finds mainly deriving from burial deposits (map 4.1). Snodgrass (1980) argued that Vergina and Athens held a leading role in iron working among other EIA centres such as Lefkandi or Knossos based on typological comparison of iron objects. The finding of slag pieces at Vardaroftsa (Axiochori) by Heurtley (1939) raised some early speculations concerning local iron production by the end of the Bronze Age, while Photos (1987) provided analytical data to support the hypothesis of a long iron bloomery tradition in Macedonia since the EIA. The important assemblage found at Kastri (LBA-EIA) on Thasos which includes bronze and iron objects as well as slag of both types (Koukouli-Chrysanthaki 1992) offered significant information concerning the transition from the smelting of copper to the smelting of iron on this mineral-rich island.

Innovations in metalworking associated with the use of iron include the 'Corinthian' helmet, the cuirass, the use of bow and chariot in battle and the widespread use of the iron sword (Treuil *et al* 1989). Important production centres were located in Laconia, Corinth and Euboea the latter of which had started a pioneering expansion strategy to the north Aegean in search for new sources of raw materials to sustain their industries.

## 4.3 Mining and metallurgy during Antiquity

### 4.3.1 The Archaic Period

The motives behind Late Geometric-Early Archaic colonisation, its impact on non-Greek populations and the social mechanisms that led to the formation of a wide *koine* within the Aegean and across the Northern Mediterranean and the Black Sea shores still remain controversial (Boardman 1980; Cunliffe 1988; Lemos 1998). Demographic pressure, scarcity of arable lands and a search for new markets for the traded goods have been offered as possible explanations. The search for raw materials to sustain metal production has been emphasised as an equally significant motive (Mazarakis-Ainian 1998). Within this context of colonialism Thrace, eastern Macedonia and the Chalkidiki peninsula have become places of great importance due to the rich mineral deposits and the favourable climate for agriculture as well as their location on age-old communication routes. Since Chalkidiki was a place of long interaction with the south already from the LBA-EIA and familiar to southern mariners and traders it became an ideal destination for colonial expeditions. Toroni (late $12^{th}$ century), Mende ($11^{th}$ century), Potidea (625-585 BC), Sane (655 BC), Akanthos (655 BC) and Stageira (656 BC) were the major colonies, which later formed the Chalkidician 'koine', established during the Classical period (Boardman 1980; Coldstream 1977; Lemos 1998; Mazarakis-Ainian 1998).

During these early Euboean colonial expeditions the mineral wealth of Chalkidiki was soon realized as attested from evidence for metalworking activity at the hilltop settlement of Koukos, Sykia. Excavations between 1989 and 1992 revealed the remains of a workshop with metalworking waste (slag, mould fragments) and a large number of stone hammers (Carington-Smith and Vokotopoulou 1989; 1990; 1992). According to the excavators mining and metal working may have been one of the reasons for the existence of the Koukos settlement a fact that would explain its apparent connection with more southerly parts of Greece, as suggested by some of the pottery at the site's cemetery (Carington-Smith and Vokotopoulou 1992, 498) where all burials are cremations but it is practiced in a variety of ways. In the cyst tombs the offerings were found with only a token of the bones as at Lefkandi in Euboea (Lemos 1998, 54).

The Chalkidiki deposits are numerous and some have produced datable finds that have established a relative chronology for their past use. Based on characteristics of extraction, the mines at Fterouda, Metangitsi (NE Chalkidiki) have been assigned to the prehistoric and Archaic periods (Vavelidis *et al* 1983). Two outcrops in Sithonia (galena/copper and galena/iron pyrites) in close proximity to the EIA settlement of Koukos might have provided raw material to the site though no clear dates exist. The rich mines of Stageira, an archaic colony of Chalcis, were most probably at Frosyni, Olympiada (NE Chalkidiki) a place that according to Davies (1935) was systematically exploited in the time of Philip II, and later in the Hellenistic era.

Around the middle of the 7th century Thasos entered a phase of colonial expansion towards the Thracian coasts and gradually managed to establish a string of fortified towns and emporia stretching from the Strymonic delta to Cape Molyvoti near Maroneia. This extended coastal zone became known as the Thasian 'continent' or Peraia and included important sites such as Galepsos, Apollonia, Oesymi, Antisara, Neapolis, Akontisma, Pistyros and Skapte Hyle (figure 4.2). By the end of the 6th century the island state was a vibrant political, economic and commercial centre in possession of fertile land, rich gold and silver mines and a substantial fleet. Ancient historians inform us that these Thasian colonies extracted a large output in precious metals until the Athenians took control of their mines (Lazaridis 1971; Koukouli-Chrysanthaki 1990). Later Philip II who conquered most of the region founded the city of Philippoi to gain access to the mines, which by that time became a significant source of wealth for the Macedonian dynasties (Hammond and Griffith 1979).

Archaeological research investigated some of the major Archaic colonies of the Peraia and a few studies focused on locating the rich mines of the Thasians in the region (Casson 1926; Lazaridis 1971; 1972; Koukouli-Chrysanthaki 1990). Among these colonies the most intriguing one concerning mineral exploitation has been Skapte Hyle, which according to Herodotus (6.64) and Thucydides (4.105.1) provided large outputs of gold and silver. The exact location of Skapte Hyle puzzled researches for many years and most have proposed Mt Pangaeon as the appropriate landscape to situate such a renowned metallurgical centre (Lazaridis 1971). Lately it has been suggested that the place name does not signify a single settlement but rather an administrative centre for coordinating mining activity over a wider region that was probably situated in the Lekani mountains north of Neapolis (Koukouli-Chrysanthaki 1990; Photos *et al* 1986a).

This highland region known as Palaea Kavala which belongs to the Lekani range is rich in iron, copper and precious metal deposits that have been the subject of intensive mining since Archaic times (Papastamataki 1975; 1985; Photos *et al* 1986a; Vavelidis *et al* 1997). The major ore occurrences across an area roughly covering 100 $km^2$ are numerous, reaching approximately 150 in total. These are associated with the lower marble and the upper gneiss strata and based on their geochemistry they divide into three deposit types. The first type consists of Fe-Mn ores found within carbonate minerals with Au contents up to 26 ppm. The second type is Fe-Mn rich in Pb, Zn and Ag, which could be found in carbonate bodies as well, with Ag contents reaching 2500 ppm (Vavelidis *et al* 1996). The third one consists of quartz bodies rich in iron pyrite and arsenopyrite, elongated bodies of iron pyrite-chalcopyrite at the contact of marble/gneiss and gneiss, with Au contents up to 38 ppm (Vavelidis *et al* 1996).

The mineralogical composition of the Fe-Mn deposits of Palaea Kavala was thoroughly investigated by Spathi *et al* (1982) who concentrated on the oxides, carbonates, arsenides and sulphides they reported. In addition to these Vavelidis (1994) located Ag-bearing jarosite, tetrahedrite freibergite, proustite-pyrargite, native silver and gold. The major ores encountered at Kechrokambos and Elafochori are mixed sulphides and Mn-rich iron pyrites. Geological investigations have located nine major slag deposits at Makrychori, Petropigi, Anestiada, Kastanies, P. Kavala, Chalkero, Zygos, Madra Kari and Tria Karagatsia. Makrychori has been investigated as part of this research and is thoroughly examined in chapter 5 along with all the other surveyed sites. The estimated overall volume reaches 5.000-6.000 $m^2$ but additional numerous heaps covered under vegetation could not be easily estimated. A common feature of slag from all sites is the high levels of Ag compared to other regions in Macedonia.

#### 4.3.2 The Classical Period

The most significant known metallurgical extraction centres of classical antiquity were established at Lavrion, Serifos, Sifnos, Kythnos, Thasos, Pangaeon and Rhodope (Healy 1978; Shepherd 1993). Mining and metallurgical techniques of the classical period are thought to have been highly sophisticated judging on the remains of complex draining and ventilation systems within galleries and the well-known ore washing and smelting facilities at Lavrion (Cordella 1869; Conophagos 1980; Kakavogiannis 2005). Such innovations allowed for substantial enrichment of the ore prior to smelting.

Numerous mining galleries and shafts have been located and described by the Institute for Geological and Mineral Explorations during surveys across regions mentioned above in the 1960's and early 1970's (Maratos and Andronopoulos 1966; Stavropodis 1983; Papastamataki 1975; 1985). Close to such galleries there is substantial evidence of scattered and piled metallurgical waste accumulated through long periods of metal extraction. Any given quantity of discarded slags suggests the processing of ores within furnaces or any kind of similar structures for primary smelting i.e. separation of the metal from its ores (Papastamataki 1975, 21) but dating such activities is highly problematic. Simple description of the evidence for metallurgical operations and assigning these as 'ancient' does not give any information on their chronology and spanning through time.

Papastamataki (1975) created one of the first catalogues on slag deposits across Greece and also sampled and analysed some of the material in view of investigating their potential levels of precious metals. The mineralogical and chemical results shown low levels of Au and Ag and thus state funded exploitation and the idea of a large scale re-melting operation for extracting the valuable metals was abandoned as being inefficient and non economic, leaving the deposits untouched (Maratos and Andronopoulos 1966). However some of the sampled heaps had been already severely disturbed by various agents such as erosion or human intervention as road construction, levelling for farming or even by incorporation of slag into building material. Therefore recording of the threatened archaeologically significant remains of metallurgical operations has been realized in later decades but no programmes for systematic surveying, dating and interpretation have been formulated probably due to lack of funding. McGeehan-Liritzis (1983) also reported numerous slag heaps which are known to occur in Phthiotis, Chalkidiki and Rhodope but even today they lack accurate dating due to restricted studies concentrating on such material evidence.

Photos-Jones (1987) applied a unified archaeometallurgical model in relating iron ore, slag and artefact from various Macedonian sites. Her study on slag and iron artefacts from Iron Age, Classical and Hellenistic sites provided rough estimates of volume, detailed information on the process relation and valuable analytical results mainly on mineral phases and chemical composition. Some slag samples from Serres, Drama and Kavala were included in the analyses but no firm chronology for the accumulated deposits was provided. It has been assumed that activity in the sites of Drama belongs to Ottoman times.

Numerous 'ancient' excavations for native-reef gold, silver and gold placer tailings spread out mainly over northern Greece and the neighbouring countries as has been shown by Mack (1964). Again dating such activity to the years of classical antiquity without considering associated archaeological evidence such as pottery seems to be arbitrary. The deposits east of Axios River have been explored for more than 30 years by a number of geologists in co-operation with IGME (Kockel and Walther 1965; Kronberg *et al* 1970; Walther 1974; Kaufmann *et al* 1976). The area consists of the Rila-Rhodope massif, which is built up of thick crystalline series with gneisses and schists in the lower part overlain by thick marbles in the middle and schists, gneisses and marbles in the upper part (Kronberg *et al* 1970). The ancient sites of mining activities and recent exploration works provide evidence that gold in the placer deposits is derived not only from the polymetallic sulphides, the porphyry copper deposits and quartz veins, but is also distributed in various layers of the Rila-Rhodope and Serbo-Macedonian massifs as fossil placer deposits (Mack 1983, 378).

Confirmed major evidence for Classical gold extraction concentrates at Mount Pangaeon, the area of Palaea Kavala-Zygos-Makrychori and Thasos Island while debris from similar activity around Mount Angistro has not been accurately dated (Mack 1983; Arvanitidis *et al* 1989; Epitropou *et al* 1983; Vavelidis 1994). Signs of exploitation on a minor scale were probably located at sites of Falakro and the Vrontou range. Ano Vrontou is one such site that has been examined through field survey (see chapter 5).

Sites of gold and lead-silver extraction as well as copper and iron smelting activity have been noted either on the mountain plateaux or on the slopes and foothills of the Lekani Mountains at Amygdaleonas, Zygos, Chalkero, Perni and Petropigi (Vavelidis *et al* 1997). Slag heaps were recorded and sampled at Makrychori, Tria Kargatsia, Dipotamos, Pyrgiskos and Kastanies (Photos *et al* 1986a). By the time when Photos *et al* (1989) carried out their survey a substantial slag heap of a few hundred tons occurred at Makrychori whereas today most of the material is scattered on top of highland paths near the village. Speiss (a metallic 'waste product' of iron arsenides) was also recovered from the slag heaps but in smaller quantities. Analyses on slags from Philippoi, Pyrgos Apollonias (P. Kavala), Sidirochori and Domatia (Mt. Pangaeon) were also conducted in the past (Photos 1987).

Mt. Pangaeon stretching to a total length of 50km divides eastern Macedonia into north and south and slag heaps have been recorded in numerous sites such as Livadia, Giannaki Vrisi, Avli, Valtouda, Lofos Sina, Antiphilippoi, Moni Analipseos and Proti. The estimated volume of slag from all the above sites is in the order of 35.000-40.000 $m^2$ and in most cases high As levels and speiss fragments have been reported (Papastamataki 1985). A comparison of the chemical data from Palaea Kavala and Pangaeon speiss showed the same composition suggesting similar methods for precious metals extraction (Photos 1987).

In Aegean Thrace minting of silver coinage concentrated in regional colonial centres near metal bearing deposits, as is the case of Abdera, Maroneia and Mesembria while Thracian towns in the hinterland such as Pistyros yielded evidence of local production in iron artefatcs (Koukouli-Chrysanthaki 1990; Katincarova-Bogdanova 1999; Papastamataki *et al* 2001).

#### 4.3.3 The Hellenistic and Roman Periods

According to historical sources the Hellenistic period was a time when substantial amounts of gold and silver were being extracted from Macedonian ore deposits to the point that some became exhausted (Mack 1983). Direct archaeological evidence for probable Hellenistic iron metallurgy in northern Greece derives from the presence of typical sherds of the period in the vicinity of mining galleries and slag concentrations. During a recent combined survey undertaken by the archaeological service and IGME, mining works dated to the Hellenistic period have been located close to Maroneia in Thrace (Papastamataki *et al* 2001). The workings consist of shafts and galleries opened to extract the oxidised sulphide ore rich in hematite and goethite. Associated ceramic evidence dates the opening of galleries to the 2nd century

BC but mining spanned a short period of time. It appears that all activities were interrupted fairly quickly after initiation probably due to the low quality of the ore.

Further evidence for the sophistication and innovative nature of metals technology reached at that time comes from Macedonian sites. Ni-rich metallic prills in a small number of iron slags from the Hellenistic settlement of Petres, western Macedonia suggests that lateritic iron ores may have been exploited in the region, doubtless in addition to the more common hematite ores (Photos *et al* 1986b). Moreover the complex extractive metallurgical practices, by which Pb was added during smelting of the Mn-rich ore to act as a precious metals collector at Palaea Kavala which have developed in Classical times, gained momentum during the Hellenistic period and provided large quantities of gold to the Macedonian kings.

Mining and extractive metallurgy in Roman times intensified and concentrated on large deposits across the vast territories of the empire such as Rio Tinto in Spain and the precious metals-rich deposits of Anatolia, Macedonia and Thrace. Titus Livius (XLV 29, 10-11) mentions that the Romans kept under their control the exploitation of gold and silver mines within the province of First Macedonian Meris (between Strymon and Evros) leaving the exploitation of the copper and iron mines to the native population, presumably the Thracians (Kostoglou 2003). The province of Thracia (roughly coinciding with Herodotus' description of extended Thrace) was one of the 44 armour production centres recorded in *Notitia Dignitatum*, compiled in the beginning of the 5$^{th}$ century AD.

Roman silver and lead extraction is evidenced at Thracian sites such as Thermes and Kotyle (Triandafyllos 1990) and copper mining at Kimmeria in Xanthi, whilst iron working centres at Kalyva-Kastro in Xanthi and Mesembria in Rhodope prefecture (Kostoglou 2003) reveal the potential of Roman craftsmanship at its early attempts of iron carburization and the production of steel.

Evidence for iron smelting and smithing of Hellenistic-Roman dates from southern Greece comes from excavations at the Unexplored Mansion at Knossos where about 35 kg of iron and bronze melting slag were found along with furnace remains (Photos *et al* 1986b) and surveys in the Peloponnesus at Achramboli, the region of Cape Malea and Isthmia (Rostocker and Gebhard 1981) where slag heaps date to the $4^{th}$-$5^{th}$ centuries AD. There is also an increasing number of reported sites with slag concentrations located at Paroikia on Paros (plano-convex slag), Kionion and Drakano on Ikaria where remains of a roasting furnace exist, Nerotrives on Euboea and Olynthos in Chalkidiki (tap-slag) appearing to belong to Hellenistic times (Bassiakos pers. communication).

### 4.4 Byzantine mining and metallurgy ($4^{th}$-$15^{th}$ centuries)

Byzantine mining and metals technology is often considered to have been built upon this long tradition described above. However such a hypothesis needs to be reconsidered in view of the recent progress in material culture studies. It is generally accepted that shortly after the contraction and fall of the western Roman provinces to barbarian tribes, the eastern territories remained under Roman control gradually transforming into a Greek speaking imperial formation which consolidated control over much of eastern Mediterranean. The northern Greek mines (figure 4.3) of the earliest periods are supposed to have fallen into idleness or became a secondary source of iron and precious metals compared to the rich mines in Egypt, Asia Minor and Serbia (Vryonis 1962; Bryer 1983). State owned mines were in operation across the eastern Roman Empire at metal-rich regions such as Armenia and the Pontus but the development, articulation and interactions of such industries has not been thoroughly studied in the past.

During the days of Constantine, Theodosius and Justinian, master craftsmen active within the palatial workshops were producing high quality gold and silver objects often intended for diplomatic exchange. Paulus Silentiarius in the 5th century informs us that Aghia Sophia was decorated with all sorts of precious materials and that: '*... mount Pangaeon and cape Sounio opened all their silver veins*' for the adoration of the marvelous Byzantine temple par excellence. Throughout the Byzantine millennium the Orthodox Church played a crucial role in traditional craft production among monastic communities and often encouraged metalworking activities at Mount Athos and other monasteries such as at Synaxis, Mt. Papikion and other ecclesiastical estates (*metochia*) (Papaggelos 2003a; Koufopoulos and Mamaloukos 1997; Harvey 1996; Bakirtzis 1996). Although the trade in Byzantine metalwork is known to have been extensive and far-reaching there is little archaeological evidence to be used for a reconstruction of procurement of raw materials and production sequences followed by Byzantine miners, metallurgists and metalworkers.

The general question of the circulation of gold in the Middle Ages was discussed by Bloch (1933) and Lombard (1947) who suggested a model by which Byzantium was, up to the 7th century, the domain of gold *par excellence* for three reasons. A favourable balance of trade which brought in a steady stream of gold; arrival of new gold from neighbouring lands which possessed gold mines; and the already existing stock of gold within the empire (Vryonis 1962). A significant diminishing of gold stock after the seventh century was attributed to the Arab conquests and the loss of contact with gold mining lands. This hypothesis however leaves unexplained how the gold solidus of Byzantium remained pure and stable up to the middle of the 11th century. Even though Bloch and Lombard sustained the explanation that Byzantium acquired a favourable balance of trade with the west Vryonis (1962) was the first scholar to support that Byzantium might have obtained gold, or other metals within its own diminished borders. He emphasised the central role of gold and other metals and their importance for understanding technology, trade and economy in Byzantine society. Following similar lines Bryer (1983) provided a concise review of the references on mining in the Pontus region during Byzantine and Ottoman times and attempted at elucidating characteristics of metallurgical operations.

The supply of raw materials for the running of craft industries as described above was fundamental for balanced and uninterrupted production. The procurement of ore minerals and the mechanisms behind the organisation of metal extraction centres, the work of the labour force and their social relations with the peasantry, as well as the village communities and estate holders as capital investors for such activities are investigated below. Mining and metallurgy and their role and associations within the economic system as strategic supplier mechanisms for manufacturing, sustaining trade, coinage circulation and eventually providing the infrastructure for a taxing system of the Byzantine state are being discussed.

References to mining in historical documents albeit rare, have been useful for an understanding of the articulation of the Roman metals industry mainly in terms of administrative organization. Thus the Theodosian Code mentions gold miners in Illyricum, Macedonia, Thrace, Pontus and Asia during the 4th century. It also contains regulations for the appointment of *procuratores metallorum* among the curial class in Macedonia, Dacia, Moesia and Dardania and includes vague references to *metallarii* in Italy and Gaul (Vryonis 1962; Edmondson 1989). Other legal documents such as the decree of Theodosius II dated 424 and the decree of Valentinian and Valens dated 365 provide guidance on the transferring of miners according to place of origin and discuss the advantages gained from mining on individual and communal level. Further technical recipes in chemical Byzantine codices dated from the 10$^{th}$ to the 15$^{th}$ century refer to branches of metalworking, especially to gold and silverwork (Papathanasiou 2002).

The medieval treatise *On Divers Arts* (1122-1123) compiled by Theophilus represents one of the earliest attempts at recording the accumulated knowledge of the Middle Ages on colourants, glass and metals used for the fabrication of artefacts. It is interesting to note that the author desiring a pseudonym chooses the Byzantine name of Theophilus in recognition of Byzantium's excellence in the techniques described (Hawthorne and Smith 1963). Unfortunately no Byzantine technical treatises of that sort have survived so that informed comparison could be made. Later Renaissance scholars Vanochio Biringucio and Georgius Agricola compiled the earliest treatises exclusively focusing on mining and metallurgy of their time. In their monumental works *Pyrotechnia* (1540) and *De Re Metallica* (1556) respectively, they inquired on the most important aspects for the conduct of mining and metallurgical operations (Smith and Gnudi 1990; Hoover and Hoover 1950).

### 4.4.1 Archaeological evidence from the Eastern provinces: Egypt, Anatolia and the Pontus

Bir Umm Fawakhir, a remarkably well preserved gold mining settlement in the Eastern desert of Egypt initially assigned to the Roman period has been lately proven by survey and excavation to belong to Byzantine times (Meyer and Heydorn 1998; Meyer *et al* 2000). The site's dating to the 5$^{th}$-6$^{th}$ centuries based on pottery and epigraphic evidence led to a reappraisal of the view that Byzantine control of the desert was very weak at that time. On the contrary sustaining such a large settlement and provisioning for the miners' needs testify to the increased interest of the Byzantine state to exploit its economic resources even in harsh, marginal locations. Studies of Byzantine history and geology of the vicinity suggest reasons why this site existed here, at this time. The Byzantine Empire in these centuries faced urgent demands for gold for a multitude of purposes: wars, the navy, improving the loyalty of dubious allies, ransoming hostages, the court itself, and major building projects from Ravenna in Italy to Aghia Sophia in Constantinople to St. Catherine's on Sinai (*The Oriental Institute Annual Report* 1991-1992). Experiments with ancient mining and ore reduction techniques show that these low-grade, difficult-to-smelt sulphides in quartz veins in Precambrian granite required a very sophisticated, multi-stage reduction, smelting, and purification technology (Meyer *et al* 2000).

Other significant mining districts of the early Byzantine period were concentrated in the border regions of Armenia where gold washed out on the surface of mountain slopes, and the central-eastern Anatolian Taurus range with mines in the Bolkardağ, Ergani and Kestel (Yener *et al* 1991). Through a focused field survey undertaken in the 1980's, late Roman and early Byzantine mining camps and tools within galleries were located at various sites of the Bolkardağ, testifying to the continuity of mining and smelting activity in the region, starting from prehistoric and spanning through to medieval times (Yener 1992; Yener and Ozbal 1987; Yener and Toydemir 1986). Pitarakis (1998) recently undertook a thorough study of mining and metallurgy in Byzantine Anatolia where she recorded 54 mining regions spanning between the 5$^{th}$ and 15$^{th}$ centuries (figure 4.4). Two wooden shovels have been found within mining galleries at Espiye and Bulancak and a trough within a slag heap close to Tekmezar all dating between the 11th and 13th centuries (Kaptan 1989). The material used for the tools, the workmanship associated for their construction and their wear pattern provided valuable information on mining techniques employed in Anatolian mines at that time.

Even though the 7th century witnessed the loss of important mining regions to the Arabs and Slavs mining activity did not cease entirely (Matschke 2002). Compositional analyses on coins have shown that newly mined gold and silver were supplied to the mints. Throughout the following centuries mining became linked to landownership and as a result public interest in organizing mining activities gradually declined. State regulations were enforced so that property taxes from owners of ore-rich land were collected and the output of precious metals was transferred to the state's treasury.

### 4.4.2 Documentary evidence on the eastern provinces

In his *Natural History* Pliny included some scattered remarks on iron ores 'which occur in greater quantity than those of any other metal' (*Nat. Hist.* 34.149) and 'in Cappadocia only, the question is raised, whether iron is to be placed to the credit of the water or the earth, for the earth yields iron to the smelter only where the water of a certain river has flooded it' (*Nat. Hist.* 3.142) (Rackham 1942). An important iron and silver producing region was Chalybia, firstly mentioned in the *Iliad* as Alybe:

*'But of the Halizones Odius and Epistrophus were captains from afar, from Alybe, where is the birth-place of silver'*

(2.856-857)

Other documents include Strabo's (Jones 1928) description of the region 'full of mines and forests' from *Geography* (XII, iii, 19) and a passage of Apollonius of

Rhodes from his *Argonautica* who reported that the Chalybians knew nothing of agriculture or cattle breeding:

*'...but they cleave the iron-bearing land and exchange their wages for daily sustenance; never does the morn rise for them without toil, but amid black sooty flames and smoke they endure heavy labour'*

(2.1002-1008)

There is documentary evidence for iron mining in Cappadocia mentioned in a letter by Basil of Caesarea, written in 372, requesting from the mine administrator to reduce the taxes on iron mining (*siderou synteleian*) to a tolerable level (Matschke 2002, 116). Apart from mining the ores rich in iron such as hematite, goethite and limonite the process of collecting iron rich magnetite sand was an alternative method for raw material acquisition probably practiced as early as the Iron Age (Tylecote 1981). It is known from medieval ecclesiastical and lay documents of the Byzantine state that such practices were carried out at various locations of the Black Sea shores. Nicetas Magistros provides information on iron metallurgy in his *Lettres d' un exile* (Westernik 1973) where he mentions:

*'The river brings iron to the sea like a secret wedding gift by the groom to his wife. But the sea desiring to make her gift public crushes it on the beach in the form of sand in full view to all'*

Lettres d' un exile (928-946)

Recent research has confirmed that in 10th century Propontis (Sea of Marmora) the natives collected lumps of iron from estuary sands and after roasting they introduced the charge in a smelting furnace (Matschke 2002). The pig iron produced was heated once again and probably shaped into ingots before being handed over to blacksmiths (Bryer 1983).

Chalybia, the territory between Oinaion and Tripolis, close to the mouth of Harsit R., so profoundly synonymous with iron survived by name as a 13th century district and a 14th century emirate of the Empire of Trebizond (Bryer 1983). There were probably silver deposits at classical Argyria, near the mouth of the Philabonites River and silver was probably mined somewhere in the mountains of the upper Philabonites valley in the medieval period. Bryer and Winfield (1985, 3) argued that if that was the case, such mining activity was concentrated between Tzanicha (Canca) and Pairetes (Bayburt) and probably out of the hands of the Grand Komnenoi of Trebizond; at all events these mines should not be confused with the later ones of Gumushane (see below). The account of one Castilian ambassador named Ruy Gonzalez de Clavijo's dated 1404, wherein iron working in the same region is included, provides the only direct evidence for mining of any sort except alum in the Empire of Trebizond.

In 1836 when the English traveller Hamilton arrived at Oinaion the Chalybians were still working iron sands following similar methods with those described by Apollonius of Rhodes and Strabo (Jones 1928). His description is one of the best surviving today: 'they dug the ore by scraping up the soil...with a mattock, and collecting small nodular masses ...the mode of extracting the iron is however very slow and laborious, the ore is smelted in a common blacksmith's forge. The blast of the furnace is kept up for twenty-four hours, during which time the mass must be constantly stirred, and the scum and scoria raked off, after which the melted iron is found at the bottom, which from the specimen I saw, appeared of very good quality' (*Researches*, 1836). R. Tylecote's (1981) sampling and further analyses showed that half the Chalybian sands were magnetic whilst only 26% of the Kireson (east of Chalybia) had such properties.

### 4.4.3 Archaeological evidence from the Balkan states: Serbia, Bosnia, Bulgaria

The rich mines of the Balkans (i.e. Trepca, Novo Brdo, Rudnik) formed a direct source of wealth for the Romans who turned their attention to 'inner Macedonia' in search for precious and base metals. As early as 1932 Davies suggested that the Byzantine Empire seems to have mined mainly further north of southern Macedonia, as Procopius' Ferraria seems to be near Božica while he noted that mining shafts at Dobrevo closely resemble Greek work. According to the same author the Slavonic kingdoms mined extensively with the help of Saxons at Novo Brdo, Stan Trg and Čiprovac (Davies 1932, 162).

Numerous mines were in operation in medieval Serbia, Kosovo, Bosnia and Bulgaria (figure 4.5) and the substantial output in iron, copper, silver and gold extracted from Balkan ores became a source in metals highly valued across Europe at times of shortage in silver (Beldiceanu 1964; Murphey 1980; Inalcik 1973). Large metallurgical centres concentrated across the Morava R. valley in Serbia and Kosovo namely at Trepca, Novo Brdo, Pristina and Rudnik further north, while the Bosnian centres were established across the Drina R. valley at Srebrenica, Zvornic and Sase (Davies 1935; Inalcik and Quataert 1994). Excavations at various sites in the district of Rudnik revealed mining shafts, waste dumps, charcoal kilns and smelting furnaces (Mrkobrad 1990; Jovanović 1980). Sites such as Kraku'lu Yordan in northern Serbia are special given the highly organized and to some extent specialised character of the workshops, bearing substantial evidence for crucible smelting that has come to light during excavation (Werner 1985). As far as precious metals extraction is concerned rivers Hebros and Strymon and their estuaries have been under constant mineral exploration and gold panning was common.

Although ancient mining and metallurgy in Bulgaria is well documented through surveys and archaeological work there have been very few studies focusing on Byzantine metallurgy in Bulgarian territories, which have probably been of great significance at times of shortage in precious metals elsewhere in Europe. As Vryonis (1962, 14) pointed out coin finds from the vicinities of Bulgarian mines and in one case inside the mines at Stara Planina and Etropolje from the period of Anastasius I to Isaac II Angelus indicated that possibly ancient and Roman mines were not completely abandoned. Numerous sites associated with metalworking that were in operation since Byzantine times, indicated by coinage, flourished in the years of Bulgarian rule.

Turnovo is a typical case of a significant medieval crafting centre of the north Danube plain that developed substantially to become the economic and political capital of the Bulgarian kingdom. The beginning of manufacturing activities dates to the Byzantine period (late 11$^{th}$ century) for which time there is evidence for iron, copper, glass and ceramic production. Iron furnaces and blacksmith's workshops, copper melting furnaces, kilns for the production of kitchenware, domestic and building ceramics begun to operate at least before 1186 (Dochev 2002). A large amount of Komnenian coins from 1081 to 1186 testifies to the growth of Turnovo as a typical Byzantine urban centre of the twelfth century. After 1186 Turnovo became the capital of the newly restored Bulgarian kingdom a fact that fostered population growth and stimulated iron and copper production which became the most important activities of its inhabitants (Dochev 2002). Archaeological investigation around the monastery of the Forty Holy Martyrs revealed eight furnaces (dimensions 1x2 m) dug into the ground among ore pieces, charcoal and around 3,000 kg of slag mixed with iron pieces. The metallurgical debris predates the construction of the monastery in

1230 after which date the activity moved at its precincts. Blacksmiths workshops were established around the furnaces which produced tools, building articles and weapons.

The reorganisation of prospecting and raw materials management implemented by the Ottoman administration favoured innovations in production such as blowing devices for the smelting furnaces and more efficient division of labour. Such organization of production within the blacksmith family unit is elaborately depicted in ecclesiastical iconography of 14$^{th}$ century, examples of which can be found in Zemen monastery (figure 4.6). The technical developments found direct application in metal rich districts in central and southern Bulgaria as in Samokov where substantial iron smelting and foundry installations powered by waterwheels of the Ottoman period have been recorded (Georgiev 1971). The chronology of such large-scale proto-industrial activity is not clear but appears to have spanned between the 15$^{th}$ and 19$^{th}$ centuries.

#### 4.4.4 Historical accounts from Balkan Provinces

The intensification of mining in medieval Serbia was a direct outcome of the arrival of Germanic miners (Sasi) during the reign of king Uroš some time before 1254. Those Saxon settlers brought along the new technology of mining, organization of workforce and professional staff and their own miners code (Bogosavljević 1990, 251). The development of mining and metallurgy brought about new towns, markets and colonies as well as merchants and most importantly an increase in the number of domestic population involved with metalworking. The demand for Serbian silver and gold, given the decline of European and Byzantine metal stock, increased severely to reach its peak in the first half of the 15$^{th}$ century (Bogosavljević 1990; Vickers 1998).

Rudnik was an important mining centre firstly mentioned in source-books of 1293. Various records refer to the arrival of Saxon miners to establish a settlement around 1312. They introduced a better quality of technology, better organization of activities and training of craftsmen, thus succeeding to train the locals in performing complex metallurgical procedures such as the separation of precious metals (Mrkobrad 1990, 244). This is why German terminology related to crafting survived in Serbian mining districts throughout the medieval period.

Silver mines significantly declined throughout central Europe in the middle of the 14th century due to both geological and technical parameters. Most of the mines had reached depths at which the shafts could no longer be pumped dry with the available technology as happened in copper mines, which in some districts was a by-product of silver mining (Cowen 2000). By 1390 silver was short all over Europe, except in Venice. The silver mines at Kutná Hora had begun to decline in the 1370s, and finally closed down after being sacked by King Sigismund in 1422. The only significant new sources of silver left operating in Europe were mines at Srebrenica in Bosnia and Novo Brdo in southern Serbia, and they shipped most of their production through the Venetian ports and fortresses that controlled the coast of Dalmatia (Vickers 1998). As the Bosnian mines declined in the 1430s, the stage was set for a financial disaster, completed when the Turks overran the major mines in the 1450s.

The ethnic backgrounds and affinities of the labour force of the Balkan industries could not be inferred through archaeological evidence though some indication could be found in descriptions of professions and the people involved with such undertakings. Hence in narratives concerning Gypsies there is regular reference to smelters, gold washers and smiths often socially stigmatised due to their origin and profession. The virtual absence of a working class made welcome the skills which

Gypsies brought with them from Byzantium and beyond. Two of these skills were smelting and the manufacture of firearms and shot, probably learnt in Armenia and the Byzantine Empire (Kenrick and Puxon 1972).

The earliest legal documentation referring to Gypsies as slaves date back to the reigns of Rudolph IV and Stefan Dušan (1331-1355) who made one fifth of their number the property of the monasteries and landowners (Ozanne, 1878, 65; Kinder and Hilgemann 1964, 205). Throughout the Balkan principalities, Gypsies were distributed in the following way: the overall population was divided into house slaves (*tsigani de casatsi*) and field slaves (*tsigani de ogor*) (Kinder and Hilgemann 1964). There were three principal occupations among the Slaves of the Crown: that of *rudari* (or *aurari*) or goldwasher, that of *ferari* or blacksmith, that of *ursari* or bear-trainer, and that of *lingurari* or carver of wooden spoons. A number of travellers such as Dembsher (1777), Grellmann (1807), Hoyland (1816), Clarke (1818), Groome (1899) and Wilsdorf (1984) who travelled through the region described the activities of gold washing. Grellmann's account from the late 18th century indicates that, unpleasant as their job was, gold washers were seen as a privileged group, and distinct from the slaves: 'Gold washing, in the rivers, is another occupation, by which many thousand Gypsies, of both sexes, procure a livelihood, in the Banat, Transylvania, Wallachia and Moldavia' (Grellmann 1807).

Given the high mobility of populations in late medieval times (Vakalopoulos 1973) and according to travellers' accounts the towns of eastern Macedonia mainly Serres, Drama and Kavala had mixed populations. Belón observes that the old Greek population was predominant and Greek was the language the inhabitants spoke. The country people around Serres though spoke Greek and Serbian the latter being doubtless a left over from the days of Stefan Dušan (Vakalopoulos 1973, 148). Most of the Serbian settlers were farmers or herdsmen practicing a seasonal transhumance model of subsistence but some itinerant craftsmen have also travelled southwards bringing new technological innovations with them. Gypsies who travelled far and wide across the Balkans are also mentioned as skilled blacksmiths in Byzantine literary sources.

### 4.4.5 Archaeological evidence from North Greek Byzantine provinces: Macedonia, Thrace

The tradition of iron sand smelting that was common to Black Sea metalworkers since the Iron Age, occurs in late Roman and Byzantine northern Greece and survives at places through the Ottoman years. Examples of such smelting operations come from eastern Macedonia where the raw material derives from the decomposition of the Vrontou granite and were also common on the island of Thasos (Photos 1987, 159). Close to the village of Orini in Serres, a defended fortress with evidence of iron smelting was preliminary investigated in the 1970s (Samsaris 1979). Based on architectural characteristics and pottery sherds the citadel was conventionally dated to the Roman period ($2^{nd}$-$4^{th}$ centuries) when military forces were based at various sites of the Rhodope for repelling the Gothic invasions.

The evidence for metalworking recorded through the current field survey consists of large slag heaps covering the motes of the fortress as well as smithing debris in its interior (see chapter 5). Although no analytical studies have concentrated on material from Orini it is probable that iron sands were the major ore source used for bloomery practices (Samsaris 1979). The surface magnetite ore that leached out by river action in the region was captured in small lakes and was easily gathered by prospectors. Similar evidence comes from Pyrgoi in Drama where a Byzantine fortress with smelting debris deposited on the slopes was located but not thoroughly studied. The evidence consists of slag pieces and refractory materials possibly deriving from operations of iron metallurgy i.e. smelting and smithing (Bassiakos per. communication).

Confirmed archaeological evidence for mining and metalworking settlements in Byzantine Greece are extremely rare but there is one such case at Chalkidiki. According to contemporary documents and substantial archaeological evidence, an extensive metallurgical centre developed in Late Byzantine times at Sidirokapsia, a mining settlement that grew larger and more significant in Ottoman times (Dimitriadis 1986; Vakalopoulos 1973; Vryonis 1962). An early reference to the village of Sidirokapsia could be found in an Act from Iviron monastery dating to 995 while it appears as a site name in later Acts from Esphigmenou and Protaton (Lefort 1985; Lefort 1973; Papachrysanthou 1975). It was close to that settlement that Ioannis Kolossos founded the monastery of Sidirokapsa some time in the 9$^{th}$ century. An Act from the archive of Xeropotamou confirms that the mines of Sidirokapsia were in full operation by 1445 (Bompaire 1964) while the French traveller Belon provided an eloquent description of the industry during his visit in the 1500's. The economic significance of the area has been further outlined by registers of revenue given to the monastery of Aghia Lavra which owned land at Stratoniki and Madem Lakkos where some of the mining shafts and underground galleries were located.

#### 4.4.6 Historical accounts from the North Greek Provinces

The classical sources of antiquity refer to Thasos, Pangaeon and Skapte Hyle as three significant metal-rich areas of northern Aegean and the Thracian coast, which are described as gold and silver producers. Attempts to locate Skapte Hyle were based on the classical sources which point to a place in the southern Lekani foothills. Herodotus states clearly that at the time of Xerxes' invasion in 490 BC the Pangaeon mines were exploited by Thracians while the Thasians did not penetrate inland until a century later in 360 BC. Since Skapte Hyle was a Thasian territory as early as the 5$^{th}$ century it could not have been situated on Pangaeon but somewhere within the metals-rich Lekani range north of Neapolis (Koukouli-Chrysanthaki 1990). It can be assumed that part of the metalliferous Peraia would have been ceded to Neapolis to provide the metal for its mint (Photos *et al* 1987).

Mining activities and extraction of metals are rarely referred to in Byzantine documents but the golden 'solidus' of Constantinople was the strongest currency even after Byzantium lost its eastern provinces to the Arab conquests suggesting that the empire was self sufficient concerning resources within its own diminished borders (Photos 1987; Vryonis 1962). The Theodosian Code of AD 370-386 clearly states the problems faced by the state to keep itinerant Thracian miners prospecting for gold outside the boundaries of the Diocese of Macedonia, a situation that worsened by the defection of the former, who were expert in following veins of gold, to the Gothic army (Vryonis 1962). Such references suggest the depletion of ore bodies and might be taken as proof that some Macedonian and Thracian mines were idle at least in the proto Byzantine period.

Direct historical reference to iron metallurgy for eastern Macedonia is documented in a Mount Athos manuscript of Aghia Lavra dating to 1347 (Actes De Lavra III: Chrysobulle de Stefan Dušan). The manuscript refers to privileges granted to the monastery and its territories by the Serbian ruler Stefan Dušan. It is clearly stated in the document that 600 ingots (*mazia*) of iron per annum were coming from the mines of Trilision (Τριλίσιον) and Vronte (Βροντή) which were situated north of

Serres (Lemerle *et al* 1979). The rich revenue in the order of 30 hyperpyra per annum coming from Trilision is mentioned in a second document from Aghia Lavra, a Chrysobulle of Stefan Uroš dating to 1361. As Photos (1987, 52) has pointed out the first document does not specify whether iron was mined or extracted from magnetite sands but the work of Davies (1935) and Anhegger (1943) rather suggest the latter. Other relevant documents include the Xeropotamou monastery and Saint John Prodromos monastery archives where iron production in the highlands north of Serres is mentioned.

Smelting activity has been recorded close to the modern village of Ano Vrontou which must have been the mining region of Vronte mentioned in the manuscript (see chapter 5). It is important to note in this context that *vrontesios* (βροντήσιος) is the Byzantine word for bronze, an alloy of copper and tin, suggesting the possibility of bronze working in parallel with iron production at Vrontou (Papathanasiou 2002). Although the site name Trilision has not been yet identified with a certain mining-smelting region somewhere between Serres and Kato Nevrokopi it is proposed here that the site of Trisla on the Vrontou range, where mining activity has been recorded, could be a possible candidate for the Byzantine Trilision. Ostrogorsky (1965) mentions both iron producing regions referred to in the Chrysobulle of Stefan Dušan and provides a map where Trilisi is situated not further than 20 km northwest of Vronte close to the mines of Trisla (figure 4.7). Therefore the smelting evidence of the lowlands close to Katafyto and Vathytopos reported in chapter 5 might represent the remains of smaller production sectors within the extended iron producing district of Trilision and Vrontou active during the 14$^{th}$ century. The continuation of iron mining and smelting in the region during the

Ottoman period is attested by numerous slag heaps at the Vrontou range, Mt. Angistro and Mt. Tsingeli which according to Anhegger (1943) date to the 15th-18th centuries.

## 4.5 Ottoman metallurgy in Greece and the Balkans (15th-19th centuries)

The Ottoman military successes against Byzantine cities across the Anatolian plateaux in the 13th and 14th centuries consolidated their political claims on the region. However other Turkmen tribes dominated eastern parts of the peninsula blocking in this way Ottoman expansion to this direction. As Turkmen principalities were established in the east and former Byzantine silver mines were reopened, the Ottomans were able to move quickly into the Balkans accelerating territorial expansion in that direction, driven partly by the existence of rich silver mines (figure 4.8).

Pamuk (2000, 37) noted that 'from the 1390s through the 1460s the Ottomans captured, lost and recaptured the leading silver-mining sites in Macedonia, Serbia and Bosnia'. Their silver coins, *akces* with various dates of minting at certain sites helps at following the expanding access of the Ottomans to silver from the Balkans. Thus there are exact dates of issuing for *akces* from Serez dating to 1413, Uskub/Skopje dating to 1422 and Novo Brdo dating to 1430. Other mines such as Kratova, Sidrekapsi and Srebrenica were captured by the 1460s but no gold or silver coins were issued at these sites until late in the 15th and early 16th centuries (Pamuk 2000).

Sidrekapsi –former Sidirokapsia- was already in use during Byzantine times but its output in silver increased dramatically during Ottoman times. The huge slag heaps around Stratoniki and Stagira reflect the volume and significance of operations of the 16th century. Novo Brdo has been the second largest silver mining region in terms of output at less than half that of Sidrekapsi. According to Sima Cirkovic the total silver production of the Balkan Peninsula during the first half of the sixteenth century could be estimated at 26-27 tons of silver per year (Pamuk 2000). More recently Murphey (1980) based on tax-farming and related records from mines in Serbia, Bulgaria, Macedonia, Thrace and Thessaly has estimated the total annual output of the Balkan silver mines around the year 1600 at 50 tons (figure 4.9).

Confirmed evidence for precious metals extraction in Ottoman 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 (figure 4.10). 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 assaying 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.

In 17th century Macedonia dispersed small-scale industries were established across the river valleys and gorges near Drama, Serres and Chalkidiki and various sites near Thessaloniki. Often smelting was taking place near older workings and it has been suggested that re-melting of slag from ancient and Byzantine operations was a common practice (Koukouli-Chrysanthaki 1990). Researchers in the past have argued that the town of Eleutheroupolis, mentioned as Pravista in Ottoman sources, where gun founding was common, is built on top of a large substratum of ancient slags (Papastamataki 1975). Smaller slag concentrations could also be found at the villages of Domatia and Aghia Paraskevi about 2.5 km west of Eleutheroupolis. Numerous late Byzantine and Ottoman glazed pottery sherds were noted among the slag coverage at Domatia providing some clues on chronology. Further evidence comes from Sidirochori and Folea where slag fragments bearing spots of metallic copper were noted (Papastamataki 1975). Further evidence for the production of cast iron comes from this region at Avli suggesting the operation of a blast furnace. The metallic prills within 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).

The 18$^{th}$ century was marked by a recession in metallurgical output and for that reason a new decentralised exploitation strategy was established. Some of the earlier production centres close to highland villages yielded post-Byzantine ceramic evidence indicating the use of locations that were suitable for smelting in past periods. 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 smelting. Demir Hisar (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-melting ancient slag.

The nature of the evidence suggests an increase in output as production was funded by the state, coordinated by master metallurgists and undertaken by specialised groups of smelters who provided revenue (*mukataa*) to the Sultan. At sites in Serres iron sands have been a continued 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).

### 4.5.1 Ottoman records and other contemporary documents

During Ottoman times ($15^{th}$-$19^{th}$ centuries) renewed interest in iron metallurgy led to the establishment of new centres for processing metals in Macedonia. Travellers' accounts and Turkish tax documents have shed some light into mining, smelting and iron-work and its shipment through towns and ports across Rumelia and Anatolia. The towns of Pravi (Eleutheroupolis) and Demir Hisar (Sidirokastro) are referred to as major centres of iron and silver working associated with smaller smelting sites around Vrontou while Sidrekapsi in Chalkidiki became one of the largest metal production centres in the Balkans (Inalcik and Quataert 1994; Vakalopoulos 1996).

In regards to official state documents the Ottoman tax records 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 in Northern Greece. *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 very useful 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 running of Ottoman state economic policies. Laonikos Chalcocondyles, a Byzantine historian of the Palaeologan period, informs us that the total revenue from European provinces reached 900,000 staters (*Laonici Chalcocondylae historiarum demonstrations I*, 1922). Various taxes are being described such as the *harac* and taxation for herding and transporting of agrarian produce. In addition we find reference to duties for hiring pack animals (horses and camels) reaching 300,000 staters, ferry duties around 200,000 staters and duties for rice transportation around 200,000 staters (Zografopoulos 2002). It is interesting to note that the duty paid for the transportation of metals was 100,000 staters, a figure 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. Such conditions are in accordance with a decentralized production scheme where unmanageable transportation costs over long distances to reach marginal workshops would be countered by low prices.

### 4.5.2 Sidrekapsi-Medemochoria and Pravista

Chalkidiki has been undoubtedly the wealthiest and most profitable mineral region in Ottoman Rumelia and thus most 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).

Sidrekapsi attracted a stream of workers from far and wide. In addition to the Greek labourers, there were workers of an astonishing variety of races: Bulgarians, Serbs, Turks, Albanians, Jews and Germans (Vakalopoulos 1973, 153). Belón informs us that 'most of the technicians were Germans who started to work in recent years and from them the inhabitants had picked up the German names of metals and metallurgical tools'. Apparently, miners were also called 'Safi', coming 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; Issawi 1980).

Increased industrial activity of the 18$^{th}$ century called for a reorganisation of the legislation 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 2003b). These were Galatista, Vavdos, Plana, Stanos, Varvara, Liaringovi (Arnaia), Novoselo, Mahalas (Stagira), Isvoro, Chorouda, Ravenikia (M. Panagia) and Ierissos.

At the same time, a government 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*. 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.

Smaller centres 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 Pravista around 1698 where specialised production of cannon balls and iron for construction material was taking place (Photos 1987). Further information is mentioned in Imperial Decree, 586-28820, dated Hicri 1255 that "...the monthly salaries of the trainer summoned from England by written instruction to be employed at Samakocuk, Pravista and Samako factories, and of the engineer and the translator that accompany him shall be extracted from the said provinces as ordered by the Sultan..." (Danisman 2007). Although Samacocuk in eastern Thrace, Turkey and Samako in Bulgaria have been investigated by survey and excavation Pravista still remains largely unexplored in regards to its significant metal production history.

### 4.5.3 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 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 (Tschihatshceff 1865; 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 public 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 (figure 4.11). 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. 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 17$^{th}$ 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 14$^{th}$ to the middle of the 17$^{th}$ 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).

#### 4.5.4 The case of the Taurus Mine (Buga Maden)

The Taurus Mine (Buga Maden or Bulgarmaden) has been one of the many metallurgical settlements in Asia Minor of the 19$^{th}$ 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). Its importance for the current study lies on the fact that it appears contemporary with those iron working regions in Macedonia (Vrontou, Sidirokastro, Makrychori, Vathytopos) with manpower of a similar background given that many refugees from Pontus settled in Drama and Serres during the 19$^{th}$ century.

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 and adversities, 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 kings and later by Romans and the Byzantine Comnenoi 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. 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 archimetallurgist (*madentsibasis*) was Chatzi Leuteris Apostologlou from Koronixa, Argyropolis who established mining installations and commenced extracting argentiferous lead which was assayed to produce silver despite the obsolete means available. The Ottoman *ferman* which authorised the founding of the settlement and right to open and exploit the mines was issued in 1826. As chief inspector of the mine Apostologlou represented all metallurgists 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 adjudged 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 the extortionate amounts proposed, the Company abdicated from its claims (Chatzikyriakidis 1999). The miner's privileges remained intact, with some interruptions when the government claimed the whole annual output in 1905, until the outbreak of the Balkan Wars.

#### 4.5.5 The case of Samakov (Samacocuk) 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 Lakidis 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 tradition refers 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 Lakidis 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 *vignes* (βίγναι), the furnaces as *odzakia* (οδζάκια), while the charge consisting of charcoal and iron sand was known as *pohonia* (ποχωνιά) which was approximately 80-100 *okas* (= c.130 kg). Mining 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 the Turkish government 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 hour's walking distance from the village within ravines of the river valley. Under Chatzi Yusuf pasha, who was appointed commander in 1810, Samakov witnessed dramatic increase in production coinciding with the establishment of three major state foundries 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 pasha 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* (= 63.2,000 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. This case represents a remarkable example where documentary evidence and archaeology could provide important results when seen in conjunction.

### 4.6 Mine administration, division of labour and workforce characteristics

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 regulations on mines were simply a translation of the previous regulations in which the original German (Saxon) terminology was preserved (Inalcik and Quataert 1994, 59). Tax registers from the regions being studied refer to miners either as miners (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 (1929) a scholar from Chanes provides detailed information concerning the division of labour, wages, working methods and names of the General Directors of mining regions.

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, establishing new mines 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*. Among the specialized workers, the miners (*madentsides*) were organized in a guild with Prophet Elias as their patron saint. Their insignia were the bronze badge on their hats depicting hammer, rod and fuse. They were tied to the work and were not allowed to pursue a different profession. The conditions of working were harsh and sometimes miners died trapped within collapsing galleries.

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. 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 crushing, the *tsaoultsides*.

Washing and separation was the responsibility of 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.

Important information about the lives of miners comes from the writings of Kandilaptis, official documents of the Oustabasis and the surviving folklore customs and songs. An emphasis on the risks and perils associated with their work is evidenced on recorded cases of tragic events such as the collapse of a mine due to gunpowder detonation, where 800 miners perished among which forty were named Paul. They also faced high mortality rates due to working conditions under increased humidity and restricted natural light often causing severe outbreaks of tuberculosis. Judging on such information we can speculate that their social stature was low and was expressed by manifestations of common identity in form of songs, beliefs and material culture.

### 4.7 Modern Greek mining

With the advent of the Industrial Revolution a reorientation of economic strategies towards large-scale production associated with profit and mass consumption altered the balance of producer and consumer states. Long distance trade mechanisms and mass production severely lowered the price of iron and steel that was provided by the rich industrial powers of the west. Ottoman industries failed to follow, became non-competitive and gradually declined to the brink of extinction. Adapting to the western European model of industrialization former Ottoman provinces begun to progress towards industrial modes of production by the middle of the $19^{th}$ century.

Between 1821 and 1861 industrial extraction in Greece concentrated on lignite, emery, gypsum and millstones organized and funded by the newly found independent Greek State. The first concession of a mine by force of the mining law was that of sulphur extraction on Melos around 1862 (Papastamataki 1975). Since then metallurgical operations were gradually being funded by foreign companies which invested to more efficient and profitable exploitation. Modern installations appeared in northern Greece at Kirki in Evros (1910), Limenaria on Thasos in the early 1920s (Mentza 1999; Epitropou 2003) and Granitis in Drama (mid 20$^{th}$ c.).

The 19$^{th}$ century meant that the Mademochoria described above, would pass from self-governing to dependent work, under the power of a Corporate Administration for the exploitation of mines. In the furnaces the company had processed until the year 1900, 72,000 tons of mineral (Perantonis 1994). The enterprise exploited the secondary minerals of manganese, the ferrous layers of Mavres Petres, Piavitsas, Basdekou and Olympiada. In 1901 the company initiated surface exploitation of iron pyrite in the Madem Lakkos mines which was continued until 1974, mainly through underground methods of exploitation.

In Palaea Kavala of the 15$^{th}$ century renewed interest in minerals expressed by the Ottoman administration's need for metals caused a re-flourishing of industrial activity. Intensive mining and smelting was once again pursued in the late 19$^{th}$ and early 20$^{th}$ centuries by which time modern machinery was introduced for efficient exploitation. The last phase of industrial activity in the region lasted for about three decades initiated in the 1950's by Economidis Bros Company and followed in the 1970's by the American company IPAMCO Ltd. The Mining Company of Northern Greece also worked in the area between 1970 and 1975 during which time part of the extracted ore was being transported to Drama in the facilities at Granitis for further processing (Vavelidis *et al* 1996).

**4.8 Conclusion**

Archaeological projects undertaken at various European and Asian sites have revealed a great wealth of material evidence concerning the production of metalwork through the last four millennia. The quantity of archaeological material deriving from excavations across Greece is quite substantial but is almost universally from prehistoric and ancient sites. For the most recent periods historical accounts have been used as complementary to the limited archaeological findings but more too often these strands of evidence are in disagreement.

For eastern Macedonia with the Pangaeon mines and the legacy of a Macedonian gold rush initiated by Philip II the ancient sources appear to exaggerate what would have been actual facts. This is mainly for political reasons which lead historians to obscure factual information on precious resources or might derive from ignorance on certain technical issues. Likewise travelers' accounts tend to be descriptive but do not include any detailed information on specifics of the organization of production since most writers were often led astray by practice. Also mineral processing can be clandestine and severely secretive and thus often escapes meticulous recording. Since only restricted fieldwork has been undertaken to date across eastern Macedonia and historical sources appear ambiguous the proposed method to characterize the evidence is by field survey and an analytical programme focusing on the actual production residues themselves.

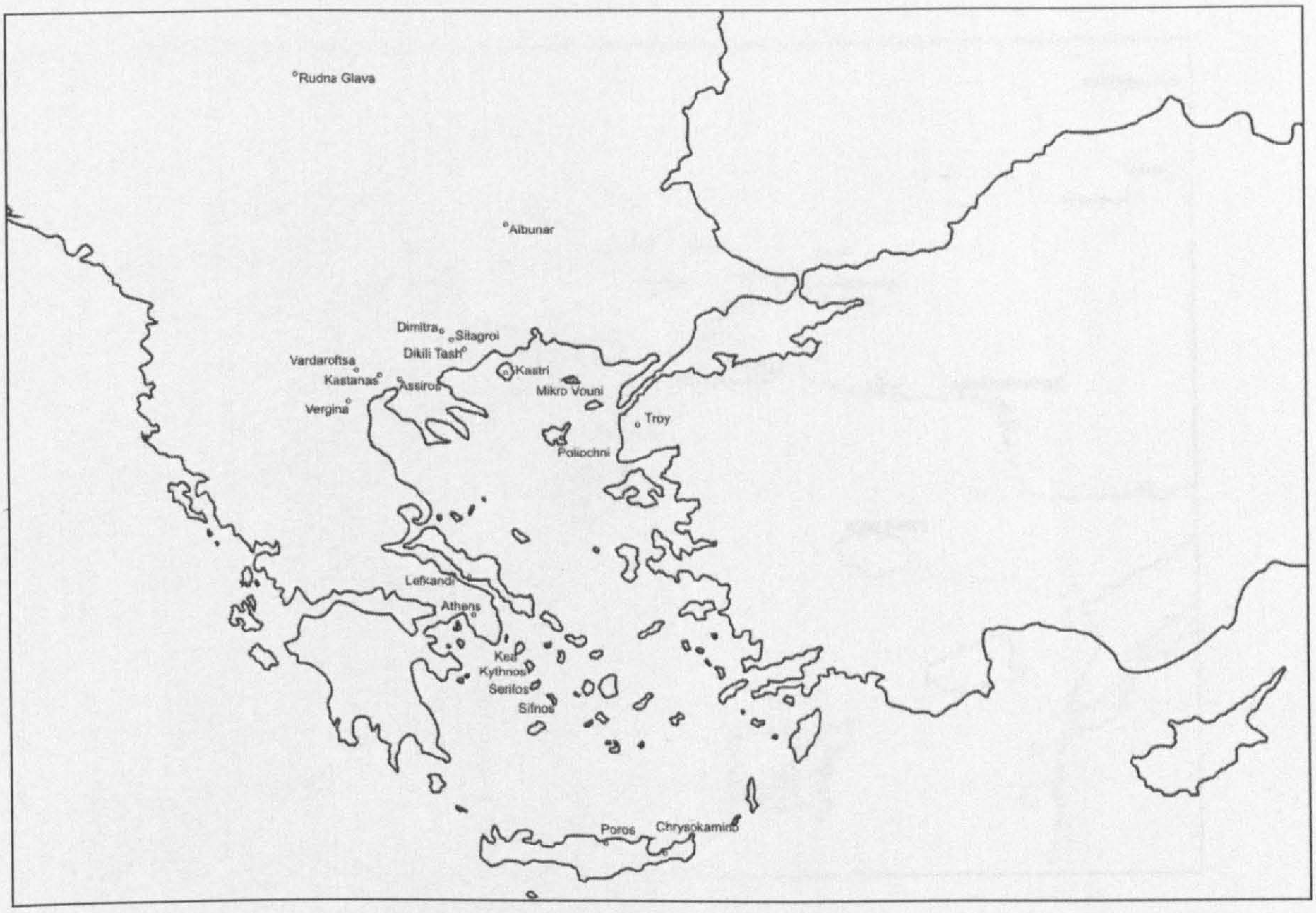



Figure 4.1 Prehistoric sites of early metalworking mentioned in the text

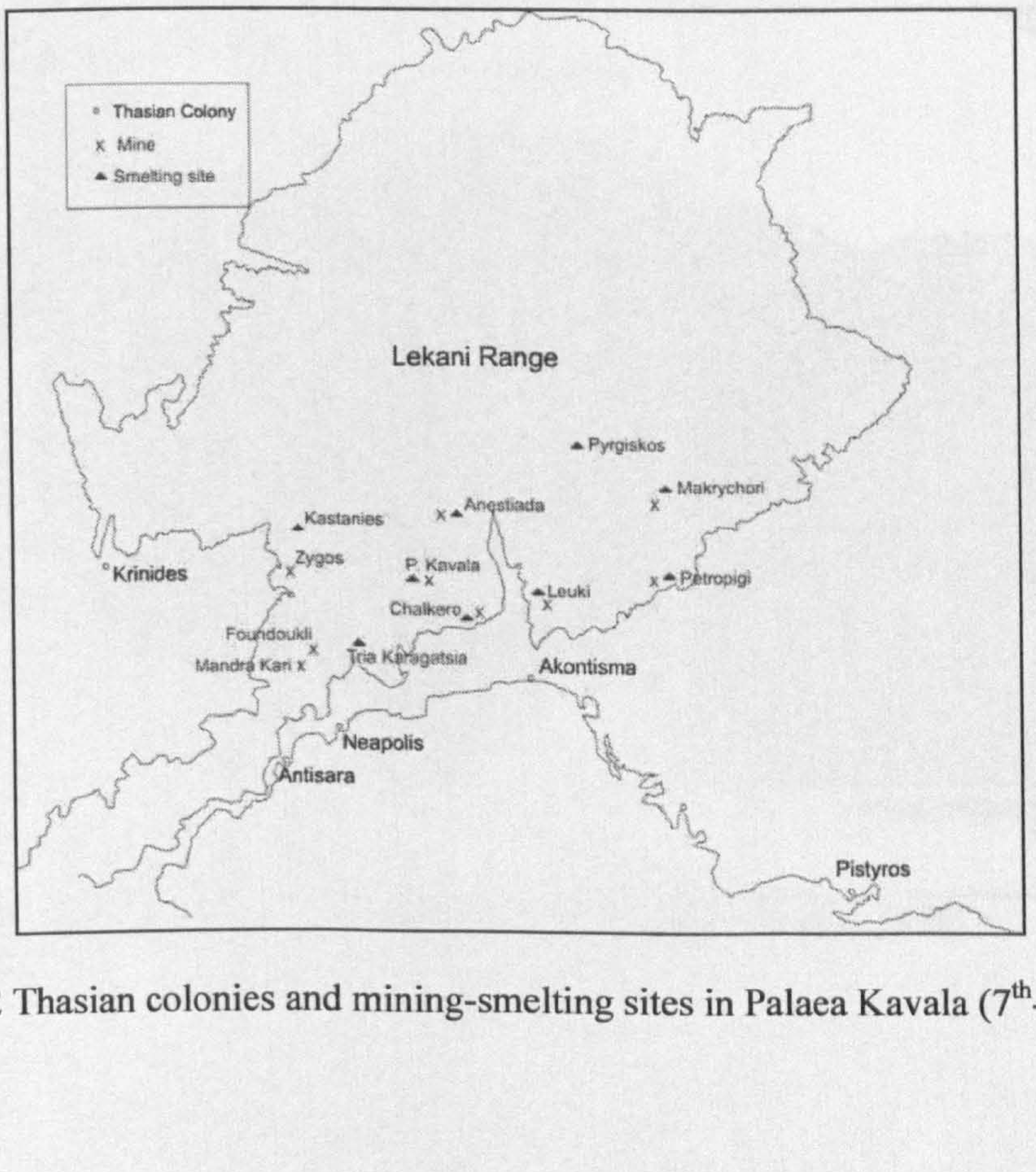



Figure 4.2 Thasian colonies and mining-smelting sites in Palaea Kavala ($7^{th}$-$5^{th}$ c. BC)

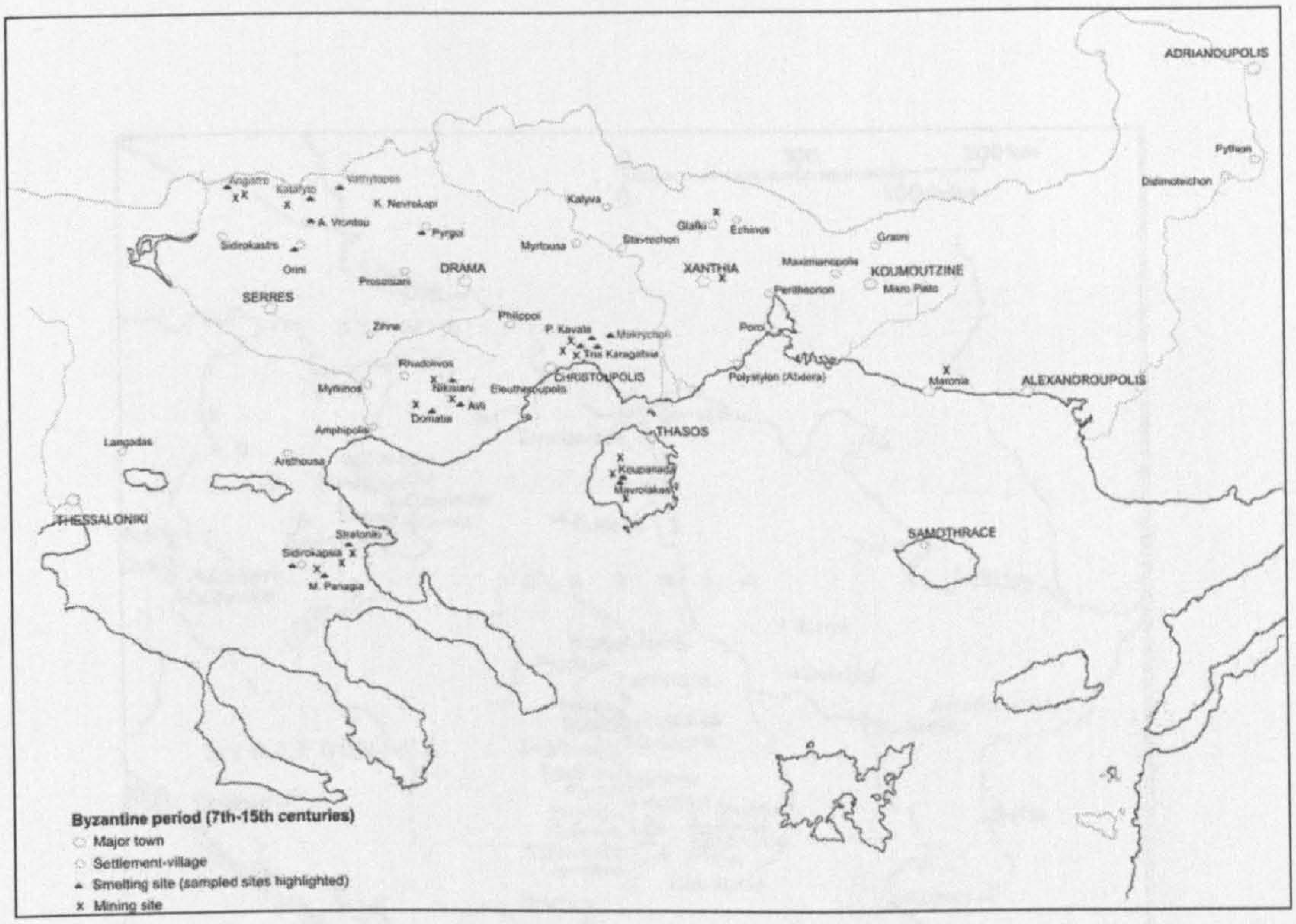



Figure 4.3 Mining and smelting sites in Byzantine Eastern Macedonia and Thrace

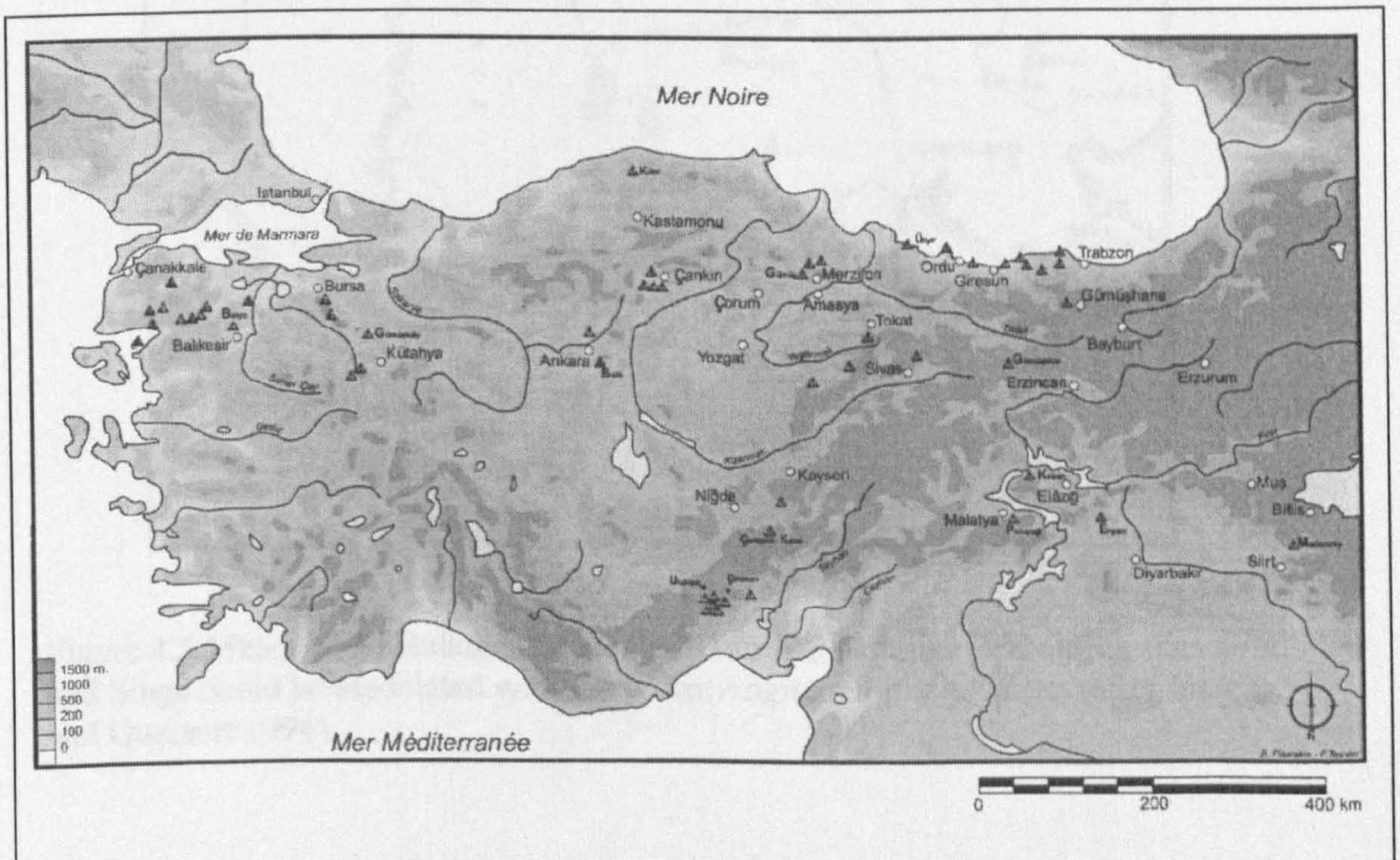



Figure 4.4 Byzantine mining regions in Anatolia (after Pitarakis 1998)


Figure 4.5 Mines in the Balkans, Byzantine-Ottoman periods. The mining sites Brin and Singe could be associated with the wider Angistro mining district (after Inalcik and Quataert 1994)

Figure 4.6 Wall painting depicting a smith and his family at work, Zemen monastery, $14^{th}$ century Bulgaria (after Papanikola-Bakirtzis 2002)


Figure 4.7 The Serbian Principate of Serres (mid 14th century). The sites of Trilision (Трнлнсн) and Vrontou (Вронд) listed as iron smelting centres in the A. Lavra manuscript are shown on this map (after Ostrogorsky 1965)

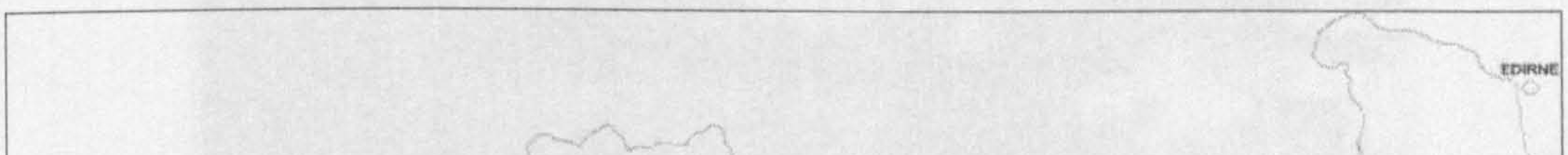



Figure 4.8 Eastern Macedonia in the Ottoman period

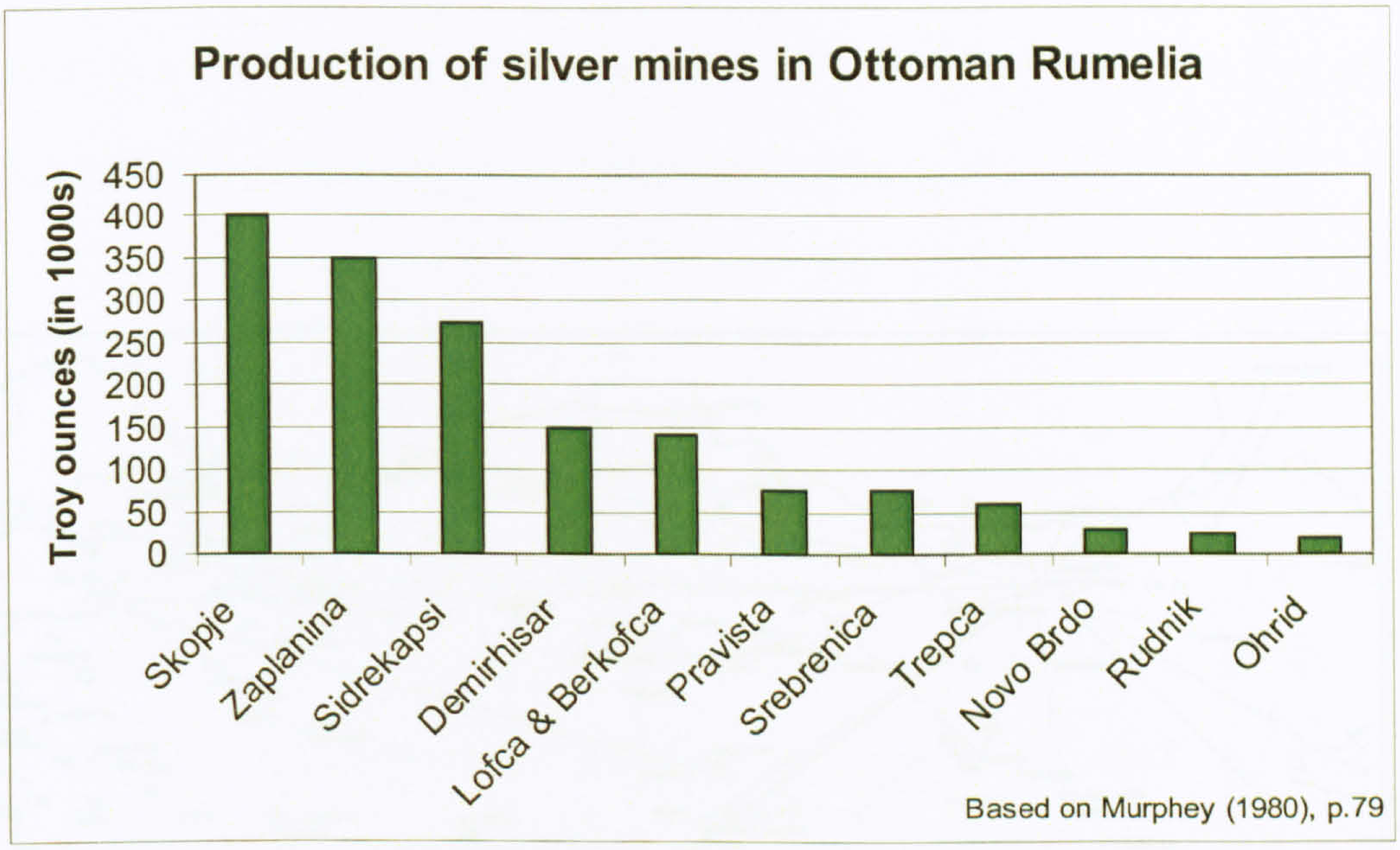



Figure 4.9 Estimated output in silver from the mines of Ottoman Rumelia (after Murphey 1980)

Figure 4.10 Double furnace for lead-silver smelting excavated at Livadia, Nikisiani, mid 16th century (after Papastamataki 1985)

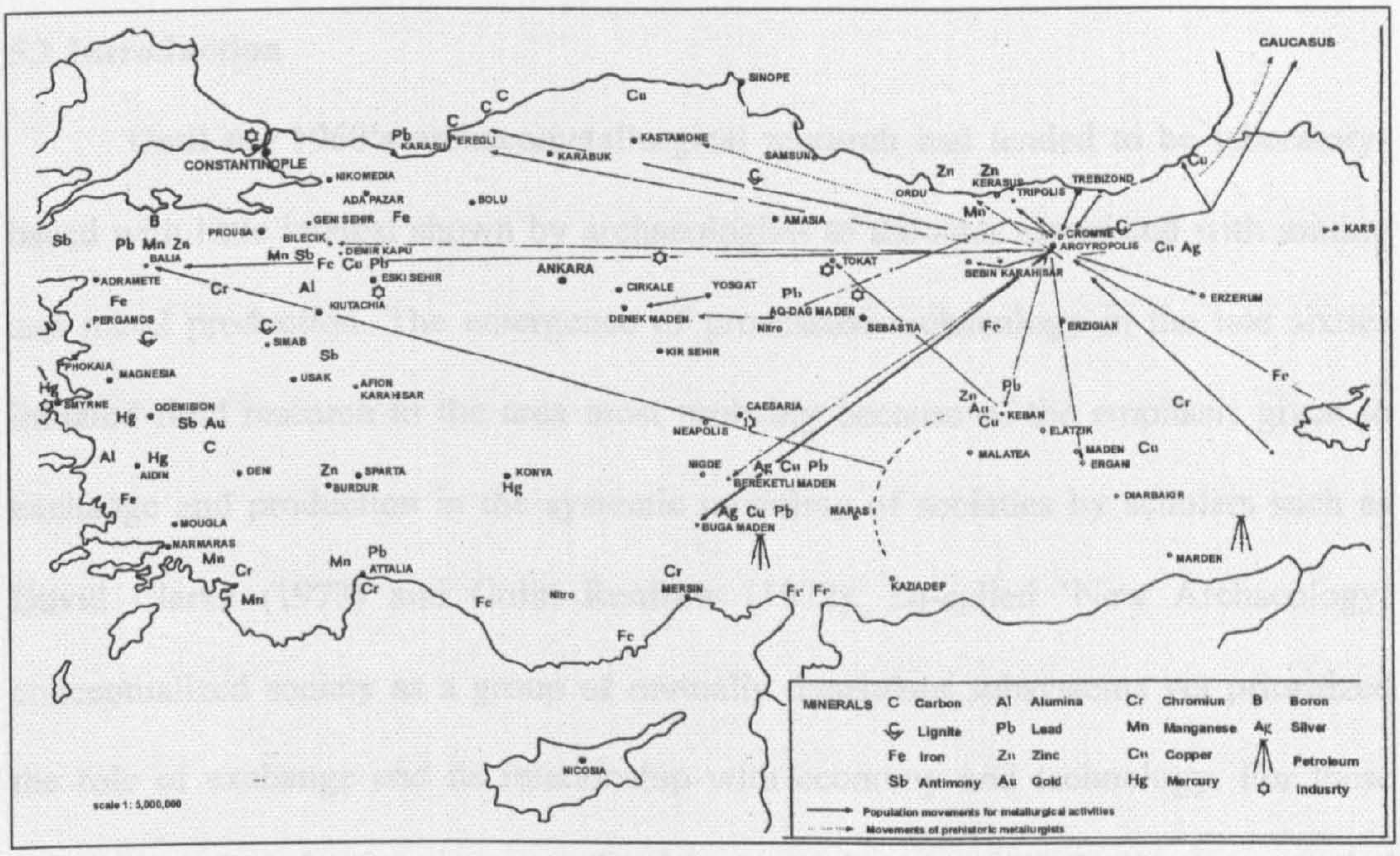



Figure 4.11 The spread of Pontic miners across Asia Minor (after Chatzikyriakidis 1999)

## *CHAPTER 5*

# *Field survey of mining and smelting sites*

### 5.1 Introduction

Until the 1960's archaeometallurgical research had tended to be laboratory-based with little interest shown by archaeologists to the sites associated with mining and metal production. The emergence of processual archaeology in the late sixties initiated field research in the area most probably because of the emphasis given to exchange and production in the systemic modeling of societies by scholars such as David Clarke (1973) and Colin Renfrew (1972). So-called 'New Archaeology' conceptualized society as a group of mutually dependant subsystems yet prioritized the role of exchange and its relationship with economy and technology. For these reasons metal production sites, or rather how control was exercised over them coupled with their importance to provenance (exchange) studies made the investigation of such sites a new and important area of research (Goodway 1991). Despite this engagement with field survey and excavation many key studies emerged in the seventies and eighties which again emphasized the role of laboratory studies at the expense of field based studies, most notable the lead isotope programmes which all but ignored the effect of technology (i.e. smelting process, recycling etc) upon alloy composition and the implications that this would have for provenance studies.

Alongside, the laboratory-based provenance studies process characterization studies relied more on the increasing knowledge of slag systems and their analysis and alloy composition (elemental and isotopic) and again explicitly scientific approaches tended to overshadow field-based approaches. Clearly seen in Aegean prehistory where extensive provenance studies were undertaken whilst the excavation of smelting sites such as Scories on Kythnos and Chrysokamino on Crete were scarcely attended too (Betancourt 2006). Only recently have they been studied in detail and the knowledge they provide is profound and further complicates and undermines the series of assumptions that underpin lead isotope studies (Gale and Stos-Gale 1981; Gale *et al* 1985).

With these considerations in mind this study attempted to balance field survey with laboratory analysis. Whilst analytical studies have been extremely useful in discovering the range and type of processes enacted at sites the material analysed depends heavily on strategic sampling, something which can only be done with any confidence in light of detailed and significant survey, in short the critical role of effective field survey is difficult to overstate. To address the aims set out in chapter one, a field survey programme was undertaken in two seasons (2005-2006). The fieldwork programme was organized into a series of phased undertakings which began with broad speculative survey in and around published sites and known mineral deposits, targeted field visits, followed by metric survey of chosen sites and the sampling of metallurgical debris from these surveyed sites.

The methods used aimed at addressing two major issues: type of process being carried out and scale of such activity for each examined case. Dating of such sites although problematic is crucial for an understanding of the evidence and, although not ideal due to the limitations of this project, it was approached through the collection and identification of associated pottery from both surface scatters and stratified contexts. Prior to fieldwork a desk-based assessment of topographic and geological data in collaboration with IGME, helped at evaluating certain mineral deposits where past communities focused for extracting their raw ores. Other important resources such as clay beds, water and timber have been assessed due to their crucial role in metal production, specifically the smelting operation. Earlier archaeological interventions, past activity suggested by local geology, documentary evidence and a study of place-names were also included in the desk-based assessment.

Having completed reconnaissance over a large area it was decided to narrow down the investigation in an attempt to assess representative mining and smelting sites that could account for all processes documented in this region. In total around 25 mining and 30 smelting sites were visited representing the great majority of available evidence yet not covering its entire extent. Given this multitude and diversity of working sites the small-scale intensive survey, was designed as a means to characterise certain processes considering time and funding constraints, and thus concentrated on fewer sites.

The final choices to sample particular locations were based on previously published accounts referring to post-Roman mining and processing sites for which however detailed information is lacking. After discussions with local geologists who provided basic descriptions and assessments on mineralogy, collection of surface pottery indicative of post-Roman periods (Byzantine-Ottoman) and gathering of archaeological information it was decided to focus on nine mines and thirteen smelting sites (figure 5.1). The large areas covered together with the difficulty of access to some sites and the limited funding and resources available dictated the choice of some already published sites and a few yet unexplored that would reflect a partial but representative picture of the region's metallurgical history. The number of mines chosen for survey reflects roughly one third of the existing evidence (9 out of the 25 mines) while 13 smelting sites represent more than a third of the 30 known sites. In this way results from the survey became quantifiable and at the same time proportional and comparable to a hypothetically full-scale exhaustive analysis.

Although all types of site were sought -whether mines, smelters or workshops- the survey was conducted with several specific issues in mind; firstly whether the local miners were exploiting highland ores and/or coastal and alluvial ores (i.e. iron sands), secondly what are the overriding criteria that determine the locations of smelters and lastly what types of smelters and smelting processes were in use in eastern Macedonia. According to researchers some highland mines in this region have been initiated during antiquity while others have been heavily exploited in recent times (Koukouli-Chrysanthaki 1990; Photos *et al* 1987; Vavelidis 1994; Vavelidis *et al* 1997). Collecting sands rich in iron from coastal and riverside environments has also been a common practice but such mineral sources proved difficult to trace.

Since the current study focuses on the Byzantine and Ottoman metals technologies the mines selected were according to published accounts mostly active during these periods. However since mining sites tended to attract recent exploitation resulting in destruction of the earlier phases, only nine mines that show relatively little disturbance, which yielded Byzantine and Ottoman pottery were selected. Likewise although the sites with smelting evidence abound in the survey area, thirteen of these were selected mainly due to the presence of Byzantine pottery that provides some dating indication. Further field observations on external characteristics i.e. deep mining shafts, ore crushing areas, large slag heaps and vitrified ceramics helped in discriminating the medieval phases of exploitation upon which this survey focused.

Through the course of field reconnaissance various pivotal resources such as water, timber and other landscape features or roads and pathways were taken into account. The investigated sites represent the breadth of evidence across eastern Macedonia since their distribution covers the geographic extent, diversity of landscapes (upland and lowland) and also the range of extracted minerals.

## 5.2 Detailed survey and sampling of smelting sites

Upon completion of the field visits the first issues to be raised were those of scale and dating. The region shows a non-uniform pattern with some small, discrete smelting sites and others stretching over large areas with substantial volumes of metallurgical debris (Table 5.1). Since compositional analyses on the various ores present across the study region are being systematically conducted by professional geologists for a number of years now, it was decided to use any such relevant results instead of proceeding to sampling material from the nine surveyed mines. Moreover it was impossible to discriminate between various mining phases and therefore sampling from within mining shafts without any stratigraphic control was avoided. As discussed in chapter 6 the results on ore analyses provided by geologists used in comparison to slag compositions proved highly useful for matching potential sources of raw materials to metal production centers.

In order to sensibly assess the metallurgical evidence and draw more concrete conclusions, four smelting sites that represent both middling and large-scale activity were chosen for more intensive topographic survey and sampling. Such a choice has been made primarily in terms of field observations and constraints concerning the permissible volume of sampled material. Careful examination of the 13 chosen sites has shown that slags are primarily the only witness to archaeometallurgical processes. Judging on macroscopic characteristics the material is relatively uniform (four or five types of slag) and present in considerable amounts, and therefore a relatively limited number of samples was considered sufficient to provide conclusive results. Further the presence of refractories that offers additional information has been noted in only five sites (see table 5.1). Thus it was decided to conduct sampling on four sites that present all characteristic slag types and also furnace material (tuyères, lining and conglomerates) in order to gain as much information possible with the least amount of specimens. These chosen sites all show evidence for Byzantine presence in form of pottery and in some cases architectural fragments but are not all restricted to single phase activities. Two of them are in Drama Prefecture, one in Serres and one in Kavala forming in this way a representative assemblage of Byzantine smelting evidence from across eastern Macedonia.

Permission to sample metallurgical debris and any associated material was granted by the Greek Ministry of Culture after an application was approved by the Central Archaeological Committee (ΥΠΠΟ/ΣΥΝΤ/Φ44/1240/4-4-2005). At that stage site selection was based on permit allowance restrictions as much as a consideration of strategic choices. Having that in mind those four sites that represent the breadth of evidence in the region have been selected. Sampling of slag heaps was undertaken under the supervision of archaeologists of the 12$^{th}$ Ephoria of Byzantine Antiquities, Kavala and was coordinated by archaeologist Dr. Konstantinos Tsouris. Sampled sites include Katafyto and Vathytopos both in Drama, Angistro in Serres and Makrychori in Kavala. Standard field identification techniques as described by Bachmann (1982) for slags, their contexts, typology and external properties were followed. Ceramics were also recovered representing two broad groups. Pottery sherds and refractory ceramics associated with metallurgy. Survey on these four sites focused on characterization, volume and variation of slag, site extent and hypotheses on the processes being carried out.

Based on data gathered during the field survey some preliminary remarks on the nature of the material under study could be made. Most of the evidence comes from upland sites with ranging heights 200-800 m O.D. more often used for grazing and occasionally for farming purposes. This zone coincides with the surface metal-bearing deposits that were clearly recognizable and relatively easy to spot during prospecting (figure 5.2). In numerous cases metallurgical activities took place close to streams and rivers suggesting easy access to a water source, which is an important factor during ore washing, sorting and further processing. Given that no great differences in vegetation (mixed deciduous forests) occurred in the regions since prehistory, metallurgists had access to abundant timber for fuel. As discussed in chapter 2 forest regeneration during the Little Ice Age (16$^{th}$-19$^{th}$ centuries) that coincided with the Ottoman period has benefited the local industries in terms of fuel acquisition. Oak might have been more preferable than pine due to the better quality of charcoal produced.

In most cases the organisation of working space is dictated by a gravitational axis according to which furnaces are built on top of hills and slag is discarded on the slopes. The process was in constant movement due to rapid formation of large volumes of unwanted material that constrained operations. Once the accumulated debris reached the heights of the hilltops the furnaces moved upwards and newly formed slag covered the older deposits. Although through such practice stratigraphy might appear to have formed in a straightforward manner disturbance complicates the picture. Levelling of slag heaps or dumping of material in more than one heap was common and succession of layers through time was often interrupted. In worksites like these described above artefacts of daily use are restricted and they rarely become entrapped in the deposits, hence the almost complete absence of pottery. Scatters of sherds however could indicate specific dates for restricted areas of the contexts where they belong (figure 5.3).

What follows is a report on the field visits of the 22 sites upon which this study has focused. In each case the location and surroundings are considered in association with a description of the major characteristics of mining or smelting evidence. Wherever previous research provided data on the site under consideration such information is reported in sections on previous work. The four sampled smelting sites are presented in greater detail.

| Site | Date | Size | Metal Process | Secondary | Primary | Environ. | Finds |
|---|---|---|---|---|---|---|---|
| **Katafyto** | L. Byz | 500m² | Iron smelting | | X | Upland | S, T, Fc |
| **Vathytopos** | L. Byz | 300m² | Iron Smelting | | X | Upland | S, Fc, Wm |
| **Kalithea** | Ottom.-industrial | 200m² | Iron Smithing | X | | Lowland | S |
| **Leukogia** | L. Byz | 100m² | Iron Smelting | X | | Lowland | S |
| **Exochi** | L. Byz | 100m² | Iron Smelting | X | | Lowland | S |
| **Panorama** | L. Byz | 200m² | Copper Smelting | X | | Upland | S |
| **Magnesia** | Ottom. | 20m² | Iron Smelting | X | | Upland | S |
| **Makrychori** | Class-Ottom. | 15000 m² | Iron, precious metals | | X | Lowland | S, Fc Sp |
| **Nikisiani** | Class | 50 m² | precious metals | X | | Upland | S |
| **A. Vrontou** | L. Byz-Ottom. | 100m² | Iron Smelting | X | | Lowland | S, T Wm |
| **Orini** | E. Byz | 200m² | Iron Smithing, Bronze casting | X | | Upland | S, M |
| **Faia Petra** | Ottom. | 100m² | Iron Smelting | X | | Upland | S |
| **Angistro** | L. Byz-Ottom. | 30000 m² | Iron precious metals | | X | Lowland | S, Sp, T, Fc |

S: slag, Sp: speiss, T: tuyère, Fc: furnace conglomerate, Wm: watermill, M: mould

Table 5.1 Surveyed sites: major characteristics

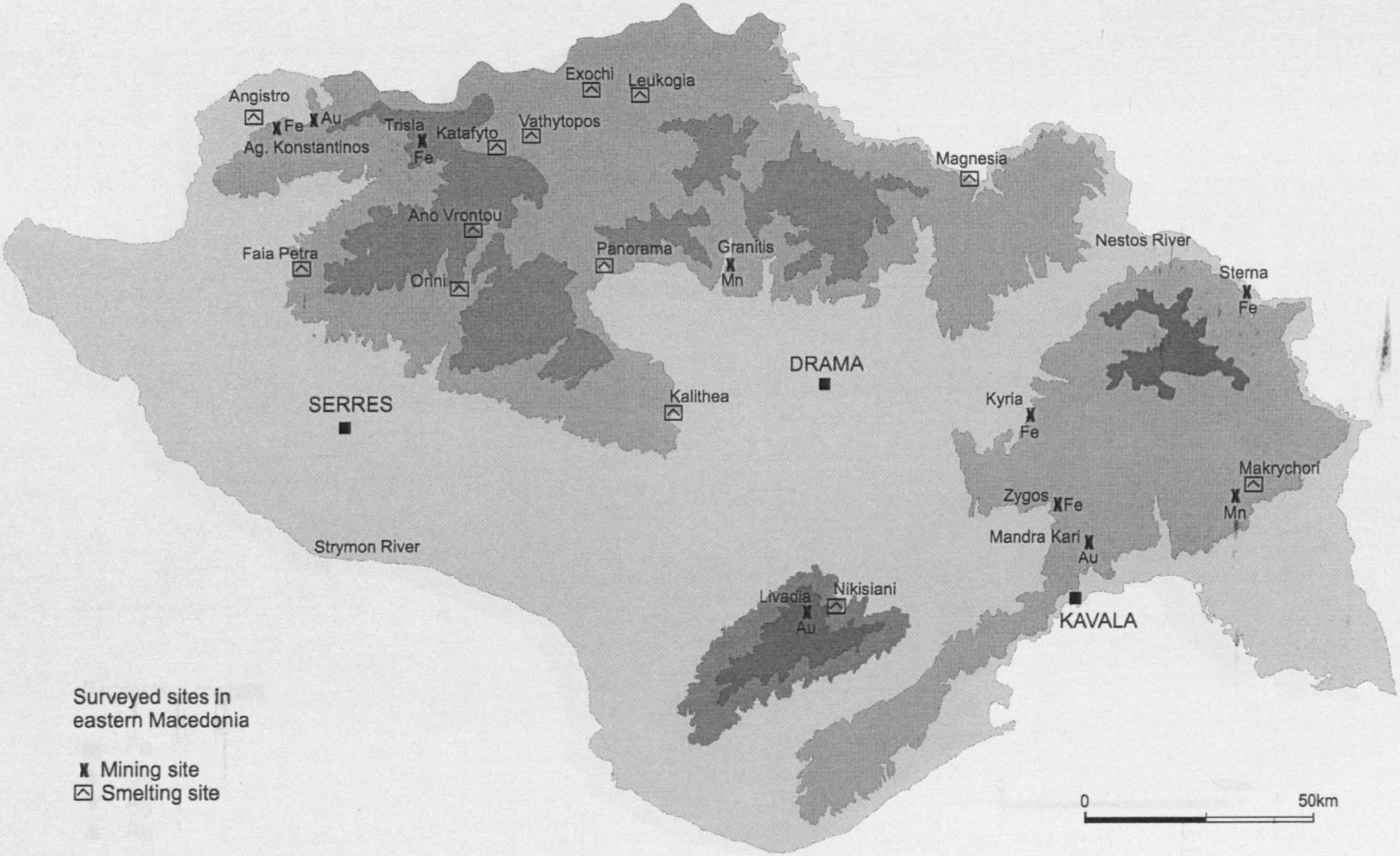



Figure 5.1 Surveyed sites of mining and metallurgical activity in the study area

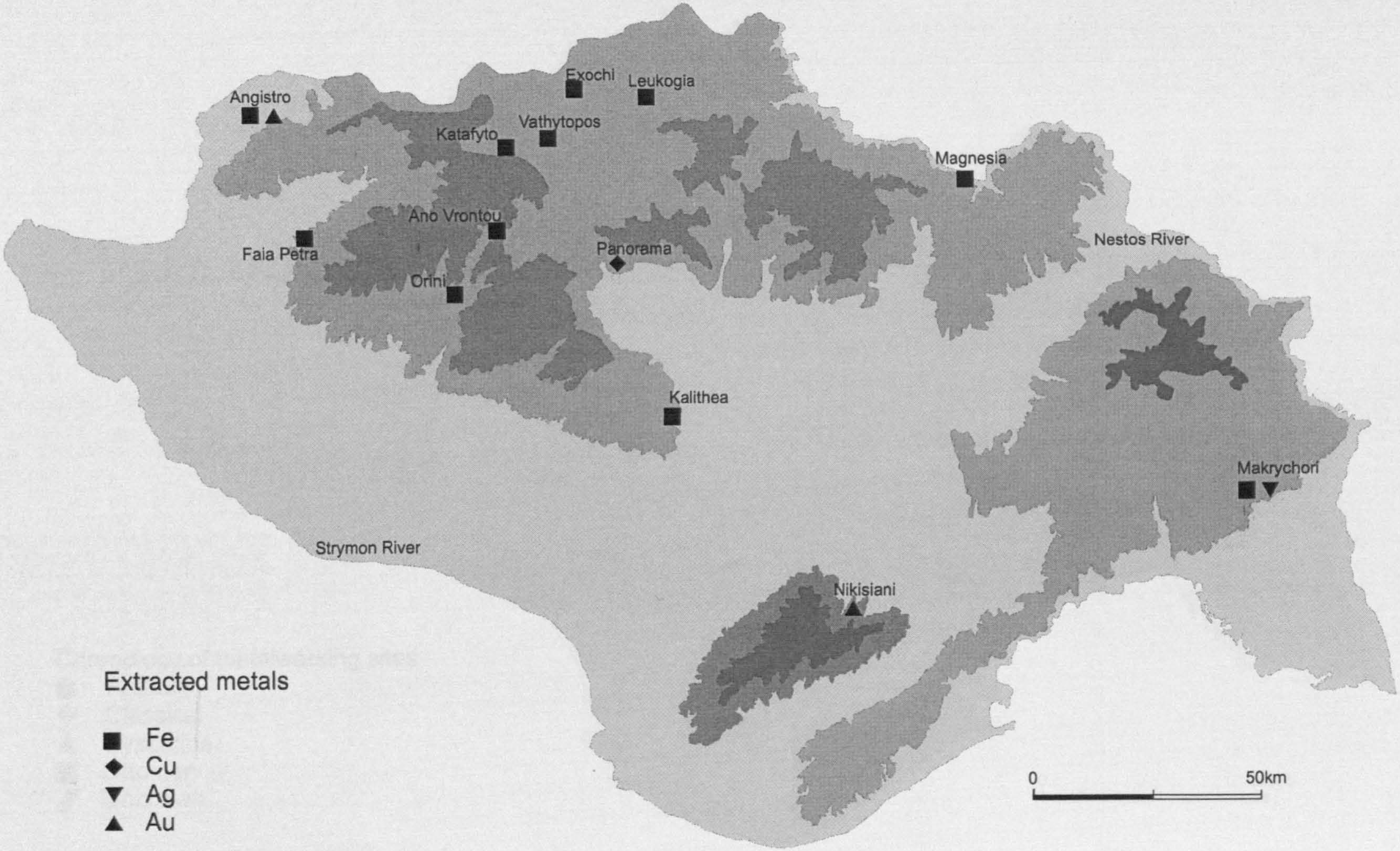



Figure 5.2 Surveyed smelting sites, extracted metals

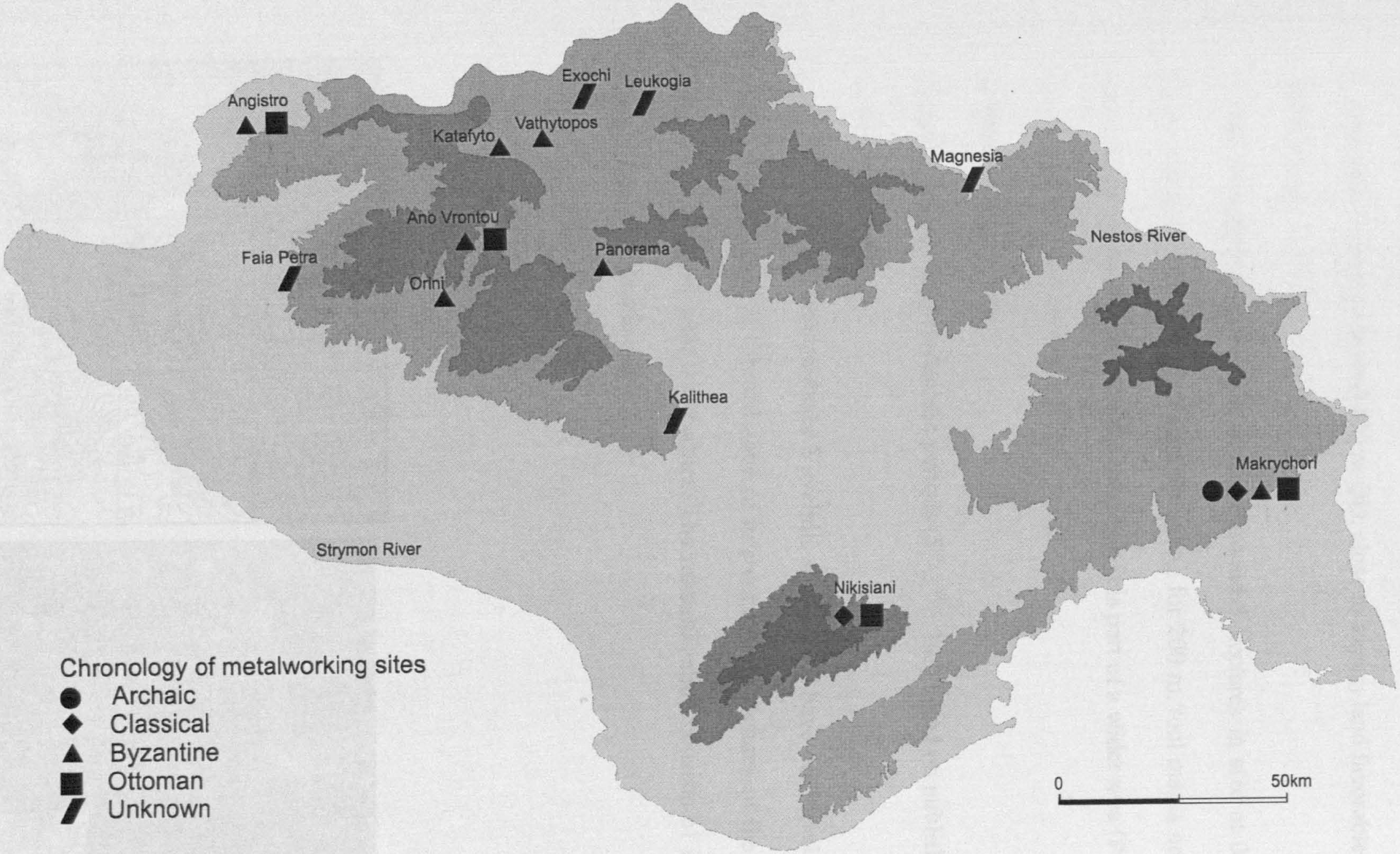



Figure 5.3 Surveyed smelting sites, broad chronology

## SITES CATALOGUE

**01. Site Name:** Zygos, Kavala **map ref:** 41°01'09.87"N 24°18'08.68"E

**1. Location:** Hill slope around 220 m OD, close to stream land favorable for grazing and farming

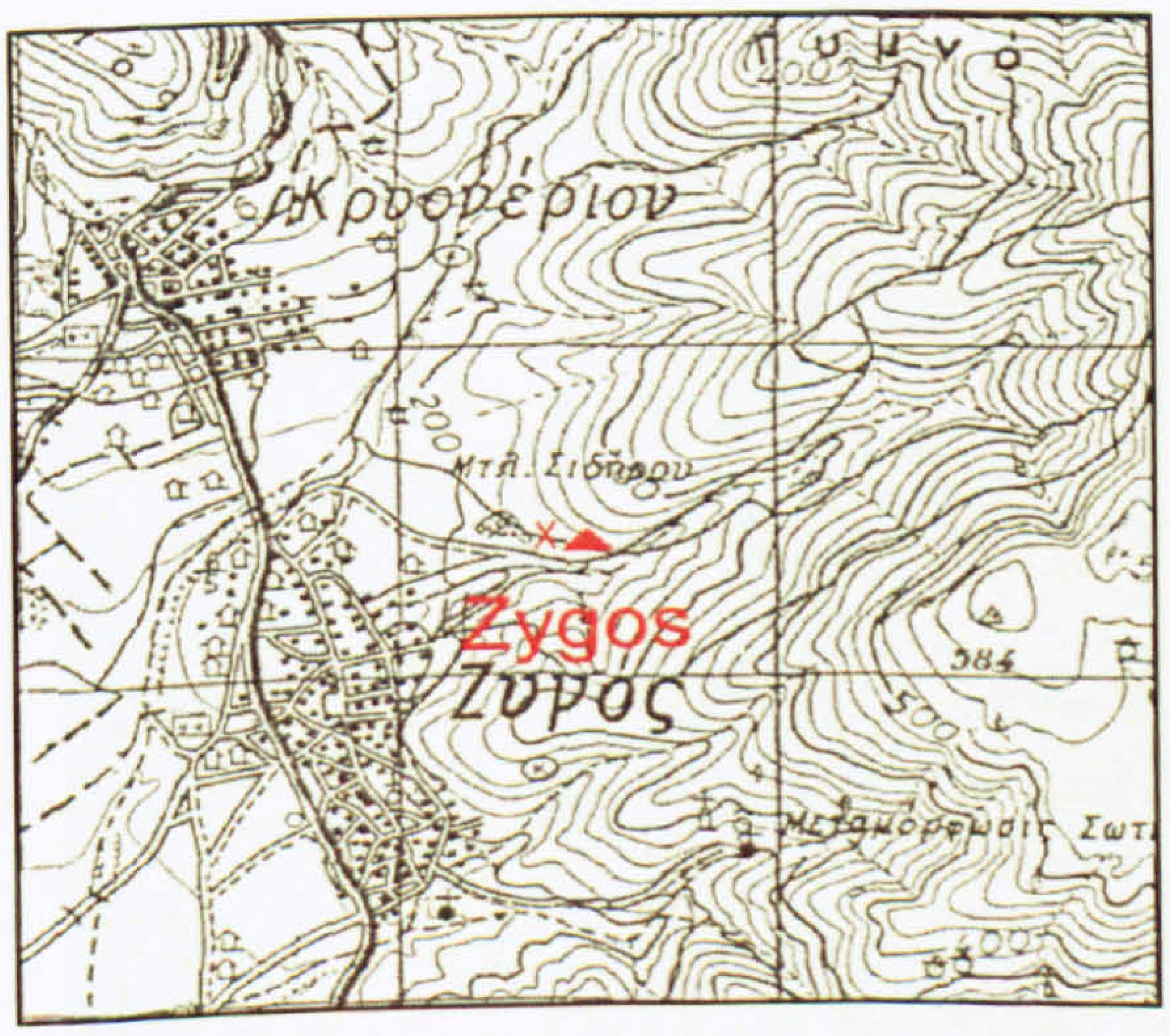
**2. Site Description:** Iron mine outcrop around 5 hectares in size at 0.5 km NE of Zygos village. Underground mining extending for 200 m, tool marks on the galleries walls, heaps of crushed ore near the entrance. It is part of a wider area (Palaea Kavala) where remains from mining activity abound.

**3. Mineral/metal:** iron

**4. Date:** Classical and Hellenistic periods ($5^{th}$-$3^{rd}$ c. BC) based on published evidence

**5. Previous work:**

During geological reconnaissance Vavelidis *et al* (1997) have described the mine as a vein deposit formed in a broad zone of interconnecting fissures of the metamorphic schists and gneisses with the marbles. The mineralization consists of iron oxides of hydrothermal magmatic origin.




**02. Site Name:** Mandra Kari, Kavala **map ref:** 40°58'55.58"N 24°25'02.89"E

**1. Location:** Uplands around 450 m OD, mountainous terrain

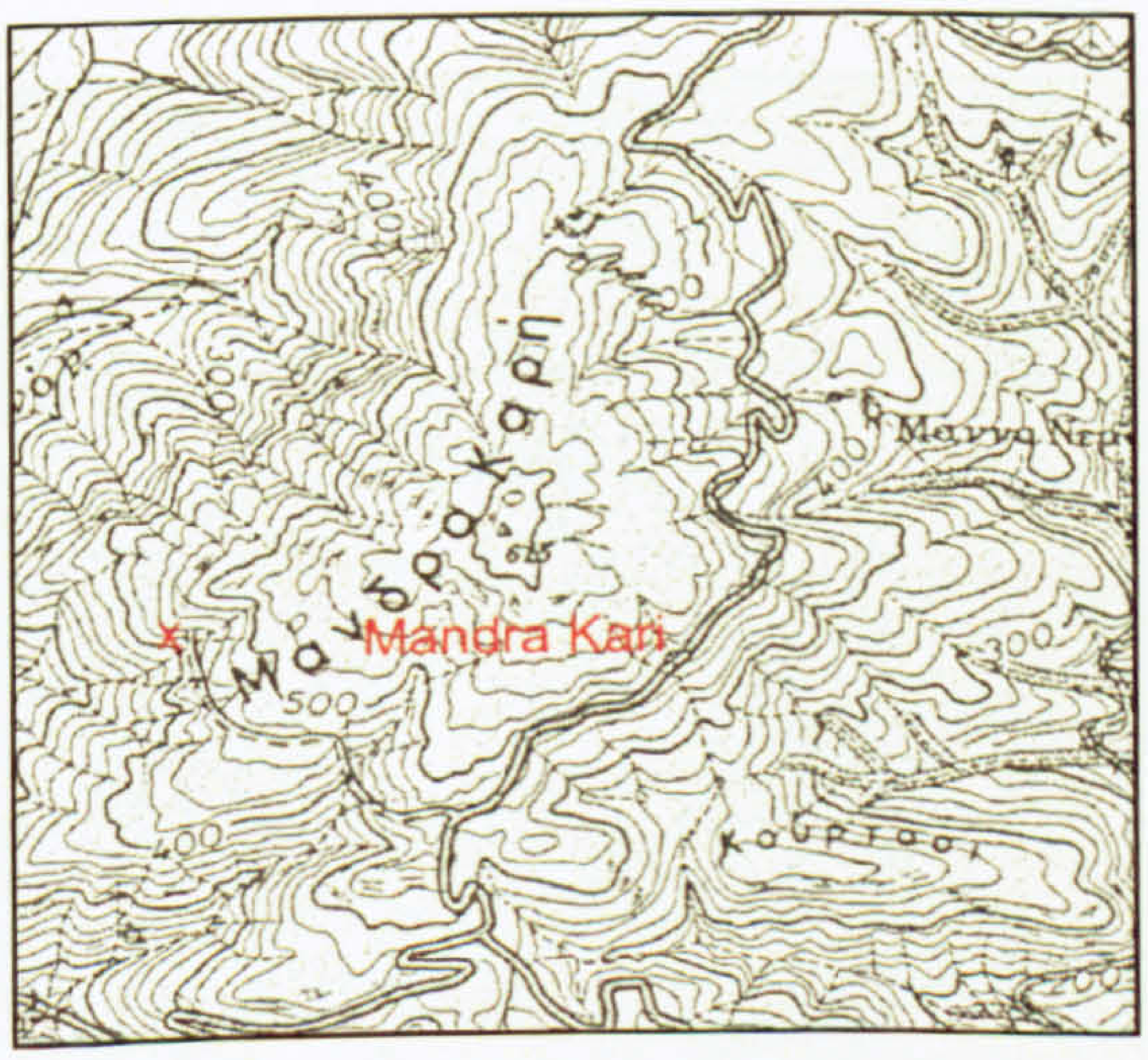
**2. Site Description:** Gold mine outcrop with underground galleries of 85 m on average length, extending towards a NW direction. A large cavity at the crest of the hill has two entrances, adits nearby and narrow galleries around 80 cm wide and 90 cm high. Tool marks from ore extraction are visible on the walls and safety columns of undisturbed ore for supporting overhead levels are common. Large heaps of crushed ore near the entrance.

**3. Mineral/metal:** gold

**4. Date:** Classical-Hellenistic based on abundant pottery found ($5^{th}$-$3^{rd}$ c. BC) based on published evidence

**5. Previous work:**

Through geological survey Vavelidis *et al* (1996) identified this outcrop as one of the gold mines of the Thasian Skapte Hyle described by Herodotus. The dominant minerals consist of iron oxides (goethite, lepidochrocite), manganese oxides, arsenides and traces of iron pyrite, hematite and gold.




**03. Site Name:** Aghios Nikolaos-Makrychori, Kavala

**map ref:** 41°01'12.85"N 24°35'59.90"E

**1. Location:** Hill slope around 200 m OD, pasture land, 3 km south of Makrychori smelting site

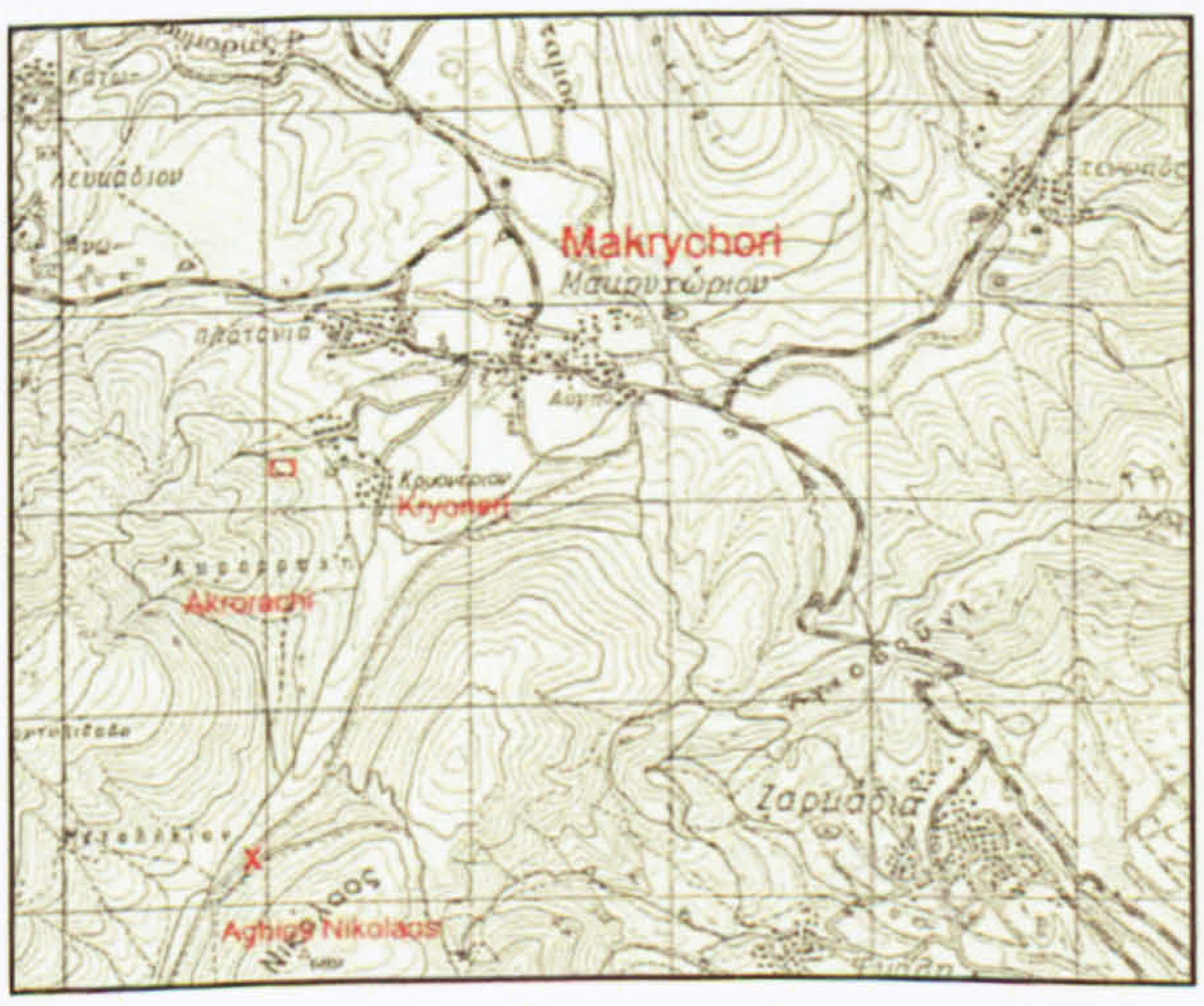
**2. Site Description:** Deep shaft mine and associated adits, probable indications of fire setting, evidence of reuse in late industrial times. Iron and possibly gold/silver found within the iron pyrites of the Mn rich deposits were exploited.

**3. Mineral/metal:** manganese, iron

**4. Date:** Possible dates for mining activity are the Archaic and Classical period ($8^{th}$-$5^{th}$ c. BC) although most recent periods could not be discounted ($19^{th}$ c.).

**5. Previous work**

Archaeometallurgical research reported by Koukouli-Chrysanthaki (1990) identified these shafts with one of the mines exploited by the Thasian emporion of Pistyros as part of the Skapte Hyle mining region.




**04. Site Name:** Livadia-Pangaeon, Kavala **map ref:** 40°55'17.64"N 24°06'38.68"E

**1. Location:** Highland around 800 m OD, mountainous terrain

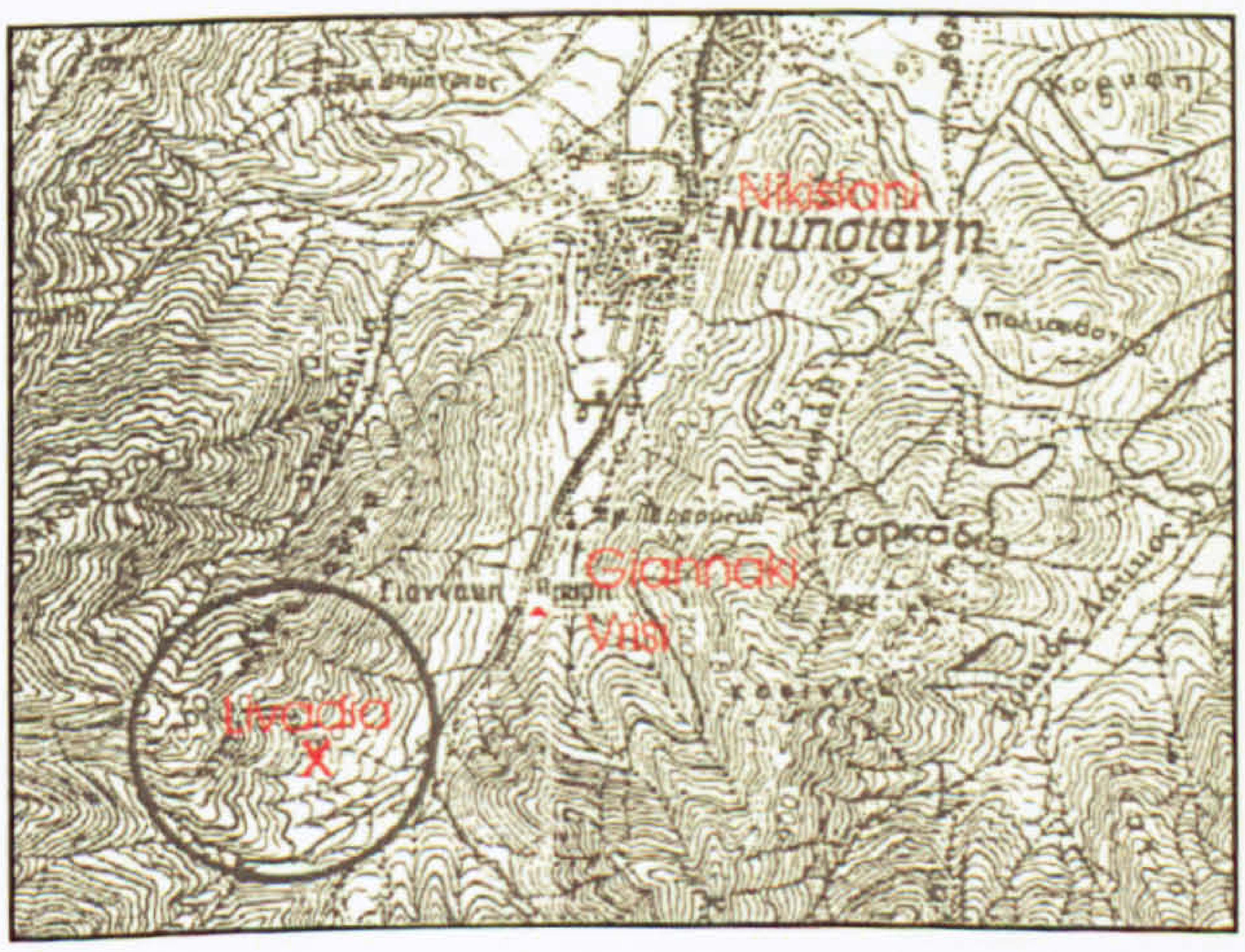
**2. Site Description:** Shaft mine opened for the exploitation of auriferous arsenopyrite and chalcopyrite ore bodies at Livadia on Mt Pangaeon. Tool marks on the walls and the shape of adits for air circulation point to the Classical period. Other mines in the vicinity have been noted east of Palaeochori where iron and copper extraction concentrated. Mining for iron minerals is also evidenced at Ofrynio. Ceramic finds and documentary evidence suggest three major chronological phases of activity for the mines of Pangaeon. The first coincides with the Classical period the second with the Byzantine years and the third and most intensive one falls within Ottoman times.

**3. Mineral/metal:** gold

**4. Date:** Classical (5th c. BC), Ottoman (15th-19th c.) based on published evidence

**5. Previous work**

Vavelidis (2000) undertaken a geological investigation in this region and noted that gold could be found within quartz, arsenopyrite and chalcopyrite. Analytical data for gold concentrations include Nikisiani ores (Au: 16.3 g per tonAg: 72 g per ton), Palaeochori copper deposit (Au: 8.5 g per ton), Ofrynio iron ore deposit (Au: 12.6 g per ton).




**05. Site Name:** Granitis, Drama **map ref:** 41°15'37.63"N 23°58'28.58"E

**1. Location:** Ravine at Mt. Falakro by the banks of Kuru Cai stream, passage between the plain of Drama and K. Nevrokopi plateau

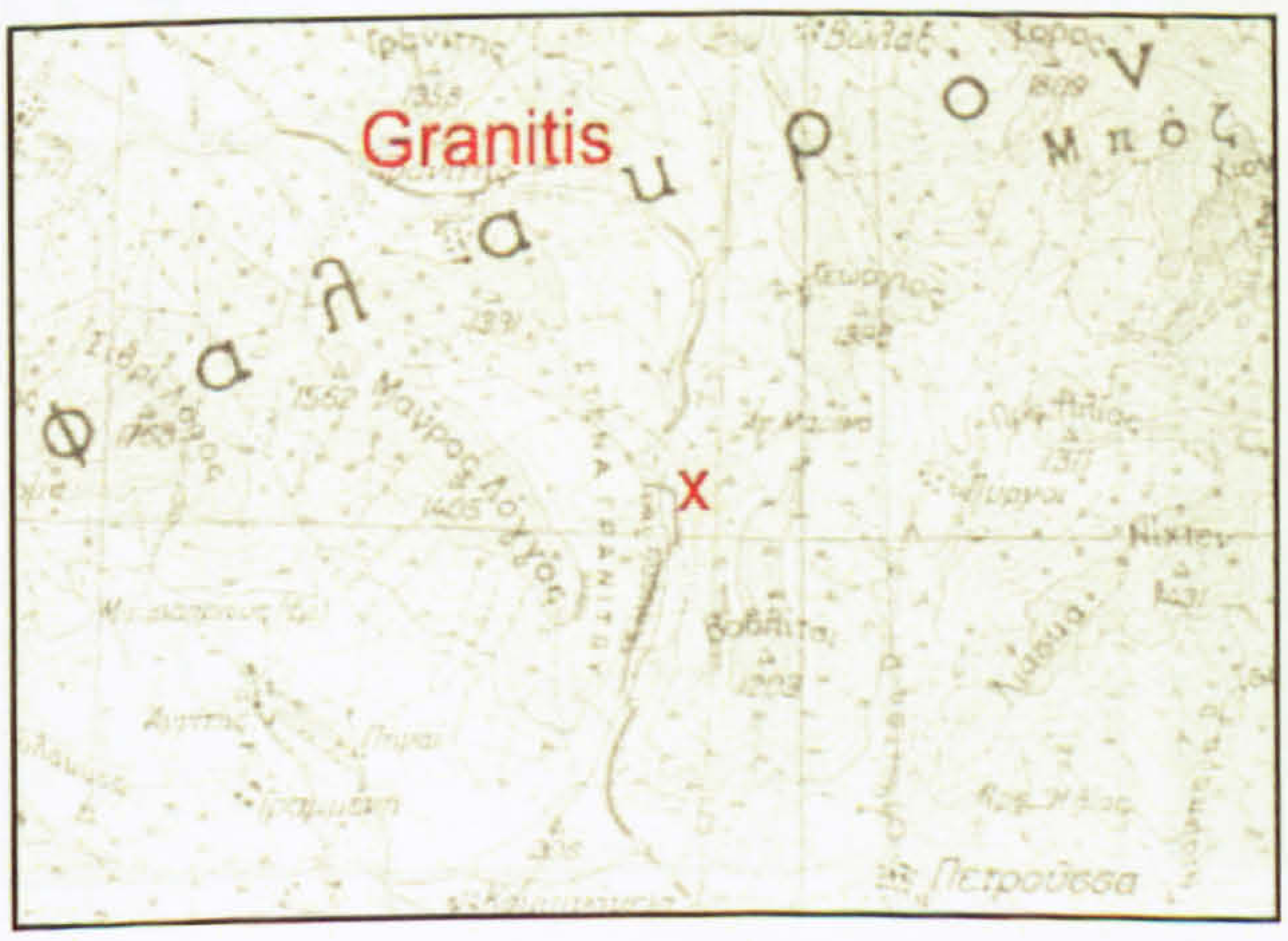
**2. Site Description:** Industrial mining complex established for the exploitation of the rich manganese deposit of K. Nevrokopi, which is of hydrothermal origin and contains pyrolusite, rodonite and manganite. Modern activity was carried out by the Eleusina Mining Corporation between 1960s and 1990s. The mining complex was established on the ravine and extends for about 30 hectares on a north-south axis. Major features include large mining shafts opened at the brow of the surface mineralization, heaps of crushed manganese ore and coal, remnants of ore sorting, washing and floatation facilities as well as water tanks, fuel stations and other buildings.

**3. Mineral/metal:** manganese

**4. Date:** Industrial activity of the twentieth century (20th c.) based on published evidence

**5. Previous work**

In work by Epitropou and Chatzipanagis (1989) and Chatzipanagis (1999) there is valuable information on the Mn deposits of Drama and also a proposed strategy to increase the output from the mine at Granitis.




**06. Site Name:** Trisla, Drama **map ref:** 41°21'25.46"N 23°37'45.73"E

**1. Location:** Highland around 1100 m OD, mountainous terrain

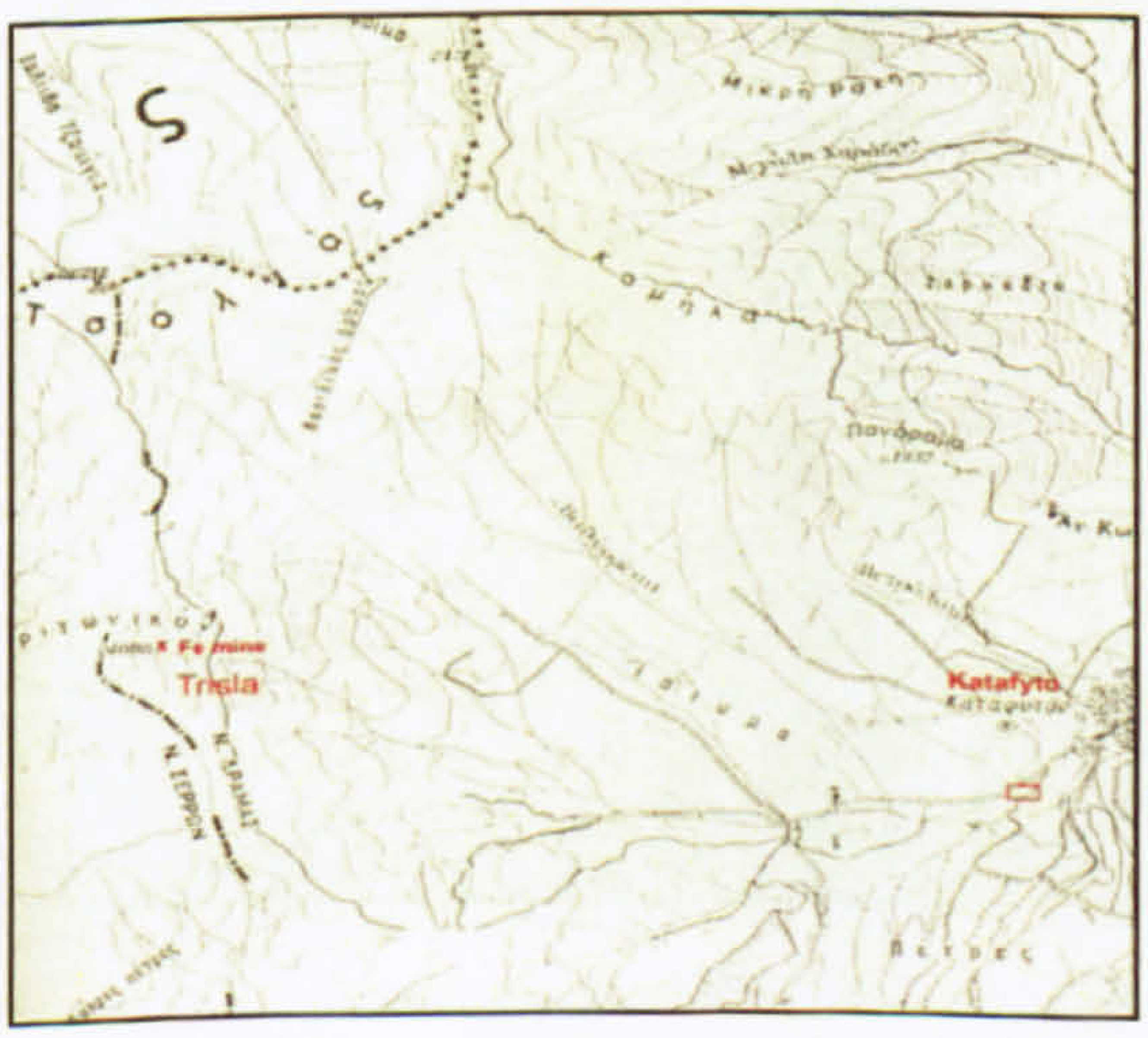
**2. Site Description:** Vertical shaft mine opened for pyrites and mixed sulphides extraction. Thick marble and quartz lenses facilitate the minerals that were formed as vein deposits within fissures of the hosting rocks. The morphological characteristics of diggings point to pre industrial use of probable Ottoman date.

**3. Mineral/metal:** iron

**4. Date:** Late Byzantine-Ottoman ($13^{th}$-$16^{th}$ c.) based on published evidence

**5. Previous work**

Epitropou (pers. communication): Provides mineralogical data on sampled ores from the deposit and notes that morphological characteristics in galleries point to pre-modern activity.




**07. Site Name:** Kyria, Drama **map ref:** 41°05'24.11"N 24°17'10.68"E

**1. Description of Location:** Hillslope, around 180 m OD, pasture land

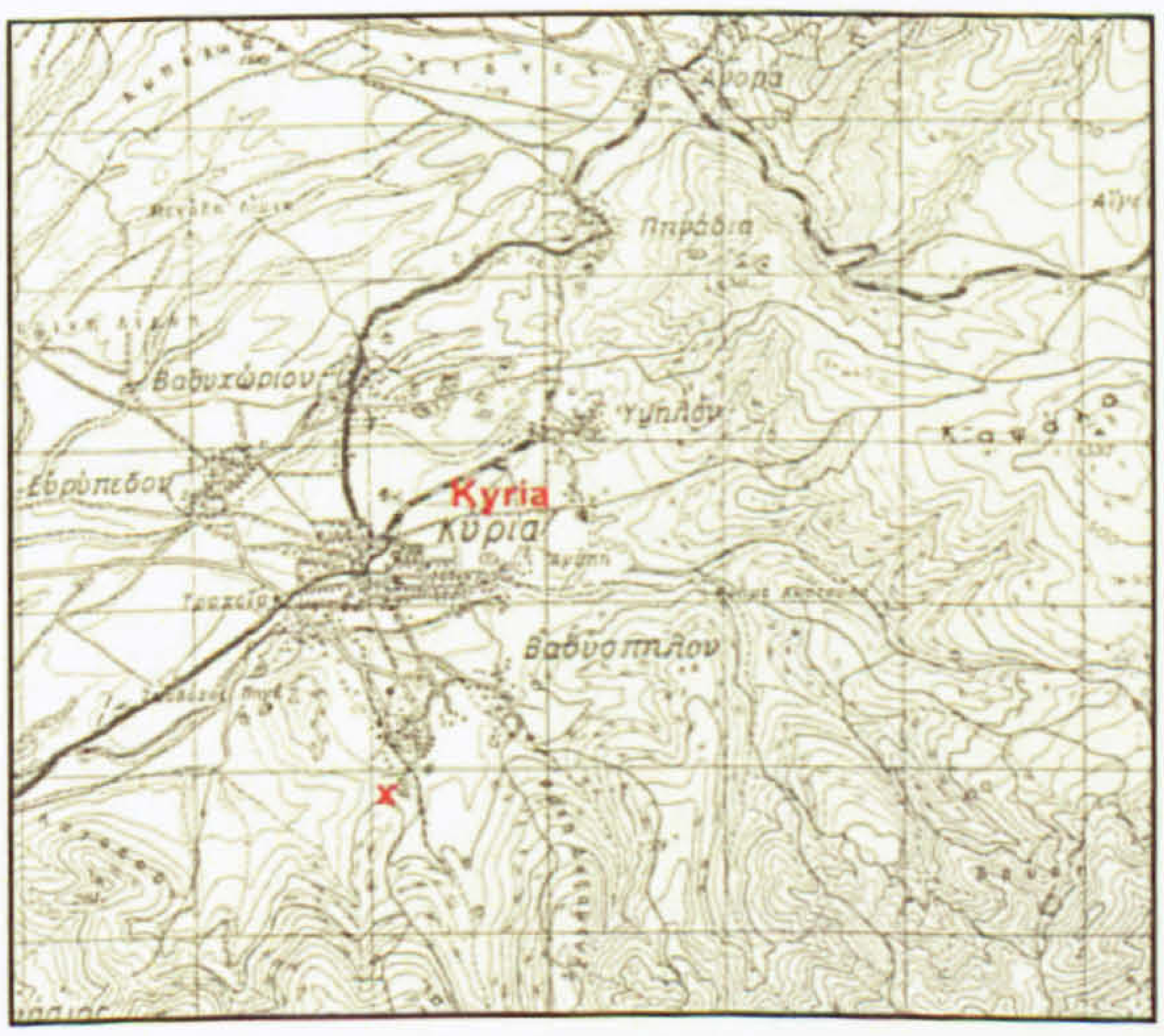
**2. Site Description:** Surface iron mineralization. Accumulated ore concentrates in small heaps near the main trench. The major mineral exploited is limonite for uses as ochre and as raw ore for smelting. It is small-scale and there is no ceramic evidence to provide any estimates for dating.

**3. Mineral/metal:** iron

**4. Date:** modern industrial (19th-20th c.) based on published evidence

**5. Previous work**

Papastamataki (1975): Refers to metal extraction in the area in the form of extracted ore and slag but does not provide any clues on chronology.




**08. Site Name:** Sterna, Drama **map ref:** 41°15'17.87"N 24°35'04.03"E

**1. Location:** Hill slope, on northern banks of Nestos, pasture land

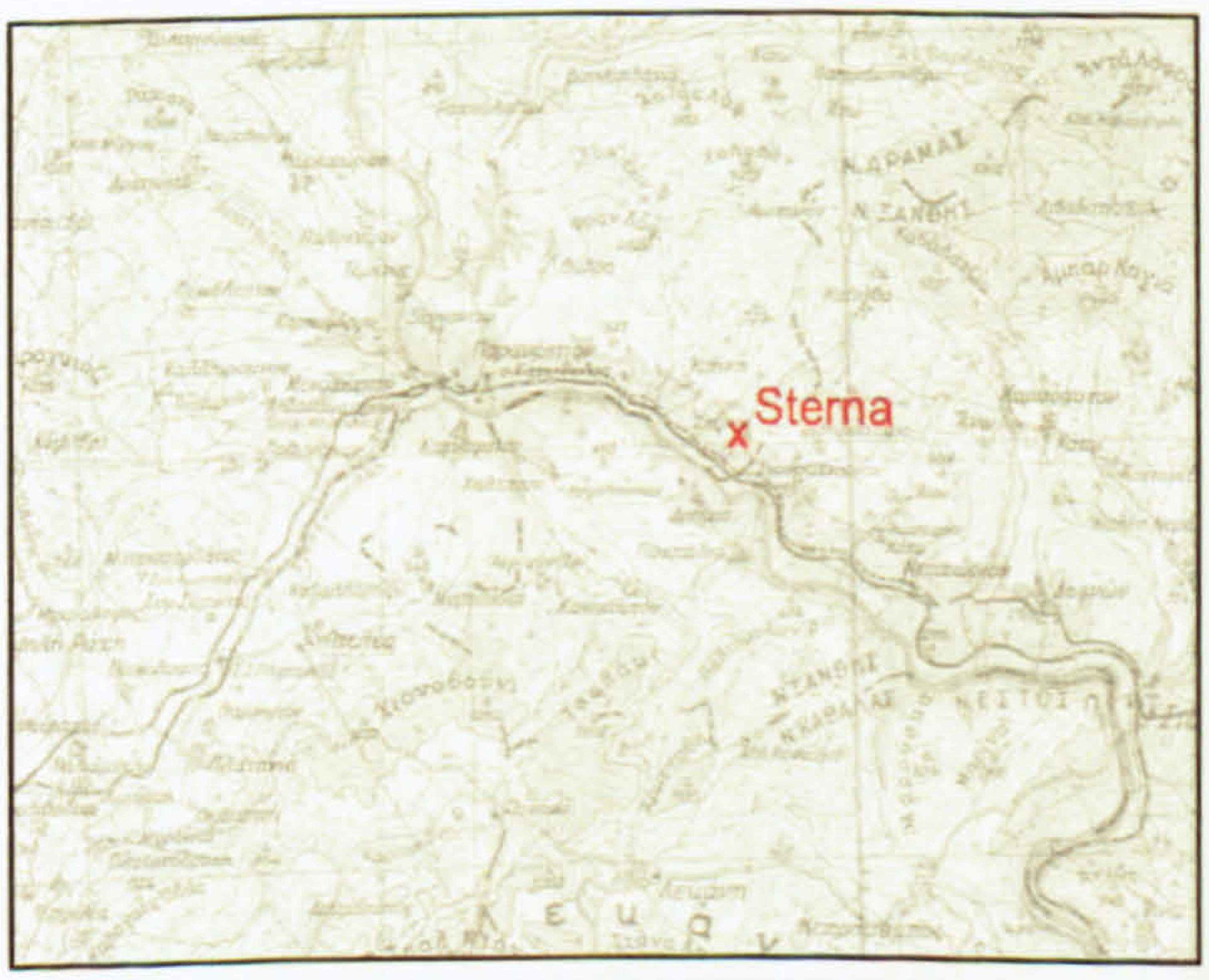
**2. Site Description:** About 500m east of Sterna village a small outcrop of a surface iron gossan with traces of mining has been located. The entrance of the mine is blocked while heaps of broken iron ore exist in the immediate vicinity. It is a small-scale operation that probably yielded low quality ore and was abandoned shortly after initial opening. Apart from digging underground to acquire ores prospectors might have probably encountered the magnetic iron sands deposited along the banks of the river close to the village of Pappades.

**3. Mineral/metal:** iron

**4. Date:** Ottoman-modern industrial ($15^{th}$-$20^{th}$ c.) based on published evidence

**5. Previous work**

Maratos and Andronopoulos (1966): Refer to iron sand deposits deriving from the decomposition of granite from the uplands, which become re-deposited through water action and are rich sources of iron ore.




**09. Site Name:** Ag. Konstantinos, Ag. Georgios-Angistro

**map ref:** 41°21'57.60"N 23°26'33.90"E

**1. Location:**

Hill slopes, around 120 m OD, heavily wooded southeast and south of Angistro village

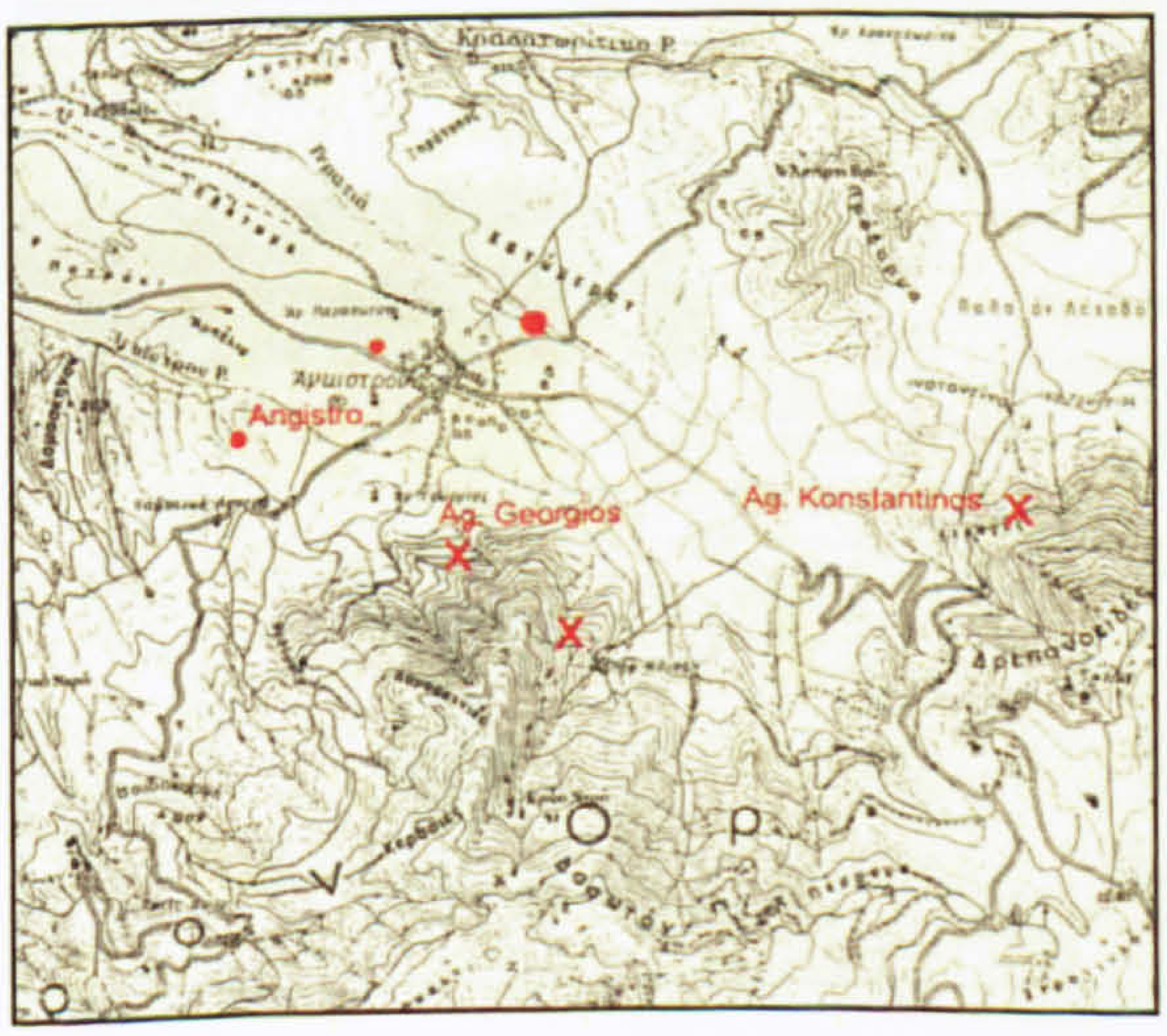
**2. Site Description:** Intensive mining activity was noted at Aghios Konstantinos for the extraction of oxidized iron ore while iron pyrite and pyrotine with some arsenopyrite and chalcopyrite has been extracted at Aghios Georgios. The entrances to mines are generally small less than 1 m width, developing into large chambers extending over 300 m in the largest example. Significant reserves of iron sulphides are still in place while the limonitic ore has been completely extracted.

**3. Mineral/metal:** iron, gold

**4. Date:** Late Byzantine ($13^{th}$-$15^{th}$ c.) based on radiocarbon dating

**5. Previous work**

Chiotis *et al* (1996): Investigated mining evidence around Angistro and provided radiocarbon dates on charcoal samples from a mine gallery. The material was partially covered by a stalagmite and was dated within the range of 1330±310.




**10. Site Name:** Kalithea, Drama **map ref:** 41°07'47.43"N 23°55'48.72"E

**1. Location:** Lowland, arable farms and low hills, 3 km south of Kalithea village

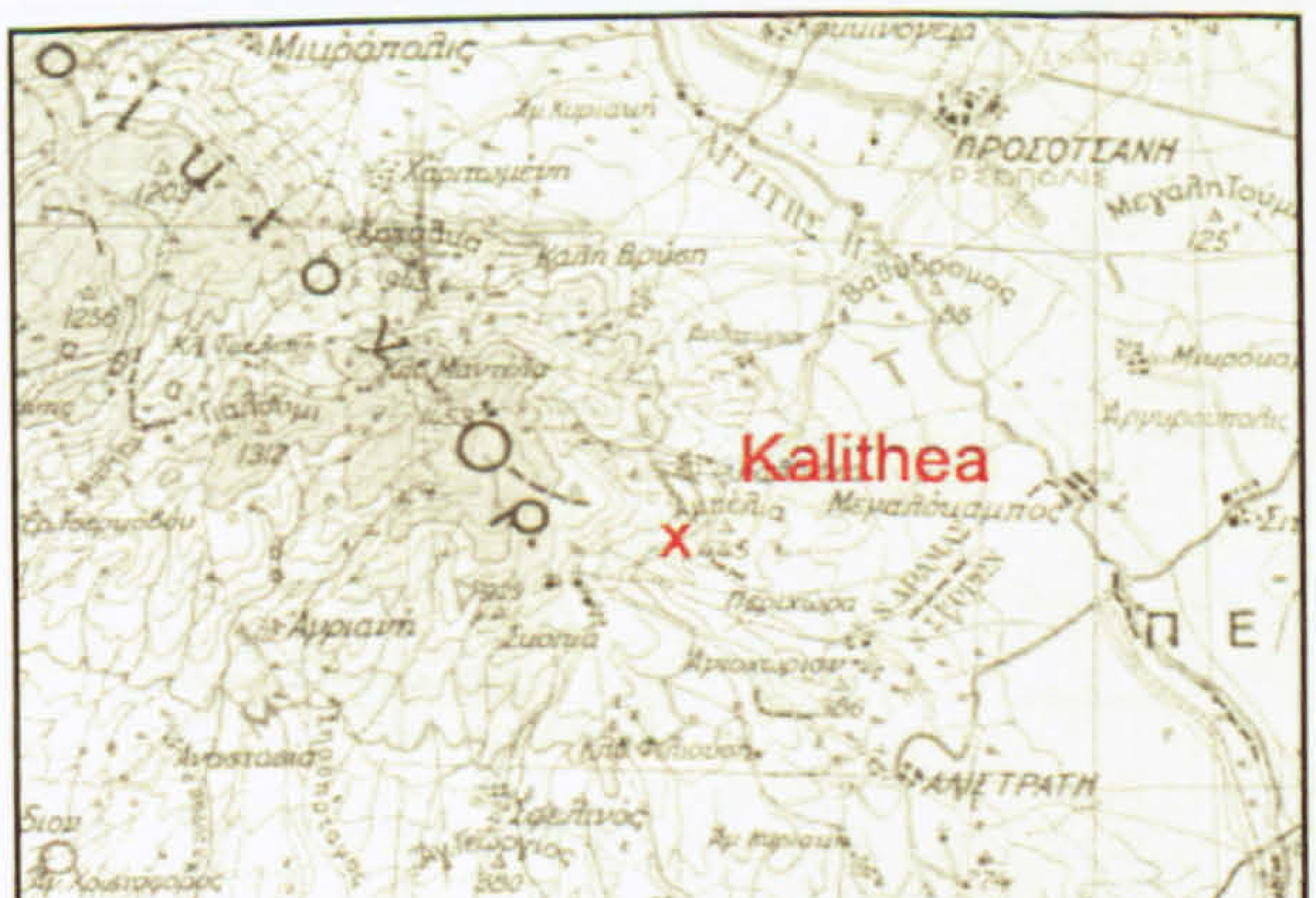
**2. Site Description:** The evidence consists of accumulations of stones among which numerous slag fragments and pottery sherds can be found. Smithing slags and speiss were also noted. Such deposits have formed through land clearance for farming purposes i.e. the gathering of stones and rubble from arable farms towards the edges of field boundaries. It has characteristics of a secondary metalworking site where smithing was practiced. The closest ore deposits to this site are the manganese mineralization of Granitis at 20 km to the northeast and the iron sands of Vrontou around 35 km to the northwest.

**3. Mineral/metal:** iron

**4. Date:** Ottoman-modern industrial ($15^{th}$-$20^{th}$ c.) based on local inhabitants' accounts

**5. Previous work**

No previous data are known for this site




**11. Site Name:** Leukogia, Drama **map ref:** 41°24'47.62"N 23°54'12.59"E

**1. Location:** Lowland, arable farms and low hills

**2. Site Description:** The site consists of a small artificial mound on top of which pieces of slag were recorded. Slag coverage is about 20-50 cm thick and seems to be a surface deposit. Compact, porous and occasional tapping slag accumulated in a thin layer cover much of the area on top, which has been estimated roughly around 350-400 $m^2$. There is no mineralization in this region and it appears as a secondary metalworking site for smelting and primary smithing of the blooms. The closest ores to Leukogia are the iron mine at Trisla 35 km to the east and the iron sands from various locations on the Vrontou range.

**3. Mineral/metal:** iron

**4. Date:** Late Byzantine ($13^{th}$-$15^{th}$ c.) based on surface pottery

**5. Previous work**

No previous data are known for this site


**12. Site Name:** Exochi, Drama **map ref:** 41°24'51.66"N 23°49'17.59"E

**1. Location:** Lowland, arable farms and low hills

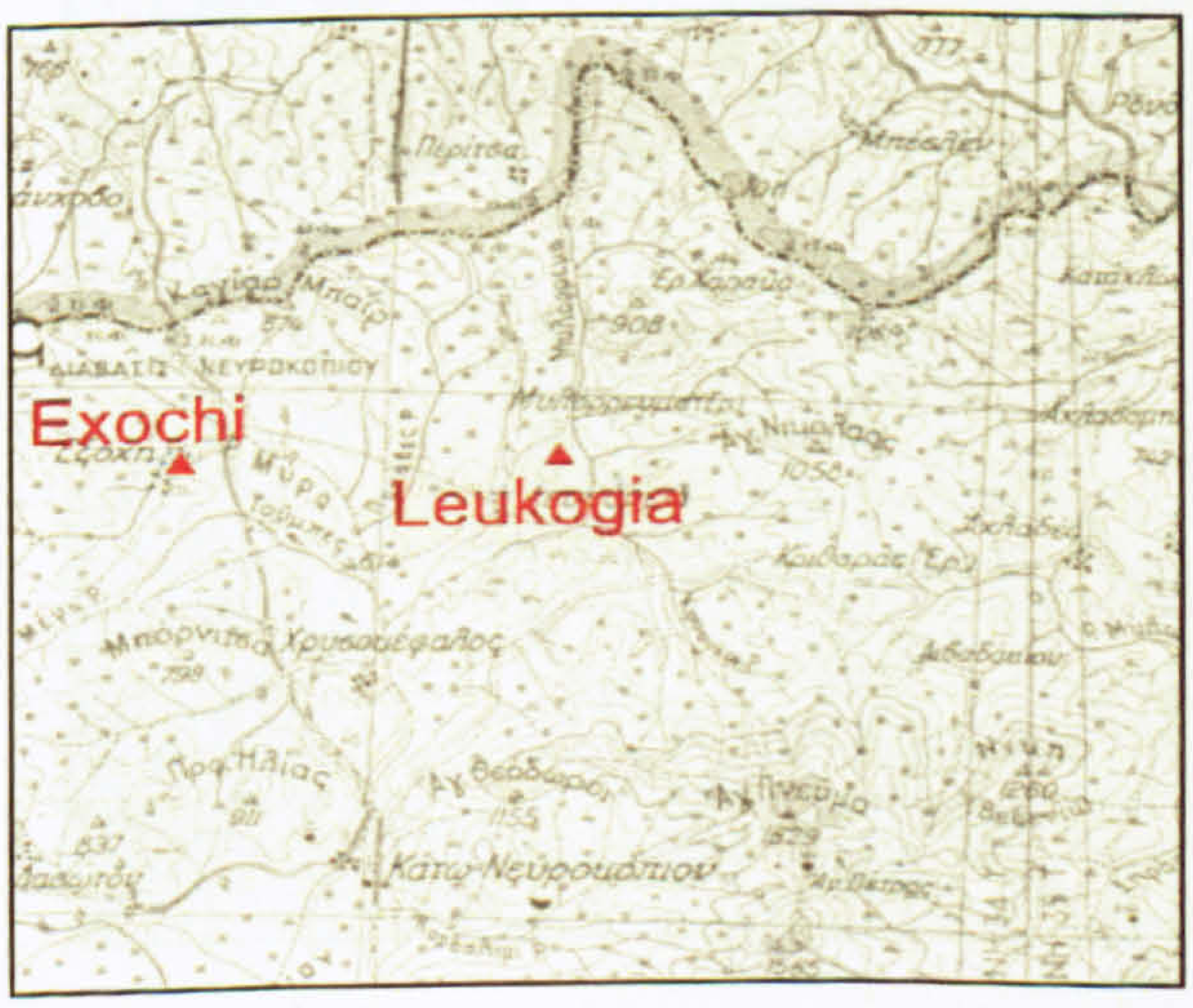
**2. Site Description:** Around the village of Exochi north of Kato Nevrokopi several small slag heaps were noted with an approximate overall volume of 50-100 m³. The heaps are mostly scattered across farming fields and derive from extraction of the iron bearing deposits of the region. As part of a wider region of decentralised iron production sites Exochi was incorporated in a network of raw and semi-finished materials circulation. In order to sustain production, charcoal and raw ore as well as smelted blooms from upland zones would have been transported in those lowland intermediary locations where the final stages of smithing would have taken place. Furthermore such locations would effectively pass the products over to consumption centres of the surrounding villages. The mine at Trisla and the iron sands from Vrontou are the closest ore sources.

**3. Mineral/metal:** iron

**4. Date:** Late Byzantine-Early Ottoman ($13^{th}$-$16^{th}$ c.) based on surface pottery

**5. Previous work**

Papastamataki (1975): Describes evidence for small-scale activity i.e. slag scatters




**13. Site Name:** Ag. Dimitrios, Panorama **map ref:** 41°14'58.62"N 23°48'45.71"E

**1. Location:** Uplands, 3 km north of Panorama, wooded landscape

**2. Site Description:** The monastery of Aghios Dimitrios at Panorama is situated on the southwestern flanks of Mt. Falakro on the Kalapoti passage connecting the plain of Drama with that of Nevrokopi. Slag fragments were found scattered within a radius of around 500 m around the monastery. Other finds include Byzantine pottery sherds, marble architectural fragments and remains of a baptistery. Signs of an ore deposit (skarn) were found close by consisting of malachite and magnetite but no firm evidence for their exploitation occurs. The slag most probably derives from iron smithing operations undertaken to cover the needs of the monastery in utensils and tools.

**3. Mineral/metal:** copper

**4. Date:** Late Byzantine ($13^{th}$-$15^{th}$ c.) based on surface pottery

**Previous work**

Bassiakos (pers. communication): Provided information on slag scatters from the site


**14. Site Name:** Magnesia, Drama **map ref:** 41°21'39.70"N 24°19'12.00"E

**1. Location:** Uplands, northern banks of Nestos, wooded

**2. Site Description:** Scanty smelting evidence was recorded east of Sidironero village at Magnesia where the ruins of a synonymous abandoned village are found. Close to the banks of a stream, scattered slag pieces were noted, not concentrated in heaps of any sort. Their distribution is random and the volume is restricted to few pieces though a more focused survey might reveal more. Manganese mines exist in the region while the slags probably derive from a local source.

**3. Mineral/metal:** iron

**4. Date:** Ottoman (15th-19th c.) based on surface pottery

**5. Previous work**

Forbes (1950): The place-name probably refers to a white earth (clay) though the use of magnetite as a source of iron has been associated in the past with places called Magnesia. Pliny's *magnes lithos* does not imply magnetism and there is an apparent confusion when contrasting haematites and magnetites.


**15. Site Name:** Nikisiani, Mt Pangaeon, Kavala

**map ref:** 40°56'02.34"N 24°08'08.99"E

**1. Location:** Uplands, 400 m OD, pasture land 1 km south of Nikisiani village

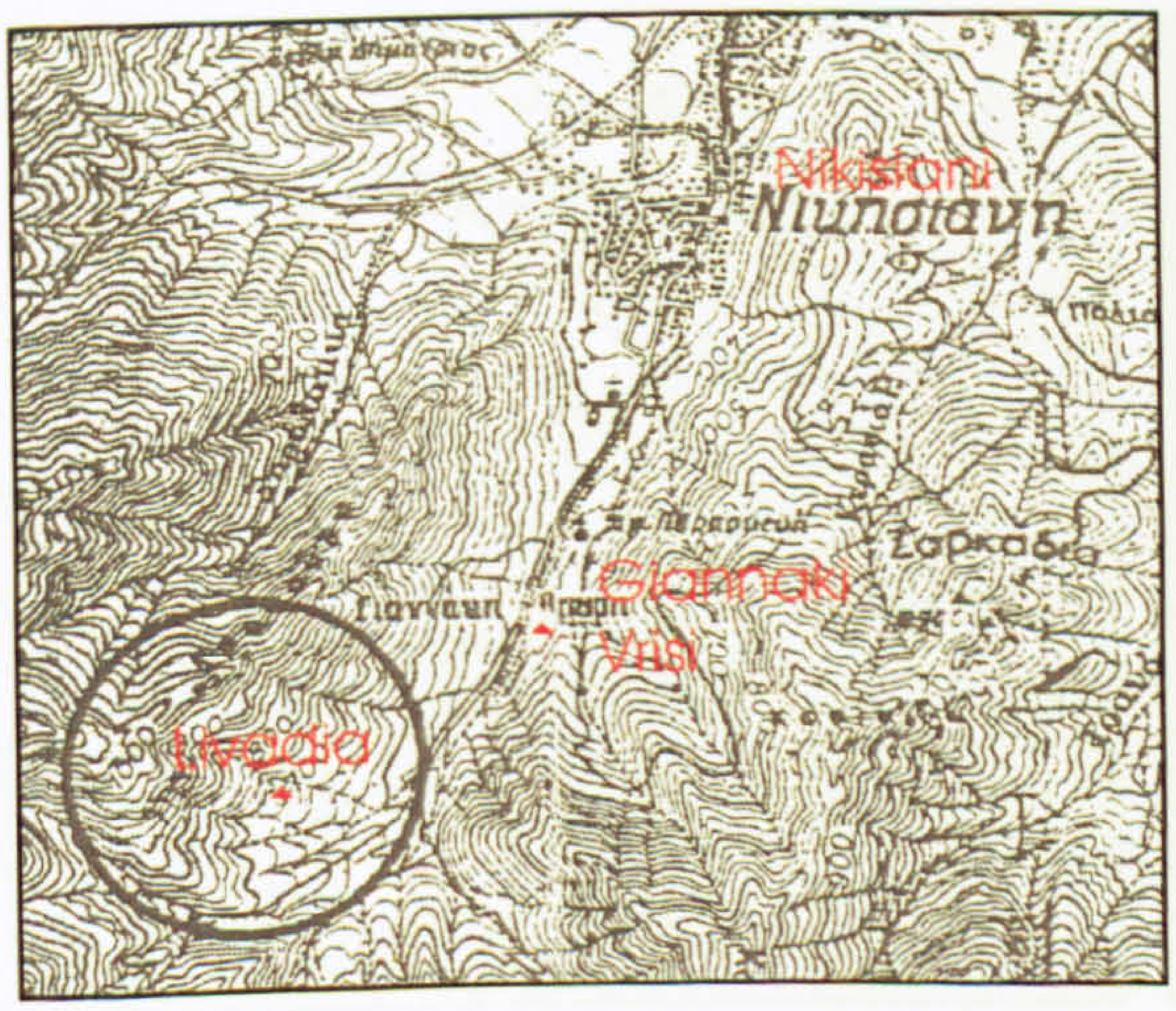
**2. Site Description:** Discrete small slag heap at Giannaki Vrisi south of Nikisiani which consists of dark brown and black, iridescent compact slags, many of which show a ropey appearance. Estimated volume: 8 tons of slag from a single phase operation. At Livadia 0.5 km southwest of the site lie the remains of an excavated smelting furnace dated to the Ottoman period. A number of rich sliver and gold bearing deposits could be found at Asimotrypes less than 20 km south of Nikisiani.

**3. Mineral/metal:** iron, silver, gold

**4. Date:** Ottoman ($15^{th}$-$19^{th}$ c.) based on published evidence

**5. Previous work**

Photos (1987): Refers to the smelting furnace at Livadia and also reports slag heaps in the region of Nikisiani and Palaeochori.




**16. Site Name:** Ano Vrontou, Serres **map ref:** 41°16'18.04"N 23°41'23.37"E

**1. Location:** Highlands around 960 m OD, near a watermill by a stream, 4 km south on A. Vrontou

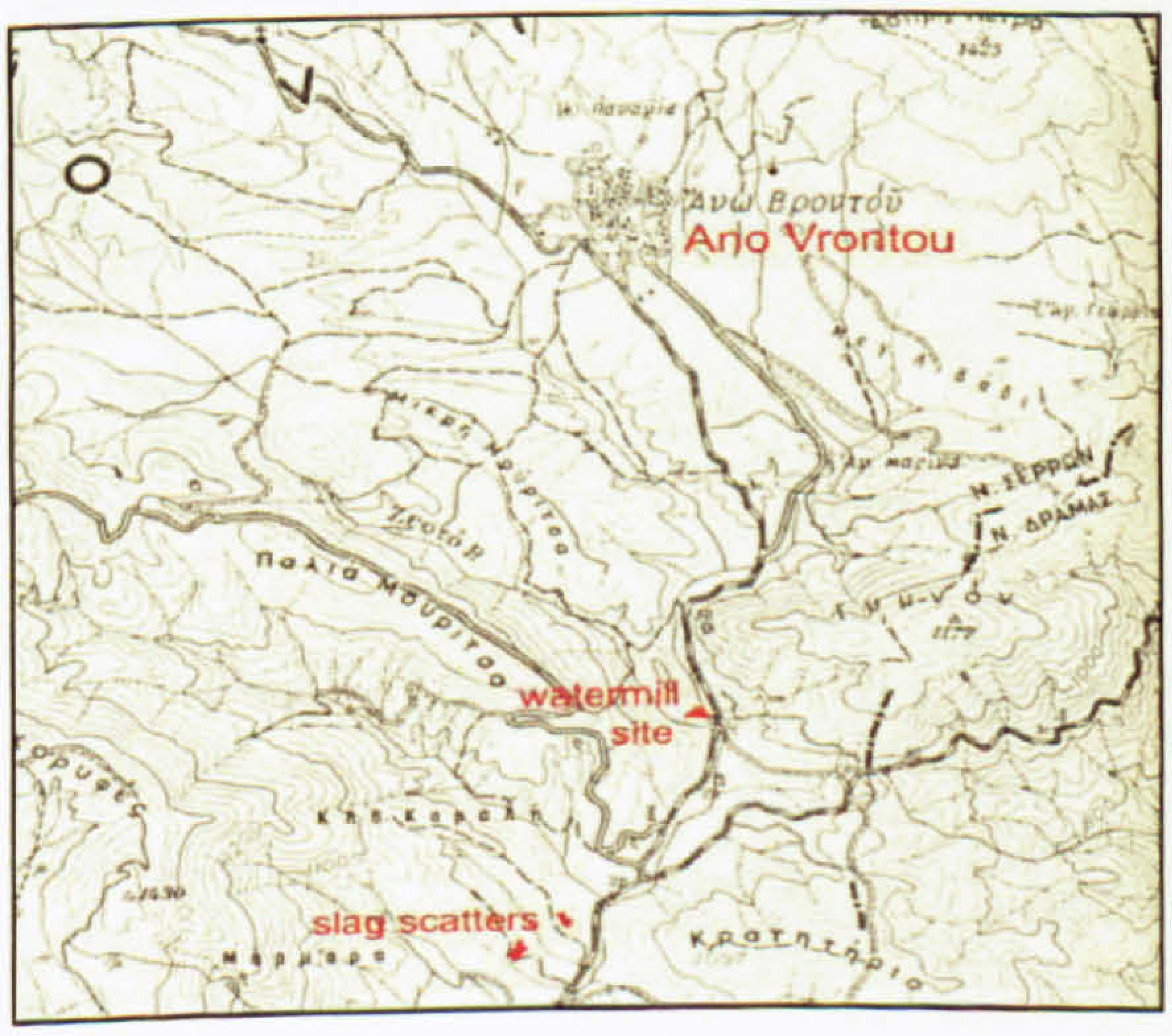
**2. Site Description:** Thin deposit of slag within the stream bank in the immediate vicinity of a watermill and small concentrations were noted. Slag heaps of a few tons disturbed by ploughing were also found across arable farms further south. In some of the fragments entrapped charcoal was observed but no furnace residues, refractories or associated pottery sherds were collected. Activity appears to have spanned for considerable time periods of Ottoman date. The ore source was probably the iron sands that abound in the surrounding region.

**3. Mineral/metal:** iron

**4. Date:** Ottoman ($15^{th}$-$19^{th}$ c.) based on published evidence

**5. Previous work**

Papastamataki (1975): Provides data from chemical analyses on slag found at various locations around Ano Vrontou which indicate a bloomery process.




**17. Site Name:** Orini, Serres **map ref:** 41°11'58.56"N 23°35'32.21"E

**1. Location:** Uplands, around 800 m OD arable farms, pasture land

**2. Site Description:** Close to Orini village a fortress of Late Roman date (4th c. AD), founded on top of an earlier Thracian citadel produced metallurgical finds of appreciable scale worthy of consideration. Slag could be found covering the slopes below the northern defensive walls but the process represented is not clear. Primary smelting of iron sands could be suggested based on furnace slag and debris in addition to smithing and casting of other metals based on moulds and casting implements found during previous investigations.

**3. Mineral/metal:** iron

**4. Date:** early Byzantine (4th-6th c.) based on published evidence

**5. Previous work**

Samsaris (1979): Reports findings including a stone and clay mould fragments, tuyères and other casting implements and suggests that the strong north winds would facilitate smelting in low shaft furnaces built close to the walls.


**18. Site Name:** Faia Petra, Serres **map ref:** 41°16'01.97"N 23°27'10.92"E

**1. Location:** Uplands, around 350 m OD, on steep slopes of Krousovitis gorge, pasture land

**2. Site Description**

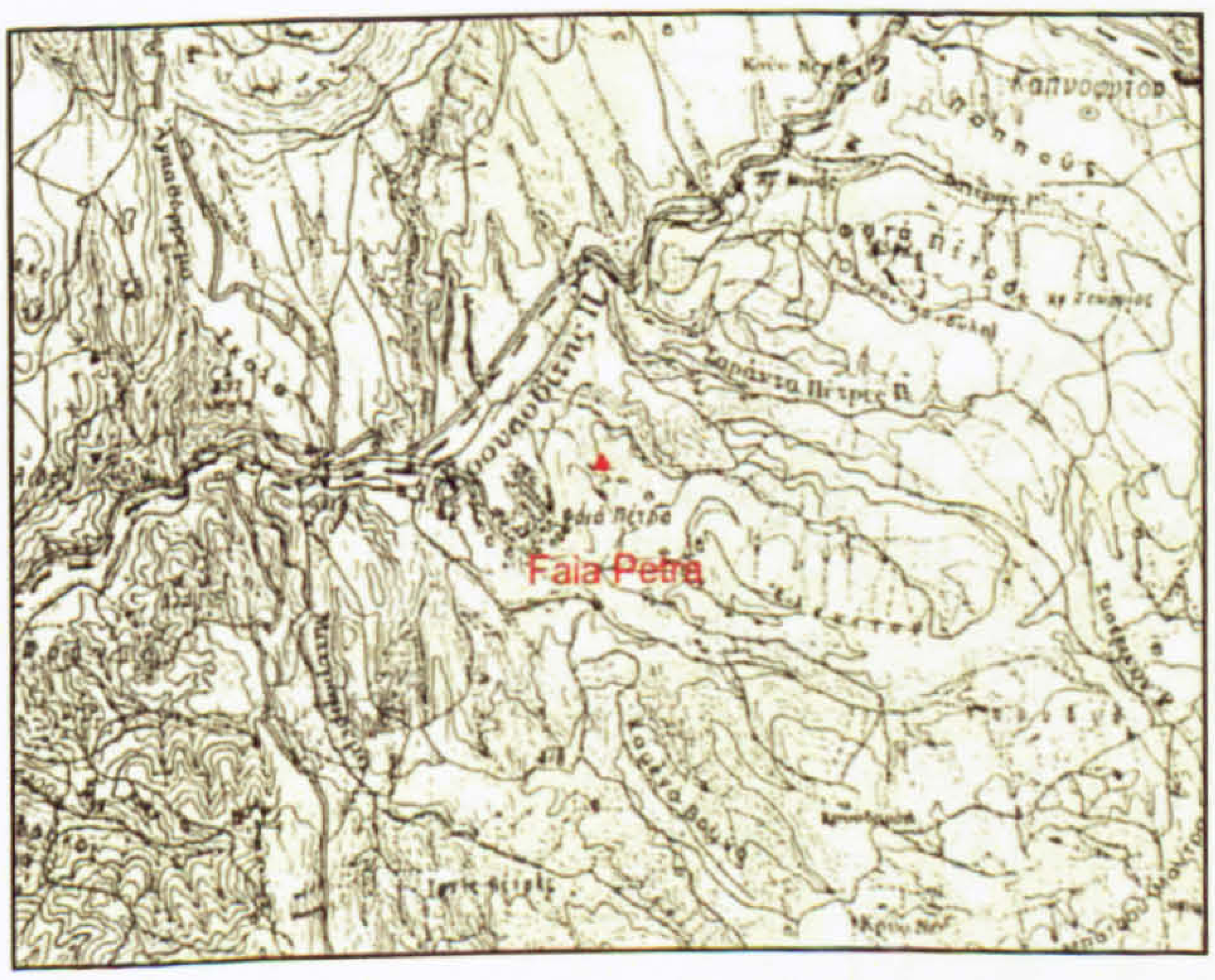
Two sites of smelting activity have been located around the village of Faia Petra about 7 km northeast of Sidirokastro. The first one consists of scattered material close to a monastery situated 300m west of the village. Charcoal entrapped within slag fragments is a common occurrence and a few typical Macedonian pottery sherds belonging to Classical and Hellenistic times have been noted. The second slag concentration is about 100m west of the village covering a slope facing eastwards at a site with natural springs. Except for slag, tuyère fragments of greyish clay, furnace lining and a charcoal layer were found associated with undated pottery sherds. The mines around Angistro are the closest deposits of ore.

**3. Mineral/metal:** iron

**4. Date:** Ottoman (15th-19th c.) based on pottery finds

**5. Previous work**

Papastamataki (1975): Refers to slag heaps around Faia Petra




**19. Site Name:** Katafyto, Drama **map ref:** 41°20'38.84"N 23°40'46.65"E

**1. Location**

Woodland, next to stream 0.5 km SW of Katafyto village, pasture and arable

**2. Site Description**

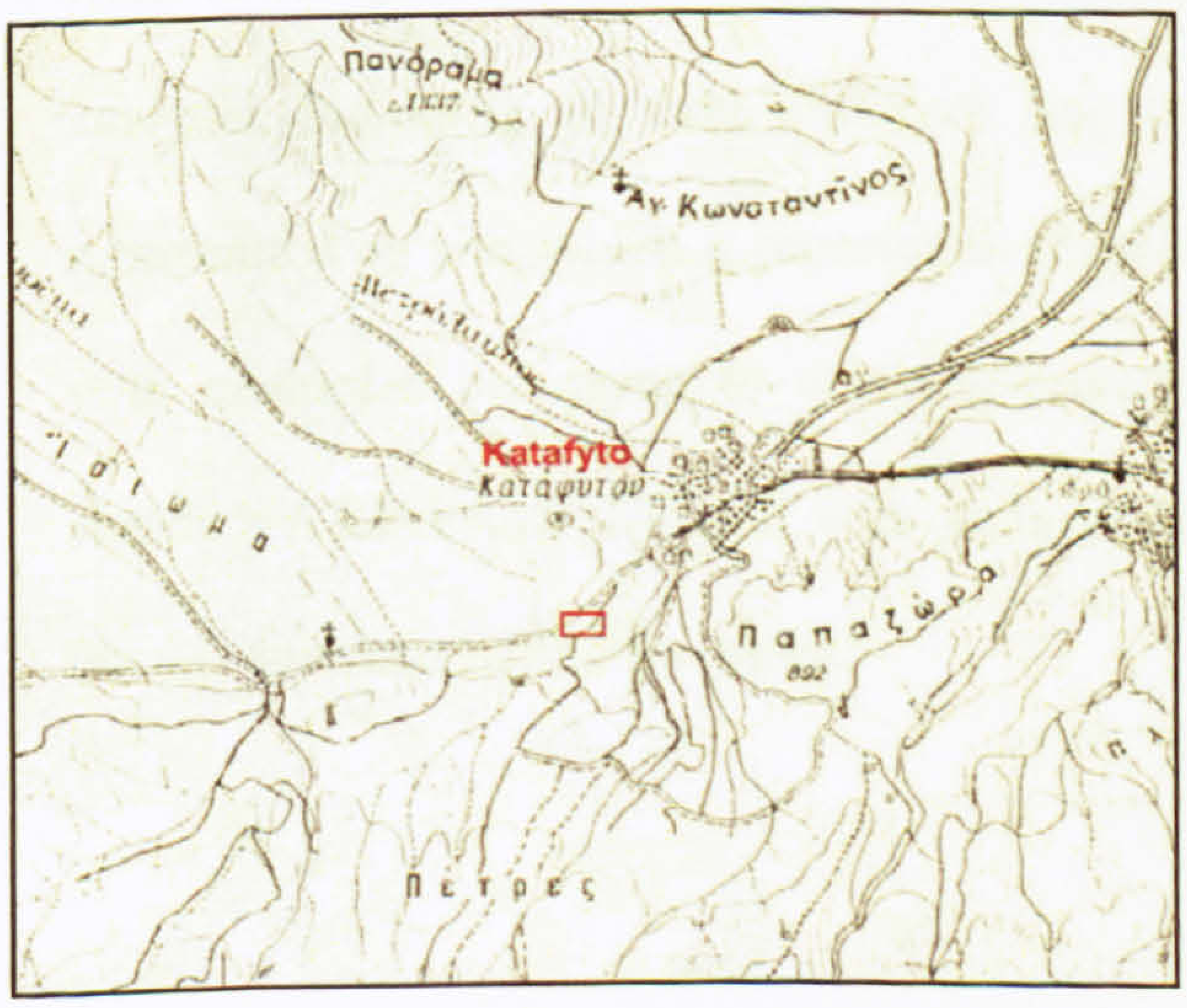
Extensive mound stretching parallel to a stream with lower eastern slopes and a steep peak to the west. It was chosen as the first site for intensive survey and sampling. The eastern edge of the mound yielded a concentration of moderately porous reddish brown and black slags some showing a ropey appearance and others bearing various inclusions. Large stones with adhering slag also exist. The western edge yielded substantial evidence of large slag pieces and furnace lining, conglomerates, hearth bottoms and tuyères. Estimated size: $500m^2$ slag coverage, volume: 100-200 tons, single phase.

**3. Mineral/metal:** iron and shortest distance from a deposit is estimated around 15 km due west at Trisla which has been identified with Trilision (see chapter 4).

**4. Date:** Late Byzantine ($13^{th}$-$15^{th}$ c.) based on pottery finds

**5. Previous work**

Photos (1987): Sampled and analyzed slag which was found to derive from iron smelting operations, high Ti levels reported.




### 6. Topographic survey and sampling

The site consists of a mound where slag deposition designates a discrete unit of metallurgical production established by the course of a stream (figures 5.4-5.5). It extends on an east-west axis at roughly 30 m in length by 20 m in maximum width (figure 5.6-5.7). Stone debris has been recorded following the brow of the southeastern slope and descending to lower ground with a NW-SE direction (figure 5.8). Two roughly circular cavities on the flat eastern peak of about 1.5 m in diameter seem to be associated with the stone structure. The evidence is fragmentary and hence no clear picture of the architectural characteristics is available. Entrapped tuyères within slag conglomerates (largest: 20x10 cm) and other vitrified clay fragments were noted on the western peak indicating the existence of furnace material on the slopes of the mound (figures 5.9-5.10). This peak which rises to six meters above the stream course appears to have formed through dumping of smelting debris particularly furnace conglomerates. The wooded landscape and proximity to mineral resources made Katafyto a favourable place for smelting activity with easy access to raw materials. A few sherds of Byzantine date provide information on relative chronology. The general characteristics of the evidence suggest iron metallurgy being practiced on site. In total 30 slag samples were taken from the mound's top and slopes as well as from lower ground. Based on external features 10 samples were chosen for further analysis, including all three different slag types (compact, semi-compact, porous) represented on site, which is reported in chapter 6. Associated pottery is generally rare with examples belonging to drinking vessels (KAT.P.3 and KAT.P.4) while two sherds KAT.P.1 and KAT.P.2 with yellow glazing provide a relative chronology for the site into late Byzantine times.


Figure 5.4 Satellite image of Katafyto showing the smelting site location (source: Google Earth)

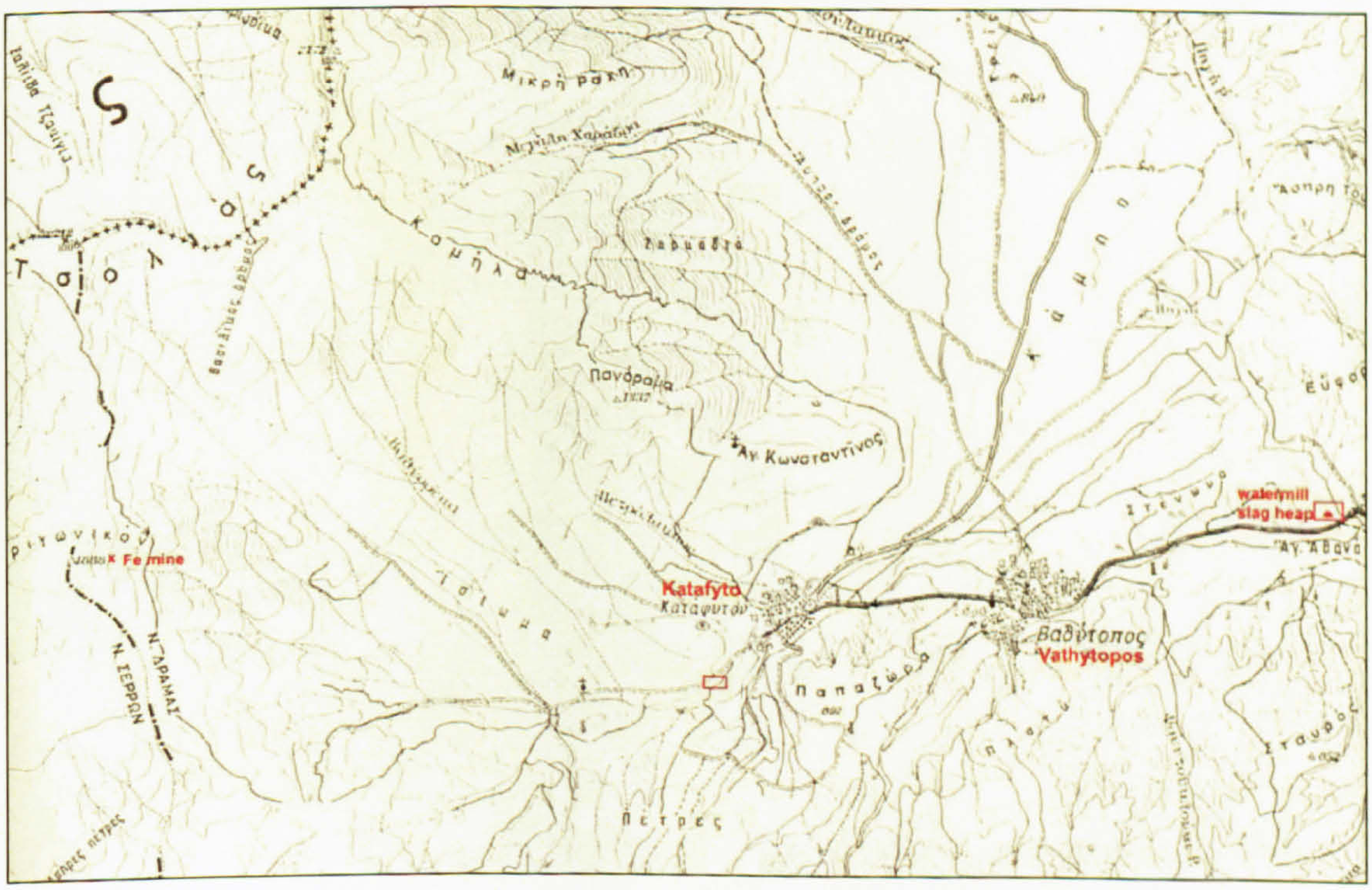



Figure 5.5 Topography of the site and immediate vicinity (□: smelting site, X: mine

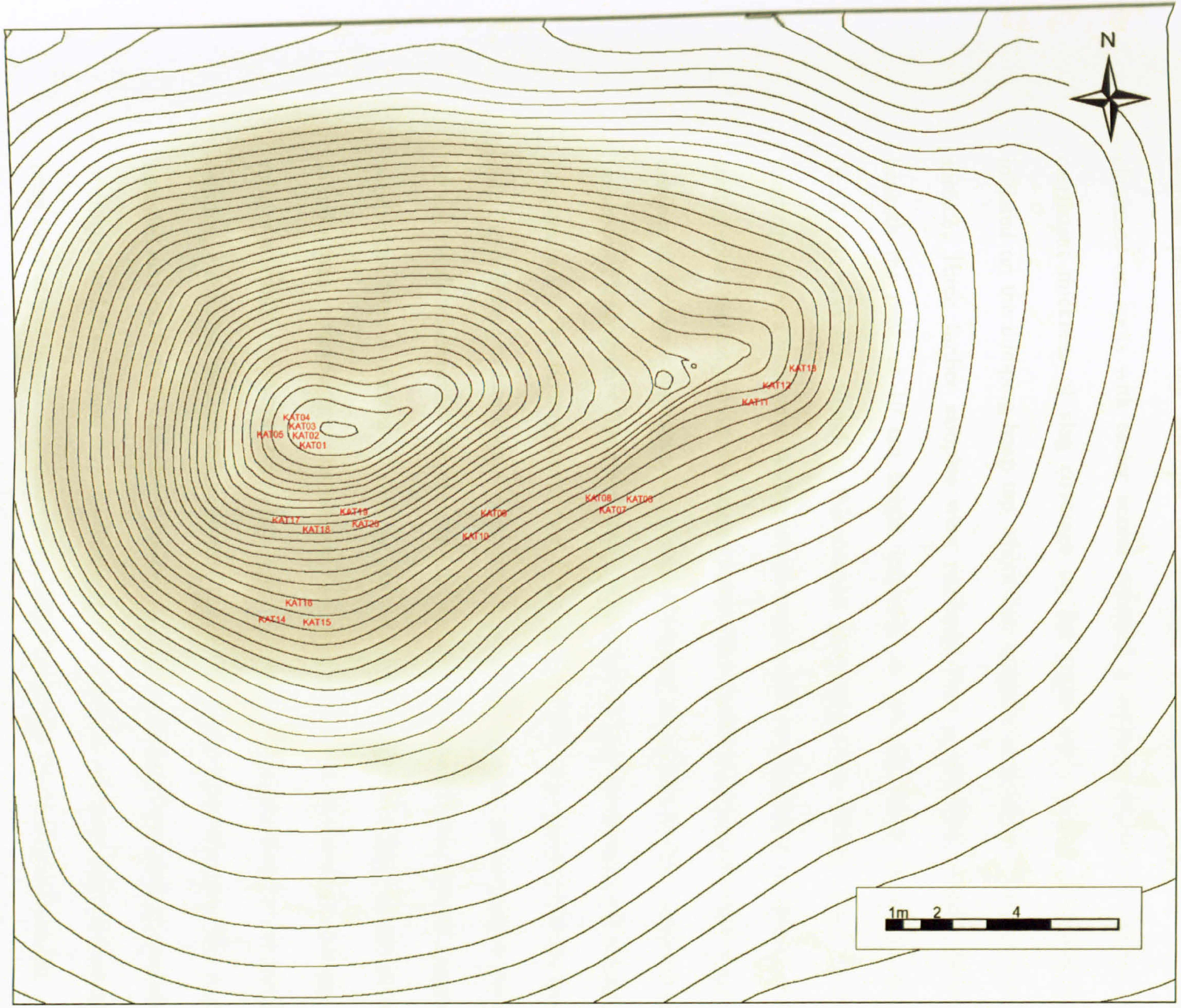



Figure 5.6 Sketch plan of site and samples context

Sampling concentrated primarily on the southern slopes of the artificial mound produced by accumulated residues (Table 5.2). Vegetation overgrowth on its northern section prevented any attempts to thorough investigation. However restricted clearance on spots with easier access revealed a uniform deposition pattern and consistent thickness of slag coverage on the entire site's extent. Sampling was initiated on the dumping heap top where two samples were taken from its current surface. Three further samples were retrieved from a stratified context directly beneath the peak at 10 cm height intervals. A late Byzantine decorated sherd (KAT.P.1) was also found in this context providing some dating clues. On the southern slopes a transverse cutting where anthropogenic disturbance revealed a clear stratigraphic section provided a secure context for further sampling. Besides slags, a number of furnace conglomerates, pieces of bloated lining and tuyères indicated the presence of fragmentary furnace material from which a few specimens were retrieved (Appendix V). Two pottery sherds (KAT.P.2 and KAT.P.3) that derive from this layer date the evidence to late Byzantine times. Three samples were extracted again every 10 cm height intervals on the eastern edge of the cutting while two further samples were taken from a context of slightly more elevated height. The next cluster of six samples was retrieved from the eastern boundary of the site where slag coverage is thinner and might represent secondary deposition mixed with rubble and some sort of building debris. A surface un-diagnostic sherd was taken from this spot. Six more samples derived from the southern lowest part of the dumping heap among a number of fragmented tuyères and furnace lining. A last cluster of samples derived from the heap slope at mid height and were taken as four pairs from 10 cm height intervals.

**Table 5.2**
***Katafyto: slag samples context***

| | |
|---|---|
| Sample No. KAT01 | western edge-top of heap/surface (1 slag piece) analysed |
| Sample No. KAT02 | western edge-top of heap/surface (1 slag piece) analysed |
| Sample No. KAT03 | western edge-top of heap/stratified (1 slag piece) analysed |
| Sample No. KAT04 | western edge-top of heap/stratified (1 slag piece) analysed |
| Sample No. KAT05 | western edge-top of heap/stratified (1 slag piece) analysed |
| Sample No. KAT06 | southeast slope-lower ground/stratified (1 slag piece) analysed |
| Sample No. KAT07 | southeast slope-lower ground/ stratified (1 slag piece) analysed |
| Sample No. KAT08 | southeast slope-lower ground/stratified (1 slag piece) analysed |
| Sample No. KAT09 | southern slope/surface (1 slag piece) analysed |
| Sample No. KAT10 | southern slope/stratified (1 slag piece) analysed |
| Sample No. KAT11 | eastern edge of the mound/surface (2 slag pieces) |
| Sample No. KAT12 | eastern edge of the mound/surface (2 slag pieces) |
| Sample No. KAT13 | eastern edge of the mound/stratified deposit (2 slag pieces) |
| Sample No. KAT14 | southern slope of heap low height/surface (2 slag pieces) |
| Sample No. KAT15 | southern slope of heap low height/surface (2 slag pieces) |
| Sample No. KAT16 | southern slope of heap low height/surface (2 slag pieces) |
| Sample No. KAT17 | southern slope of heap middle height/stratified (2 slag pieces) |
| Sample No. KAT18 | southern slope of heap middle height/stratified (2 slag pieces) |
| Sample No. KAT19 | southern slope of heap middle height/surface (2 slag pieces) |
| Sample No. KAT20 | southern slope of heap middle height/surface (2 slag pieces) |
| | TOTAL: 30 slag pieces |

Figure 5.7 Three dimensional representation of the smelting site

Figure 5.8 Southeastern edge of the slag heap with stone debris

Figure 5.9 Southern slopes of the slag heap, concentration of conglomerates

Figure 5.10 Furnace wall fragments with entrapped tuyères

## 7. Pottery sherds

KAT.P.1: Painted sherd 5cm in length. On the outer surface one edge is painted white and there is a brown curved motif on the other. On its interior surface half the sherd is glazed with a colourless agent. Date: Late Byzantine ($13^{th}$- $15^{th}$ c.)


KAT.P.2: Base fragment 6cm in length belonging to a plate. The inner surface bears traces of yellow glazing applied on a white substratum of slip. Date: Late Byzantine ($13^{th}$- $15^{th}$ c.)


KAT.P.3: Handle 5cm in length with double ridge on its exterior. There are traces of glazing applied in form of wavy lines across the breadth of the handle.

KAT.P.4: Non-diagnostic coarseware fragment 7cm in length.

**20. Site Name:** Vathytopos, Drama **map ref:** 41°21'28.33"N 23°44'26.81"E

**1. Location**

Woodland, next to stream and watermill, 2 km west of Vathytopos village

**2. Site Description**

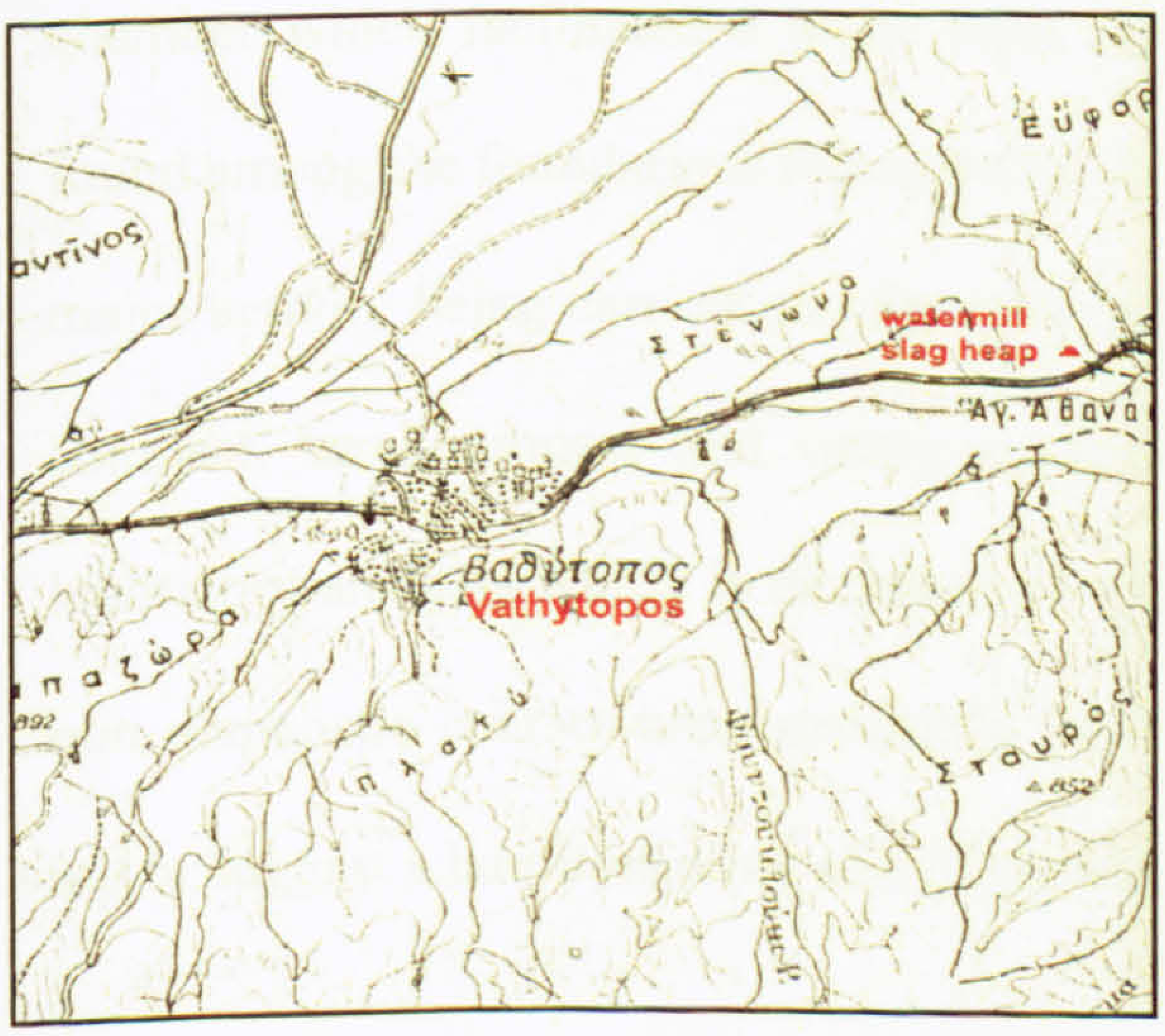
Small heaps and patches of trampled slag lay on a plateau formed between the water mill and the current course of the stream at a distance of 50 m from a bridge. This site has been selected for intensive survey and sampling. A large volume of material has been washed down a modern cut. Compact and porous slag types predominate on site while no conglomerates or refractory ceramics were found. There is an extensive leat system for water transportation to the mill. Estimated size: 300 m² slag coverage, volume: 100-200 tons.

**3. Mineral/metal:** iron and closest ore source is located at Trisla about 20 km west

**4. Date:** Late Byzantine-Early Ottoman (13$^{th}$-16$^{th}$ c.) based on associated structures (i.e. watermill, leat system)

**5. Previous work**

Photos (1987): Sampled and analyzed slag, study of inclusions (Ti, V, Cr) points to the use of laterite ores or iron sands.




**6. Topographic survey and sampling**

Main characteristics of the site include heaps of slag and scatters over a plateau between a water mill and the stream covering a total area of around 300m² (figures 5.11-5.13). There is evidence for surface and deposited material exposed by modern disturbance (figures 5.14-5.16). External features of the residues suggest bloomery smelting while no furnace lining or vitrified clay fragments were noted apart from one tuyère. Most slag pieces are compact while a few ropey slag cakes, that had been tapped out of the furnace were found (figure 5.17). The water mill was probably used for the operation of bellows during smelting. Its substantial height (c.8m) necessary for efficient and economic operation demanded a constant water supply, which was provided for by the stream course running northwards (figure 5.18). Thus a long leat system was constructed of beaten earth and stones to direct water towards the tower, at the top of which a stone built duct (c.4m in length) directed the flow of water into the circular hopper (figure 5.19). The wheel chamber was a low rectangular room about 4.20x 3.50m built on the NW face of the tower to facilitate a horizontal wooden wheel. On top of the wheel chamber there was space for the apparatus consisting of the rotating axle and gear box which was connected to the bellows. The stone foundations to the SE most probably represent the remains of a chamber which facilitated a stone built furnace. Stones with slag adherence were found among the foundations representing furnace debris. Iron smelting appears as the major activity being carried out. Sampled slag pieces are 30 in number consisting of compact, semi-compact and spongy examples among which 10 were chosen for laboratory analysis which is discussed in chapter 6. All pottery sherds recovered are non diagnostic coarsewares unsuitable for dating but the presence of the watermill might suggest a late Byzantine-early Ottoman date for the site.


Figure 5.11 Satellite image of Vathytopos showing the smelting site location (source: Google Earth)

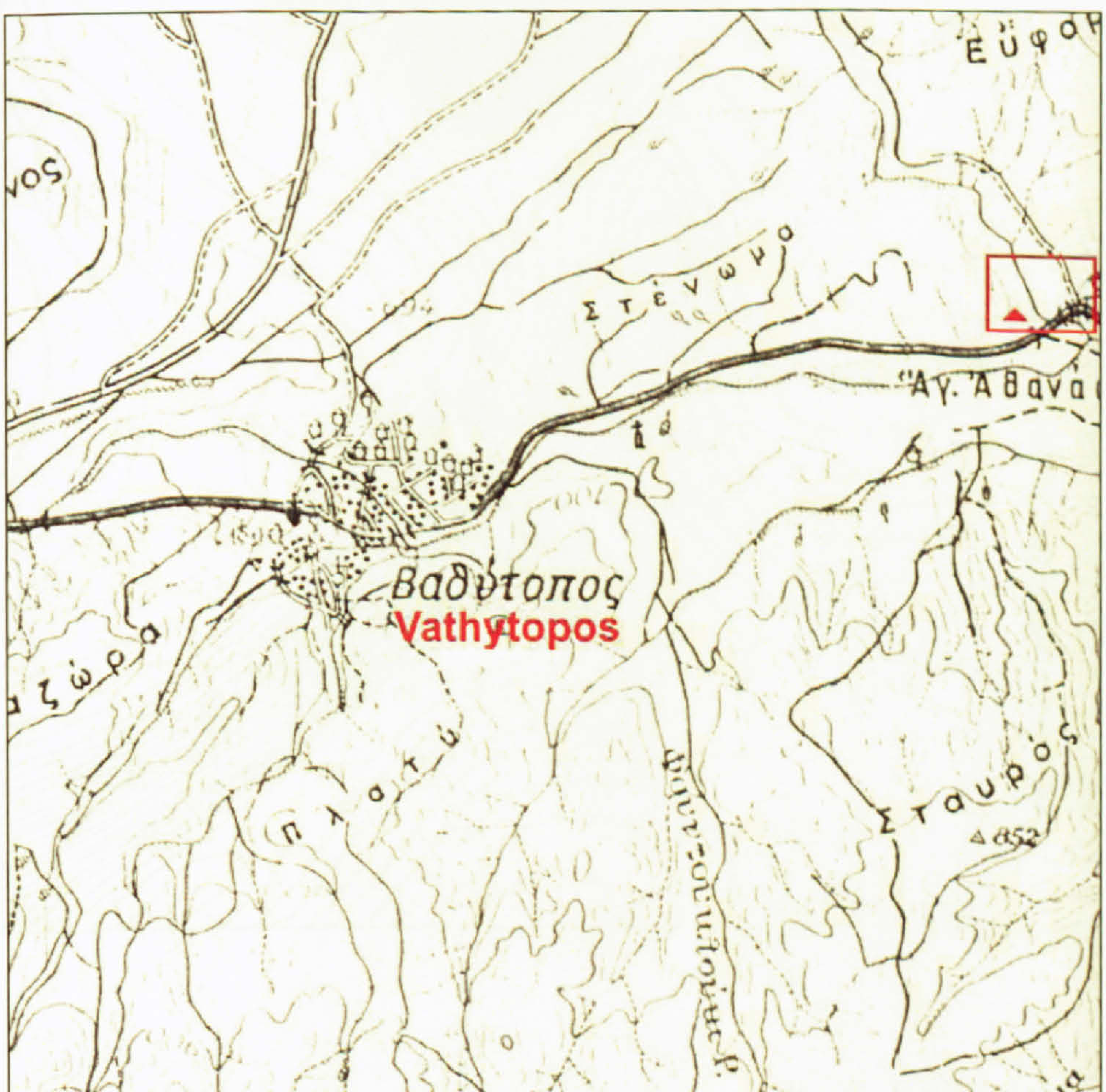



Figure 5.12 Topography of the site and immediate vicinity

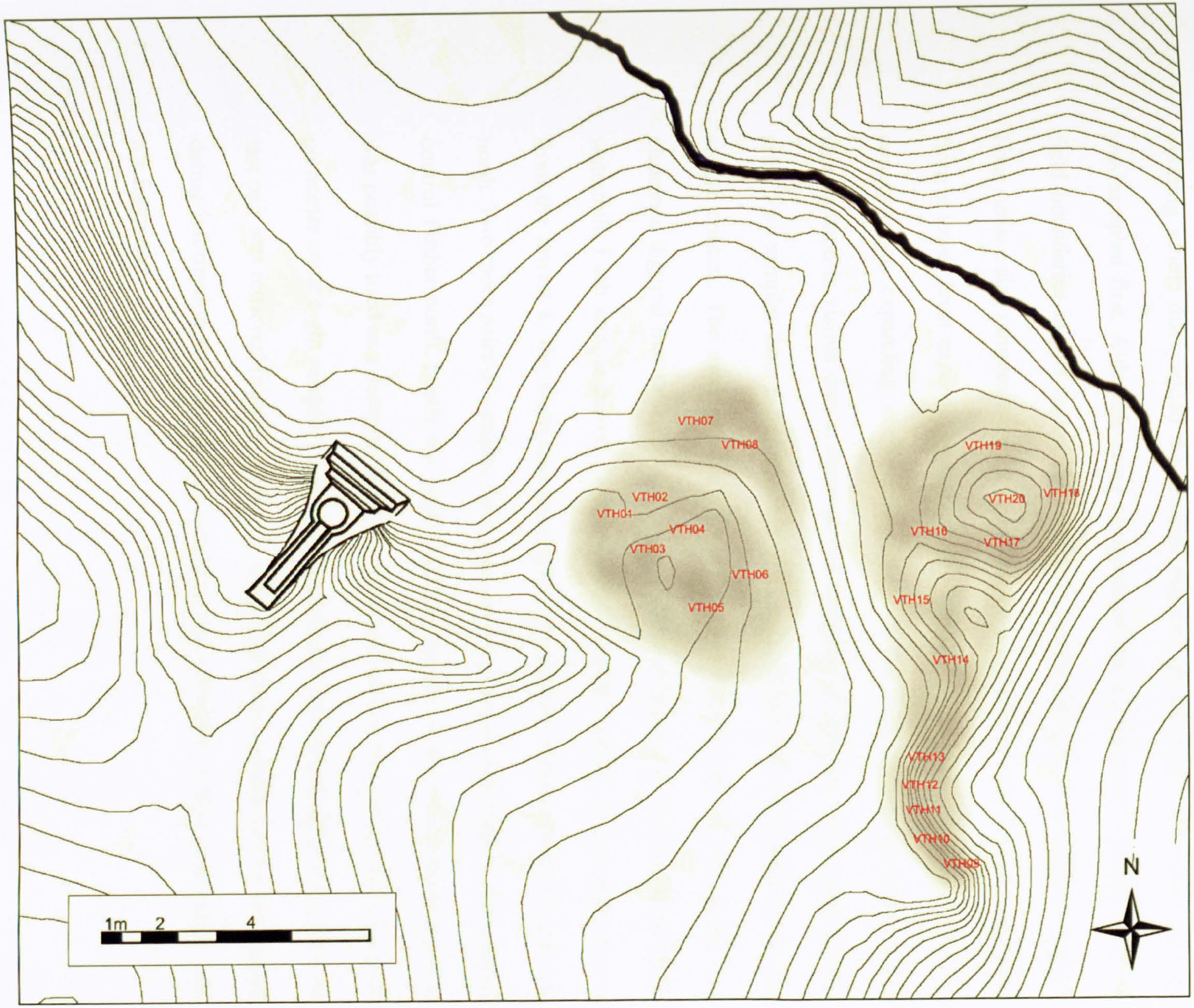



Figure 5.13 Sketch plan of site and samples context

Sampling was conducted on the area stretching to the east and southeast of the watermill (Table 5.3). The large concentration of debris consisting of slag and building rubble that yielded the greatest majority of secondary deposition material was sampled first. Although being re-deposited due to periodical alterations of the field boundaries in this region the materials remain close at their original context. Four surface slag samples were retrieved from that certain spot and two more deriving from a lower level exposed by careful vegetation clearance. The edges of this slag concentration expanding northwards appear as an exposed section where some stratification is visible due to removal and dumping of material on the large central area. Two samples from different levels (20 cm depth interval) were acquired on this secure context. The next set of eight samples was taken from the substantial land clearance digging that provides a clear stratification surface to the southeast of the watermill. Each sample derives from a distinct layer at roughly 10 cm apart starting from the lowest to the south and moving to successively higher levels towards the north. Two more pairs of samples were acquired from spots with relative stratigraphic control further north. Lastly the small artificial mound close to the stream bed that was possibly used as a dumping heap provided a set of five pairs of samples. From its perimeter came eight samples (four pairs) each from a different height level while the last pair was retrieved from the peak. No distinctive pottery sherds that would provide dating information were found and sampling was restricted to few coarsewares and tile fragments.

**Table 5.3**
***Vathytopos: slag samples context***

| | |
|---|---|
| Sample No. VTH01 | central area scatter/surface (1 slag piece) analysed |
| Sample No. VTH02 | central area scatter/surface (1 slag piece) analysed |
| Sample No. VTH03 | central area scatter/stratified (1 slag piece) analysed |
| Sample No. VTH04 | central area scatter/stratified (1 slag piece) analysed |
| Sample No. VTH05 | central area scatter/surface (1 slag piece) analysed |
| Sample No. VTH06 | central area scatter/surface (1 slag piece) analysed |
| Sample No. VTH07 | north area scatter/stratified (1 slag piece) analysed |
| Sample No. VTH08 | north area scatter/stratified (1 slag piece) analysed |
| Sample No. VTH09 | east cut low height/stratified (1 slag piece) analysed |
| Sample No. VTH10 | east cut middle height/stratified (1 slag piece) analysed |
| Sample No. VTH11 | east cut/stratified (2 slag pieces) |
| Sample No. VTH12 | east cut/stratified (2 slag pieces) |
| Sample No. VTH13 | east cut/stratified (2 slag pieces) |
| Sample No. VTH14 | east cut/stratified (2 slag pieces) |
| Sample No. VTH15 | east cut/stratified (2 slag pieces) |
| Sample No. VTH16 | east heap/surface (2 slag pieces) |
| Sample No. VTH17 | east heap/surface (2 slag pieces) |
| Sample No. VTH18 | east heap/stratified (2 slag pieces) |
| Sample No. VTH19 | east heap/stratified (2 slag pieces) |
| Sample No. VTH20 | east heap/surface (2 slag pieces) |
| | TOTAL: 30 slag pieces |

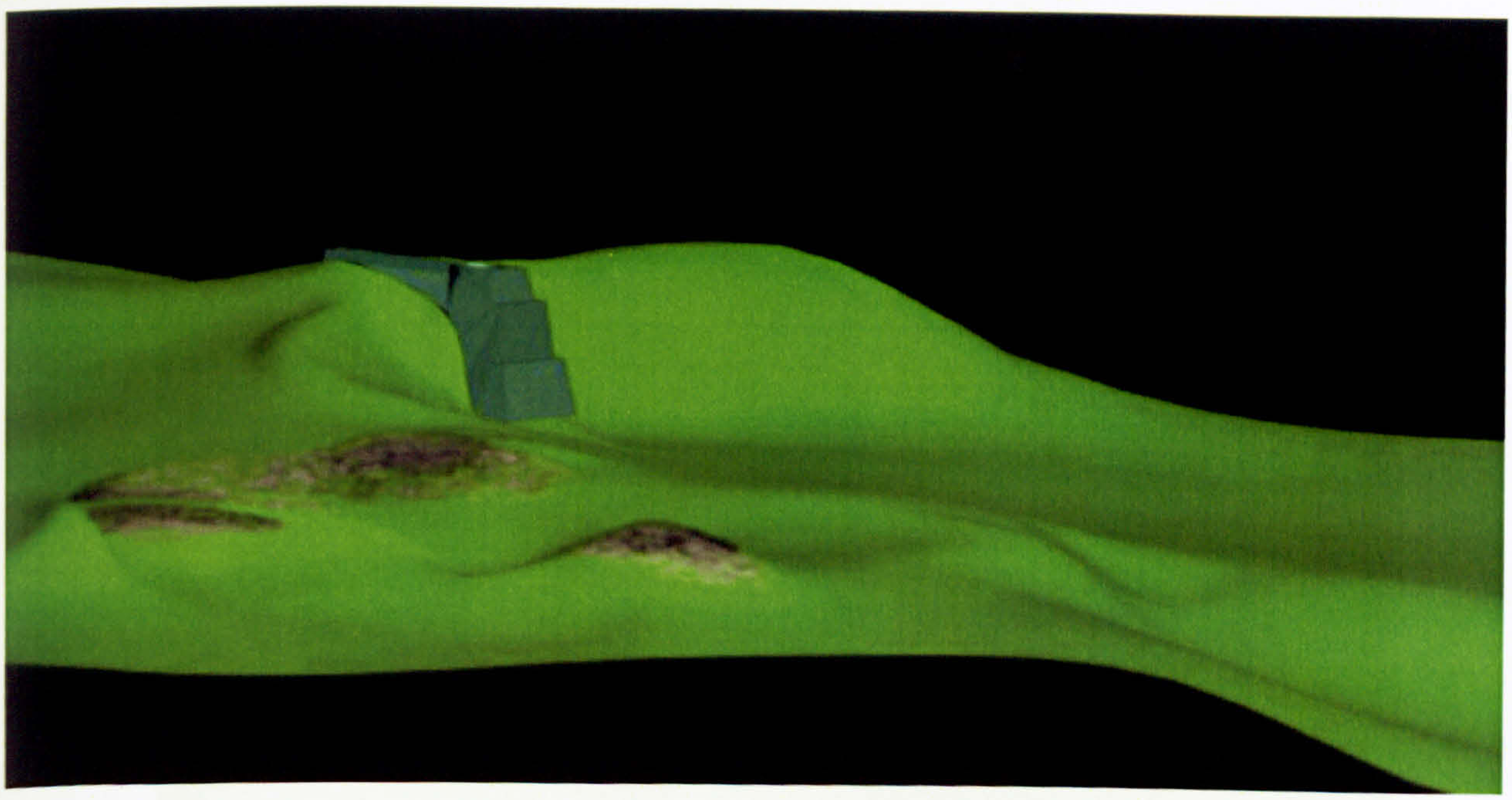


Figure 5.14 Three dimensional representation of the smelting site

Figure 5.15 Slag scatter in the foreground close to the watermill

Figure 5.16 Land clearance diggings exposing a stratigraphic section of deposited slag

Figure 5.17 Slag cake with ropey texture indicative of *tapping*

Figure 5.18 The watermill tower, view from the southeast

Figure 5.19 The stone-built hopper of the watermill

**21. Site Name:** Angistro, Serres **map ref:** 41°22'54.90"N 23°25'22.68"E

**1. Location:** Arable farms, 50 m OD around Angistro village, well watered territory

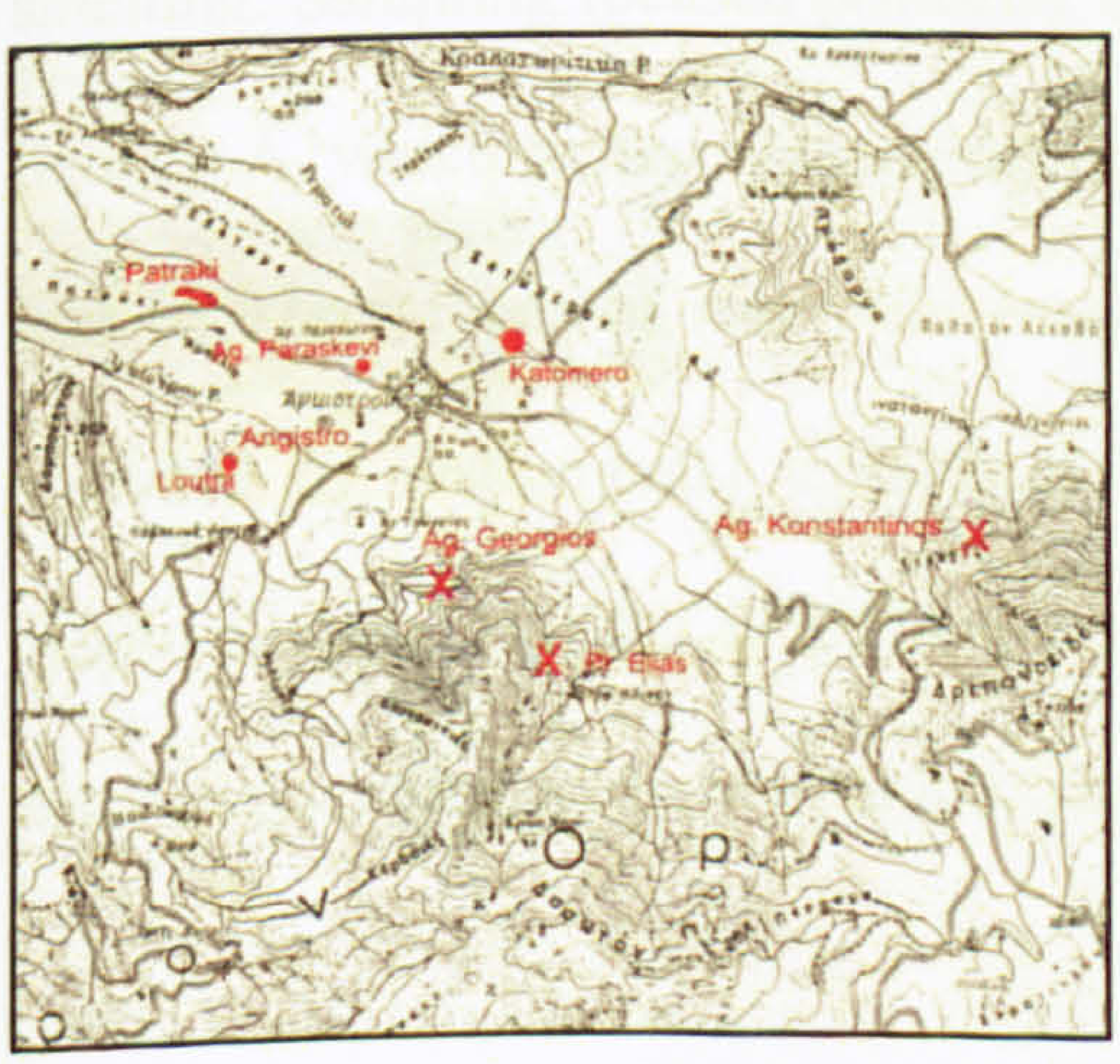
**2. Site Description**

Substantial slag heaps and scatters were noted around the village with three major concentrations at Patraki to the NW extending for about 170 m parallel to the road, at Katomero close to the fisheries and Loutra to the south close to natural springs. Smaller heaps were found near the mines of Aghios Konstantinos and Prophitis Elias. Since Patraki shows less disturbance and provides some stratigraphic depositions it was chosen for intensive survey and sampling. Compact, porous and concave slags with black-brown colours are common as well as amorphous conglomerates with clay and quartz inclusions. Speiss is also common amongst the debris with average size about 5x5 cm while larger fragments were noted measuring 20x15cm. Late Byzantine glazed pottery sherds were found at Patraki and Aghia Paraskevi. Estimated size: 30,000 m$^2$ slag coverage, volume: 150,000 tons deriving from multi-period activities

**3. Mineral/metal:** iron and possibly gold with closest mines within a 5-10 km radius

**4. Date:** Late Byzantine- Early Ottoman (13$^{th}$-16$^{th}$ c.) based on pottery finds

**5. Previous work:** Chiotis *et al* (1996) recorded eleven slag heaps and remains of two furnaces 40 m NW of Aghia Paraskevi chapel. Papastamataki (1975) conducted compositional analyses on slag that shown high levels of As (5.87-10.30%) and significant levels of Au (0.70-5.00 ppm) and Ag (11.60-22.00 ppm).




**6. Topographic survey and sampling**

Three major concentrations of metallurgical debris have been noted around the village: Katomero, Loutra and Patraki, the latter of which has been surveyed and sampled. Smaller slag heaps could be found around Ag. Paraskevi (figures 5.20-5.21). The main features and finds include slag coverage on the slopes of raised cornfields, furnace bottoms, conglomerates, speiss plates and stone configurations. Although rare, pottery comes from surface deposits and is mainly coarseware with few examples of glazed sherds. The extended concentration at Patraki has been surveyed, divided into four main sections (figure 5.22-5.23). On the upper layer of section A scattered stones with signs of vitrification might represent some sort of structural debris (figure 5.24). Section B appears as a refuse pit where rubble is mixed with slag and was probably formed through clearance of slag from within the arable farms to the north (figure 5.25). Approximately 60 m due east in section C conglomerates of substantial size and large tuyère fragments have been recorded. The conglomerates are is association with stones interpreted as furnace material (figures 5.26-5.27). The large cut at section D revealed a stratigraphic picture of slag deposition and is indicative of exploitation over long periods but is eroded (figure 5.28). The extent and volume of debris testifies to multi period activity while the external features of slag in conjunction with the presence of speiss point to other processes in addition to iron smelting. Sampling focused primarily on successive layers of the stratified deposit in Section A, which represents long deposition intervals and continued on sections B, C and D. Three types of slag were noted and 10 out of the 30 samples were further analysed by instrumental techniques described in detail in chapter 6. Associated glazed pottery (AGS.P.1 and 2) which probably derives from the workshop of Serres dates the sampled contexts to late Byzantine-early Ottoman times ($13^{th}$-$14^{th}$ centuries).

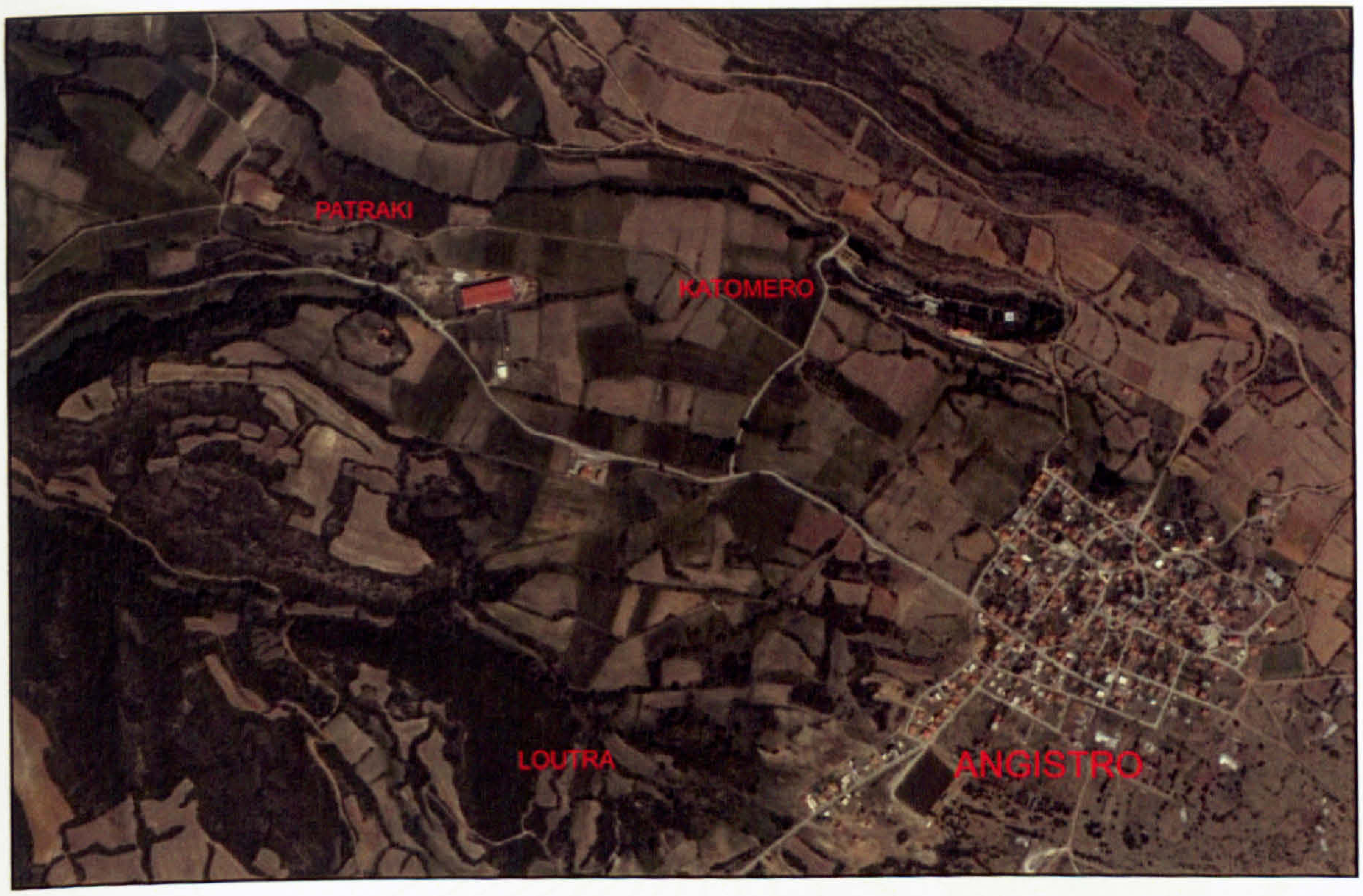



Figure 5.20 Satellite image of Angistro and the major smelting sites (source: Google Earth)

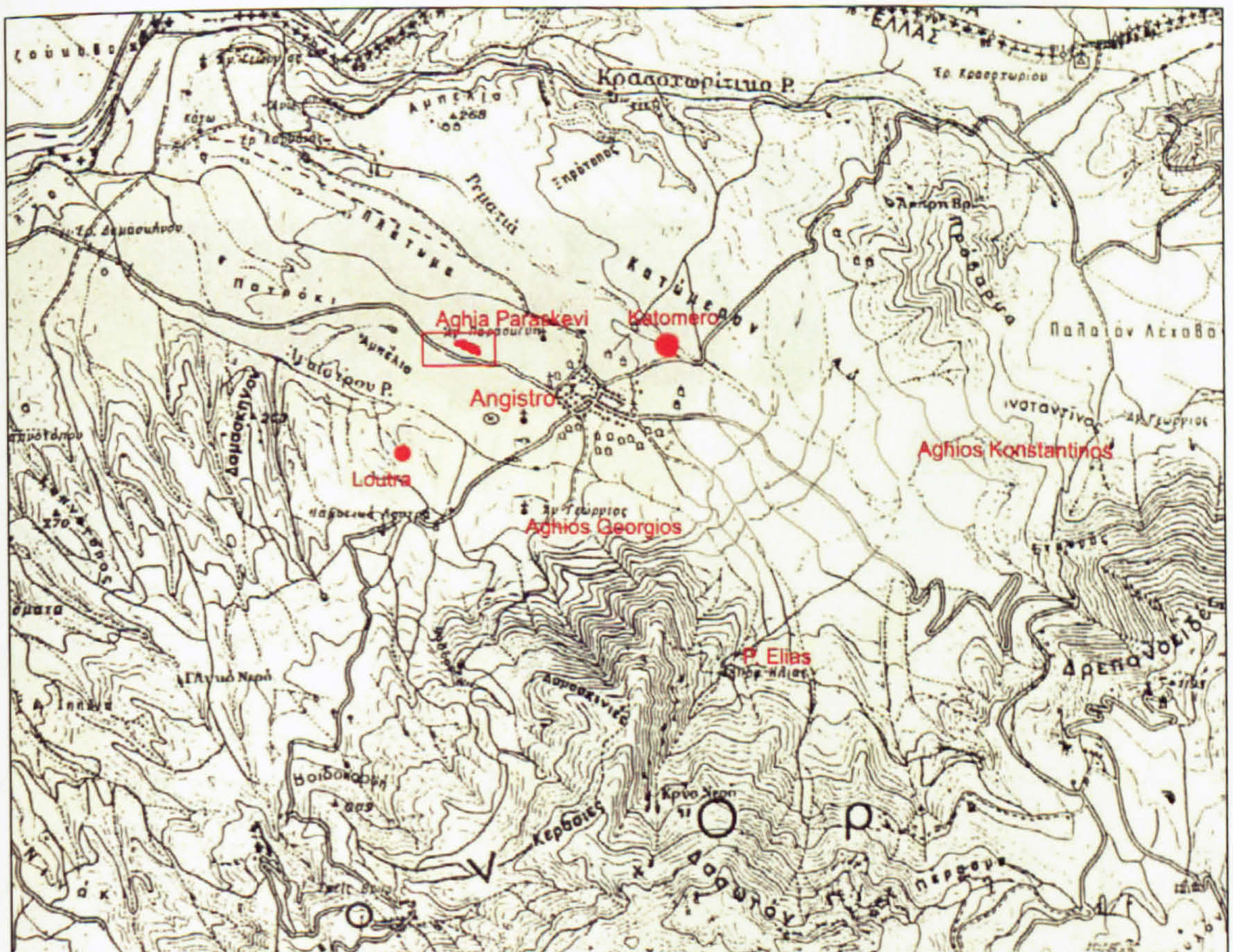



Figure 5.21 Topography of the site and immediate vicinit


Figure 5.22 Sketch plan of site and samples context

Sampling concentrated on all four discrete sections that comprise this site (Table 5.4). Ten samples were retrieved from section A where the evidence is better preserved. Since it consists of a stratigraphic section exposed through recent path openings and field boundary modifications it was decided to acquire samples from the three major distinctive layers. The upper layer has an average thickness of 1.00-1.50 m from which five samples were taken at roughly 0.20 m intervals. In this way the entire depth of this deposition phase has been sampled while the presence of two glazed Byzantine sherds (AGS.P.1 and AGS.P.2) date the latest activity on site between the 12$^{th}$ and 15$^{th}$ centuries. Two slag samples were acquired from the middle layer which represents a longer deposition phase of 1.75 m average thickness. This layer also yielded speiss fragments of a plate-shaped outline and one such specimen was retrieved for further examination. The last three samples deriving from this section were taken from the lowest layer at 0.20 m intervals in a context that yielded a few pottery sherds. Sampling continued into section B where the large amount of rubble was taken as evidence for secondary deposition and therefore only four specimens were acquired. Although section C produced important finds and in particular furnace material, the associated slag formed a thin surface scatter without any deposition information and thus only eight slag samples and a large tuyère were retrieved. Two further samples were taken from lower ground around 5 m south of this concentration. Section D consists of a highly disturbed exposure of a thick slag deposit with a general outline similar to that at section A but showing greater erosion and less intact contexts. The last six samples were taken from a spot that preserved a secure deposition profile with two distinct layers.

**Table 5.4**
***Angistro: slag samples context***

| | |
|---|---|
| Sample No. AGS01 | section A western cut/surface (1 slag piece) analysed |
| Sample No. AGS02 | section A western cut/surface (1 slag piece) analysed |
| Sample No. AGS03 | section A western cut/surface (1 slag piece) analysed |
| Sample No. AGS04 | section A western cut/surface (1 slag piece) analysed |
| Sample No. AGS05 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS06 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS07 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS08 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS09 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS10 | section A western cut/stratified (1 slag piece) analysed |
| Sample No. AGS11 | section B/surface (2 slag pieces) |
| Sample No. AGS12 | section B/surface (2 slag pieces) |
| Sample No. AGS13 | section C scatter over field edges/surface (2 slag pieces) |
| Sample No. AGS14 | section C scatter over field edges/surface (2 slag pieces) |
| Sample No. AGS15 | section C scatter over field edges/surface (2 slag pieces) |
| Sample No. AGS16 | section C scatter over field edges/surface (2 slag pieces) |
| Sample No. AGS17 | section C slope/stratified deposit (2 slag pieces) |
| Sample No. AGS18 | section D eastern cut/stratified deposit (2 slag pieces) |
| Sample No. AGS19 | section D eastern cut/stratified deposit (2 slag pieces) |
| Sample No. AGS20 | section D eastern cut/stratified deposit (2 slag pieces) |
| | TOTAL: 30 slag pieces |

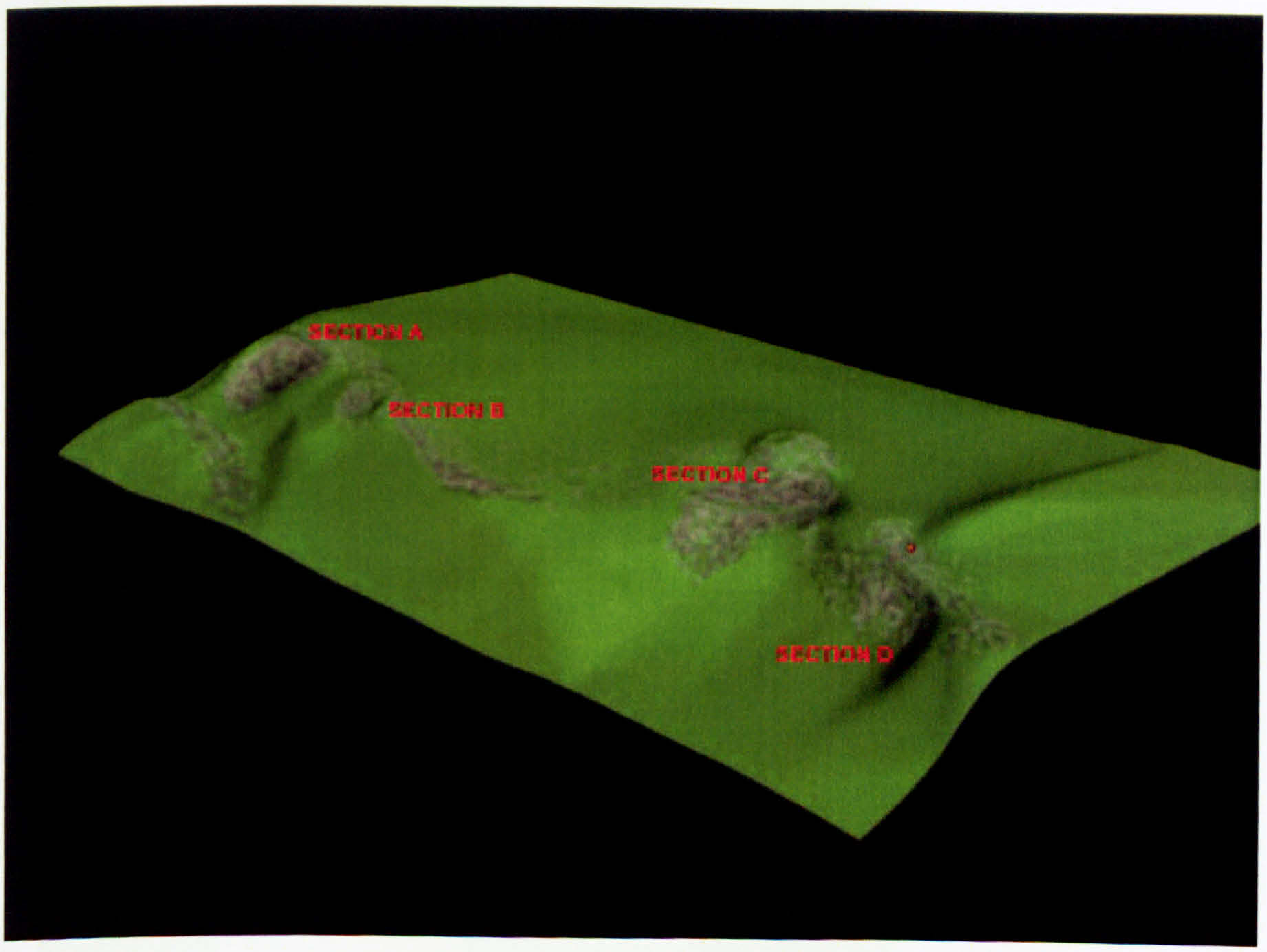



Figure 5.23 Three dimensional representation of Patraki smelting site

Figure 5.24 Section A, slag coverage

Figure 5.25 Section B, rubble and slag

Figures 5.26 Section C, furnace conglomerate

Figure 5.27 Section C, furnace conglomerate

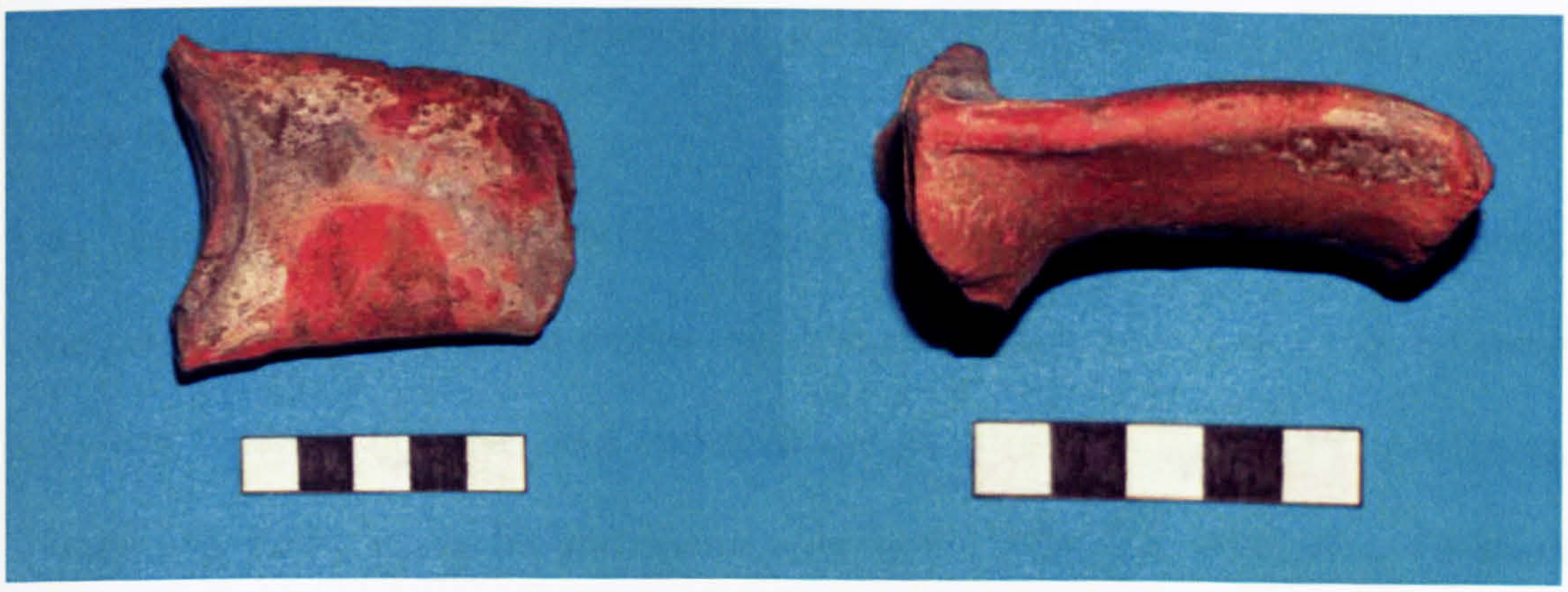
Figure 5.28 Section D, land-clearance disturbance exposing stratigraphy of slag deposit

**7. Pottery sherds**

AGS.P.1: Glazed sherd 3.5cm in length deriving from a bowl or jar of Late Byzantine date. The glazing is creamy white, pal green and yellow on the exterior and there are signs of shallow grooves (possibly remains of sgraffito ware decoration). The interior surface is glazed with a creamy white agent. Date: Late Byzantine ($13^{th}$ -$14^{th}$ c.)

AGS.P.2: Glazed sherd 2.5cm in length probably belonging to the same bowl as fragment AGS.P.1. Similar three coloured glazing poorly preserved. Date: Late Byzantine ($13^{th}$ -$14^{th}$ c.)

AGS.P.3: Handle belonging to a water storage vessel with signs of glazing. Its length reaches 7cm while the greyish white glaze is uneven on the upper surface.



AGS.P.10: Non-diagnostic coarseware fragment 4cm in length

AGS.P.11: Non-diagnostic coarseware fragment 5.5cm in length

**22. Site Name:** Makrychori, Kavala **map ref:** 41°02'23.28"N 24°35'55.83"E

**1. Location**

Hill slope around 200 m OD, pasture land, 0.5 km SW of Makrychori village

**2. Site Description**

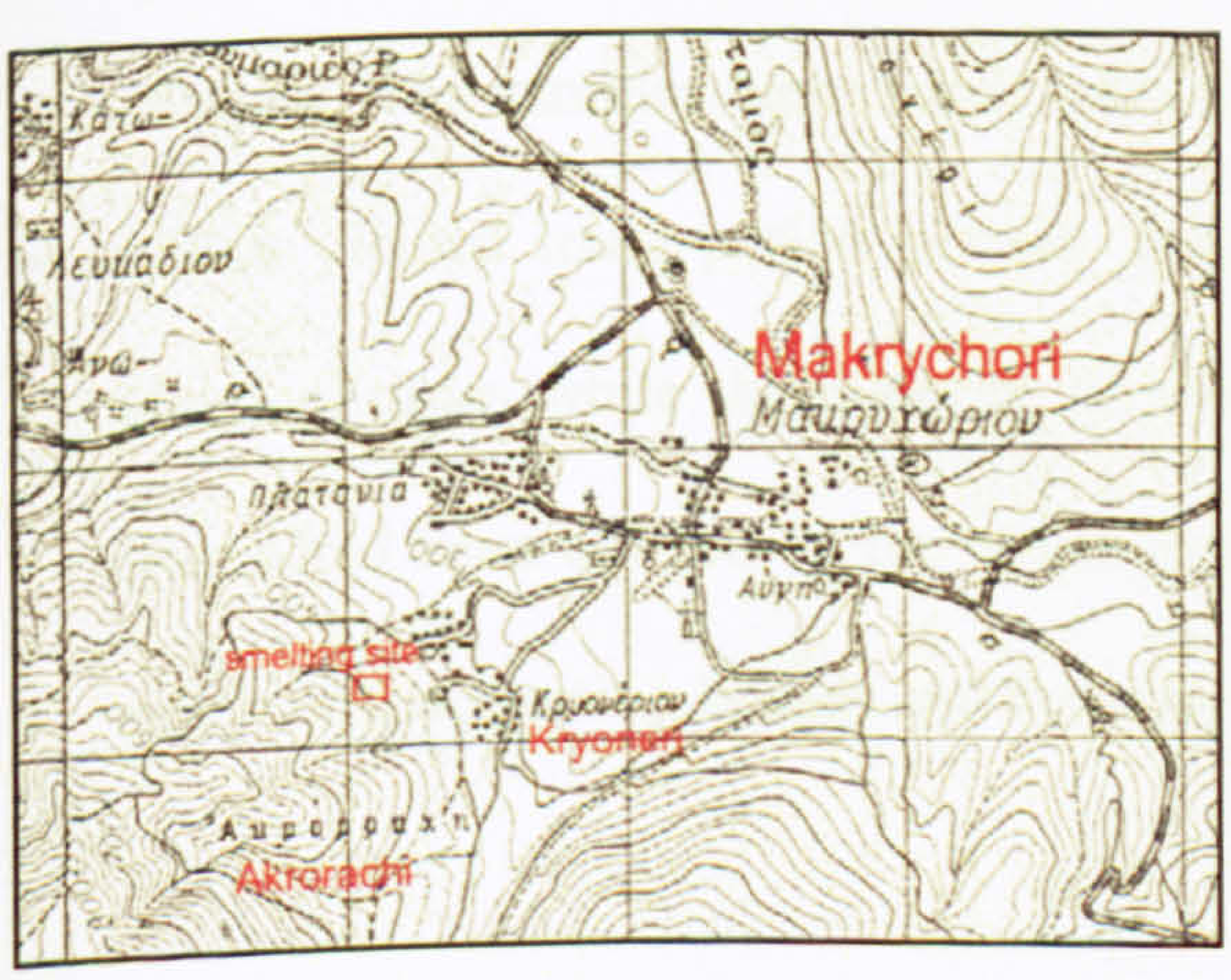
Slag heaps spreading across 80-100 hectares, surface scatters used for path laying. Fine sorted rubble rich in iron oxides might represent the remains from ore crushing activities. One slag heap has been surveyed and sampled. Iron smelting slag, tapping, spongy and glassy examples and speiss were noted. Classical, Byzantine, Ottoman pottery found among the debris and also finds belonging to 20$^{th}$ century industrial activity. It appears as a multi-period site spanning long periods of various minerals exploitation through time. Slag coverage: 15,000 m², volume: 500 tons of slag.

**3. Mineral/metal:** iron, manganese, silver with the closest iron deposit at about 8 km

**4. Date:** Classical, Byzantine, Ottoman, modern industrial based on published evidence and pottery finds

**5. Previous work**

Koukouli-Chrysanthaki (1990) and Photos *et al* (1987) based on sherd typology suggested that the activities may date as early as the 4$^{th}$-2$^{nd}$ century BC. Lead-rich slags raised the issue of complex extractive metallurgical practices, by which Pb was added during smelting of the Mn-rich ore to act as a precious metals collector.




**6. Topographic survey**

The surveyed area is part of a large number of smelting sites in the region of Palaea Kavala including Pyrgiskos, Dipotamos and Petropigi all of which were active during Classical and Hellenistic times (see chapter 4). Surface scatters of metallurgical waste spreading across 80-100 hectares deriving from substantial, severely damaged slag heaps have been located. The material covers short paths and plateaus on inclined terrain of marble and gneiss geology with occasional stone built terraces and herding stalls (figures 5.27-5.32). The concentration of debris that has been surveyed and sampled consists of dark brown and black porous slag as well as glassy specimens indicative of iron smelting operations while the presence of speiss hints to precious metals extraction (figures 5.33-5.34). On the highest levels of the concentration tailings within terraces have been noted. This fine sorted rubble rich in iron oxides might represent the remains from ore crushing activities which were taking place in crushing floors defined by the terrace walls. The long history of mineral exploitation at the site could be attested by finds spanning from Classical times up to the early last century. Specifically a marble column base from some ancient building (figure 5.35) and a corroded component of pneumatic machinery manufactured by the English Alldays and Onions Pneumatic Engineering Company, active between 1898 and 1918, were found in proximity (figure 5.36). Three types of slag were noted (compact, semi-compact, glassy) and 10 out of the 30 collected samples were subjected to further analysis. The samples were taken from three successive layers of a stratified context which yielded multi-period pottery sherds. An amphora base and handles date to classical times while the majority of non-diagnostic sherds suggest that low quality wares had been utilised by the workforce throughout different periods to cover basic needs of transporting liquids and cooking or storing foodstuffs on the site.


Figure 5.29 Satellite image of Makrychori showing the smelting site location (source: Google Earth)

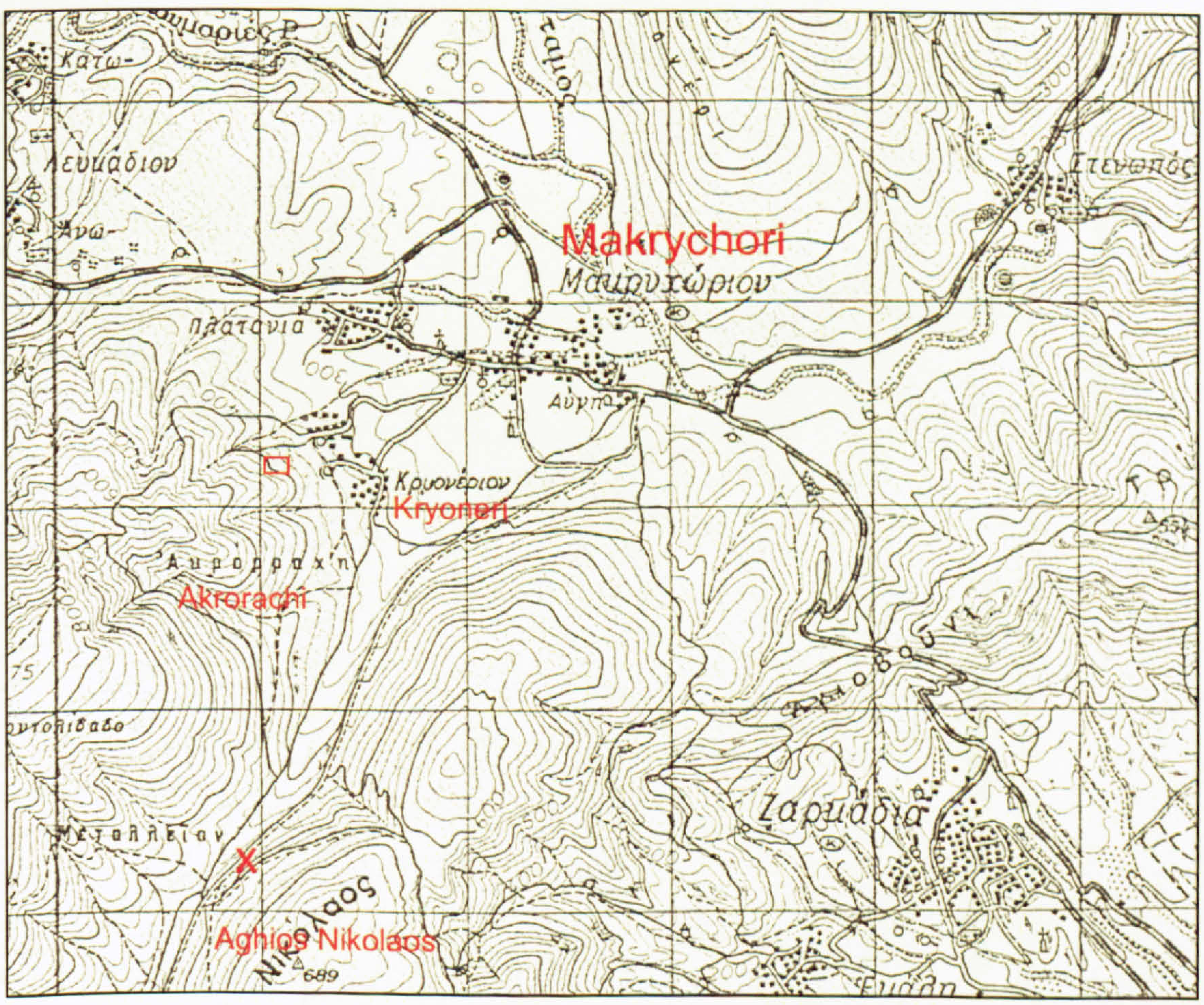



Figure 5.30 Topography of the site and immediate vicinity

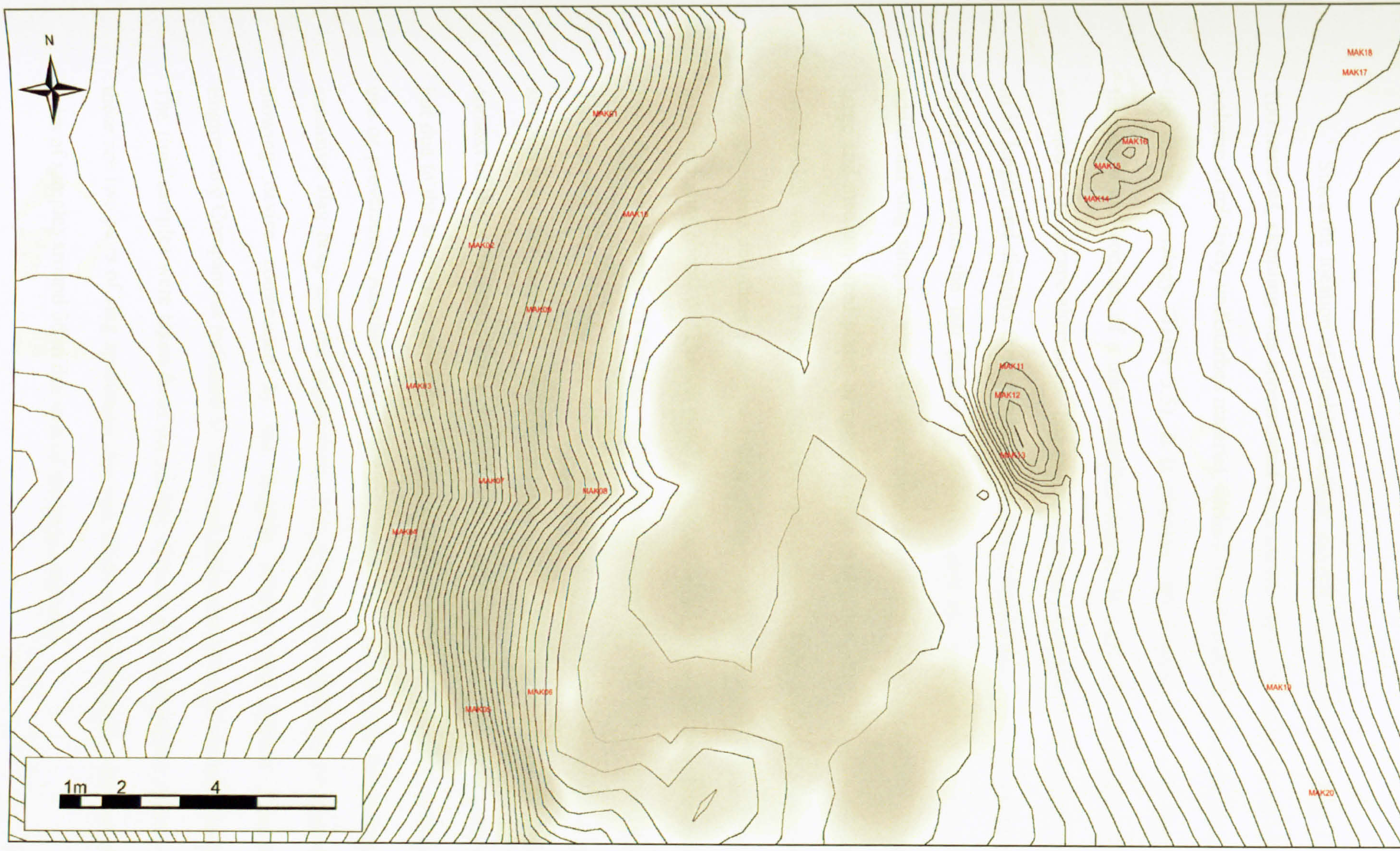



Figure 5.31 Sketch plan of site and samples context

Since the location of smelting activity extends over an area covering around 100 hectares, sampling was concentrated on a certain spot that yielded a substantial volume of relatively undisturbed material, surface pottery and other finds indicative of the site's chronology (Table 5.5). It is situated 200 m south of a cow breading farmstead and consists of a thick stratified deposit in form of a slag heap partially exposed by landscape alterations. The exposed surface is roughly 4 m in height by 45 m in length and displays three distinctive layers of deposition. From the upper layer which represents the last phases of activity came the first three samples. Four additional slag samples were retrieved from the middle layer which also produced large and medium-sized plates of speiss among which two were sampled. The lower layer which was richer in ceramic finds and speiss provided the context for three more slag specimens and three pieces of speiss. Pottery has also been collected from this layer including sherds of 'Thasian type' amphorae and some non diagnostic examples. Two shallow depressions due east of the large heap have formed by recent diggings that exposed slag coverage beneath ground level. From these two depressions more samples have been acquired, six from the south and six from the north one. Within the context of the north depression a marble column base has been found among the slag but due to the absence of any associated masonry it is difficult to surmise its original use or provenance. Another intriguing find comes from the flat area separating the extensive slag heap and the depressions. It is a metallic component of a modern blowing device constructed by the English Alldays and Onions Pneumatic Engineering Company as indicated by the brand name marked on its corroded surface. The final samples were taken from the surface without any stratigraphic control and these are two pairs of slag specimens due east of the north depression and two more pairs of samples around 36 m due east of the large slag heap.

**Table 5.5**
***Makrychori: slag samples context***

| | |
|---|---|
| Sample No. MAK01 | upper layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK02 | upper layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK03 | upper layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK04 | upper layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK05 | middle layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK06 | lower layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK07 | middle layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK08 | lower layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK09 | middle layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK10 | lower layer of stratified deposit (1 slag piece) analysed |
| Sample No. MAK11 | south digging/surface (2 slag pieces) |
| Sample No. MAK12 | south digging/surface (2 slag pieces) |
| Sample No. MAK13 | south digging/surface (2 slag pieces) |
| Sample No. MAK14 | north digging/surface (2 slag pieces) |
| Sample No. MAK15 | north digging/surface (2 slag pieces) |
| Sample No. MAK16 | north digging/surface (2 slag pieces) |
| Sample No. MAK17 | northeastern/periphery (2 slag pieces) |
| Sample No. MAK18 | northeastern/periphery (2 slag pieces) |
| Sample No. MAK19 | southeastern/periphery (2 slag pieces) |
| Sample No. MAK20 | southeastern/periphery (2 slag pieces) |
| | TOTAL: 30 slag pieces |

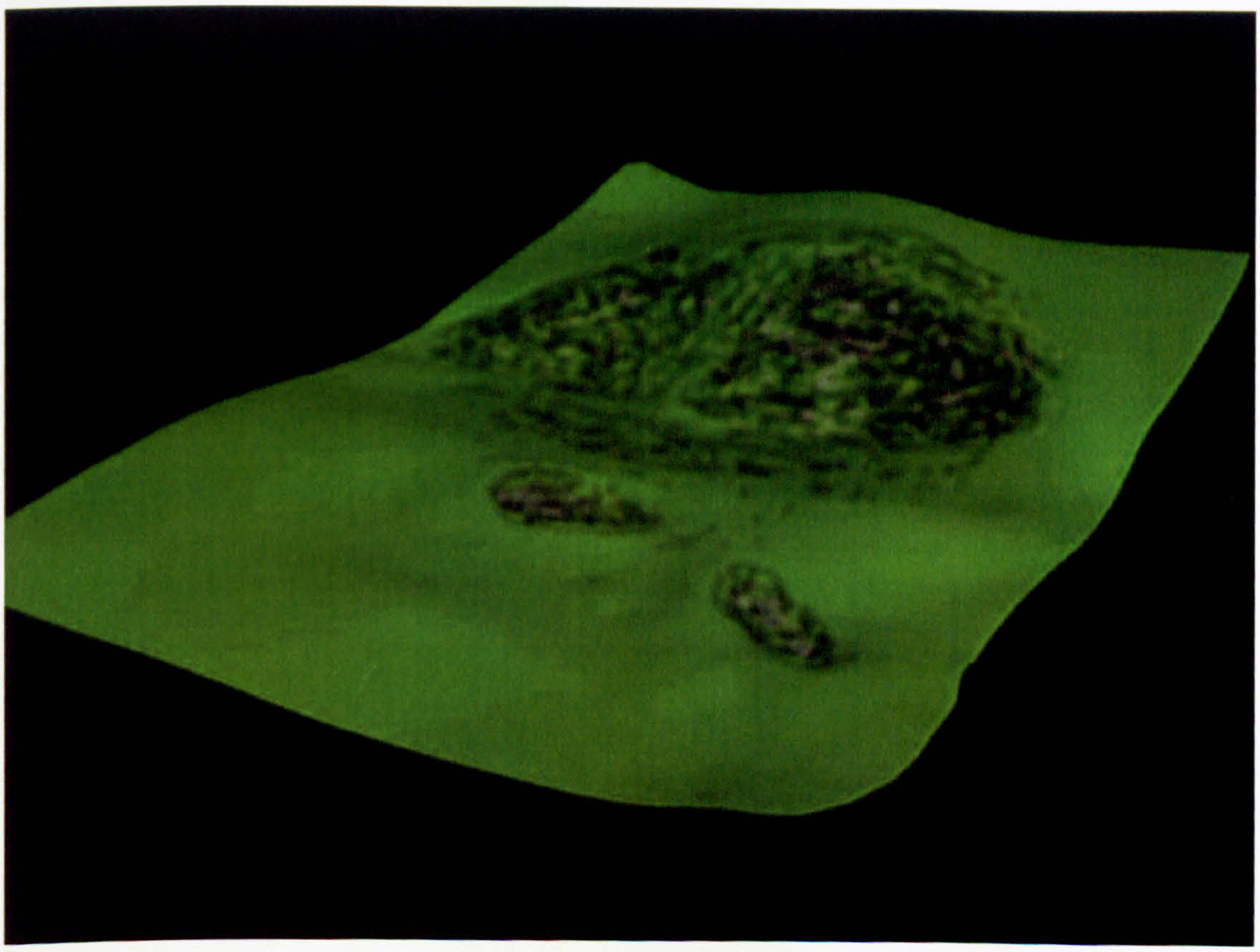


Figure 5.32 Three dimensional representation of the sampled smelting site

Figure 5.33 Slag heap and scatters around the sampled area

Figure 5.34 The sampled slag heap exposed by modern disturbance

Figure 5.35 Marble column base found among the smelting residues

Figure 5.36 Pneumatic pump-Alldays and Onions Pneumatic Engineering Company (blowing device used in smelting furnaces)

**7. Pottery sherds**

MAK.P.1: Amphora base 9 cm in height with grooves across the exterior surface. It is part of a 'Thasian type' amphora which was a widespread form in Kavala region from Classical to early Byzantine times.


MAK.P.2: Handle 6.5 cm in length belonging to an amphora.


MAK.P.3: Base fragment 3.5cm in length belonging to a plate. Numerous mica flakes.

MAK.P.4: Non-diagnostic coarseware fragment 7cm in length.

MAK.P.5: Non-diagnostic coarseware fragment 6.5cm in length.

**5.3 Conclusion**

Whilst some scholars have focused attention on the metal and mineral production sites in northern Greece (Photos 1987; Papastamataki 1975, 1985; Vavelidis 1994; Chiotis *et al* 1996) many have not been archaeologists. The fact remains that these many sites have failed to attract the attention of archaeologists. This is a pity for many reasons. Whilst it has often been presumed that such 'technical' sites are of little value in reconstructing social facts about the past such ideas have now been eclipsed by the extensive theoretical literature which exists demonstrating the social constructivist nature of technological practices (Dobres 2000, Hughes 1986; Knapp 1998; Pfaffenberger 1992). Such understandings heighten the importance of these sites and demands that they receive archaeological attention.

The survey presented here demonstrated that they are often complex sites which have witnessed successive generations of community endeavours. That the products of these sites are knowable and directly impact on local, regional and super-regional economies means that the material remains are valuable resources for the social historian and archaeologist alike. Whilst this study has been limited in extent and restricted by resources and to some degree governmental legislation it has succeeded in documenting further some of these sites and hopefully drawn attention to their archaeological value. In light of these results it seems likely that rich bodies of archaeological data could be gained both efficiently and economically if a better resourced program of investigation was initiated. Nonetheless this study has achieved much and seeks to demonstrate the type of histories which can be written when these resources are given the attention they deserve.

Having considered all the surveyed smelting sites it is apparent that some show extensive multi-period exploitation while others seem to be single phase ventures. The former are characterized by large-scale activity primarily focusing on iron extraction from local ore deposits when at the same time the potential for precious metals is outlined by corresponding material evidence (i.e. speiss). The single phase, small-scale sites could be characterized as discrete bloomery and smithing workshops but the possibility of exploiting ores for other metals could not be ruled out solely on findings from the field. As it has been pointed out in chapter 3 with regards to previous studies, the distribution of metal production centers is dictated by a number of parameters such as proximity to raw materials notably wood, water and clay while ore sources can be found at some distance rather than their immediate vicinity. This is supported by actual evidence derived from the current survey particularly were distance between mines and smelting locations has been established. The known mines that extracted iron ores (hematite, iron pyrites) are situated at ranging distances between 5 and 30 km from smelting locations. Infrequently mineralization occurs at walking distance or within a slightly broader radius. Apart from underground mining that supplied the ores in most cases, there are sites that exploited the magnetic iron sands from alluvial deposits close to where furnaces were erected.

A classification of all metalworking sites based on their major characteristics shows a predominance of secondary, nine in total, and four primary smelting sites (Table 5.1). The dominant process represented in secondary sites is iron smelting which in some cases relates to further treatment of the blooms by smithing. The scale of operations could be estimated along the lines of restricted production considering slag coverage which does not exceed $200m^2$. Such small-scale metalworking workshops would presumably have been supplied by raw materials or semi-finished, treated products (i.e blooms) from primary sites. Their distribution is wide-ranging covering a variety of environments from lowlands, arable parcels (Leukogia, Exochi, Kalithea) to uplands within wooded and often well watered territory (Faia Petra, Panorama). The majority of finds on these sites is slag and in one instance mould fragments (Orini) which were possibly used for casting bronze or other copper alloy implements.

In most of these small sites there is a characteristic type of tapped slags, produced during the reduction process, which seem as if they were evacuated over an artificially smoothed bed. These tapped slags found at Leukogia, Exochi and Faia Petra are light and only few millimeters thick, have a very flat shape, with smooth lower and upper surfaces. At the same sites, a completely different kind of slag has also been found. This slag has not been tapped and has frequent porosity and inclusions of big fragments of charcoal. They seem to be forging slags, coming from the first reheating and hammering of the bloom. It is therefore probable, on the basis of such data that in Leukogia, Exochi and Faia Petra reduction of iron ores took place along with the first stages of smithing. Nevertheless doubts remain about the presence of final smithing and forging on these sites. The actual hearths for reduction need not have been complex structures, perhaps simple cavities excavated in the ground, providing a low return and low productivity, designed to meet the needs of small communities. In all the cases examined the activity seems to be relatively limited, incorporated in a modest economy which related to open rural settlements, perhaps dependent on provincial towns.

Four primary smelting sites have been identified with the extensive slag coverage characterizing them as moderate to large-scale workshops. Variation in scale might relate to duration, short and long-lived or intensity in production, whereas it could also reflect administrative issues and provide estimates for dating. Katafyto and

Vathytopos are of moderate scale while Angistro and Makrychori could be assigned as large scale. In the case of Makrychori where substantial volumes of slag and finds from the Classical, Byzantine and Ottoman periods complicate the chronology of activities represented. To untangle such a complex and lengthy production history calls for detailed survey and excavation across the broader region (see chapter seven).

Based on the evidence from Katafyto it could be said that hearth furnaces were located in the open or under simple canopies, frequently being disassembled, rebuilt and moved to different places. Such practice seems to follow the diminished wood resources exhausted by cutting for the preparation of charcoal in ways similar to those described in chapter 3. In addition to compact-ropey and porous examples there are often typical slag cakes formed at the bottom of the furnace under the iron bloom and significant amounts of refractories.

The workshops at Vathytopos, and possibly also Ano Vrontou, are unique examples as they were probably equipped with hydraulic hammers and open hearth furnaces fed by bellows, which were also hydraulically powered. In such installations the reduction of the ore took place along with an immediate beating with the hammer. The construction of a smelting workshop powered by water required a large amount of technical knowledge, a high degree of accuracy in the laying of the hydraulic infrastructure, the channels and the wheels (Cortese 1997a). Both the furnaces and hammer should have been located in an established and fixed point inside or near the building, and this required a spatial organization rigidly tied to the position of the driving shafts of the water wheels. The intrinsic fixity of structures tied to the exploitation of hydraulic energy thus contrasts with the extreme flexibility of the hearth furnaces found elsewhere.

The organisation of space and arrangements for the various installations are more complicated with regards to the large production workshops at Angistro and Makrychori. Although the evidence is inconclusive it is possible that they were open hearth furnaces partially dug into clay soil or rocky ground, with a frontal opening allowing for the slag to escape through tapping. Above this was a simple superstructure made of stone and clay to protect the bellows and to contain the charge, but without particular attention being paid to thermal insulation. The bottom of the furnaces was concave and more or less oval but one could not surmise on sizes and dimensions. These structures were periodically destroyed to make way for new structures, as demonstrated in Patraki at Angistro (section D) by a stratification where dark strata formed by accumulation of slag alternate with reddish strata probably formed through the destruction of the furnaces.

Gravity seems to have been a structuring force for the spatial unfolding of certain practices on these sites. It seems, perhaps unsurprisingly, that ancient and medieval smelters took advantage of the natural slope to establish furnaces on the upper levels and dump the metallurgical debris by force of gravity to lower ground. Evidence for this comes from Angistro where the visible remains of furnace conglomerates, at the less disturbed contexts, were found on higher ground on the boundaries of elevated fields. Most heavy slag concentrations were constantly dumped to lower ground or formed discrete piles. Whilst this strategy is clearly visible on single phase sites it is apparent that more recent activity on Angistro and other larger sites has involved the dramatic reworking of the landscape. In part this could be due to the changing perception of slag from waste product to useful 'co-product' for road metalling which has been widespread around Angistro and Makrychori.

The effect of this re-use of slag and landscape most likely masks earlier workings and confounds attempts at structured survey without attempts to resort to some stratigraphic control through excavation. Such concerns are compounded by the likelihood of re-smelting old slag for iron (as calcium replaces iron in the slag – see results in next chapter for Makrychori) and to reclaim precious metals by either more efficient or more carefully administered techniques. In addition such strategies may well also reflect changes in the organisation and/or availability of labour whereby in times of shortage slag deposits become understood as ore resources. Of course how exactly such changing practices articulate with larger changes in demography and other socio-political events is a very answerable question when one is furnished with appropriate data from such sites.

Although fieldwork alone is difficult to provide any precise information on the processes represented in each case the information on spatial arrangements, use of space and scale of activities is of undoubted value. The wide distribution of mining and ore processing locations and the variety of extracted minerals including iron pyrites, mixed shulphides, gold and silver bearing arsenopyrites provided valuable information on accessibility to diverse resources. Considering this multitude and diversity of sites it could be suggested that mining and production of metals has been a common practice and an important economic element of the rural communities in this region. Nevertheless the evidence from slag heaps or scatters across larger areas as well as furnace remains are ambiguous and cannot by themselves account for accurate interpretations of smelting technology. Therefore an analytical study to further characterize the processes carried out on these sites has been undertaken and is being discussed in the next chapter.