A Metallurgical Study of West African Iron Monies from Cameroon and Liberia

by

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ABSTRACT

The aim of this thesis is to make a contribution to the study of West African iron monies through examination and analysis of a group of these objects in the collection of the Peabody Museum of Archaeology and Ethnology at Harvard University. The selection of objects from the collection includes five distinct types, representing different sizes and shapes that have been identified as monies/exchange mediums. All of these object types were originally part of a bundle or remain in bundled form; all share a provenience in West Africa, four groups in present day Cameroon and one in Liberia. The research corpus of material has dates ranging from the late nineteenth to the early twentieth century. My metallurgical studies of West African iron monies are the first such investigations to have been carried out. The results will contribute to the appreciation of the ways in which iron 'monies' functioned within late nineteenth – early twentieth century West African societies.

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CHAPTER I: INTRODUCTION

Statement of purpose

The aim of this thesis is to make a contribution to the study of West African iron monies through examination and analysis of a group of these objects in the collection of the Peabody Museum of Archaeology and Ethnology at Harvard University. The selection of objects from the collection includes five distinct types, representing different sizes and shapes that have been identified as monies/exchange mediums. All of these object types were originally part of a bundle or remain in bundled form; all share a provenience in West Africa, particularly in present day Cameroon and have been dated to the early twentieth century. Initial information regarding their origin and cultural association is available in the Peabody Museum archives, including the local names that have been associated with the objects, their possible functions and the identity of the original buyer/collector.

The application of laboratory analytical techniques to the study of non-industrial metal objects produced by craftspeople can provide useful insights and further our understanding of the manufacturing techniques, available technology and use patterns for the objects. In the case of West African iron monies, these results can be interpreted in the context of considerable published research by anthropologists and ethnographers who have studied the ethnic groups and communities in which such monies were produced and used.

My metallurgical studies of West African iron monies are the first such investigations to have been carried out. The results will contribute to the appreciation of the ways in which iron 'monies' functioned within late nineteenth – early twentieth century West African societies.

I address a number of different questions in this research. First, I examine the issue of variation between the different types of 'monies' in terms of their production technology. I will look for evidence that may identify differences in the origin of the iron as to whether it was smelted from ore or reused and forged again from the existing material.

A second question addresses variation within a given money type and, where objects are available, the variation of individual monies within a bundle. Such an analysis provides additional evidence regarding uniformity of individual objects or of bundles, the use of denominations and the exchange value mechanisms within the study corpus.

Finally, I address issues related to the sources and processing of iron ores and to the provenance of metal worked into 'monies'. There is ethnographic evidence regarding iron smelting in the Cameroon region, but considerable uncertainty exists about how the metal circulated, where it was worked to produce 'monies' and how the 'monies' were distributed among the different user groups.

Geographic areas covered by this study

The geographic area covered by this study includes a number of different nations in West Africa. The selection of the study area is directly related to the past and present locations of ethnic groups known to have made and used iron 'monies' prior to the establishment of several West African nation states in the second half of the twentieth century. In many cases, the political borders of these nations cut through the territories of ethnic groups. In terms of current nation state political geography, the focus includes the Republic of Cameroon, Equatorial Guinea, Nigeria, Liberia, Gabon and the Republic of Congo (fig. 1.1). The main ethnic groups studied within the context of this study are the Pahouin (or Pangwe) which include the Fang, Eton, Ewondo, Beti and Bulu people (fig. 1.2). There are also references to the Tiv, Mafa and Lele ethnic groups, present in Equatorial Guinea, Gabon and Cameroon (Rowlands and Warnier 1988). These groups are discussed further in the following section.

Ethnic groups in the study region

Pahouin or Pangwe is the general term used to describe a number of different ethnic groups inhabiting the region encompassing Central Cameroon and extending as far as Gabon, Congo, Liberia and Equatorial Guinea (see fig. 1.2). In addition to geographic proximity, these groups also share a common linguistic background, the Bantu family of languages. The Pahouin are also referred to as Beti-Bulu-Fang, named after the three main ethnic groups (Alexandre and Binet 1958).

Within the Pahouin groups, a common lineage division, created several thousand lineage core segments, each of which operated autonomously. These are called *mvog* in the local Bantu dialects and are composed of a headman, his wives and children, any unmarried brothers and the slaves attached to the household (Guyer 1980; Quinn 1980). The numbers of *mvog* varied depending on the prosperity of the headman, who could have thirty or more wives or only one or two. The headman was called *nkukuma* in Bantu, and in some cases a further distinction was made among *mvog* denoted by the term *nda bod* which signified each household/family. This is an important aspect of Pahouin social organization, since wives were both a sign of wealth and a means to generate additional wealth (Guyer 1985). The daughters of each individual *mvog* brought bride wealth and were a means for new social and economic alliances with *mvog* from either the same or different ethnic groups (Guyer 1980). This bride wealth took the form of iron monies, especially by the end of the nineteenth century, as will be discussed in detail in the following chapter.

General background to iron metallurgy in the study region

The first evidence for iron smelting in Sub-Saharan Africa comes from the Agades region of the Niger river, dated from the mid first millennium BC. Iron smelting was also used by the Nok culture of the Taruga region in Central Nigeria, considered contemporary to that of the Niger area (Tylecote 1975). In the period from 500 BCE to 500 AD, iron smelting and working spread over a broad area, including the region studied in this thesis (Childs and Killick 1993; Schmidt 1996).

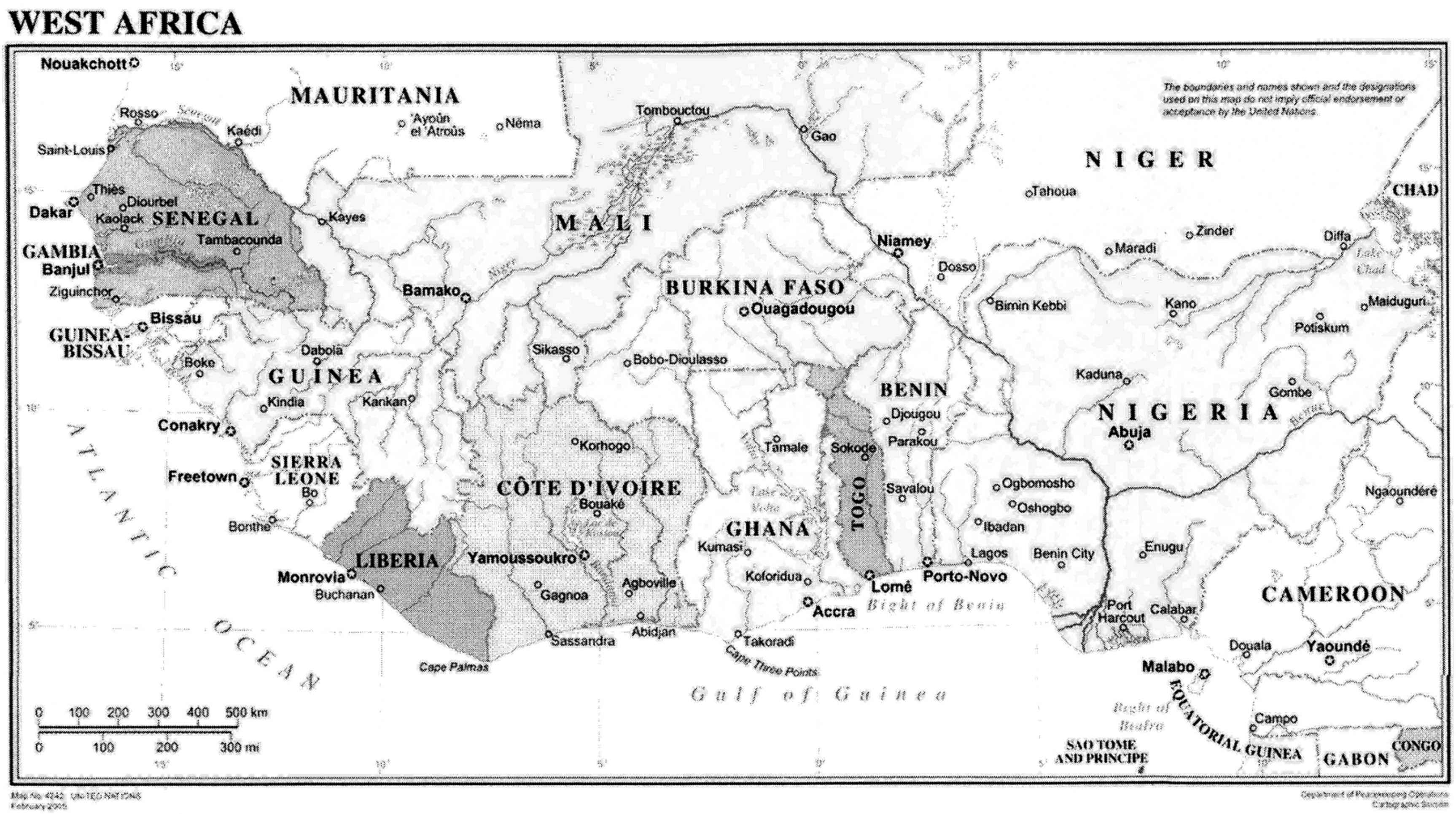
A number of researchers have studied the origins and spread of iron smelting and working technology into West Africa (van der Merwe 1980). The most common theory is that these technologies came from the north, possibly from South Morocco, and spread across the Sahara. Once they mastered the basic knowledge of the smelting process, local smiths added a “bewildering variety of local innovations and adaptations” (Herbert 1984: 9). By the late nineteenth century, local smiths had established elaborate smelting and iron working techniques throughout West Africa at the same time they were exposed, through trade, to imported European manufactured iron and steel (Childs and Killick 1993).

In terms of extractive technologies, West African iron workers most commonly used direct reduction processes (van der Merwe 1980), but David et al. (1989) documented an indirect iron-smelting process in which cast iron was produced first, then decarburized to steel in the forge. At the request of a group of archaeologists and metallurgists, the latter process was re-enacted in 1989 by a Mafa iron master from North Cameroon and thoroughly documented by the authors who sampled and analyzed the resulting iron (David et al 1989).

The region of North Cameroon was frequently mentioned in numerous travelers' accounts in the nineteenth century as having fine local metal workers (David et al. 1989). Iron production was facilitated there by the fact that there is an abundance of easily accessible, good quality iron ores and hardwoods to make charcoal (Guyer 1986). The availability of these resources seems to have encouraged numerous, small local centers of production rather that a more centralized mode of production (Holl 2000). Eugenia Herbert (1993) has suggested that in the late nineteenth century, each major lineage had its own smelter and blacksmith, and there is evidence of heterogeneity in the technology of smelting even within the same ethnic groups. On the topic of metal sourcing, Tessman (1913) in his ethnographic work on the Pahouin mentions that the Bulu were buying their metal from the Ntumu in the South, while the Yaounde and the Bene sourced metal from the Eton.

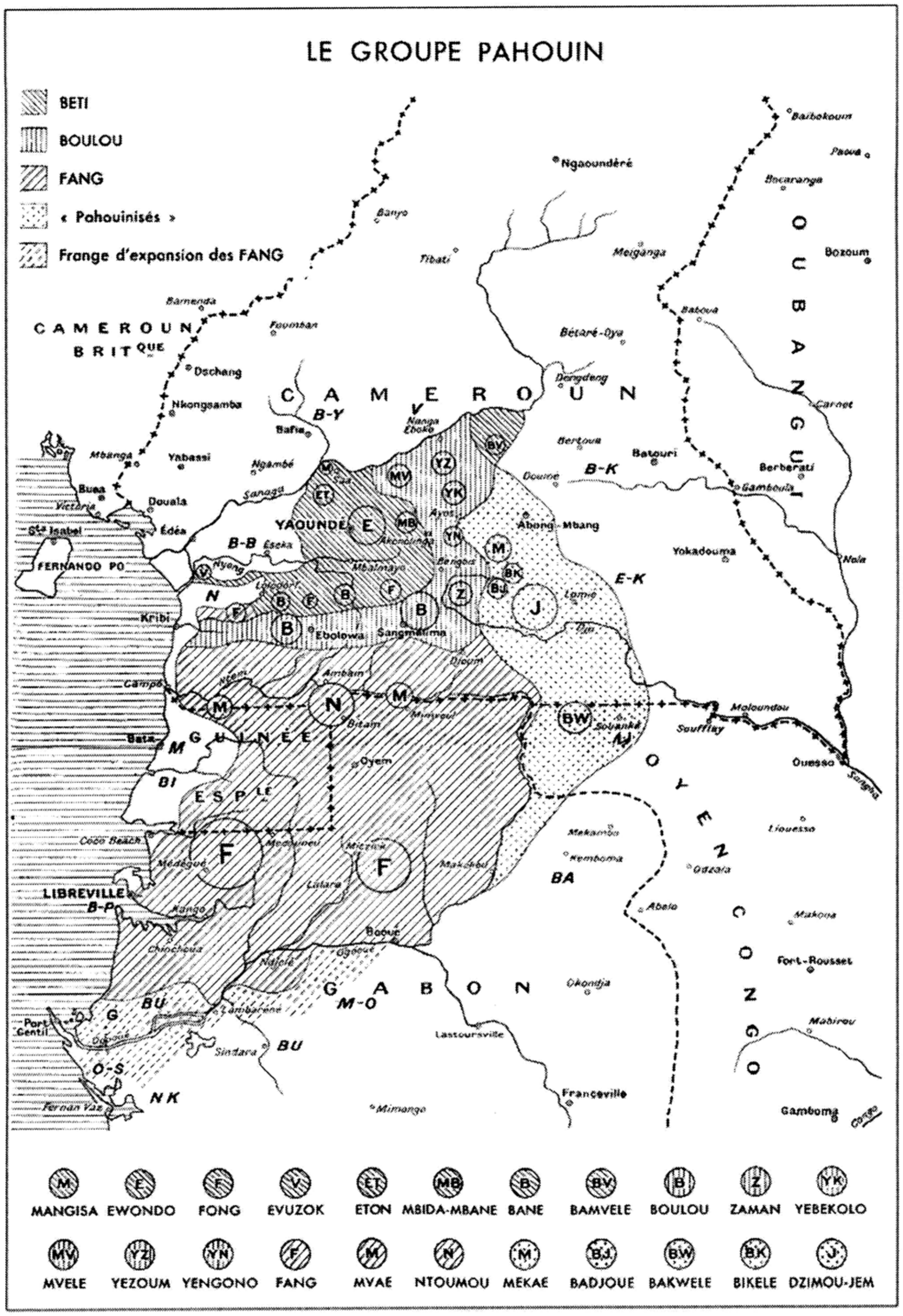
According to ethnographic fieldwork conducted in the region of North Cameroon, there was a set system for organizing, conducting and paying for an iron smelt. Among the Fang people of Gabon, the major smelting season of five smelts was paid for by a particular group of men who paid the workers involved in the process of building and operating the furnace (Guyer 2004; David et al. 1989). In exchange, this group received a substantial proportion of the iron output which they sold or exchanged with others following the completion of the process. In the case of the Eton people, located in North and Central Cameroon, the system was slightly different. The iron master, who was in charge of iron smelting, initially paid for the process and organized several large scale smelts. The bloom produced was later gradually sold by the iron master to interested parties (Guyer 1986).

Figure 1. 1: Modern map of the region



(UN cartographic section 2005)

Figure 1. 2: Map showing the location of different ethnic groups



(Alexandre and Binet 1958: 153)

Figure 1. 3: Photograph from an early 20th century expedition, showing a forge

Original caption 'Forge a Bebai, Famille Esseng, chez les Ntumu'

(Tessman 1913: 212)

CHAPTER II: GENERAL INFORMATION

Currency use in the study region

A number of scholars have documented through both archival and oral sources the use of several different materials for exchange purposes by the people of West Africa (Dorward 1976; Douglas 1958; Guyer 1986; Herbert 1984). Eugenia Herbert (1984) generally defines currency in the region as "anything that is widely accepted for goods or in discharge of other kinds of business obligations" which differs from the barter process (Herbert 1984: 185). A number of different materials have been used as currency, consistent with the definition provided here and documented by ethnographic field work carried out in the twentieth century (Douglas 1958; Guyer 1986). These ethnographic projects describe different aspects of a multicentric complex of mutually exclusive exchange categories, in each of which special-purpose monies were used. Exchanges within each category were based on a central market value system recognized by all parties involved in the exchange (Bohannan 1955; Dorward 1976).

This study addresses in particular the range of goods exchangeable against iron currencies that were designated for use in marriage contracts. This use of iron gave it the characteristics of a durable symbolic currency, which also provided a widely accepted reference point for assessing the value of a broad range of everyday and prestige goods. At the same time, each bundle of iron currency represents a proportion of the total raw material available in the area, a proportion of the iron ore smelting labor and a proportion of the labor at the forge (Guyer 2004).

Definition of monies in the study region

As mentioned above, several different materials have been identified as means of exchange in the Pahouin area. Copper, iron, salt, raffia cloth, beads, shell and ivory have been documented as currencies and means of mediating exchanges (Herbert 1984). The large variety in monies used makes this region one of the most complex examples of monetary systems in the world (Guyer 1980; Guyer 1986). By the end of the nineteenth century in Africa, these different materials were used in a great variety of transactions, including marriage and other ritual–related payments.

Different types of monies available

In this section, I review briefly the different types of monies available in West Africa and used during the late nineteenth and early twentieth century by the ethnic groups discussed earlier. Starting with salt, F. Quinn (1980) has studied in great detail the different patterns of exchange for salt and how the supply and demand were closely regulated among the salt producing and salt trading groups. In addition, cloth was widely accepted as a form of currency in the broader West African region. Mary Douglas (1957) has shown how the Lele ethnic group dominated the production and use of cloth as a medium of exchange and David Dorward (1976) in his work on West Africa discusses at length the use of cloth as currency among the Tiv ethnic group (Dorward 1976).

In her book *Red Gold of Africa* Eugenia Herbert (1984) has studied in detail the use of copper as a medium of exchange and a means of storing wealth. Both copper and brass were used in a number of different shapes, including knives, ingots, lumps, rods, bars and bullets, but rarely in coin form. Further evidence for copper currency in various forms is indicated by the widespread presence of ingots and ingot moulds in West and Central Africa. Of particular interest are the copper rods, where further denominations were made possible through the cutting of the rod. Several ethnographic sources document the practice of cutting the rod into smaller value units, a process that was highly sensitive to rapid devaluation of the rod (Herbert 1984; Tessman 1913). To illustrate this process of different size units, Eugenia Herbert provides the following information from local oral sources regarding exchange rates for copper rods: “thick rods were sold at a rate of 400 rods for a *mithqal* of gold [...] this could buy slaves, millet, ghee and wheat while finer rods were sold at a rate of 600-700 rods and brought meat and firewood” (Herbert 1984: 198).

West African Iron monies

The material of interest in this thesis is “monies” made from iron and iron alloys. The use of iron currencies in West Africa was documented early in the twentieth century by a number of ethnographers (Tessman 1913). A number of iron currency pieces documented in the region in the early twentieth century took the form of a spearhead or axe.

The available types differed from one another in the amount of iron in each piece, the size and weight as well as the degree of finish, the number of individual items making up a bundle, the binding used for the bundle and the potential for immediate uses other than symbolic functions. Jane Guyer (1986) has conducted extensive ethnographic research that illustrates how the different ethnic groups produced distinct types of money that shared some specifications characteristic of the group that distinguished those monies from others (see fig. 2.1). Starting with the Eton, their iron currency was shaped as spear heads, forged to the same specifications as the spear head produced for utilitarian use, including such details as a hafting socket. In contrast, the Ntumu money blades look as if they could be used for what their shape indicates as intentional use, such as cutting. In the case of the Ewondo and Fang, the spearhead and axe shapes used as monies are smaller in size than their prototypes, showing a clear distinction between those used for exchange only and these for everyday functional items (Guyer 1986).

Different money types circulated as bride wealth within defined areas, but they could also be exchanged for a number of other "goods" such as agricultural products, labor services, ritual fees and gambling. "The sources on geographical distribution suggest that the different types are not denominations which circulated against one another at a fixed rate of conversion, except in the case of two sizes having the same shape" (Guyer 1986: 587). All these iron currencies present in Pahouin society were known as *bikie* or *bikye* in the local Bantu dialect and were commonly assembled in bundles of tens or hundreds.

Linguistic record

B*ikie,* the generic term used for iron money, was made in a variety of forms and was called a different name by each ethnic group: short rods were known as *mimbas* by the Ewondo group, as *bizan* by the Bulu and as *ngama* by the Bene (Guyer 1986; Tessman 1913). *Kwa* is another term often used to describe iron currency. This term is actually the generic term for metal, used throughout the region under study with no distinction made between copper and iron. As Jane Guyer notes (1986), the unworked iron, before forging or in scrap form, had a different name, *mbitna* in Eton and *mimpim* in Ewondo.

Additional terms used for these objects provide an indication regarding the denominations that circulated for each type. In the case of Ewondo, the basic unit of *mimbas* was named *ntet*, which is the local dialect word for one hundred (Guyer 1986). However, further study of linguistic terms reveals that *mimba* were circulated in bundles of ten and that the term *ntet* possibly refers to the raffia weaving that secured the bundle. When these iron currencies were used as bride exchange, the total payment was named *akuda bikie*, where *akuda* is a word used to signify one thousand, ten thousand or generally large numbers (Guyer 1986).

Spheres of exchange

According to ethnographic studies in the region, the local Pahouin system did not maintain strictly separated "spheres" of exchange, as these spheres were defined by Mary Douglas (1958) in her seminal work on West African values.

There are three distinct categories or 'spheres' of exchange, ranked hierarchically: subsistence, prestige goods and women. Exchange of items within a single category was common, but an exchange from one category to the other involved questions of hierarchy and status. Such exchanges were, therefore, carefully monitored and controlled (Guyer 2004). Almost anything was exchangeable against *bikie*, but for most products their use was limited and optional or the amounts small (Guyer 1986). The ultimate aim of *bikie* and of wealth in general was marriage and the strengthening of the *mvog* family unit. The use of iron as the exclusive means of bride wealth payment became common practice by the end of the nineteenth century when earlier forms of exchange marriage declined in importance (Guyer 1980).

Value of monies

Even though the main use for iron rods was bride wealth payment, it is clear from the ethnographic record that iron rods served as a general standard of value by which "the price of every other article is regulated" (Guyer 1986: 584). Jane Guyer (1986), in her collection of oral testimonies, demonstrated how *bikie* was used to assign prices for a wide variety of everyday and prestige goods. Even though the different groups of *bikie* bear a resemblance to utilitarian objects, the absence of important detailing in their design and manufacture (e.g. the absence of barbing on *bikie* which is present on Eton spearheads) shows that there was no transfer of these objects into utilitarian usage without additional forging (Guyer 1986; Guyer 1985). In addition, there seems to be a consensus in the ethnographic data that re-use as utilitarian objects prior to additional forging or reshaping was discouraged heavily.

There were clear distinctions in the value of monies in relation to the value of the allowable items for which they were exchanged. Ethnographic data provided by Jane Guyer (1986) suggest that utilitarian objects were generally valued at less than twenty *bikie*, livestock ranged from two hundred to three hundred and marriage payments were in the thousands.

Use of and social importance of bride wealth

A common bride wealth payment in nineteenth century Pahouin society included several *bikie* (in bundle form), ivory pieces, agricultural products, palm oil, palm wine, domestic animals and European goods that the groom presented to the father of the bride (Guyer 1980). There are well-documented cases where these payments included a thousand or more iron bars for a single marriage transaction (Guyer 1986). The marriage payment was important for another function closely related to the structure of the family unit; it determined, among other things, the status of the children of a marriage. Status accrued to the man who paid the *bikie* for their mother.

It is noteworthy that the system of exchange was based on a system in which there was no central monetary authority responsible for defining the value of any exchange or regulating supply and demand. Although 'the elders' were in charge of defining prestige goods, the setting of a unit value for each type of money was a much more complex process (Douglas 1958; Guyer 1986).

The social aspects of marriage provide useful insights into the use and dispersion of iron money within the members of a single lineage. Only the father of the bride received the *bikie* for marriage money. As a result, lump sums were not broken down and dispersed among the different family or *mvog* members during bride wealth payment. The physical divisibility of the currency was not automatically associated with its social dispersal to recipients other than the bride's father or *mvog* headman. Thus individuals within a lineage could not accumulate *bikie* bundle by bundle through "indirect involvement in the marriages of lineage kinswomen" leading to the supply of *bikie* being controlled by the "embedded processes of diffused, specialist production" (Guyer 1980: 594).

In the cases where people did not have direct access to *bikie*, an elaborate system of exchange was in place, allowing the trading of indigenous goods, often associated to the marriage feasting. Kingsley (1900) in her fieldwork discussion mentions the use of rubber, salt and ebony as exchange goods for iron used in marriage payments. This served a two-fold purpose. It allowed young men to accumulate means for marriage and it ensured the continued power of those who controlled *bikie* availability (Guyer 1980).

According to Jane Guyer, the Eton *bikie* remained high quality objects "transacted in small numbers, finely wrought to be also used as spearheads" (Guyer 1980: 600). Ewondo *bikie* however, developed in a different pattern, losing quality in the process, with small sizes and poor technical quality noted in many of them (Guyer 1985). This signifies a debasement of the currency where some expansion of the raw material quantity used in a bundle coincided with lower technical standards during the forging process. These Ewondo monies bear a modest resemblance to spearheads, even though the quality of the metal seems similar to those used in the Eton *bikie* (Guyer 1986). Existing sources (Guyer 1985) point towards a standardization of *bikie* by number and not by weight, which may explain the inclusion of pieces of lower quality in some of the Ewondo bundles. Finally, the numerical content of any bundle seems to have varied significantly (Guyer 1986).

Figure 2. 1: Map showing the circulation of different monies in the region

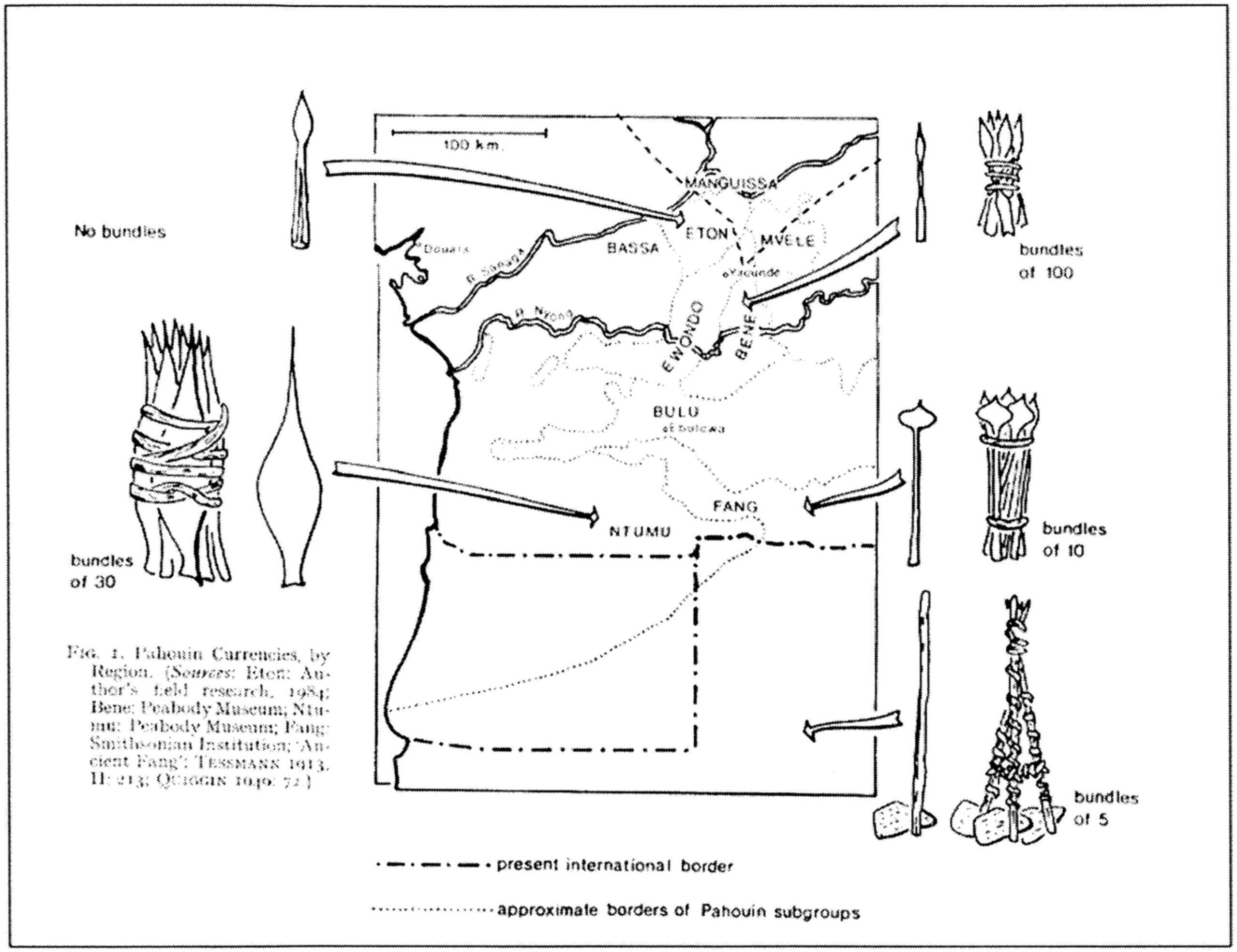


Fig. 1. Pahouin Currencies, by Region. (*Sources*: Eton: Author's field research, 1984; Bene: Peabody Museum; Ntumu: Peabody Museum; Fang: Smithsonian Institution; 'Ancient Fang': Tessmann 1913, II: 213; Quiggin 1949: 72.)

(Guyer 1986: 586)

CHAPTER III: DESCRIPTION OF MATERIAL

Peabody Museum at Harvard University

The objects for this study are from the Peabody Museum of Archaeology and Ethnology at Harvard University. They are part of a wider collection of West African ethnographic material collected for the museum in the first part of the twentieth century. In particular, George Schwab in Cameroon collected the majority of these iron monies bound in bundles in the period from 1920 to 1925, upon commission by the museum. An additional type of iron monies was added to the collection in the 1930s following a new commission made to Silas Johnson, another collector active on behalf of the Museum in Cameroon. Information regarding the origin of each bundle, its cultural association, and the possible names and functions of the items is contained in the accession cards from the Museum Archives. In addition to the monies in bundle form, the Cameroon collection contains a number of more elaborate monies shaped in the form of ceremonial daggers. The collection also contains a group of monies in loose form, whose provenance is in Liberia but they were collected by Charles Schwab.

Other major collections

In addition to the Peabody Museum, a number of other museum collections have West African iron monies with ethnic group associations identical to those in the Peabody Museum. In particular, the Royal Museum for Central Africa in

Tervuren, Belgium contains a large collection of such items. These have been studied by Prof. Jane Guyer (Dept. of Anthropology, John Hopkins University) but not published (Prof. J. Guyer, personal communication, May 2009). Finally, the Smithsonian Institution in Washington D.C. has several examples of monies with ethnic group associations related to the Cameroon material, including a group not represented in the Peabody Museum collection.

Research corpus and sampling limitations

Given the scarcity of West African monies in the Peabody Museum's collections and the general policies of the museum with regard to removing samples for analysis from their holdings, the research project was designed to concentrate on a small number of bundles only and to keep the sampling numbers low. The selection process was carried out in two stages. First, the different money types were identified, and a pilot study was carried out that included four objects, one each of four different group types (see Table 3.1: Cameroon Group types A to C and Liberia A, including individual monies labeled MIT 5398, 5399, 5400 and 5401). Examples of monies, which were originally part of a bundle but had become loose, were included in this stage.

During the pilot study, the objects were documented and sampled, following the CMRAE standard procedure for object documentation, sampling and sample preparation. The preliminary chemical composition and metallographic results were analyzed and a report was produced. The analyses provided a number of useful insights that aided the selection of the final research corpus. All four objects were likely made from iron that was the end product of a bloomery smelting process. Some variation was present in metal composition but there were no major differences in the presence of trace elements, with the exception of MIT 5398 and MIT 5399, where a small trace of phosphorus was identified (see Appendix I, listing chemical composition determinations for all four samples). The metallographic analyses showed that the metallic microstructure was not consistent in all four samples but differed, as indicated by the number and type of inclusions present in the metal (see Figs. 5.2-5.5, 5.24-5.27, 5.43-5.45 and 5.66-5.68 in the photomicrographs included at the end of Chapter V). The metallographic analyses provided information regarding the forging process used in the fabrication of each money type, which proved to be very useful in identifying and selecting the most appropriate areas for removing analytical samples from the remainder of the research corpus.

Once the pilot project was completed, the study was expanded to include a larger number of objects. Selection of the additional objects followed a set of criteria outlined below.

1. First, objects were selected based on their style with the aim to include a statistically significant number of objects from each style type. I identified five style groups, listed in Table 3.1. Several objects from each group type were included in the research corpus, with a minimum number of three objects in each group type. The limitation on the number of objects requested for study related to the policy of the Peabody Museum.
2. Second, different money groups associated with a specific ethnic group were selected in order to examine variation in technology within each

ethnic group. In some cases, two different ethnic groups are associated with one money type. Therefore, several types of monies, from a number of different ethnic groups were included in the study, as described in Table 3.1. Having chosen to study a specific region, Cameroon, the selection of ethnic groups was achieved based on their geographical proximity.

Following the pilot study, an additional group style (Cameroon group D, see Table 3.1) was added to the study. Monies in Cameroon group D represented an interesting variation in type and ethnic group association while at the same time they were very similar in style to one of the other group types (Cameroon group B, see Table 3.1). In addition, the presence of a group, Liberia group A, with a provenance in Liberia was identified and the type was included in the research corpus (Liberia group A, see Table 1). This provided an interesting opportunity to examine material traded outside this region and its possible variation in comparison with the locally produced group type materials.

3. Third, given that these monies were collected in either loose or bundle form, examples of both loose and bundled monies were included. This was decided upon with the aim of understanding the variation among individual items of the same group type. In the cases where there was more than one bundle for the same group type, additional objects from different bundles were included in the selection. This depended on the condition of the bundle. In the case of Cameroon group A, a third bundle that was available in the museum collection was not included, as it was

not possible to remove an individual item from the bundle without destroying the binding material.

One of the most important aspects of the sampling process involved the selection of the analytical samples. During the design of the project, I decided to take two samples from each object, one for metallographic examination and one for chemical analysis. The areas on any object designated for sampling were chosen taking into account the condition of the object, the quality of metal available and the minimal impact on the object's design. The total number of objects studied from the Peabody Museum collection was twenty two, representing five distinct group types with 3-5 objects for each group. All the monies analyzed are documented in Table 3.1 and discussed in detail in the following chapter.

Visual examination and documentation of macroscopic features

The objects were initially examined using an American Optical stereoscopic microscope, available at the CMRAE laboratory, at magnifications of 7 - 30. They were subsequently described, noting their current condition and any special features that needed to be recorded. Detailed drawings were subsequently made, including measurements and weight. The drawings are included in Appendix II. The objects were photographed using a Pentax K100D digital camera, under typical lighting conditions, and the photographs are edited using Adobe Photoshop. All photographs are stored as .jpeg image files.

Sample preparation

The sampling process took place within the CMRAE laboratory. Once the objects were fully documented and their condition carefully assessed, I decided on the area and type of samples to be taken. The standard procedure was followed, taking two samples, one for metallographic and one for chemical analysis. The sampling was carried out using jeweler's saw blades of varying sizes (2/0 to 6/0). The locations of the samples removed from each object are documented in the drawing of the object.

Chemical analysis

The chemical samples were sent for Instrumental Neutron Activation Analysis (INAA) and Inductively Coupled Plasma-Optical Emission Spectrography (ICP-OES) to the Activation Laboratories (1336 Sandhill Drive, Ancaster Ontario, Canada L9G 4V5). This is the laboratory normally used by CMRAE for chemical analyses of artifact samples. Particular attention was given to the presence of elements in trace or higher concentration that would indicate or suggest that the metal was a product of a modern industrial process: Ni, Cr, Mn, Ti and V (Prof. S.M.Allen, personal communication, April 2009).

Hot mounting and polishing

I carried out the metallographic analyses at the CMRAE laboratories. The samples were mounted with a hot mounting press, using Fina-Met powder at 4200 psi at 145° C. For the preparation of the metallographic samples, the standard CMRAE laboratory procedure was followed: each sample was ground on wet silicon carbide papers with progressively finer grit sizes, at 240, 320, 400 up to 600 grit. The samples were then polished, using Glennel diamond compounds of 6 micron and 1 micron, on rotary polishing wheels, lubricated with a lapping vehicle (Wendt Dunnington Formula B). Polishing was completed on a rotating wheel, with a suspension of alpha-alumina (0.05 micron).

Metallographic analysis of as-polished samples

I examined the polished samples with a Leitz HM Lux metallurgical microscope with parfocal objectives. Following completion of the examination, I took photomicrographs of the samples in the as-polished condition using a Leica DMLM metallographic microscope. All photomicrographs were edited and stored as .tiff image files in electronic form.

Etching

The samples were then prepared for etching in the CMRAE laboratory. For all objects, the samples were etched using 4% Nital, a common etchant for iron and iron alloys. The time necessary to etch each sample varied between 5 and 30 seconds.

Metallographic analysis of etched samples

I examined the etched samples with a Leitz HM Lux metallurgical microscope with parfocal objectives. Once the examination was complete, I took photomicrographs of the etched samples using a Leica DMLM metallographic microscope. All photomicrographs were edited and stored as .tiff image files in electronic form.

Table 3. 1: Research Corpus Reference Table

MIT Number	PM Number	PM Object Description	Ethnic Group	Region	Collector	MIT Group Types	Form
MIT 5400	22 2 50 B3616.1	Iron spear head money, unclassified	Ntum	Cameroon	Schwab	Cameroon group A	Loose bundle # 1
MIT 5414	22 2 50 B3616.2	Iron spear head money, unclassified	Ntum	Cameroon	Schwab	Cameroon group A	Loose bundle # 1
MIT 5415	22 2 50 B3616.3	Iron spear head money, unclassified	Ntum	Cameroon	Schwab	Cameroon group A	Loose bundle # 1
MIT 5416	22 2 50 B3616.4	Iron spear head money, unclassified	Ntum	Cameroon	Schwab	Cameroon group A	Tight bundle # 2
MIT 5421	22 2 50 B3616.5	Iron spear head money, unclassified	Ntum	Cameroon	Schwab	Cameroon group A	Tight bundle # 2
MIT 5399	29 76 50 H1102.1	Iron strips, used for money currency, Exchange medium	N/A	Liberia Cameroon	Schwab	Liberia group A	Loose
MIT 5417	29 76 50 H1102.2	Iron strips, used for money currency, Exchange medium	N/A	Liberia Cameroon	Schwab	Liberia group A	Loose
MIT 5418	29 76 50 H1102.3	Iron strips, used for money currency, Exchange medium	N/A	Liberia Cameroon	Schwab	Liberia group A	Loose
MIT 5419	29 76 50 H1102.4	Iron strips, used for money currency, Exchange medium	N/A	Liberia Cameroon	Schwab	Liberia group A	Loose
MIT 5423	29 76 50 H1102.5	Iron strips, used for money currency, Exchange medium	N/A	Liberia Cameroon	Schwab	Liberia group A	Loose
MIT 5398	20 29 50 B2166.1	Bundle of iron rods, unclassified	Bene/Fang	Cameroon	Schwab	Cameroon group B	Loose bundle # 1
MIT 5406	20 29 50 B2166.2	Bundle of iron rods, unclassified	Bene/Fang	Cameroon	Schwab	Cameroon group B	Loose bundle # 1

MIT Number	PM Number	PM Object Description	Ethnic Group	Region	Collector	MIT Group Types	Form
MIT 5407	20 29 50 B2166.3	Bundle of iron rods, unclassified	Bene/Fang	Cameroon	Schwab	Cameroon group B	Loose bundle # 1
MIT 5408	20 29 50 B2166.4	Bundle of iron rods, unclassified	Bene/Fang	Cameroon	Schwab	Cameroon group B	Loose bundle # 1
MIT 5420	20 29 50 B2166.5	Bundle of iron rods, unclassified	Bene/Fang	Cameroon	Schwab	Cameroon group B	Loose bundle # 1
MIT 5401	26 1 50 B4273.1	Native money forged from native iron, Described as currency, bundled together	Ntum/Fang	Cameroon	Schwab	Cameroon group C	Tight bundle # 1
MIT 5409	26 1 50 B4273.2	Native money forged from native iron, Described as currency, bundled together	Ntum/Fang	Cameroon	Schwab	Cameroon group C	Tight bundle # 1
MIT 5410	26 1 50 B4273.3	Native money forged from native iron, Described as currency, bundled together	Ntum/Fang	Cameroon	Schwab	Cameroon group C	Tight bundle # 1
MIT 5422	26 1 50 B4273.4	Native money forged from native iron, Described as currency, bundled together	Ntum/Fang	Cameroon	Schwab	Cameroon group C	Tight bundle # 1
MIT 5411	37 32 50 2530.1	Bundle of 100 pieces of iron	Ntum	Cameroon	Johnson	Cameroon group D	Tight bundle # 1
MIT 5412	37 32 50 2530.2	Bundle of 100 pieces of iron	Ntum	Cameroon	Johnson	Cameroon group D	Tight bundle # 1
MIT 5413	37 32 50 2530.3	Bundle of 100 pieces of iron	Ntum	Cameroon	Johnson	Cameroon group D	Tight bundle # 1

Legend PM = Peabody Museum, N/A = not available

CHAPTER IV: PRELIMINARY ANALYSIS

General Description

The first step in data analysis was the visual examination and documentation of any notable macroscopic features on individual monies in the research corpus, as mentioned in the process description earlier in the text. Remarks for each group type are summarized below:

Cameroon group A

This group consists of three different bundles (one is in loose form but the other two are shown in figs. 4.29-4.30). The first bundle, including objects 5400, 5414 and 5415 (see figs. 4.1, 4.2 and 4.3) has become loose, but the binding material used is preserved. Both 5400 and 5414 have broken edges. The remaining two objects, 5416 and 5421 (see figs. 4.4 and 4.5) are from a second bundle, still bound with binding material. The conservator at the Peabody Museum was able to remove these two objects from their bundle. The reed pattern impression on object 5421 made by the binding material is clearly visible on the surface of the object (see fig. 4.8). In the case of the third bundle however, the monies are so tightly bound that it was not possible to remove any without destroying the bundle (see fig. 4.30). As a result, no additional objects were included for this group type.

The objects are heavily corroded, with a dark orange/brown surface layer of powdery corrosion products, presumably iron oxides. In certain areas, the corrosion layer has formed stains that are bright orange in color.

All five monies share the same distinct shape, with an elongated, wide tip forming a somewhat triangular shape that ends in a fine point, and a wide, ovoid center section that tapers out to a long, narrow tip, with a flat, blunt end. The size and shape of these Cameroon group A monies fall within a tight range, but measurements of the weights showed that one example (5416) is significantly heavier than the others (data on dimensions and weight for each object are given in the following section). This example also has a groove on one side longitudinally along its entire length at mid-section (see fig. 5.6). The function of this groove is not evident.

Closer examination of the shapes of these monies provided useful insights regarding the forging process. The 'neck' on these objects shows evidence of heavy hammering of the metal from both edges in a direction inwards towards the longitudinal axis of the body. It is likely that a cross peen-type hammer was used with blows in multiple directions. The blunt tips of the objects also provided useful clues regarding the final shaping process. At the extreme blunt tip of object 5414, two different layers of metal are visible with a hollow area between them (fig. 4.8). This area appears to have been heavily worked during forging.

Liberia group A

These objects (figs. 5.9-5.13) are the only monies in the study corpus for which there is no documentation available in the museum regarding their assembly in bundle form. There are examples of these monies in bundle form, as shown in figure 4.34, from a private collection. The Peabody collection contains a number of them that were bought as a group by the collector Schwab. The shape and size of these objects are fairly consistent, with differences due mainly to broken or badly preserved items. The surface of the objects displays a grey metallic color, covered in most areas by a dark grey corrosion layer. The flattened ends of these monies, where the metal has been hammered thin, exhibit large cracks and appear more damaged by corrosion.

The most interesting feature of the objects in this group type is the long, twisted rod-like middle section that constitutes the bulk of the metal. In all five objects, the twisted rods terminate in a thin, flat rounded sheet-like form on one end and much thicker, transversely oriented form with sharp tips. Differences noted on the opposite ends of individual monies are likely a result of different levels of damage on the objects.

The weight determinations showed some variation among the Liberia group A monies. Close examination of each object reveals that each is made of at least three parts: the shaft, the flat rounded end, and the transverse pointed end. An important feature of the twisted shaft is that the shafts of monies 5399, 5417, 5419 and 5423 are right-twisted (clockwise), whereas the shaft of money 5418 is left-twisted (counter clockwise). In all Liberia group A monies the twist is tight and carefully made from the flat, rounded end to about midway along the shaft length, where it unwinds gradually into a much thicker rod long, where individual hammer blows are discernable (see fig. 5.16). In addition, careful examination of the twisted portion of the rod on at least one of the monies shaft revealed weld lines, indicating that several sections of the shaft metal were hammer welded together before the shaft was twisted.

In all cases, the flat, rounded and transverse pointed ends of the shafts were forged from separate pieces of metal and hammer welded onto the shafts. In figures 4.14 and 4.15 it is possible to see traces of the weld line on one or the other end of the shaft. In each case, the edges of the metal end pieces were folded and thickened by "upsetting".

Cameroon group B

All five objects in this group are consistent with respect to shape and style (see figs. 4.19 to 4.23). They are shaped as small blades, with one end in the form of a handle. The dimensions, provided in each drawing, show close consistency in size, and there is little variation in the weight of these individual monies. Objects 5406, 5408 are chipped on one side. All objects in this group are heavily corroded on the surface, giving them a dark brown color. The corrosion can be seen penetrating the metal in certain areas, resulting in heavy surface flaking. When examined under the microscope, a diaphanous layer with a matte sheen was identified covering the surface. This was tentatively identified as wax and although not mentioned in the museum files, it was likely part of a conservation effort by the museum staff.

Cameroon group C

This group is part of a loose bundle, the only example of this type at the Peabody Museum (see fig.4.32). The objects are varied in shape, with differences both in size as well as style. One could argue that some of the objects forming the bundle were not manufactured with the same effort and care, as a number of the blades display less attention to detail or even to basic form. In terms of shape, the objects have a curved base, probably imitating a hafting socket at one end, and a blade at the other end which terminates in a pointy tip. However, the socket on object 5410 was not well formed, with limited curvature (see fig. 4.24). Object 5422 is curved on both sides, ending on two pointy tips, which may indicate the result of either an error in forging or carelessness. The surface of the objects is corroded exhibiting a bright orange/brown color.

Cameroon group D

This group, part of a bundle, is the only example of its type at the Peabody Museum (see fig.4.33 for bundle). The three objects examined (see figs. 4.26-4.28) have a similar shape, with some variation in their size and weight. The surface of the objects is uniform in texture and color, covered by a powdery dark orange/brown corrosion layer with cracking at certain areas. The blades on all three objects were produced in a similar way. They are narrow in shape, angular, with a pointed tip. In object 5412 the end opposite to the blade widens and forms a tip (fig. 4.27). The wide end of object 5413 is broken (see fig. 4.28).

CHAPTER IV: Figures

Cameroon Group A

Figure 4.1: MIT 5400

Figure 4.2: MIT 5414

Cameroon Group A (cont.)

Figure 4.3: MIT 5415

Figure 4.4: MIT 5416

Photograph by Ismini Papakirillou.

Figure 4.5: MIT 5421

Photograph by Ismini Papakirillou.

Cameroon Group A (cont.)

Figure 4.6: MIT 5416 with groove detail

Figure 4.7: MIT 5414 with tip detail

Photograph by Ismini Papakirillou.

Cameroon Group A (cont.)

Figure 4.8: MIT 5421 with reed impression detail

Liberia Group A

Figure 4.9: MIT 5399

Figure 4.10: MIT 5417

Figure 4.11: MIT 5418

Photograph by Ismini Papakirillou.

Liberia Group A

Figure 4.12: MIT 5419

Figure 4.13: MIT 5423

Liberia Group A (cont.)

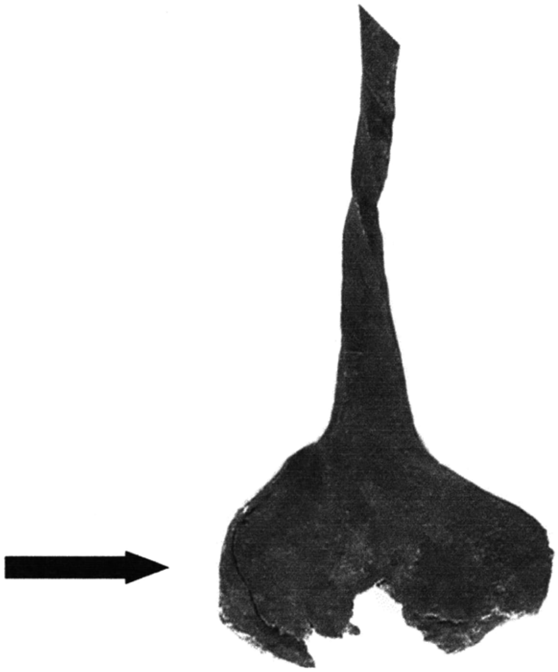


Figure 4.14: MIT 5417 detail with forging line

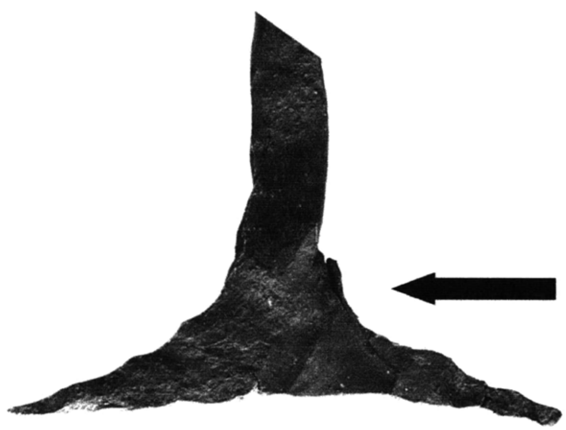


Figure 4.15: MIT 5418 detail with forging line

Liberia Group A (cont.)

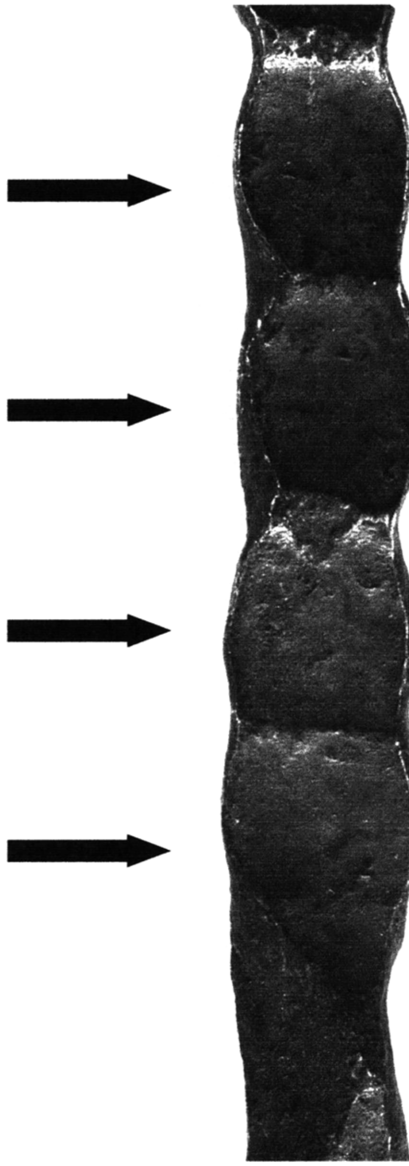


Figure 4.16: MIT 5418 detail with hammer blows

Cameroon Group B

Figure 4.17: MIT 5498

Figure 4.18: MIT 5406

Cameroon Group B (cont.)

Figure 4.19: MIT 5407

Figure 4.20: MIT 5408

Photograph by Ismini Papakirillou.

Figure 4.21: MIT 5420

Cameroon Group C

Figure 4.22: MIT 5401

Figure 4.23: MIT 5409

Photograph by Ismini Papakirillou.

Cameroon Group C (cont.)

Figure 4.24: MIT 5410

Figure 4.25: MIT 5422

Cameroon Group D

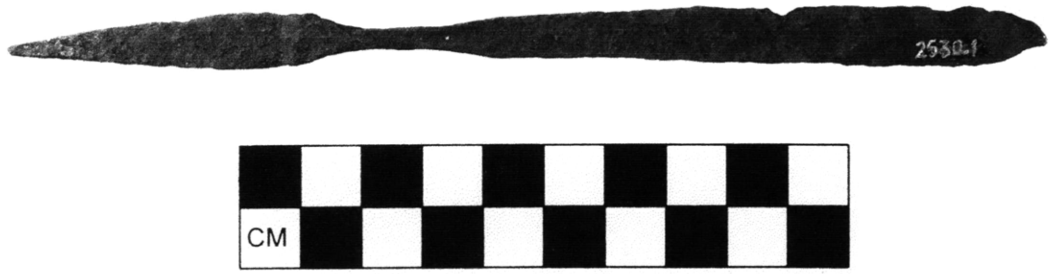


Figure 4.26: MIT 5411

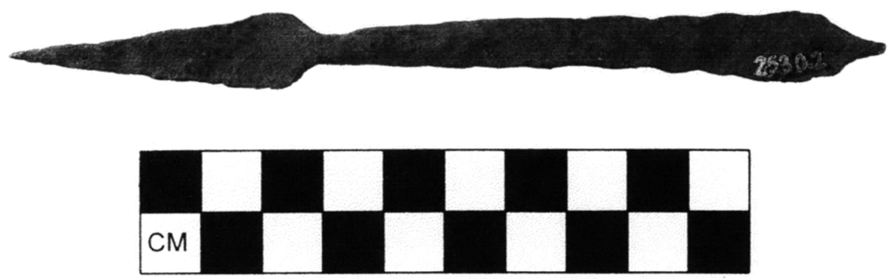


Figure 4.27: MIT 5412

Figure 4.28: MIT 5413

Cameroon Group A (bundles)

Figure 4.29: Cameroon Group A bundle #2

Figure 4.30: Cameroon Group A bundle #3

Photograph by Ismini Papakirillou.

Cameroon Group B (bundle)

Figure 4.31: Cameroon Group B bundle #1

Cameroon Group C (bundle)

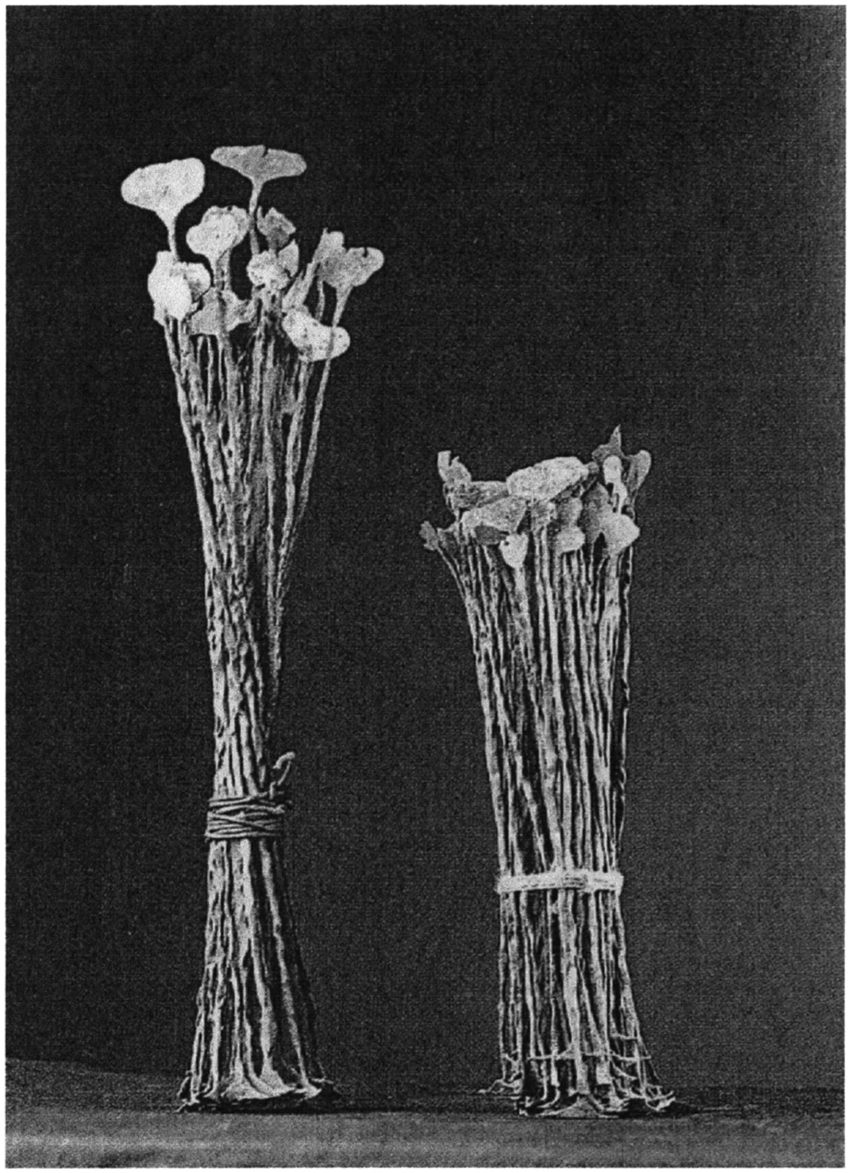
Figure 4.32: Cameroon Group C bundle #1

Photograph by Ismini Papakirillou.

Cameroon Group D (bundle)

Figure 4.33: Cameroon Group D bundle #1

Figure 4. 34: Photograph of 'kissi pennies' in bundle



(Kuhn 1997: 526)

CHAPTER V: METALLOGRAPHIC ANALYSIS

Cameroon group A

5400

The object was sampled twice, for chemical and metallographic analyses and the metallographic sample (5400_1) was then mounted transversely. Metallographic examination revealed two fissures in the metal close to the surface, one on the upper edge of the sample and the other at the lower left corner (fig.5.2). These show clear evidence that the material was worked, particularly in the corner where the surface metal was hammered onto a lower layer. The polished section also shows a number of inclusions identified as slag which appear in a variety of shapes and sizes (fig.5.3). Several inclusions are large, but the majority are small and appear as stringers, elongated and following the direction of the flow of metal during working.

The sample was etched with nital for ten seconds to reveal the metal microstructure. The metal is heterogeneous in composition. The white, equiaxed grains in the photomicrograph (fig. 5.4) are ferrite. The ferrite grains exist in a variety of different sizes across the sample. Small amounts of pearlite are located around the ferrite grain boundaries in this zone of low carbon content. The darker grains are pearlite in a zone of higher carbon content (fig. 5.5). The pearlite grain size varies, with some large pearlite grains noted on the left side of the photomicrograph. At high magnification, the typical pearlite (α-Fe (ferrite) and

Fe_3O (cementite)) lamellar structure is visible within some of the larger grains. Ferrite has formed along the pearlite grain boundaries, and massive acicular ferrite in classic Widmanstätten needle-like patterns invades the pearlite grains. The slag inclusions discussed in the as-polished section seem to be more densely distributed in the ferrite region.

5414

Object 5414 was sampled twice as shown in fig. 5.6. During the visual examination of the object, the area where the metallographic sample (5414_1) was taken was identified as having been heavily worked. The sample for metallographic analysis was mounted transversely. The polished section revealed the extensive folding of metal during the shaping of the object. A large and relatively thick piece of surface metal (b) almost detached from the bulk of the material, has been hammered around and onto the body of the metal (a) (fig 5.7). In the polished section the wide fissure formed by this folding is filled with corrosion.

The sample was etched with nital for five seconds to reveal the microstructure (fig. 5.8). The sample is heterogeneous in composition. The metallic microstructure displays two distinct areas (a and b), possibly associated to two different pieces of metal that were hammer welded together. One piece may have been from the "body" of the metal and the other the piece of metal hammered around and onto the body (fig. 5.7). The centre of the section (a) has large, equiaxed pearlite grains, characteristic of a microstructure with higher carbon content than the ferrite region. When examined at high magnification, the pearlite rich areas revealed lamellar structures typical of pearlite (fig. 5.9). Moving from the centre of the section to the edges, the percentage of carbon is greatly reduced, with ferrite being the dominant microstructure present. At high magnification, acicular ferrite is present along the pearlite grain boundaries in these areas. The possible second piece of metal (b) has a distinct microstructure, with equiaxed ferrite grains only.

5415

Two samples were taken from object 5415, as shown in fig. 5.10. The metallographic sample 5415_1 was mounted longitudinally (see fig. 5.10). The photomicrography of the polished section (fig. 5.11) exhibits zones of high density of inclusions. Two large inclusions are situated at the left edge of the sample, cutting through the metallic area and filled with corrosion. The inclusions are identified as slag stringers. They are highly elongated in shape and are oriented in the direction of metal flow. In the lower part of the metallic section, the stringers show clearly the metal flow as the object was hammered into shape (fig. 5.12).

The sample was etched with nital for 12 seconds to reveal the metal microstructure. The sample is heterogeneous in composition. The metal displays an unusual layering pattern, with zones where the grain sizes become progressively small, without a clear interface between each zone (fig. 5.13). The lower part of the section contains grains of pure alpha iron. The upper part of the sample also exhibits a zone of fine ferrite grains. Between the two large fissures, in the middle part of the section, there is a zone of fine pearlite and ferrite grains. This area has a higher carbon content than the rest of the sample. The sample is inhomogeneous in composition. The presence of elongated stringers in combination with the equiaxed grains indicates that the object was worked then heated at least once during shaping or that it was forged above the recrystallization temperature of the ferrites.

5416

Object 5416 was sampled twice and the metallographic sample 5416_1 was then mounted transversely. In the polished section (fig. 5.15) there is a dense distribution of inclusions that gives the metallic area a 'dirty' appearance. Some of the inclusions, identified as slag, are slightly elongated in shape and follow the direction of metal flow. These occur in the upper portion of the section. There is also another type of inclusion, globular in shape with a porous texture. These occur in the lower portion of the section. A deep fissure divides the upper and lower portions of the section and may indicate the location of a hammer weld. The distinct pattern in the type and location of these inclusions may be an indication of the presence of two different pieces of metal, welded together at an earlier stage in the process of manufacturing of the object.

The sample was etched with nital for twenty seconds to reveal the metal microstructure. The microstructure is characterized by the presence of equiaxed ferrite grains, of varying sizes, across the section (figs. 5.16 and 5.17). The different ferrite grain sizes are probably linked to the rate of cooling across the sample. Given the distinct location differences of the inclusions, the sample was examined to identify any additional aspects confirming the presence of two different pieces of metal that had been hammer welded. However, no distinct changes in the microstructure or an interface boundary were identified. The metal is wrought iron.

5421

Object 5421 was sampled twice and the metallographic sample 5421_1 was mounted as shown in figure 5.18. The polished section is distinguished by the large number of inclusions (fig. 5.19). These inclusions, identified as slag, are in the form of stringers, elongated in shape and oriented in the direction of the metal flow across the entire section (fig. 5.20). These stringers are broken into smaller pieces in certain areas. The smaller broken pieces of slag stringers indicate that the metal was cold worked at some stage during shaping.

The sample was etched with nital for sixteen seconds to reveal the metal microstructure (fig. 5.21). The microstructure contains ferrite grains that are equiaxed throughout the metal, with the exception of a small region on the lower right side, where the grains are elongated. The ferrite grains are present in two different sizes, large grains on the upper part of the section and finer grains, present on the lower part of the section. The sample is identified as wrought iron.

Summary of Cameroon group A

Following the metallographic analyses, the objects examined from Group A are all manufactured from bloomery iron. The high density of slag inclusions indicates that the metal used for these objects was the end product of a traditional bloom smelting process. Samples 5416_1 and 5421_1 were identified as made of wrought iron while samples 5400_1, 5414_1, and 5415_1 were heterogeneous in composition, including some regions of ferrite and others with a low carbon concentration. This heterogeneity is typical of bloom iron, as will be discussed in the next chapter. The presence of equiaxed grains and elongated slag inclusions indicate that all five objects were forged (hot worked) and in one case likely cold worked followed by heating at least once during the forging process. The presence of hammer welding could not be demonstrated conclusively for these objects.

Liberia group A

5399

The object was sampled twice and the metallographic sample 5499_1 was mounted transversely, as shown in figure 5.23. A number of inclusions, identified as slag, were observed in the polished section (fig. 5.24). These stringers are located intermittently across the section, and their elongated shape and orientation are an indication of the direction of metal flow during plastic deformation. Certain slags are large enough to exhibit clearly a dendritic phase. This phase is likely wüstite (FeO) and the cracks in the slag probably indicate forging at low temperature (fig. 5.25).

The sample was etched with nital for fifteen seconds to reveal a metal microstructure typical of wrought iron (fig 5.25). The equiaxed ferrite grains vary in size across the sample. The location of the areas of finer grain sizes does not seem to follow any pattern that might be indicative of work done on the material. This variation in grain size is probably explained by differences in the cooling process of the iron during forging (fig.5.27).

5417

Object 5417 was sampled twice in the wide area adjacent to the flat rounded end. During visual examination, a welding line was identified running across this area. The metallographic sample 5417_1 was taken by cutting through part of this welding line and was mounted transversely to the weld (see fig. 5.28). In the polished section, the welding line is visible along a short distance where the individual metal pieces have not joined completely (fig.5.29). A narrow fissure is present at this location. This is a high quality weld, as the fissure cannot be traced further. The weld fissure is now filled with corrosion.

The sample was etched with nital for twenty seconds to reveal the metal microstructure (fig. 5.30). The section exhibits a very fine ferrite grain structure. The sample appears almost free of slag; there are only a few stringers at the centre of the section. In particular, the area of larger ferrite grains has very few stringers. There are a number of regions in the section where the ferrite grains differ in size. This variation in grain size could be explained by the presence of two different pieces of metal, welded together at an earlier stage of the metal manufacturing process. However, one would then expect the piece being wrapped around the rest of the material. Closer examination of the area where the two zones of grain sizes are adjacent revealed traces of an area identified as an interface. This could be further evidence of this piece having been welded together at an earlier stage. The fact that this is an earlier addition is evidenced by the grains that cross the interface from one area to another (fig. 5.31).

Looking at the microstructure of the lower section that is adjacent to the weld, one notices that it is more homogeneous than the rest of the section. At a high magnification, the pearlite phase is well defined. Photomicrograph 5.32 clearly shows the presence of Widmanstätten (acicular) ferrite, pearlite and slag inclusions. The acicular ferrite has the characteristic short needle-like structure and high angle boundaries between the grains. Additional evidence of working on this sample can be noted in the faceting observed on the external surface of the object, on the right edge of the metallic area on the sample. This faceting was created by hammer blows during upsetting, when the object was hammered back to itself. The two distinct facets can be seen in the as polished mosaic. The sample is heterogeneous in composition.

5418

Object 5418 was sampled twice and the metallographic sample 5418_1, removed from the pointed end of the shaft, was mounted transversely as shown in figure 5.33. The polished section (fig. 5.34) revealed that the end was made from at least two pieces of metal, hammer welded together. The upper piece of metal in the photomicrograph has been wrapped around the lower piece. A fissure remains where the weld did not join, but the slag inclusions in the upper piece of metal follow the contour of the interface between the pieces.

The sample was then etched with nital for eleven seconds to reveal the metal microstructure (fig. 5.35). The sample is heterogeneous in composition. There are two microstructures present, pure ferrite and ferrite with the α-Fe – Fe_3C pearlite composite. The grains are equiaxed across the section, but they vary in size. The ferrite grains are larger than the pearlite, as noted in earlier samples. The two components – ferrite and pearlite – form distinct banded regions across the sample. The difference in grain size was likely due to variations in cooling rate rather than to the treatment of the metal during working.

The short zone where the hammer weld is complete is visible in the far left of the photomicrograph.

5419

Object 5419 was sampled twice at the base of the flat tip. As with object 5417, during visual examination, a welding line was identified at the base of the rounded end where it meets the shaft. The metallographic sample 5419_1 was taken by cutting through the welding line and mounted longitudinally, to include any other features related to the twisted shaft, as shown in figure 5.36. In the polished section (fig. 5.37), the fissure between the rounded end and the shaft is visible at the upper right corner of the photomicrograph. Another fissure in the shaft is shown midway along its left surface. It represents a place where one layer of metal was hammered down into another.

The sample was etched with nital for twenty seconds to reveal the metal microstructure (fig. 5.38). The microstructure contains mainly ferrite grains, with a low carbon concentration in the metal. The grains are small in size and equiaxed. There is a distinct region of finer grains near the upper surface of the section. In addition, there is an area of higher carbon content on both sides of the weld, as evidenced by the presence of small quantities of pearlite. The two distinct pieces of metal do not display any major differences in microstructure but it should be noted that the small side of the piece removed from the rounded end does not afford much data with regard to microstructure.

5423

Object 5423 was sampled twice in the wide, untwisted portion of the shaft where distinct hammer marks were identified during visual examination. The metallographic sample 5423_1 was taken by cutting transversely through two adjacent hammer marks and was mounted longitudinally (fig. 5.39). The polished section (fig. 5.40) showed relatively clean metal with few inclusions, circular in shape.

The sample was etched with nital for eighteen seconds to reveal the microstructure (fig. 5.41). The sample is heterogeneous in composition. There are two major bands that run longitudinally through the section. The broader, upper band is comprised of equiaxed ferrite grains. The adjacent, lower band is composed of finer grains of lamellar pearlite with acicular ferrite at the grain boundaries.

Summary of Liberia Group A

Following the metallographic analyses, the objects examined from Liberia Group A are all manufactured from bloomery iron. Samples 5417_1, 5418_1, 5419_1 and 5423_1 are heterogeneous in composition. Sample 5399_1 was identified as wrought iron. The presence of slag inclusions indicates that the raw material used for these objects was the end product of a traditional iron bloom smelting process. The sections examined contain useful information regarding the techniques followed during the shaping of the objects. The use of welding and upsetting are evidenced in the sections.

Cameroon group B

5398

Object 5398 was sampled twice and the metallographic sample 5398_1 was mounted transversely as shown in figure 5.42. The polished section (fig. 5.43) contained a high density of inclusions, many large in size and identified as slag fragments. Many of the smaller inclusions are present in the form of stringers. These are oriented along the direction of the flow of the metal and have an elongated shape. The metal is in poor condition, the corrosion moving into the metal in places (5.44).

The sample was etched with nital for twenty seconds. The microstructure (fig. 5.45) revealed the presence of ferrite grains across the sample. The presence of only ferrite indicates the object was made of wrought iron. The grains are large, equiaxed and with limited variation in size. The equiaxed grain shape in combination with the elongated slag stringers indicate that the item was forged (hot worked) to shape.

5406

The object was sampled and the metallographic sample 5406_1 was mounted transversely, as shown in figure 5.46. At the upper right corner of the section (fig. 5.47), a deep crack is visible, formed during forging, either by hammer welding an additional sheet of metal, or by folding the existing metal on to itself. There are two types of inclusions present in the metal. One type is slag, formed in stringers. These run across the length of the sample and are elongated in shape. In the larger slag fragments, the different phases present in the slag can be observed clearly. There is a light grey phase that has crystallized in the form of dendrite-like patterns and is surrounded by a different, dark grey phase. In other inclusions of the same type, the crystallized phase has formed sharp, needle-like patterns (figs. 5.48-5.49). The stringers are broken into smaller pieces across the sample, indicating that the forging to shape the object was at one stage carried at a low temperature. The other type of inclusion is very small, spherical in shape and grey in color.

The sample was etched with nital for twenty seconds to reveal the metal microstructure. The inclusions are uniformly distributed across the sample, which is heterogeneous in composition. There are two microstructures present, pure ferrite and ferrite with limited amounts of pearlite at the grain boundaries. This type of microstructure indicates a low carbon content in the metal. The grains are equiaxed across the section suggesting that the metal was forged to shape it. There are differences in the size of grains that characterize the two different microstructures. The ferrite has large grains while the grains of ferrite and pearlite form bands of very fine microstructure across the sample. There is limited pearlite present, situated around the grain boundaries of the fine ferrite grains. No clear pattern exists regarding the location of these finer grain bands (fig. 5.50-5.51).

5407

Object 5407 was sampled twice and the metallographic sample 5407_1 was mounted longitudinally, as shown in figure 5.52. In the polished section, the shape of the tip is well preserved in the surface corrosion layer. There is a large crack, almost separating the upper part of the section into two pieces (fig. 5.53). This was probably the result of intensive working of the object, perhaps through the addition of metal pieces through hammer welding. There is a high, dense distribution of slag inclusions in the sample, varying in shape and size. The inclusions are distributed as stringers or they are globular in shape. The stringers are elongated, following the flow of the metal. The location of these inclusions is not uniform across the sample. The lower portion of the section is almost free of inclusions, but it is surrounded by areas replete with inclusions. Closer examination of the area where the low and high density of inclusions is contiguous revealed traces of an interface that is followed by the grain boundaries. Based on this observation, it is likely that the lower portion of metal represents a different piece that was added by hammer welding at an earlier stage of the manufacturing process.

The sample was etched with nital for twenty five seconds to reveal the metal microstructure (fig. 5.54). The main microstructural feature is the presence of equiaxed ferrite grains, uniform in size across the sample, with the exception of a few areas with larger grains (5.55). The sample is identified as wrought iron.

5408

Object 5408 was the only object for which three samples were taken, of which two metallographic samples were mounted, 5408_1 transversely and 5408_2 longitudinally (fig. 5.56). The transverse polished section 5408_1 (fig. 5.57) contains slag inclusions, forming stringers that are elongated in shape. These are oriented in the direction of the flow of metal and indicate how the metal was worked during forging. The polished longitudinal section 5408_2 (fig. 5.58) contains a higher density of slag inclusions than 5408_1, elongated in shape and following the flow of the metal. These stringers are broken into smaller pieces in certain areas, due to intensive work at low temperatures.

Both metallographic samples were etched with nital, sample 5408_1 for twenty seconds (fig. 5.59) and sample 5408_2 (fig. 5.60) for twenty five seconds, to reveal the metal microstructure. Both samples are heterogeneous in composition. As expected, samples 5408_1 and 5408_2 exhibit similar microstructures. There are two microstructures present, pure ferrite and ferrite with pearlite at the grain ferrite grain boundaries. In the longitudinal section these microstructures form separate bands across the section. The grains are equiaxed but vary in size. In the pure ferrite phase, the grains are large while the ferrite and pearlite grains are considerably smaller in size. The latter, finer microstructure is dominated by the ferrite grains, with the pearlite surrounding the ferrite in small amounts in the grain boundaries. Both samples are heterogeneous in composition.

5420

Object 5420 was sampled twice and the metallographic sample 5420_1 was mounted transversely, as shown in figure 5.61. The polished section (fig. 5.62) revealed a large number of inclusions present in the metal. The majority of these inclusions are slag - forming stringers, elongated in shape and often broken apart into smaller pieces. Several different phases within the slag can be distinguished in some of the larger inclusions. In addition to these inclusions, the corrosion can be seen moving into the metal area, in some cases through the grain boundaries.

The sample was etched with nital for twenty five seconds to reveal the microstructure (fig. 5.63). The sample contains ferrite grains, large in size and equiaxed. The grain size of the ferrite is uniform across the sample. The sample is made of wrought iron. The fact that the slag is often broken into pieces suggests that the forging was carried out at low temperatures during some phase of the shaping process (fig. 5.64).

Summary of Cameroon group B

Following the metallographic analyses, the objects examined from Cameroon group B are all manufactured from bloomery iron. The samples 5398_1, 5407_1 and 5420_1 were identified as wrought iron. Samples 5406_1, 5408_1 and 5408_2 are heterogeneous in composition, identified as low carbon steels. The presence of slag inclusions indicates that the raw material used for these objects was the end product of a traditional iron bloom smelting process. The presence of equiaxed grains and elongated slag inclusions indicate that all five objects were forged to shape.

Cameroon group C

5401

The object was sampled twice and the metallographic sample (5401_1) was mounted transversely, as shown in figure 5.65. The sample was taken by cutting transversely through the socket. The polished section exhibits the characteristic curvature formed to recreate a hafting socket (fig. 5.66). The metal contains very few inclusions giving it a "clean" appearance. The shape of one true edge is preserved in the corrosion.

The sample was etched with nital for 20 seconds to reveal the metal microstructure (fig. 5.67). The microstructure is homogeneous and is characterized by equiaxed grains of pearlite, with some ferrite along the grain boundaries. In the central portion of the section, there is some variation in the size of the pearlite grains, with increased amounts of ferrite at the grain boundaries. The ferrite exhibits an acicular structure. Near the extreme right side of the section, the grains of pearlite are finer, and more ferrite grains are noted (fig. 5.68). The carbon content estimated from the size of the grains is in the range of 0.15 to 0.30 wt. % carbon (Prof. S.M. Allen, personal communication, July 2009). This metal can be described as mild steel.

5309

The object was sampled twice and the metallographic sample (5401_1) was mounted transversely, as shown in figure 5.69. The polished section shows slight curvature of the metal in the area sampled (fig. 5.70).

The sample was etched with nital for 20 seconds to reveal the metal microstructure (fig. 5.71). The microstructure is homogeneous and is characterized by very fine, equiaxed grains of pearlite with limited amounts of ferrite in the grain boundaries. In certain parts of the section, including the central portion, the grains of pearlite are slightly larger in size (see fig. 5.72). This may be explained by the relative cooling rates of the metal as a function of its thickness. The areas where the metal is thinner cooled faster, limiting the growth of grains and resulting in affine grain structure. In the thicker portions of the sample, such as at the middle section, the rate of cooling was slower, allowing the growth of large, pearlite grains. The carbon content estimated from the size of the grains would be in the range of 0.18 to 0.30 wt. % (Prof. S.M. Allen, personal communication, July 2009). This metal can be described as mild steel.

5410

The object was sampled twice and the metallographic sample (5410_1) was mounted transversely, as shown in figure 5.73. The polished section shows the curvature of the metal associated with the socket and characteristic of this group type (5.74). The metal has a number of slag inclusions, elongated in shape and running longitudinally across the section, following the flow of the metal.

The sample was etched with nital for twenty seconds to reveal the metal microstructure. The microstructure is homogeneous and is characterized by large, equiaxed grains of ferrite (figs. 5.75- 5.76). The presence of ferrite alone indicates that the object was made of wrought iron.

5422

The object was sampled twice and the metallographic sample (5422_1) was mounted transversely, as shown in figure 5.77. The polished section has a homogeneous appearance, with a number of small, circular inclusions (fig. 5.78).

The sample was etched with nital for twenty seconds to reveal the metal microstructure (5.79). The microstructure is homogeneous and is characterized by very fine, equiaxed grains of pearlite with limited amounts of ferrite in the grain boundaries (fig. 5.80).

Summary of Cameroon group C

Following the metallographic analysis, the objects examined from Cameroon group C are all manufactured from bloomery iron. The samples 5401_1, 5409_1 and 5422_1 were identified as mild steels. Sample 5410_1 is identified as wrought iron. The presence of slag inclusions indicates that the raw material used for these objects was the end product of a traditional iron bloom smelting process. The presence of equiaxed grains and elongated slag inclusions indicates that all four objects were forged to shape.

Cameroon group D

5411

The object was sampled twice and the metallographic sample (5411_1) was mounted transversely, as shown in figure 5.81. The polished section has a dense and homogeneous distribution of small, circular inclusions. These are uniform in shape across the sample. The section does not contain any stringers of slag, common to the other samples in the research corpus (5.82).

The sample was etched with nital for twenty seconds to reveal the metal microstructure. The section exhibits a homogeneous microstructure with large, equiaxed grains of pearlite (fig. 5.83). These are surrounded at the grain boundaries by moderate amounts of acicular ferrite (fig. 5.84). The acicular ferrite has the characteristic needle-like structure and high angle boundaries between the grains (fig. 5.85). From the carbon content estimated for this metal (0.18% wt. %) and given the size of the pearlite grains would, this metal can be described as mild steel.

5412

The object was sampled twice. The metallographic sample (5412_1) was taken by cutting transversely through the flat edge of the object, then mounting the sample longitudinally to include the section of the tip (5.86). The polished section (fig. 5.87) exhibits two types of inclusions, the first type being small and circular in shape, similar to those noted in sample 5411. The other type is in the form of elongated stringers of slag. On the upper part of the section, these slag stringers follow the direction of metal flow. On the lower left portion of the section, the metal contains a large fissure. This is now filled with corrosion that can be seen moving into the metal. It is unclear if this fissure represents a boundary between two hammer welded separate pieces of metal. It resembles more an overlap of one forged portion of the metal onto another. The shape of the tip at the extreme right end of the section is well preserved by the corrosion.

The sample was etched with nital for eight seconds, to reveal the metal microstructure (fig. 5.88). The section exhibits a homogeneous microstructure with equiaxed grains of pearlite and ferrite, distributed across the sample (fig. 5.89). Given the microstructure observed, this metal can also be described as mild steel.

5413

The object was sampled twice and the metallographic sample (5413_1) was mounted longitudinally, as shown in figure 5.90. The tip of the object can be seen at the extreme left side of the photomicrograph (fig. 5.91). The metal has been heavily hammered to shape, as evidenced by the fissures in the material and the considerable thinness of the inclusions. As a result of the presence of several fissures in this area, the material is now in bad condition due to extensive corrosion. The polished section exhibits a dense distribution of slag stringers. These are elongated and follow the flow of the metal across the sample. Some of these stringers are large enough to exhibit the different phases present in the slag. At high magnification, the light phase forms dendritic patterns within a darker phase.

The sample was etched with nital for thirty seconds to reveal the metal microstructure. The section exhibits a homogeneous microstructure of ferrite grains (fig. 5.92). These grains are large in size. When examined at a magnification of 100 the grains reveal a sub-structural pattern resembling elongated lines or cells. It is not clear what this substructure could be, given that the metal is pure iron. At a lower magnification of 50, the substructure seems to form zones running longitudinally across the sample. The sample is identified as wrought iron.

Summary of Cameroon Group D

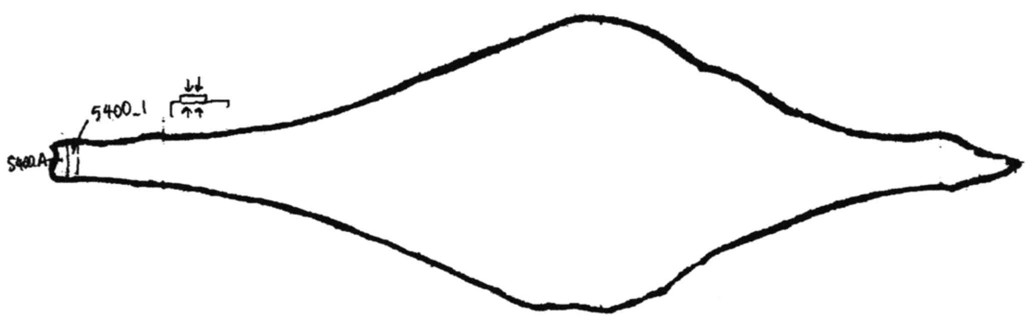
Following the metallographic analysis, the objects examined from Group D are all manufactured from bloomery iron. The samples 5411_1 and 5412_1 are identified as mild steels. Sample 5413_1 is identified as wrought iron. The presence of slag inclusions indicates that the raw material used for these objects was the end product of a traditional iron bloom smelting process. The presence of equiaxed grains and elongated slag inclusions indicates that all three objects were forged to shape.

CHAPTER V: Figures

MIT 5400

l: 18.9 cm
w: 5.71 cm
weight: 55.56 gr

Sampling



MIT 5400_1 **Sample mounted transversely**
h: 0.22 cm
w: 0.58 cm
l: 0.31 cm

Figure 5.1

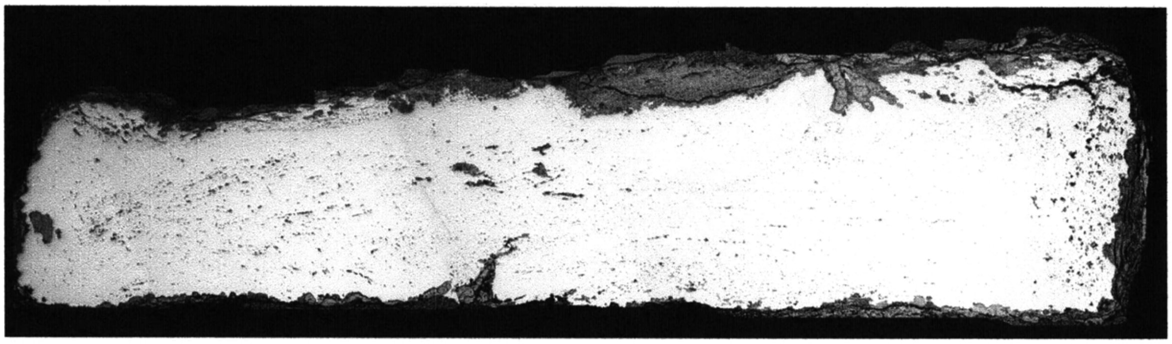


Image Number: Mosaic with MIT 5400_1-1 to 5400_1-9
Microscope: Leica DMLM
Magnification: 18
Etchant: As polished
Description: Iron object
Date: 15.iii.2009
Operator: Ismini Papakirillou

Figure 5.2

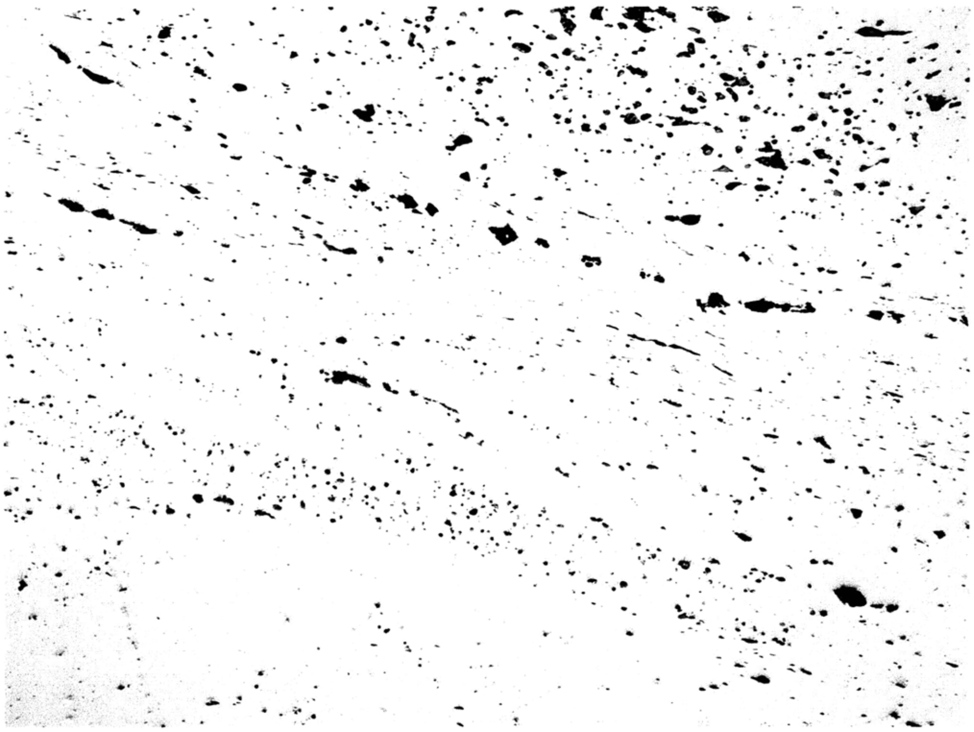


Image Number: MIT 5400_1-17
Microscope: Leica DMLM
Magnification: 200
Etchant: As polished
Description: Iron object
Date: 20.iii.2009
Operator: Ismini Papakirillou

Figure 5.3

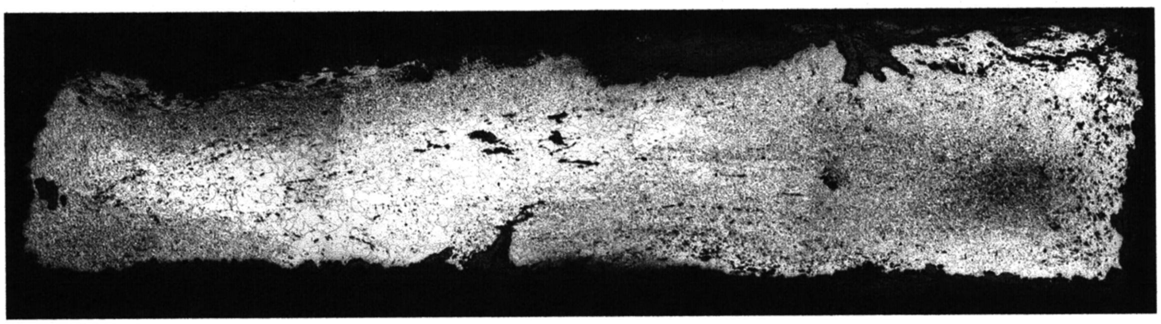


Image Number: Mosaic with MIT 5400_1-28 to 5421_1-36
Microscope: Leica DMLM
Magnification: 18
Etchant: Nital
Description: Iron object
Date: 19.iii.2009
Operator: Ismini Papakirillou

Figure 5.4

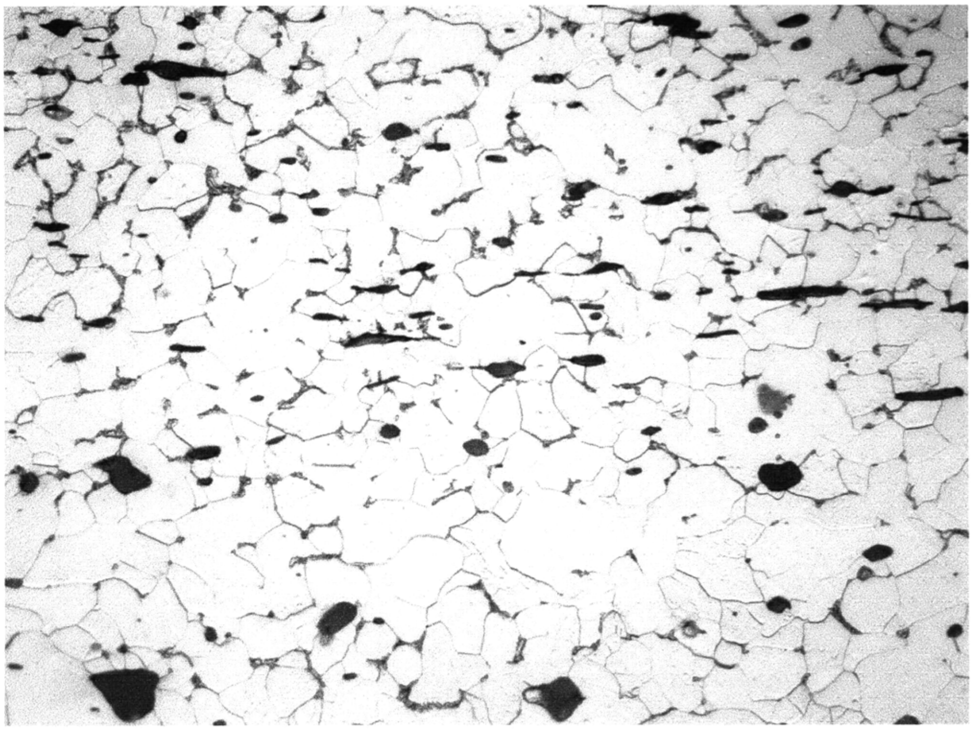


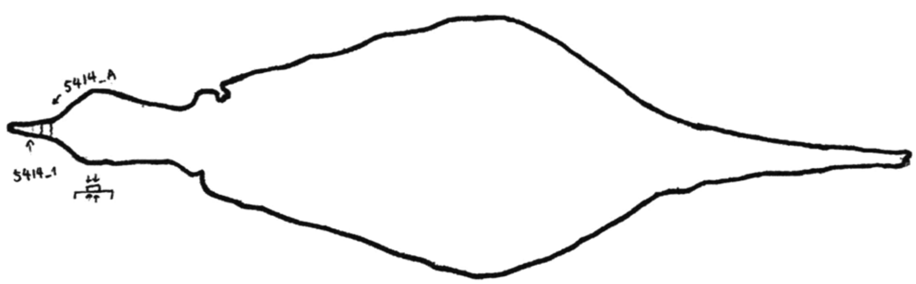
Image Number: MIT 5400_1-27
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 19.iii.2009
Operator: Ismini Papakirillou

Figure 5.5

MIT 5414

l: 22.64 cm
w: 6.59 cm
weight: 30.68 gr

Sampling



MIT 5414_1
h: 0.26 cm
w: 0.18 cm
l: 0.27 cm

Sample mounted transversely

Figure 5.6

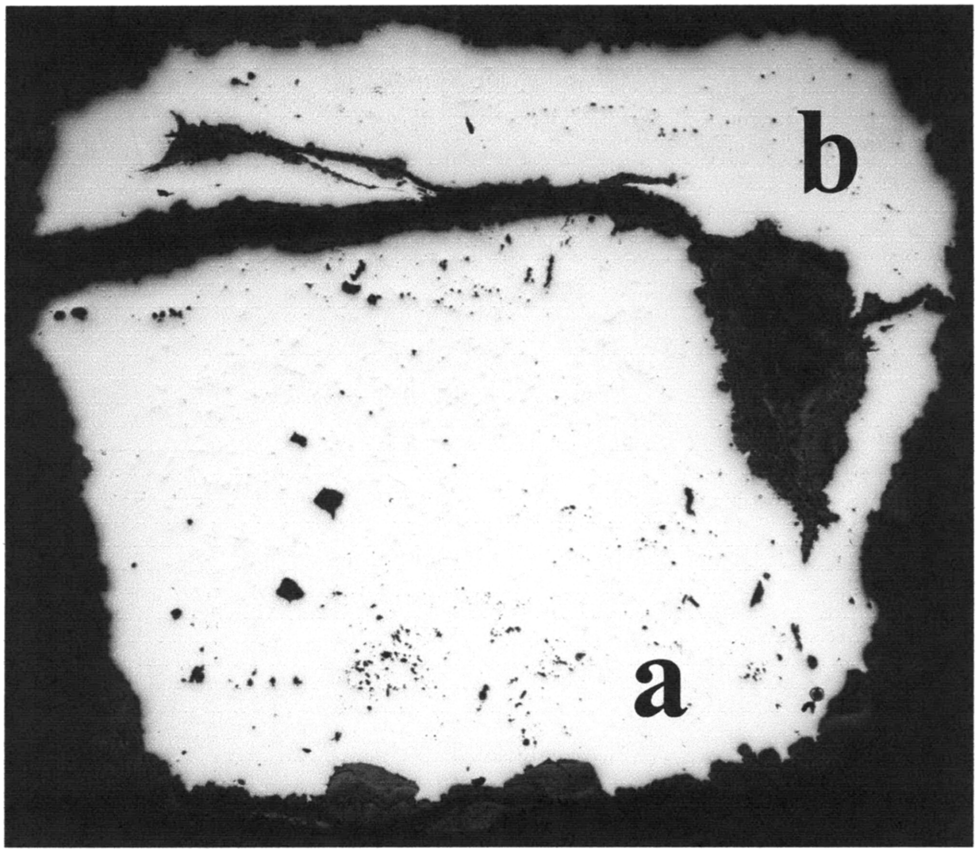


Image Number: Mosaic with MIT 5414_1-1 to 5414_1-3
Microscope: Leica DMLM
Magnification: 50
Etchant: As polished
Description: Iron object
Date: 26.vi.2009
Operator: Ismini Papakirillou

Figure 5.7

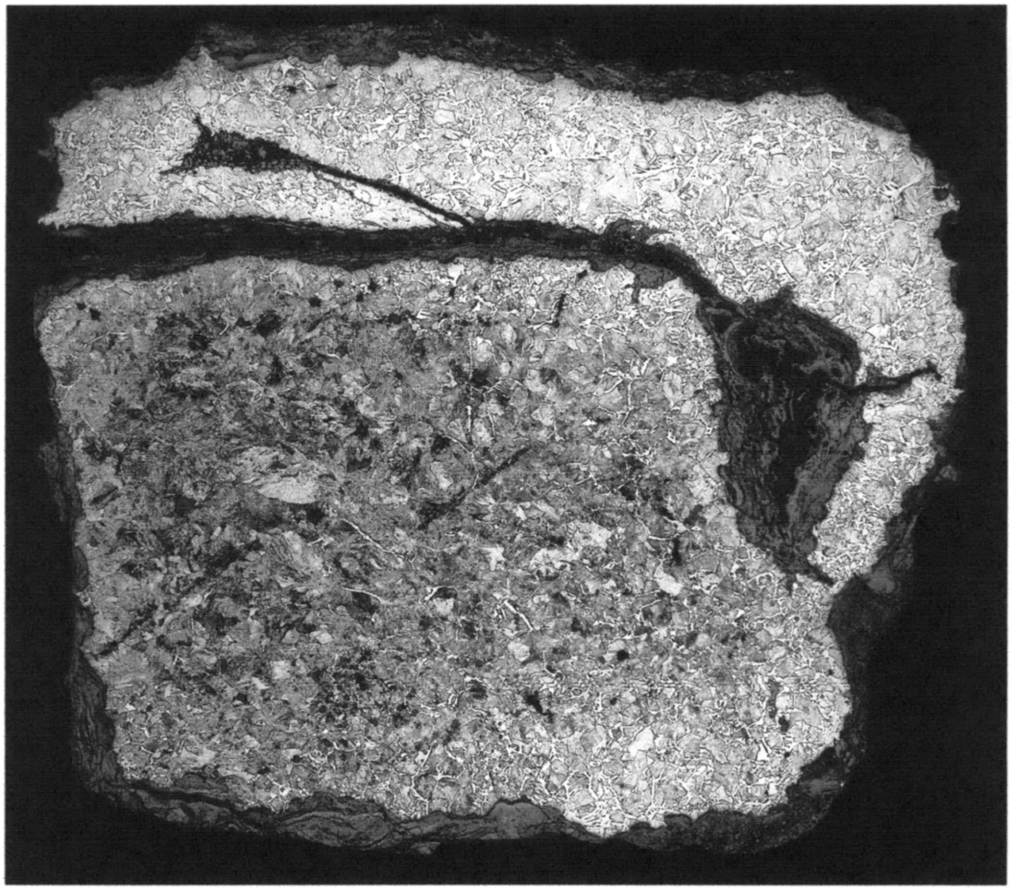


Image Number: Mosaic with MIT 5414_1-5 to 5414_1-7
Microscope: Leica DMLM
Magnification: 50
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.8

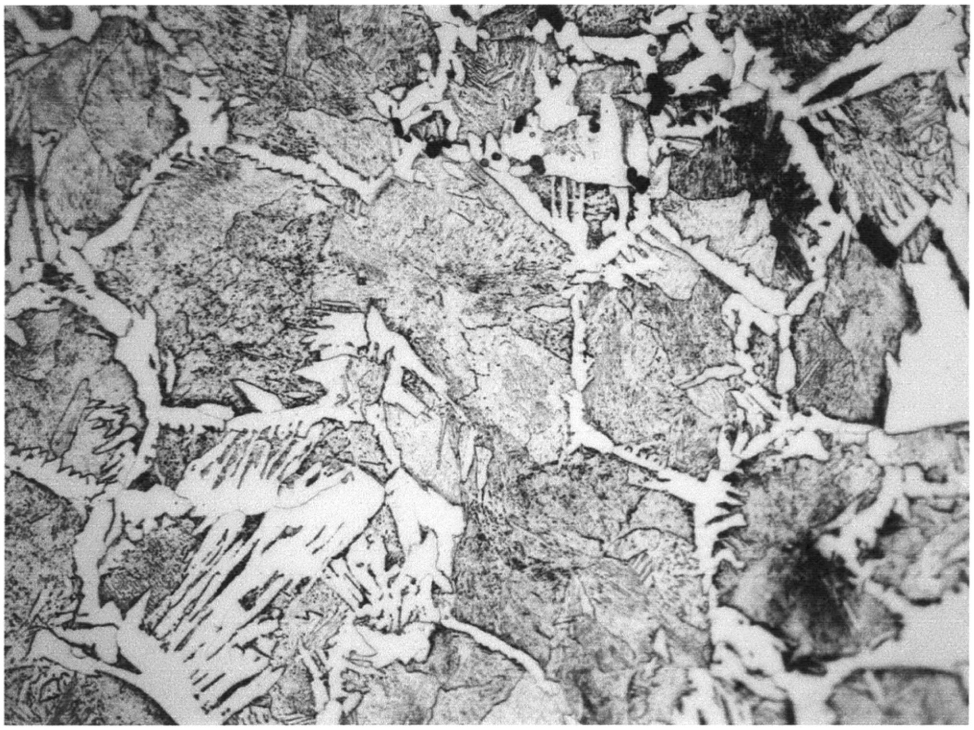


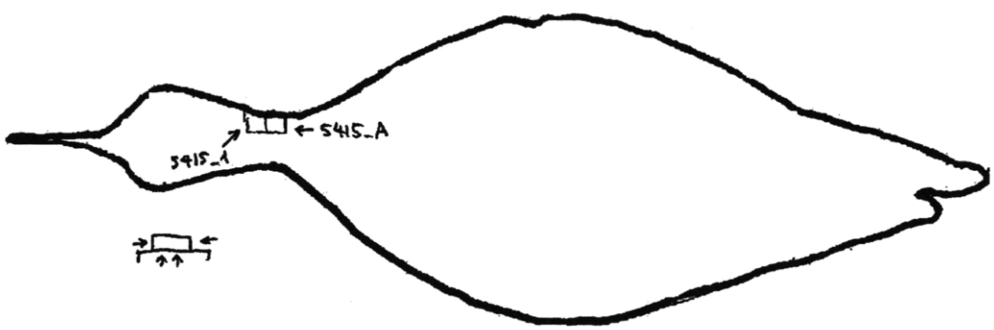
Image Number: MIT 5414_1-9
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.9

MIT 5415

l: 18.5 cm
w: 5.74 cm
weight: 37.29 gr

Sampling



MIT 5415_1
h: 0.42 cm
w: 0.29 cm
l: 0.55 cm

Sample mounted longitudinally

Figure 5.10

Image Number: Mosaic with MIT 5415_1-1 to 5415_1-9
Microscope: Leica DMLM
Magnification: 20
Etchant: As polished
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.11

Image Number: MIT 5415_1-11
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 26.vi.2009
Operator: Ismini Papakirillou

Figure 5.12

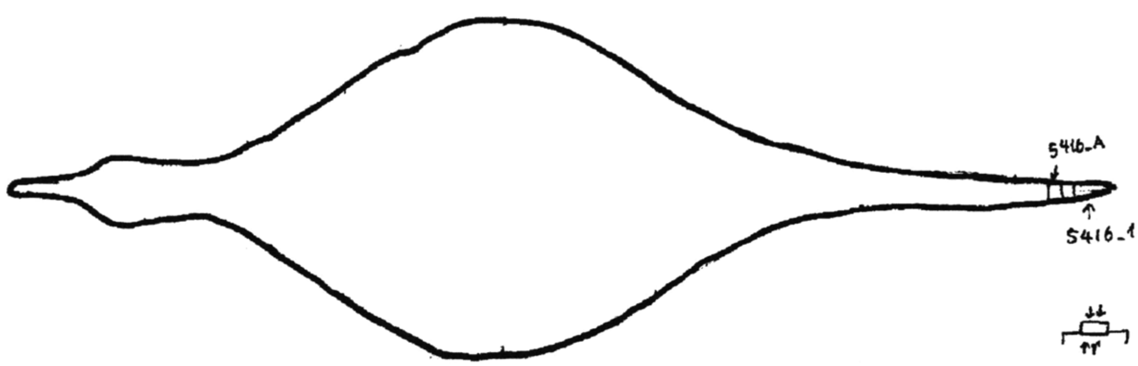
Image Number: Mosaic with MIT 5415_1-13 to 5415_1-22
Microscope: Leica DMLM
Magnification: 20
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.13

MIT 5416

l: 21.9 cm
w: 6.83 cm
weight: 78.18 gr

Sampling



MIT 5416_1 **Sample mounted transversely**
h: 0.47 cm
w: 0.29 cm
l: 0.26 cm

Figure 5.14

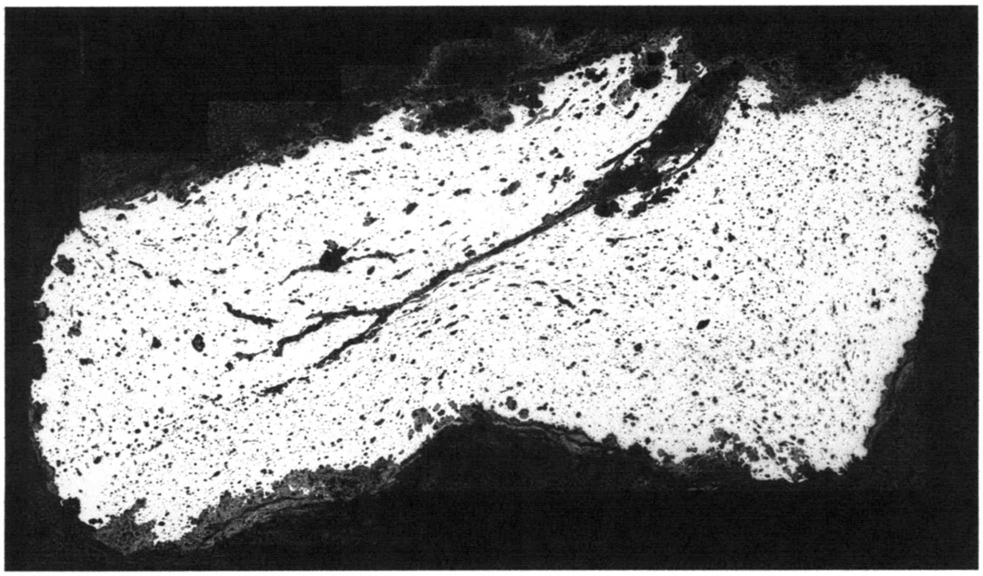


Image Number: Mosaic with MIT 5416_1-1 to 5416_1-6
Microscope: Leica DMLM
Magnification: 25
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.15

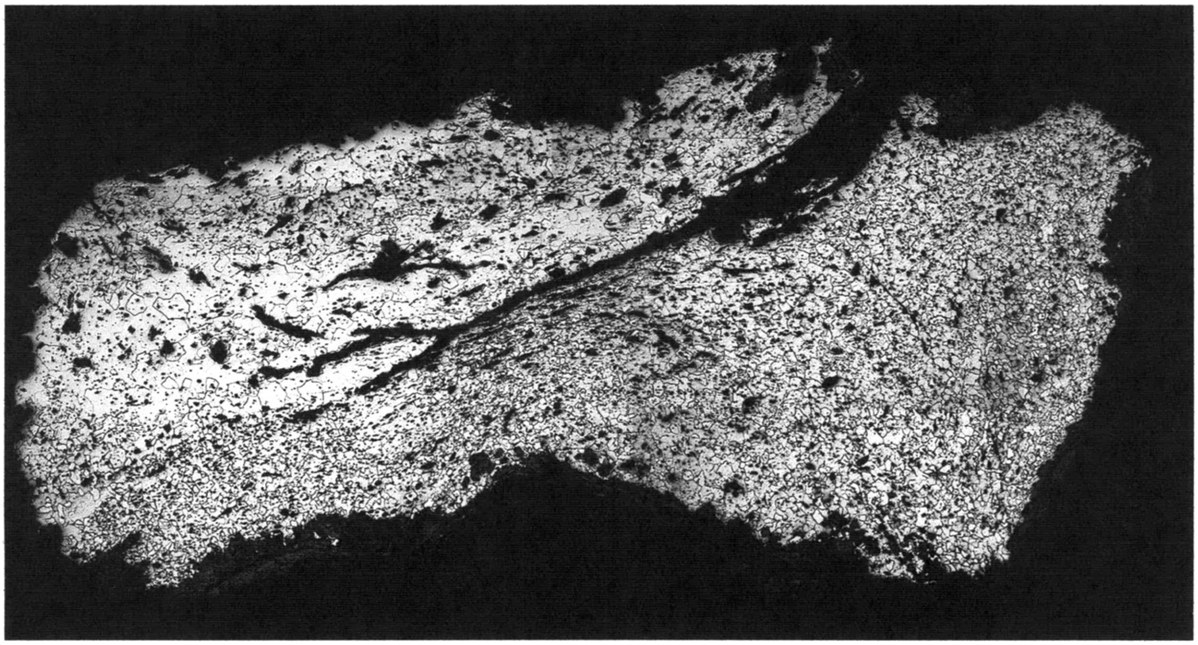


Image Number: Mosaic with MIT 5416_1-10 to 5416_1-15
Microscope: Leica DMLM
Magnification: 30
Etchant: Nital
Description: Iron object
Date: 3.vii.2009
Operator: Ismini Papakirillou

Figure 5.16

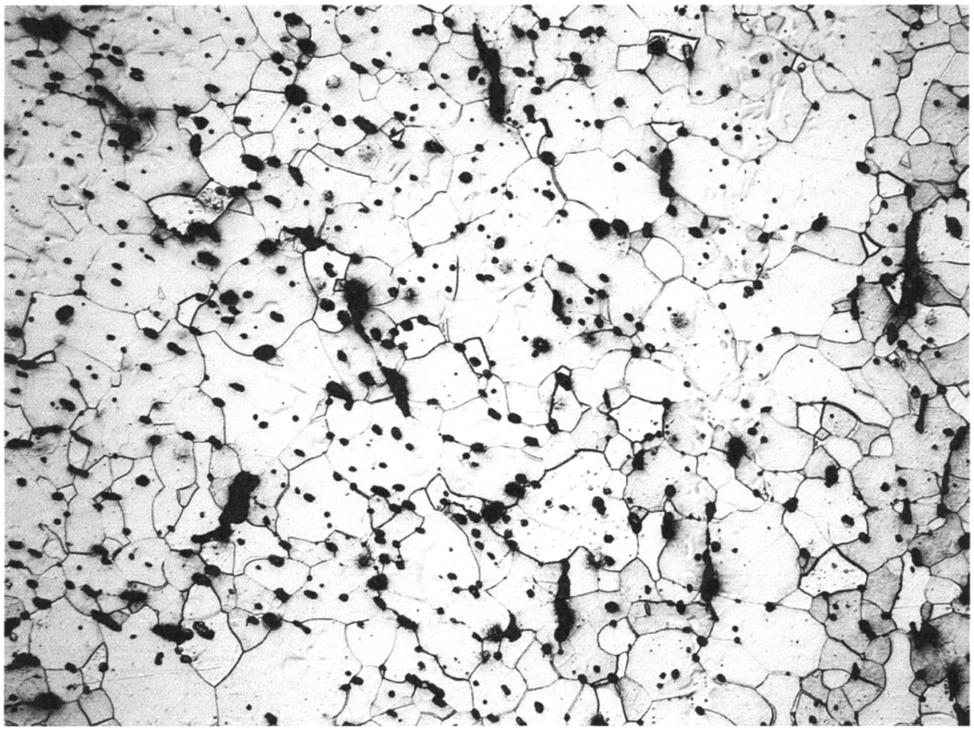


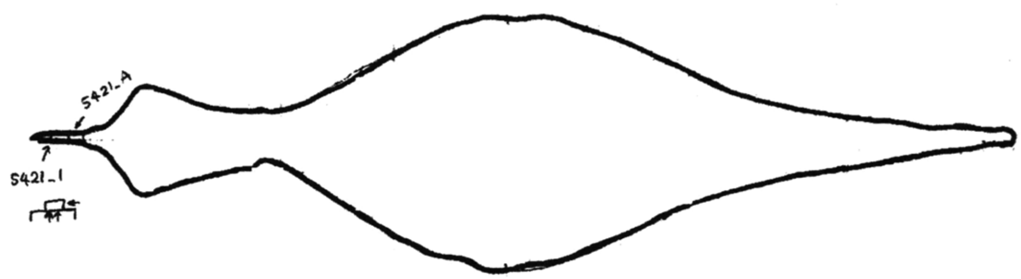
Image Number: MIT 5416_1-17
Microscope: Leica DMLM
Magnification: 200
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.17

MIT 5421

l: 22.1 cm
w: 5.73 cm
weight: 38.43 gr

Sampling



MIT 5421_1 **Sample mounted longitudinally**
h: 0.31 cm
w: 0.11 cm
l: 0.50 cm

Figure 5.18

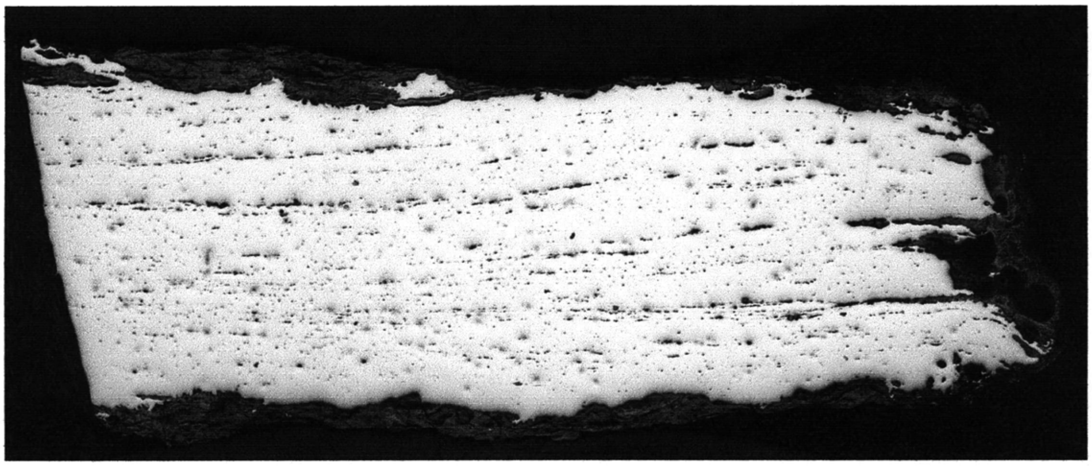


Image Number: Mosaic with MIT 5421_1-1 to 5421_1-2
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.19

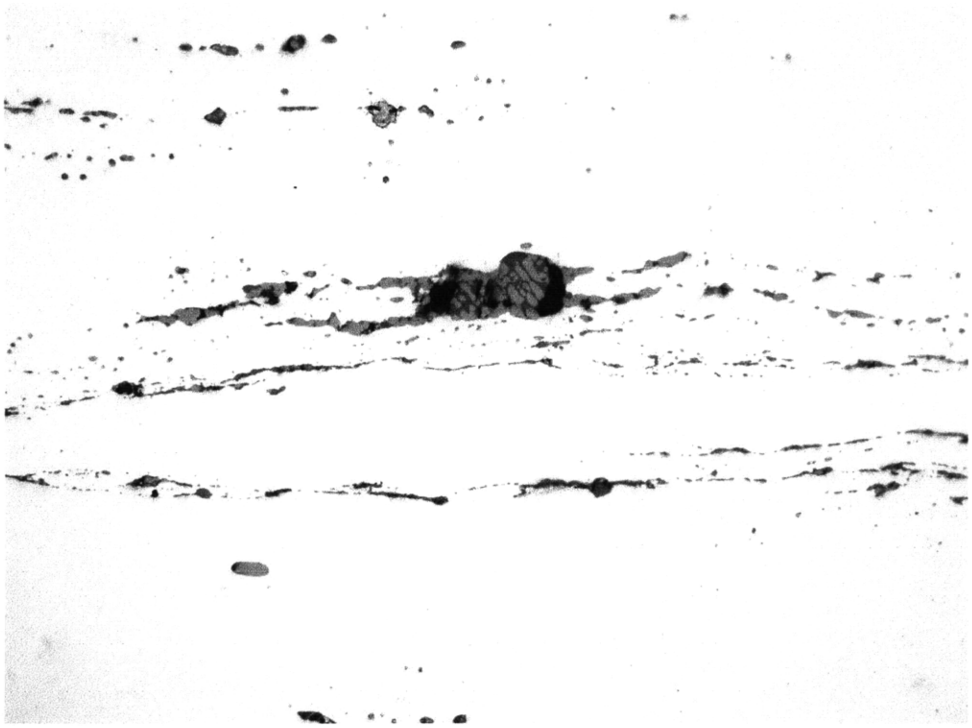


Image Number: MIT 5421_1-4
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.20

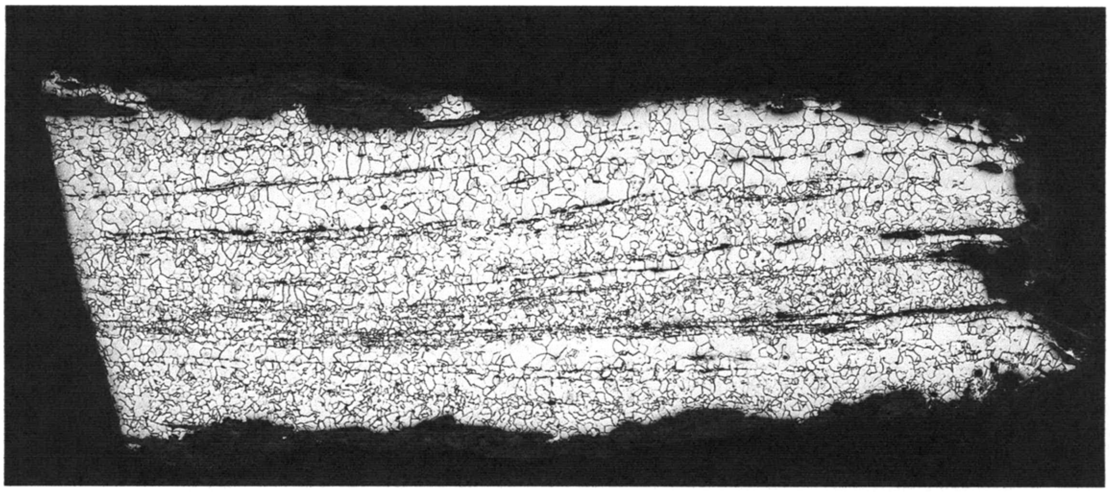


Image Number: Mosaic with MIT 5421_1-5 to 5421_1-6
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 2.vii.2009
Operator: Ismini Papakirillou

Figure 5.21

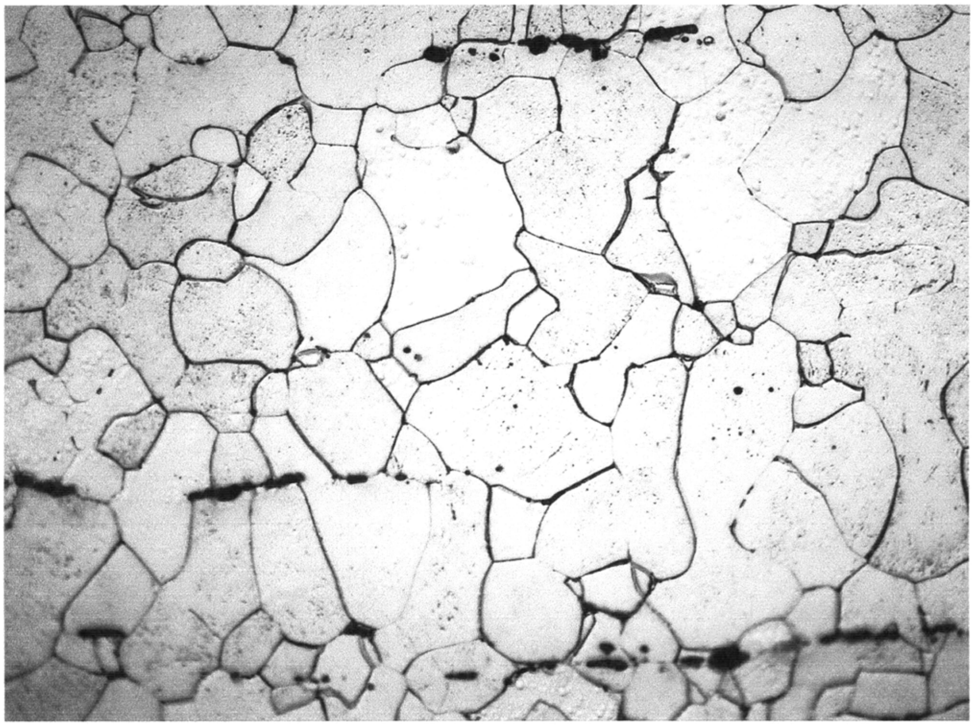


Image Number: MIT 5421_1-8
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 2.vii.2009
Operator: Ismini Papakirillou

Figure 5.22

MIT 5399

l: 43.74 cm
w: 2.68 cm
weight: 41.86 gr

Sampling

MIT 5399_1
h: 0.20 cm
w: 0.17 cm
l: 0.39 cm

Sample mounted transversely

Figure 5.23

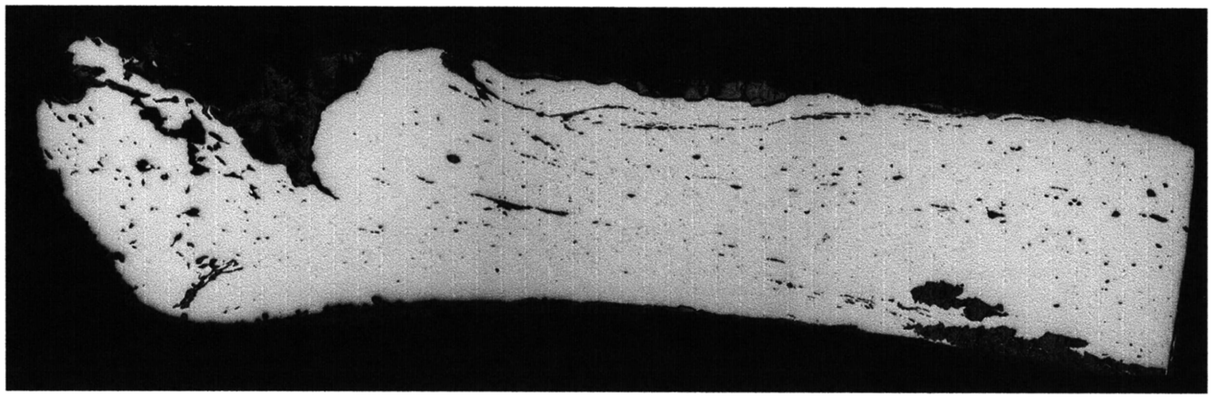


Image Number: Mosaic with MIT 5399_1-1 to 5399_1-13
Microscope: Leica DMLM
Magnification: 25
Etchant: As polished
Description: Iron object
Date: 12.iii.2009
Operator: Ismini Papakirillou

Figure 5.24

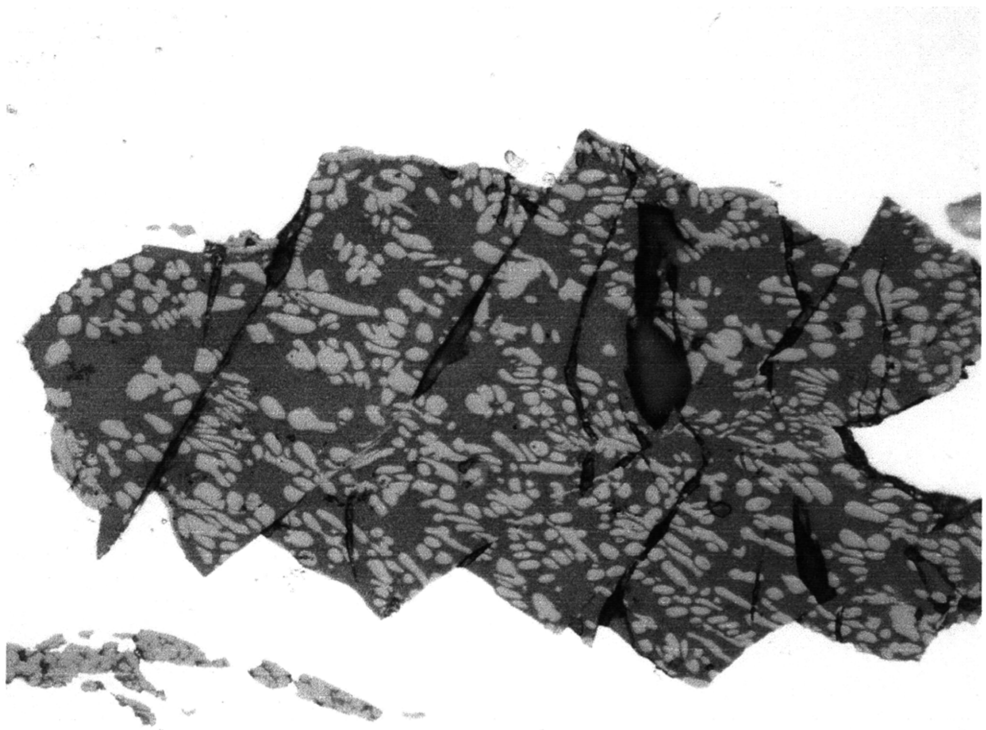


Image Number: MIT 5399_1-5
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 20.iii.2009
Operator: Ismini Papakirillou

Figure 5.25

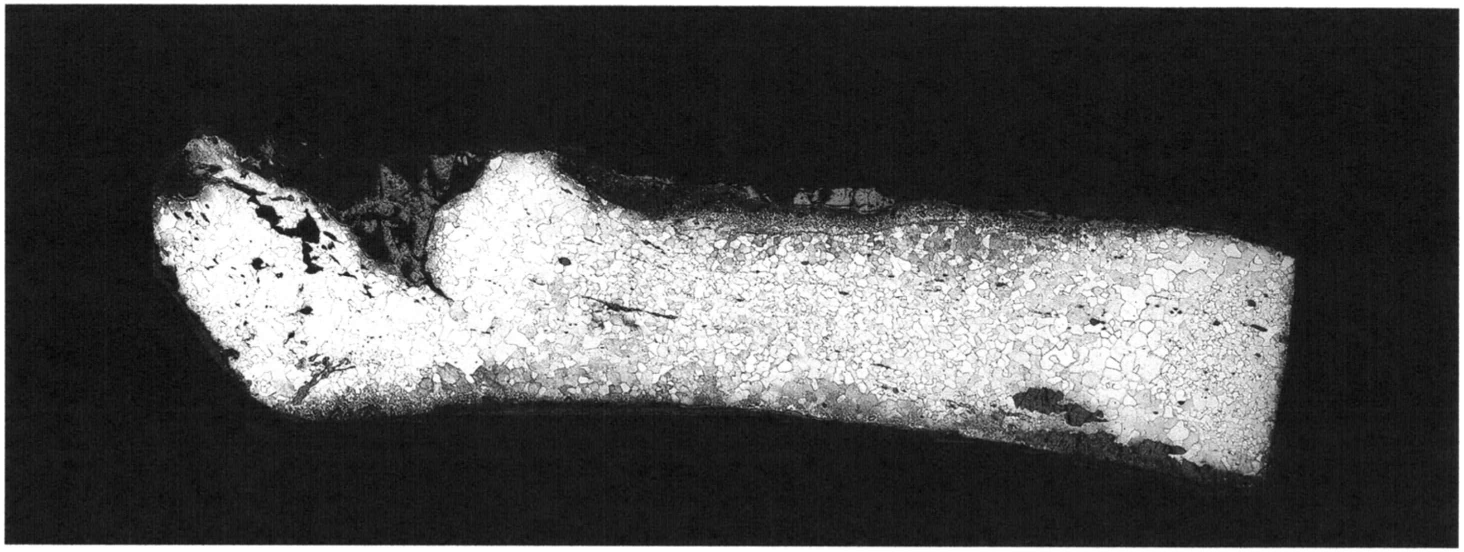


Image Number: Mosaic with MIT 5399_1-17 to 5399_1-18
Microscope: Leica DMLM
Magnification: 25
Etchant: Nital
Description: Iron object
Date: 19.iii.2009
Operator: Ismini Papakirillou

Figure 5.26

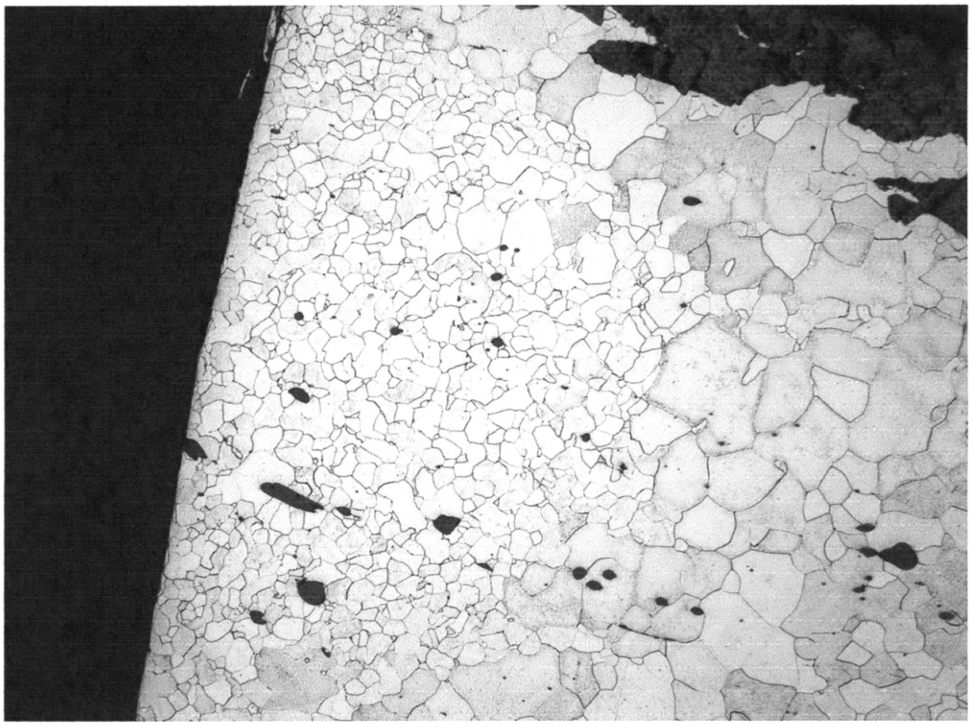


Image Number: MIT 5399_1-10
Microscope: Leica DMLM
Magnification: 100
Etchant: Nital
Description: Iron object
Date: 21.iii.2009
Operator: Ismini Papakirillou

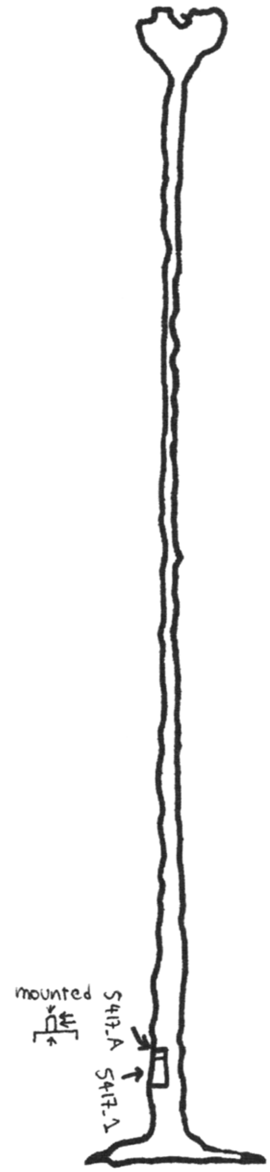
Figure 5.27

MIT 5417

l: 20.35 cm
w: 3.23 cm
weight: 48.11 gr

Sampling

MIT 5417_1
h: 0.13 cm
w: 0.17 cm
l: 0.45 cm



Sample mounted transversely

Figure 5.28

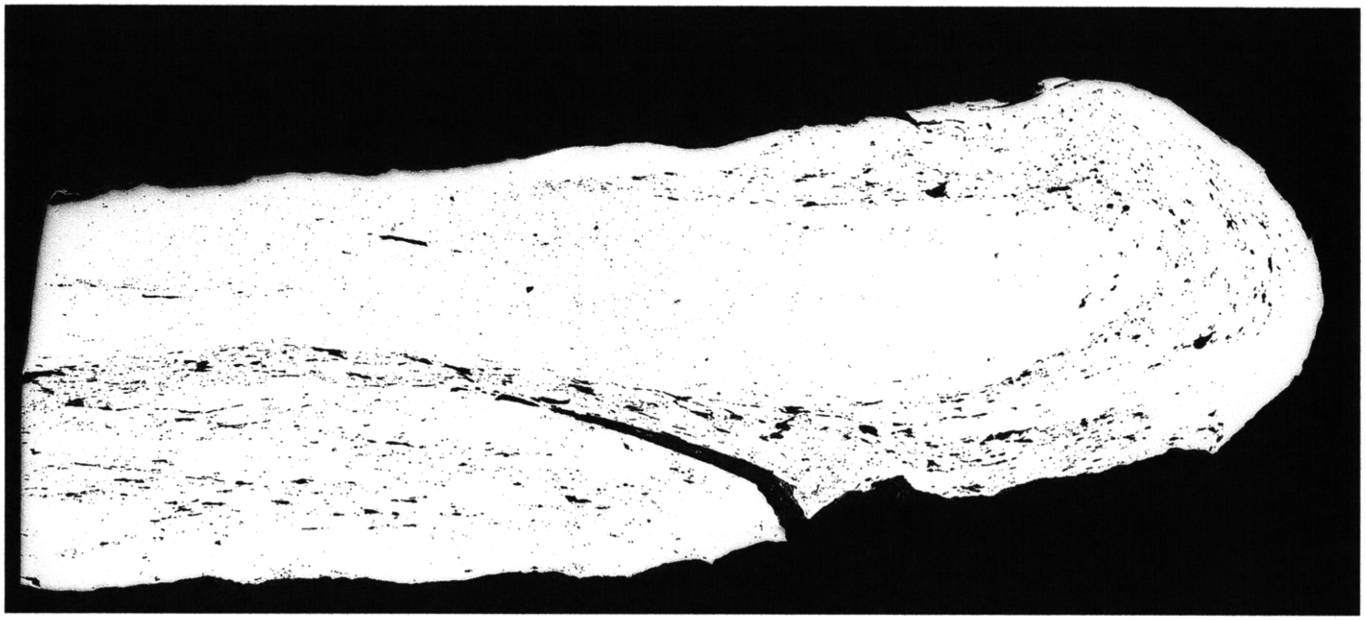


Image Number: Mosaic with MIT 5417_1-1 to 5417_1-6
Microscope: Leica DMLM
Magnification: 30
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.29

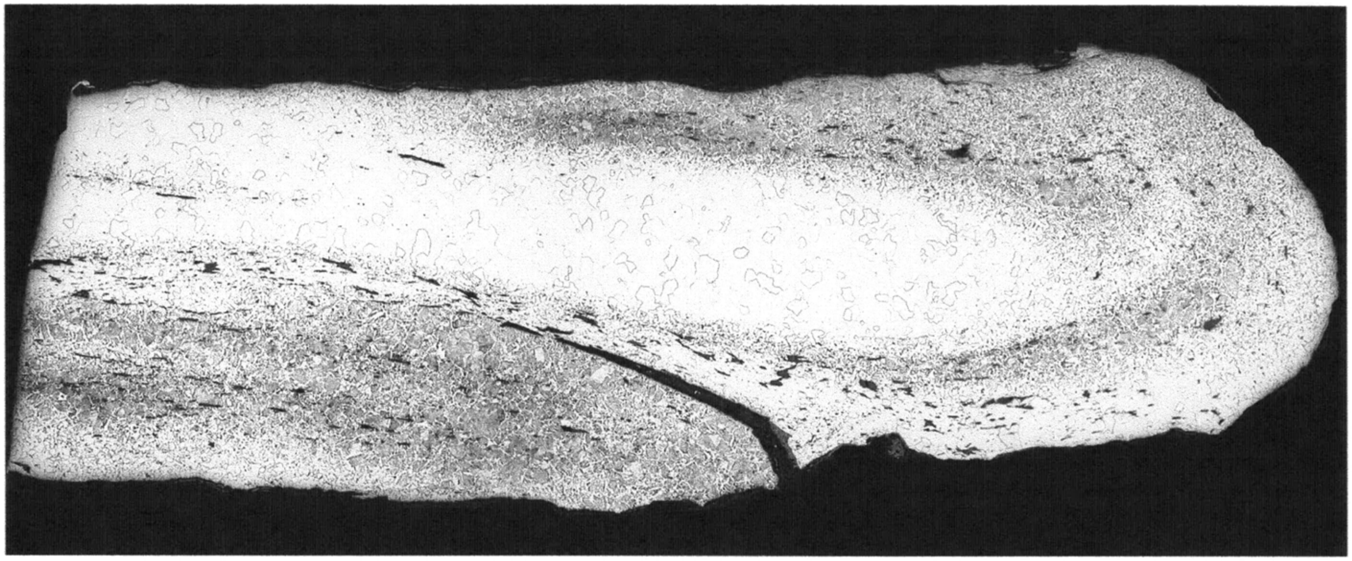


Image Number: Mosaic with MIT 5417_1-9 to 5417_1-13
Microscope: Leica DMLM
Magnification: 30
Etchant: Nital
Description: Iron object
Date: 2.vii.2009
Operator: Ismini Papakirillou

Figure 5.30

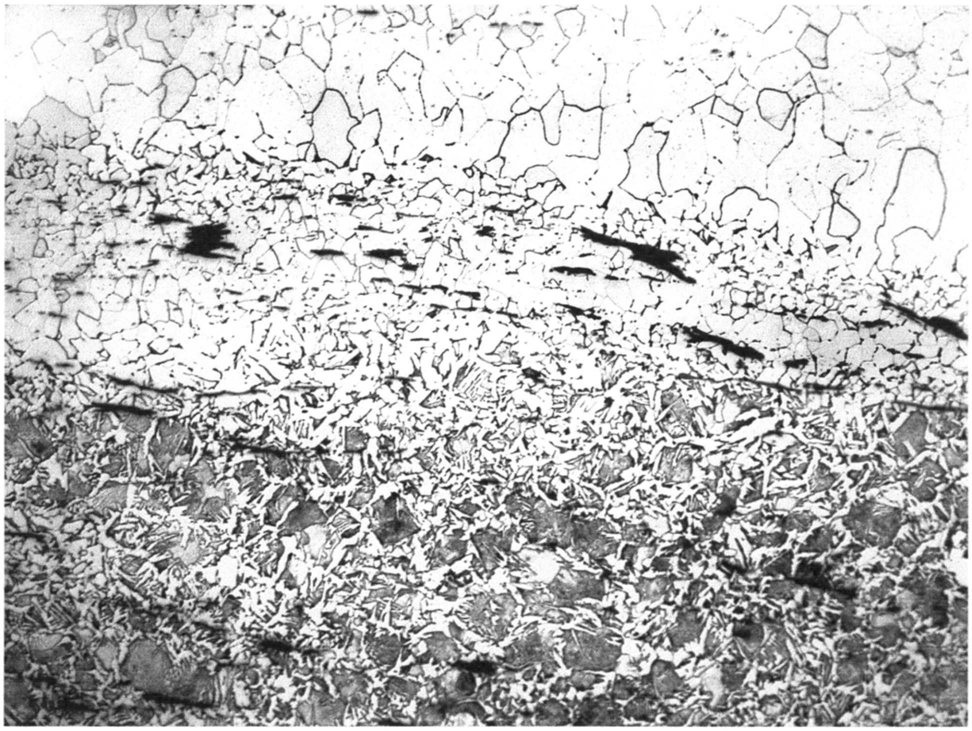


Image Number: MIT 5417_1-14
Microscope: Leica DMLM
Magnification: 200
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.31

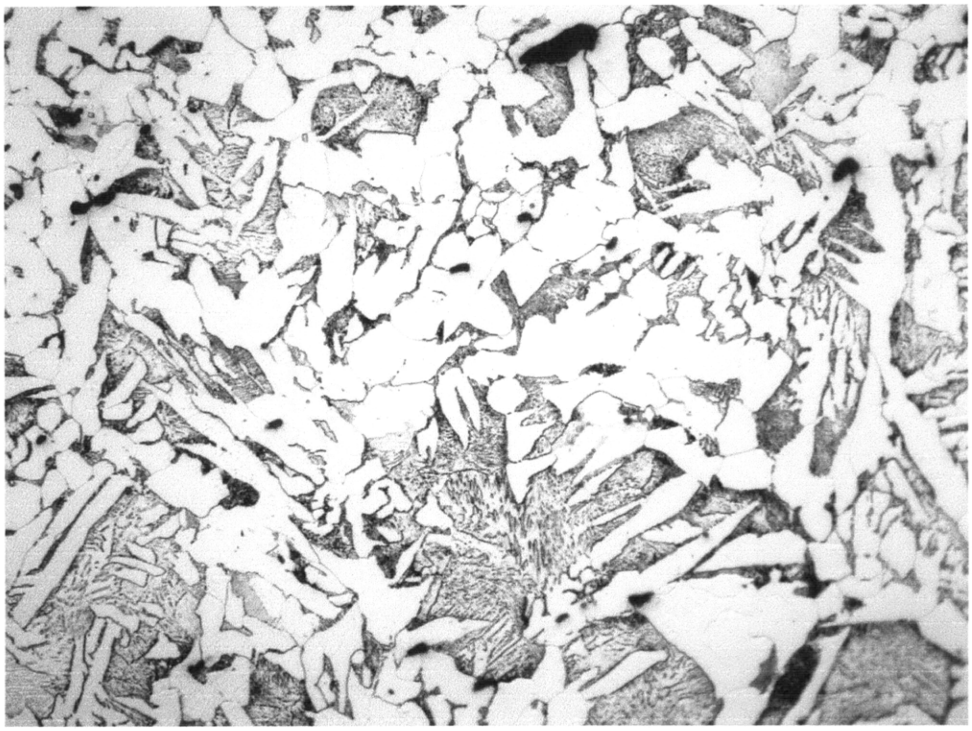
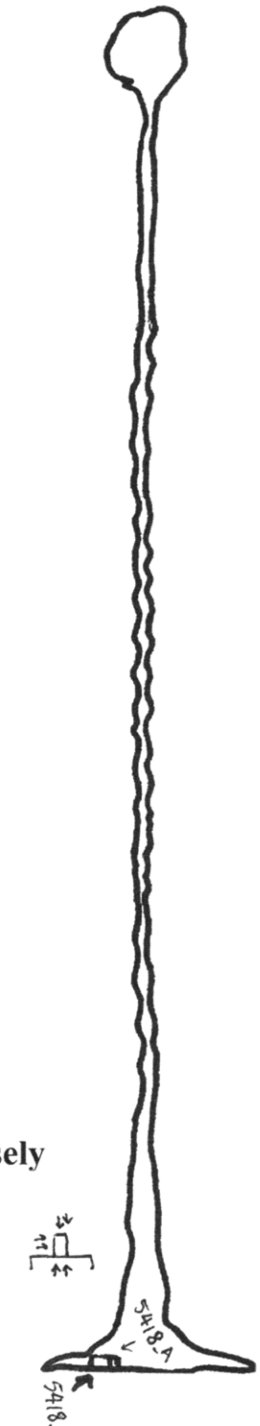


Image Number: MIT 5417_1-17
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.32

MIT 5418

l: 20.63 cm
w: 3.48 cm
weight: 35.36 gr



Sampling

MIT 5418_1
h: 0.50 cm
w: 0.11 cm
l: 0.79 cm

Sample mounted transversely

Figure 5.33

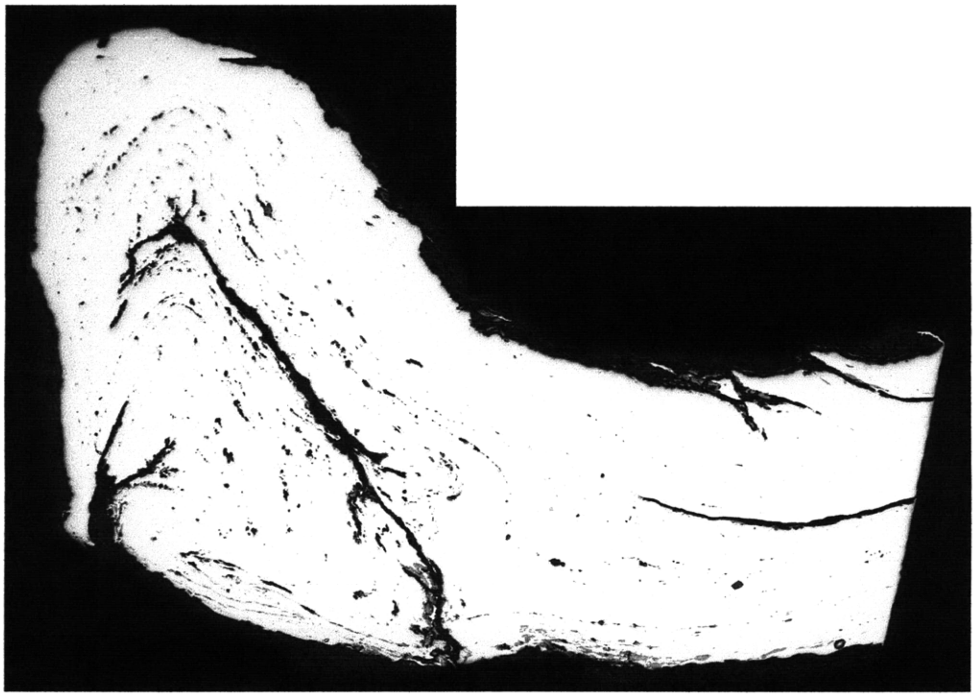


Image Number: Mosaic with MIT 5418_1-1 to 5418_1-3
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.34

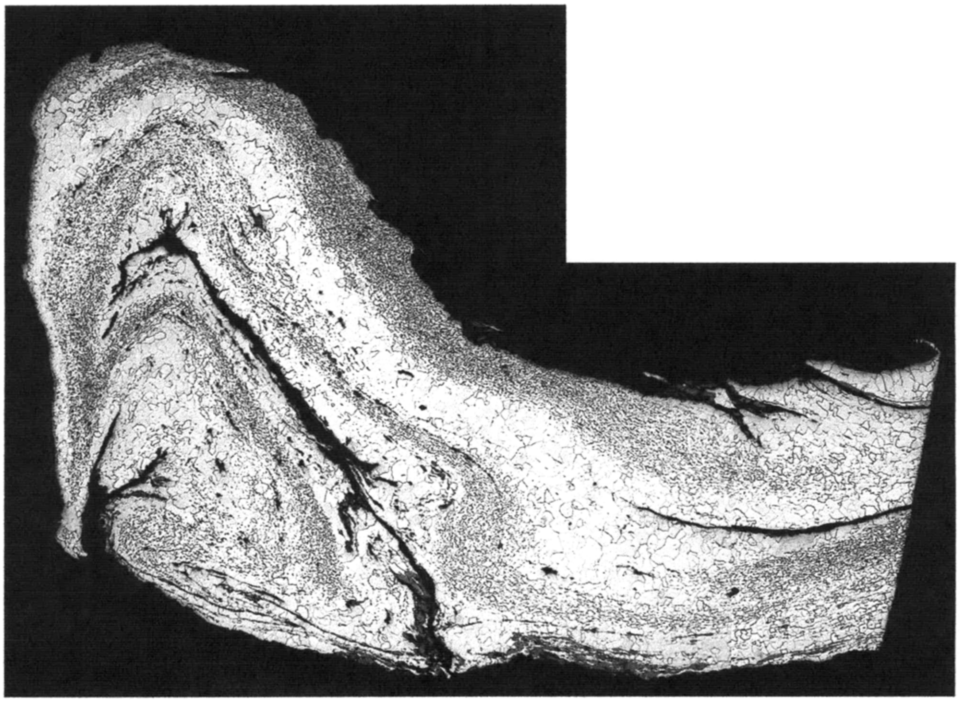
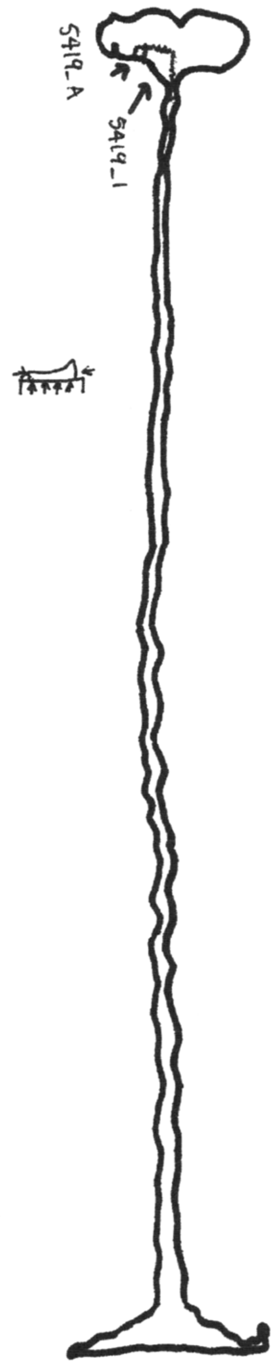


Image Number: Mosaic with MIT 5418_1-8 to 5418_1-10
Microscope: Leica DMLM
Magnification: 50
Etchant: Nital
Description: Iron object
Date: 2.vii.2009
Operator: Ismini Papakirillou

Figure 5.35

MIT 5419

l: 19.90 cm
w: 3.05 cm
weight: 44.01 gr



Sampling

MIT 5419_1
h: 0.17 cm
w: 0.27 cm
l: 1.05 cm

Sample mounted longitudinally

Figure 5.36

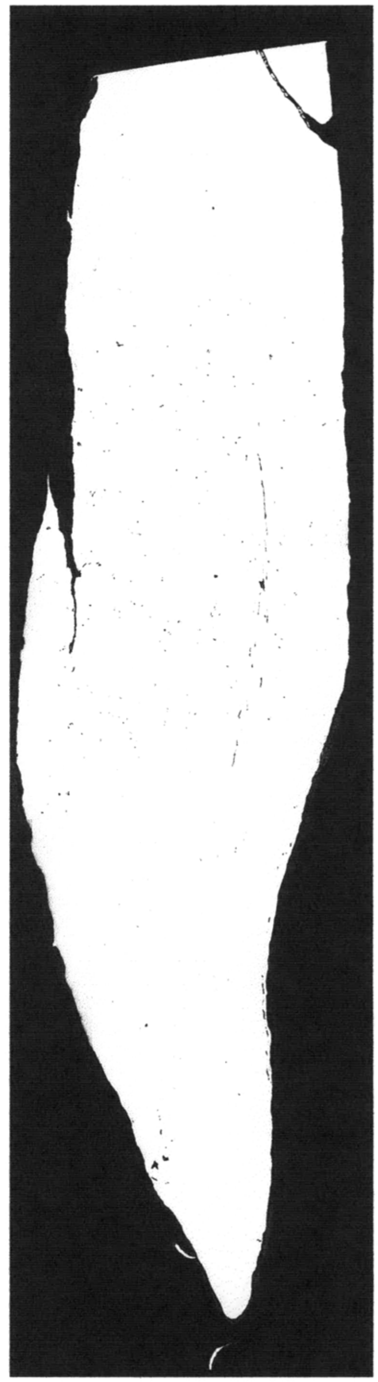


Image Number: Mosaic with MIT 5419_1-1 to 5419_1-15
Microscope: Leica DMLM
Magnification: 15
Etchant: As polisehd
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

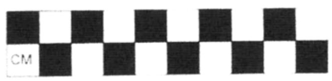
Figure 5.37

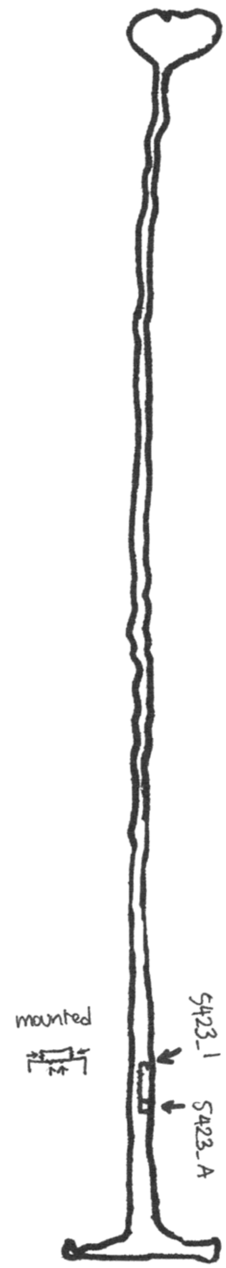
Image Number: Mosaic with MIT 5419_1-17 to 5419_1-28
Microscope: Leica DMLM
Magnification: 15
Etchant: Nital
Description: Iron object
Date: 2.vii.2009
Operator: Ismini Papakirillou

Figure 5.38

MIT 5423

l: 20.37 cm
w: 2.48 cm
weight: 45.18 gr





Sampling

MIT 5423_1
h: 0.30 cm
w: 0.22 cm
l: 0.81 cm

Sample mounted longitudinally

Figure 5.39

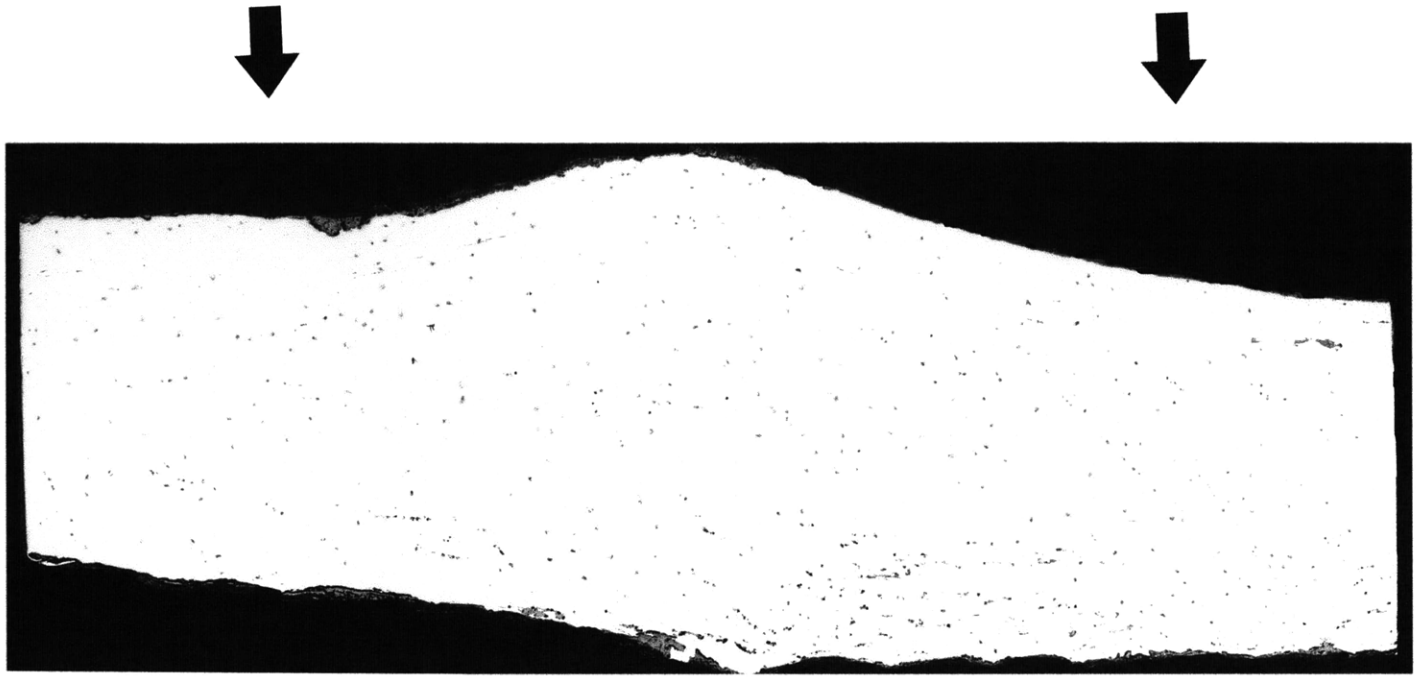


Image Number: Mosaic with MIT 5423_1-1 to 5423_1-14
Microscope: Leica DMLM
Magnification: 20
Etchant: As polished
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.40

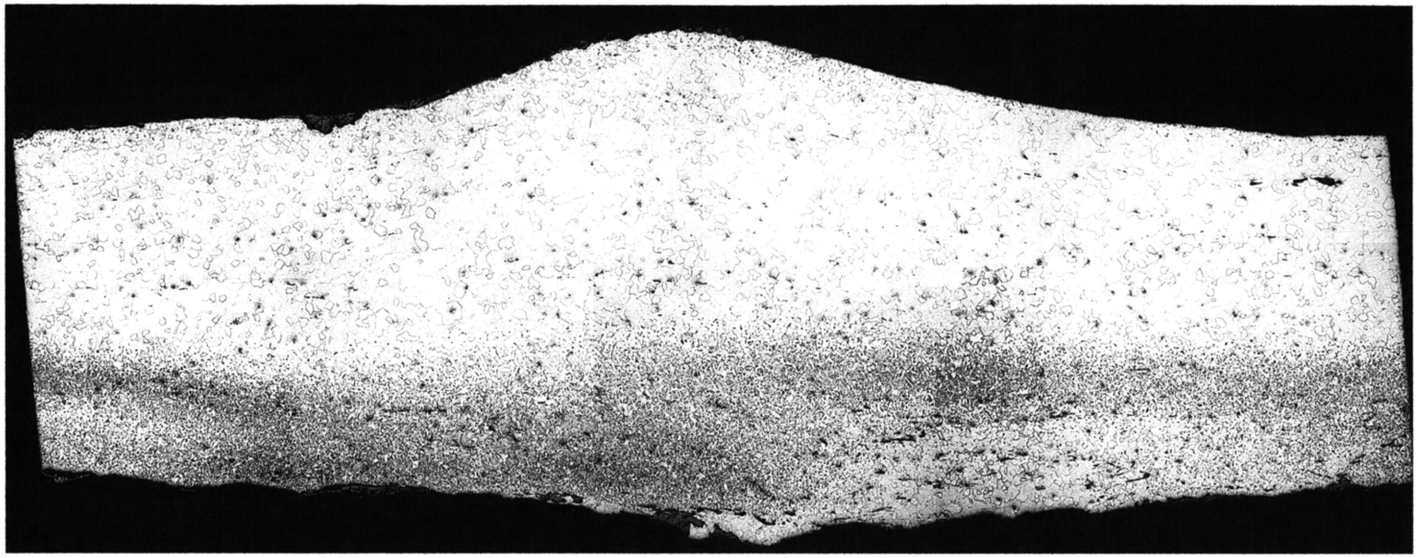


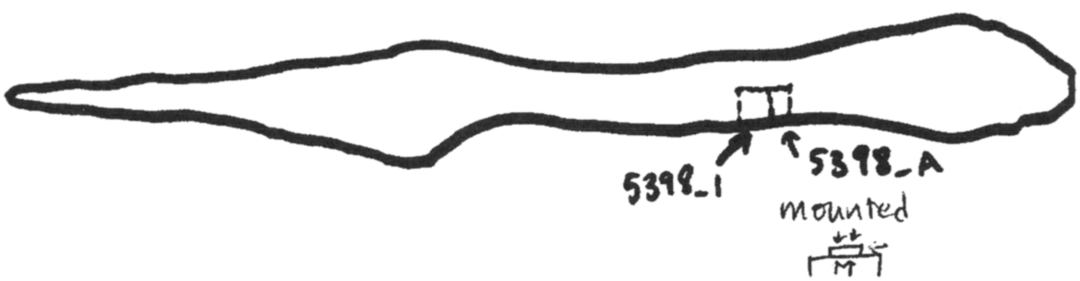
Image Number: Mosaic with MIT 5423_1-21 to 5423_1-28
Microscope: Leica DMLM
Magnification: 20
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.41

MIT 5398

l: 15.21
w: 1.50
weight: 11.90 gr

Sampling



MIT 5398_1 **Sample mounted transversely**
h: 0.26 cm
w: 0.17 cm
l: 0.43

Figure 5.42

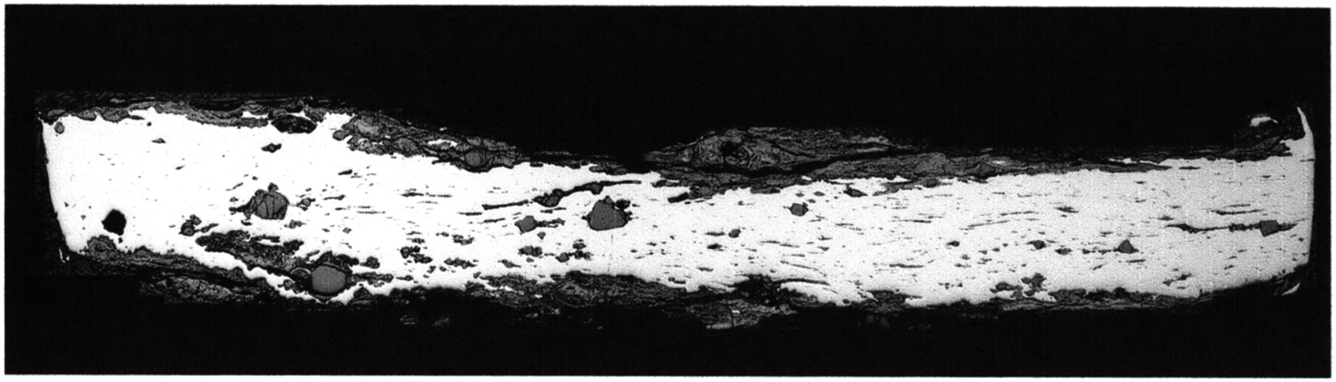


Image Number: Mosaic with MIT 5398_1-1 to 5398_1-3
Microscope: Leica DMLM
Magnification: 30
Etchant: As polished
Description: Iron object
Date: 12.iii.2009
Operator: Ismini Papakirillou

Figure 5.43

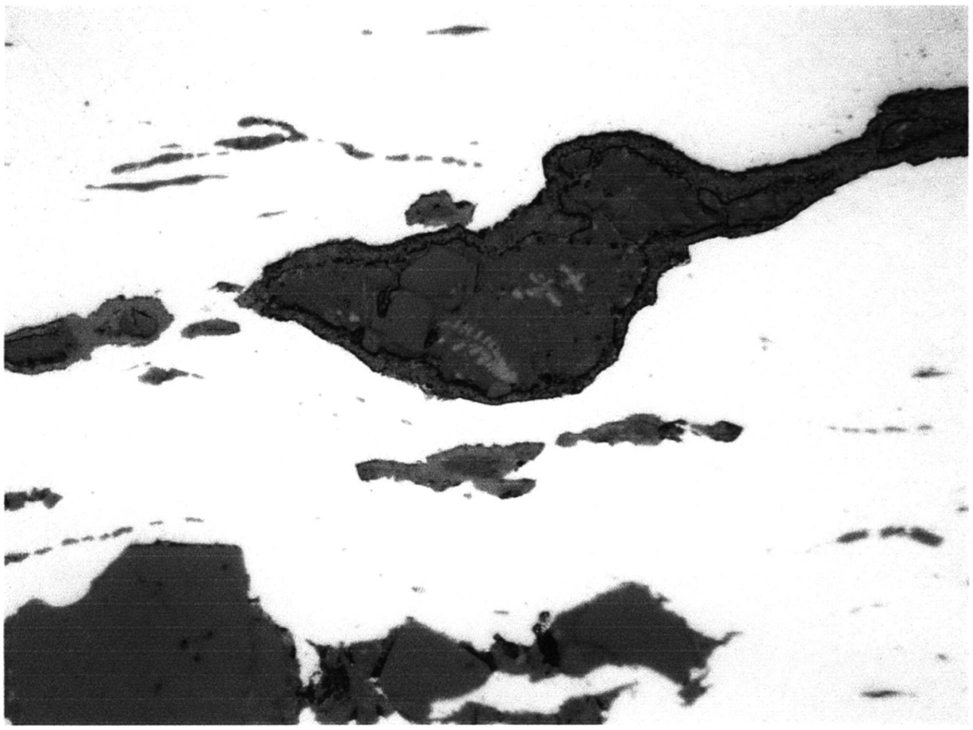


Image Number: MIT 5398_1-8
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 18.iii.2009
Operator: Ismini Papakirillou

Figure 5.44

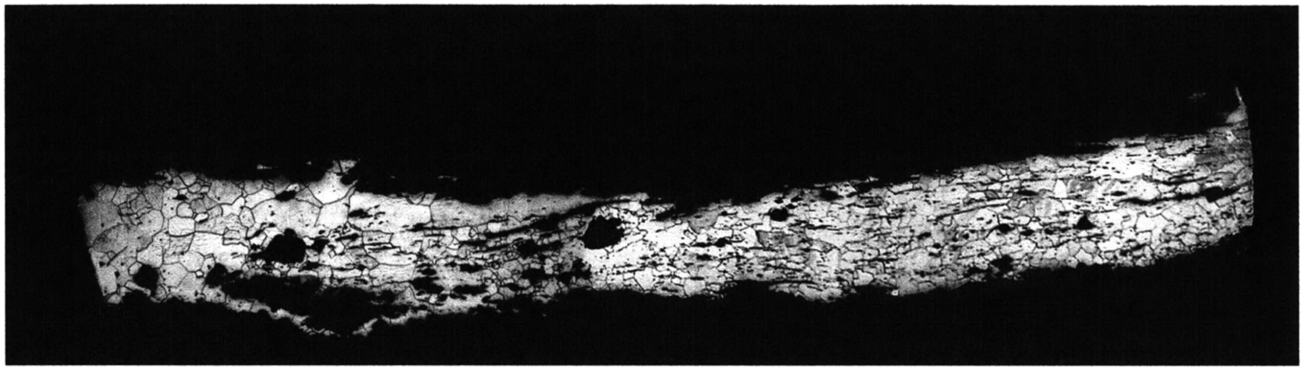


Image Number: Mosaic with MIT 5398_1-11 to 5398_1-13
Microscope: Leica DMLM
Magnification: 30
Etchant: Nital
Description: Iron object
Date: 18.iii.2009
Operator: Ismini Papakirillou

Figure 5.45

MIT 5406

l: 14.20 cm
w: 1.78 cm
weight: 13.80 gr

Sampling

MIT 5406_1
h: 0.24 cm
w: 0.23 cm
l: 0.52 cm

Sample mounted transversely

Figure 5.46

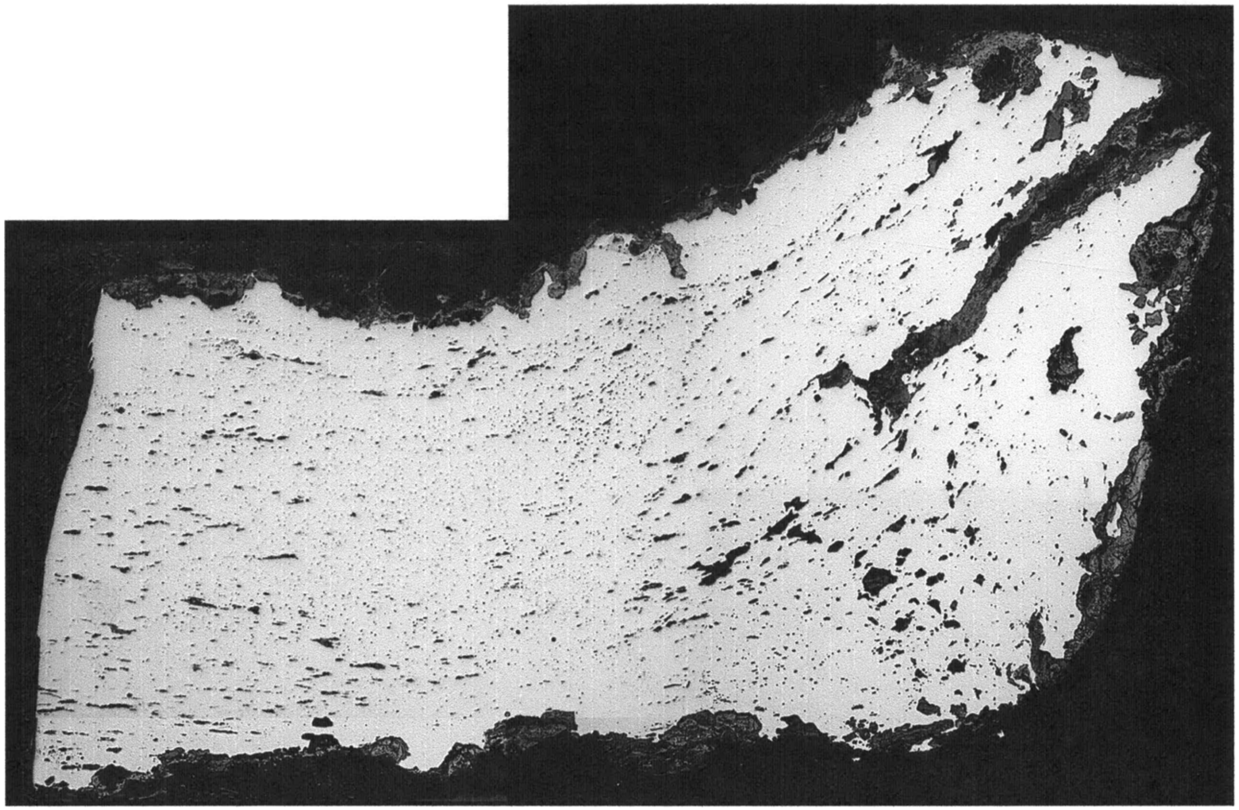


Image Number: Mosaic with MIT 5406_1-1 to 5406_1-6
Microscope: Leica DMLM
Magnification: 36
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.47

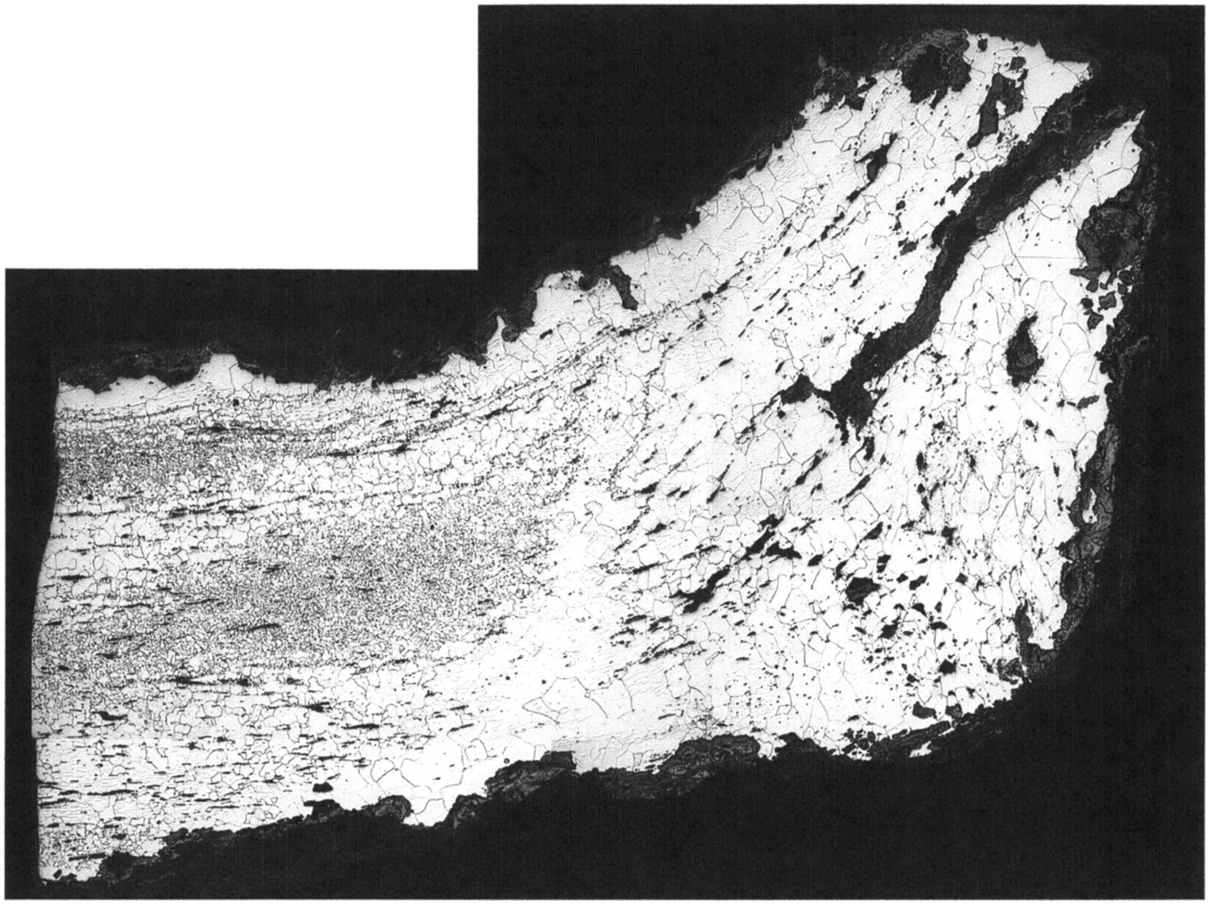


Image Number: Mosaic with MIT 5406_1-11 to 5406_1-15
Microscope: Leica DMLM
Magnification: 36
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.50

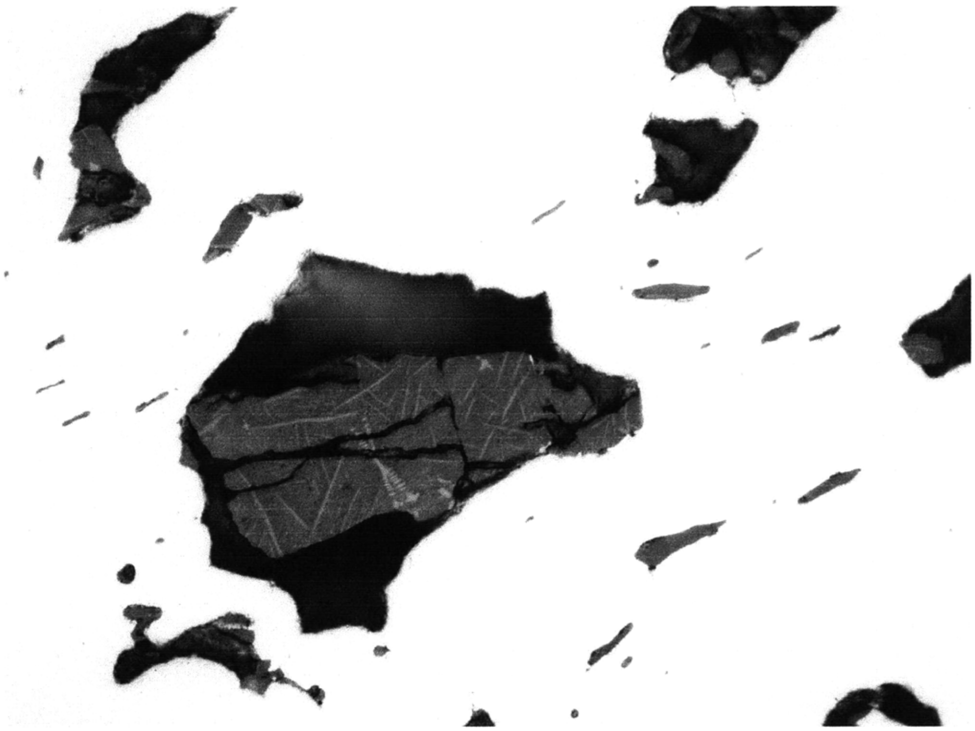


Image Number: MIT 5406_1-9
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.49

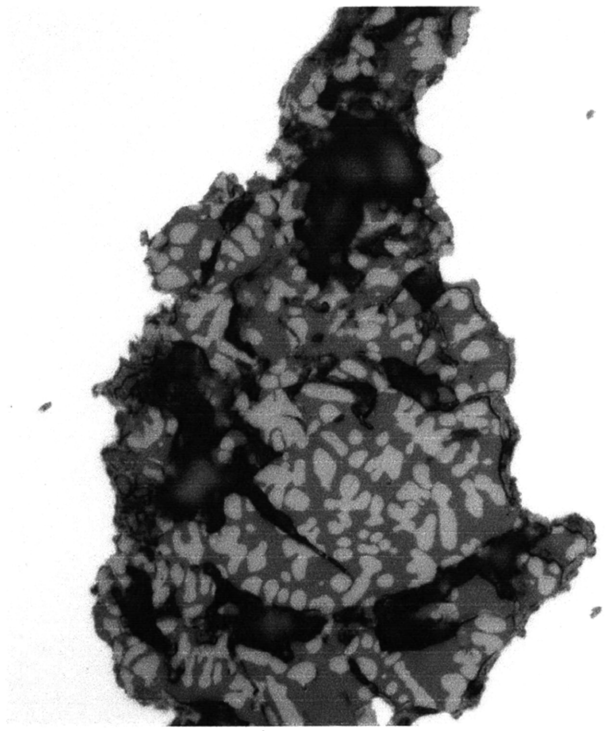


Image Number: MIT 5406_1-8
Microscope: Leica DMLM
Magnification: 500
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.48

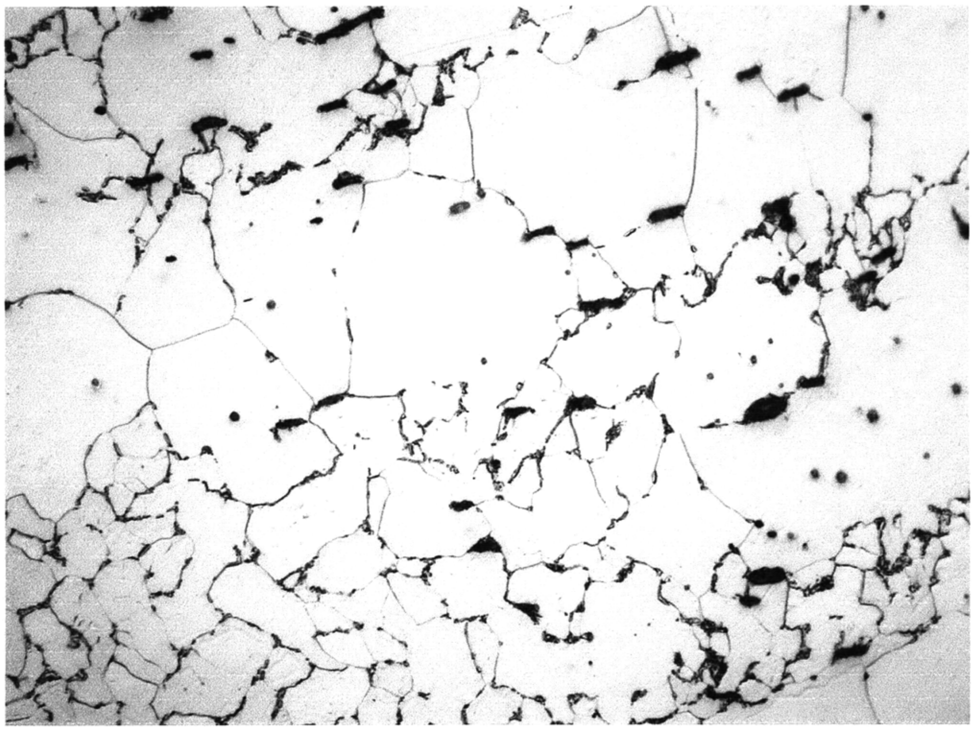
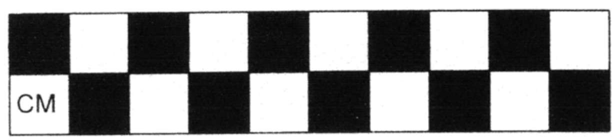


Image Number: MIT 5406_1-19
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

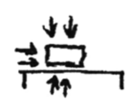
Figure 5.51

MIT 5407



l: 14.29 cm
w: 1.68 cm
weight: 15.46 gr

Sampling



Sample mounted transversely

MIT 5407_1
h: 0.43 cm
w: 0.13 cm
l: 0.59 cm

Figure 5.52

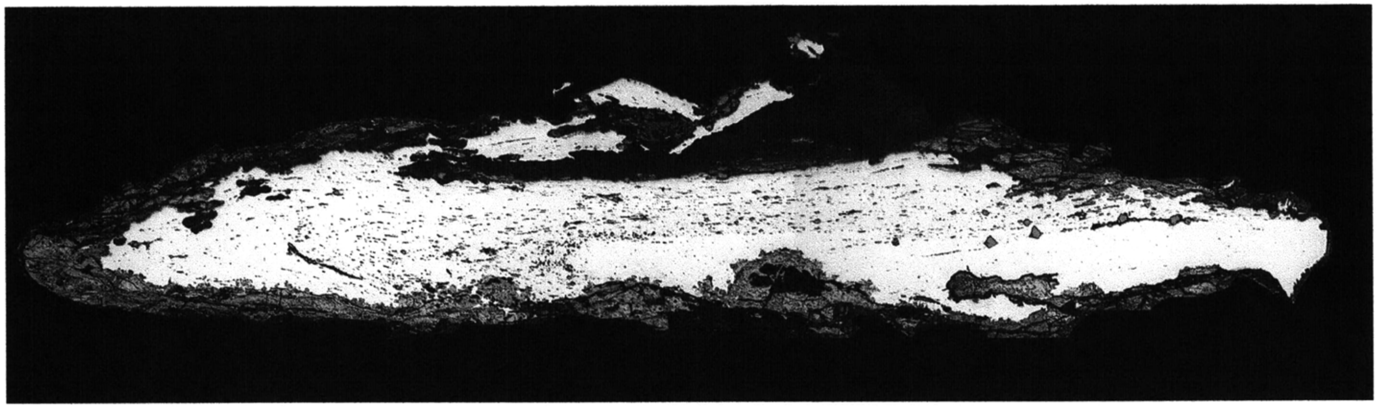


Image Number: Mosaic with MIT 5407_1-1 to 5407_1-3
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.53

Image Number: Mosaic with MIT 5407_1-6 to 5407_1-8
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.54

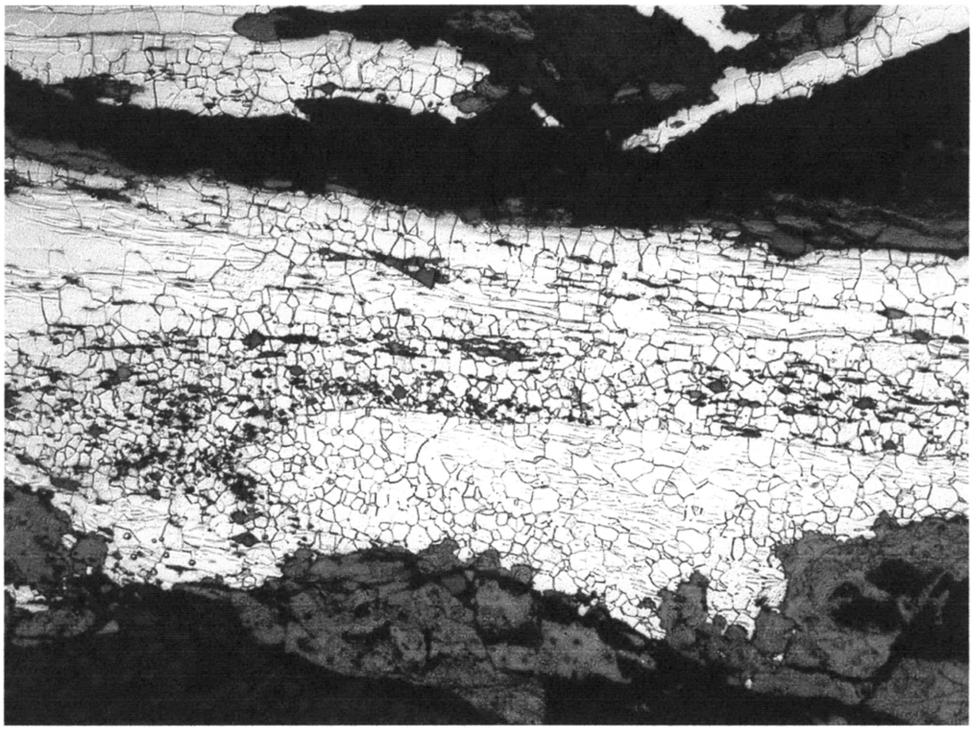


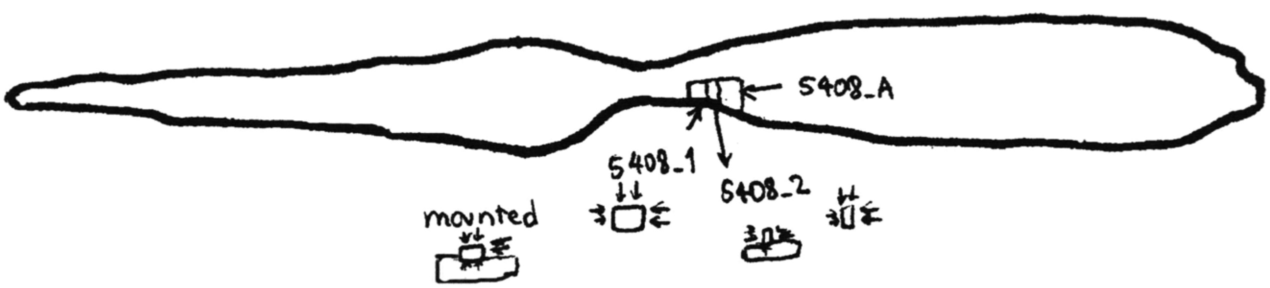
Image Number: MIT 5407_1-10
Microscope: Leica DMLM
Magnification: 100
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.55

MIT 5408

l: 15.21 cm
w: 1.50 cm
weight: 11.90 gr

Sampling



Sample 5408_1 mounted transversely
Sample 5408_2 mounted longitudinally

MIT 5408_1
h: 0.20 cm
w: 0.32 cm
l: 0.19 cm

MIT 5408_2
h: 0.12 cm
w: 0.28 cm
l: 0.28 cm

Figure 5.56

Image Number: Mosaic with MIT 5408_1-1 to 5408_1-3
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 23.vi.2009
Operator: Ismini Papakirillou

Figure 5.57

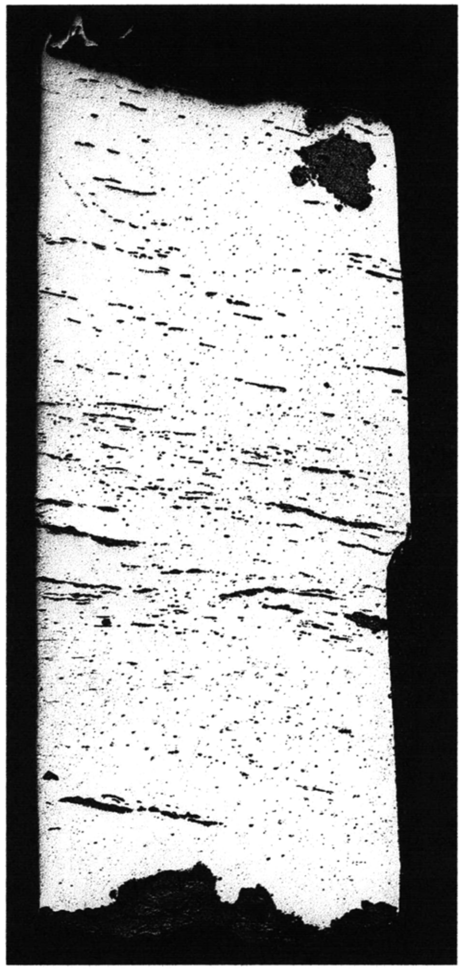


Image Number: Mosaic with MIT 5408_2-1 to 5408_2-2
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 26.vi.2009
Operator: Ismini Papakirillou

Figure 5.58

Image Number: Mosaic with MIT 5408_1-7 to 5408_1-9
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.59

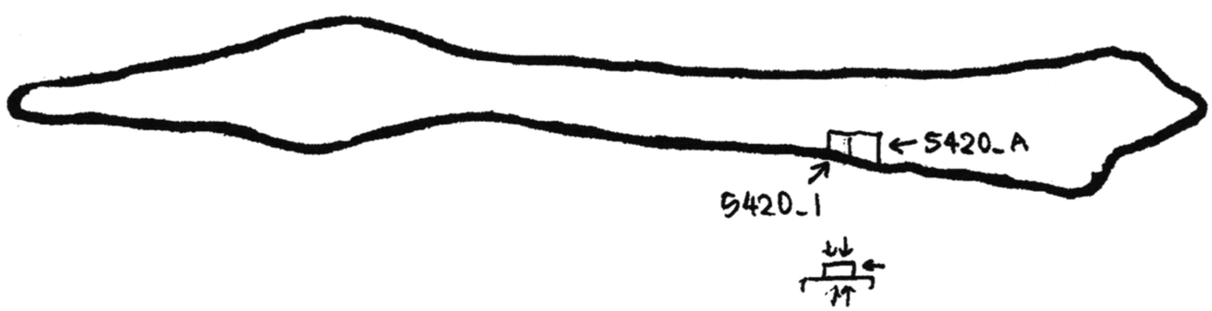
Image Number: Mosaic with MIT 5408_2-5 to 5408_2-6
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 27.vi.2009
Operator: Ismini Papakirillou

Figure 5.60

MIT 5420

l: 14.51 cm
w: 1.70 cm
weight: 11.01 gr

Sampling



MIT 5420_1 **Sample mounted transversely**
h: 0.33 cm
w: 0.14 cm
l: 0.20 cm

Figure 5.61

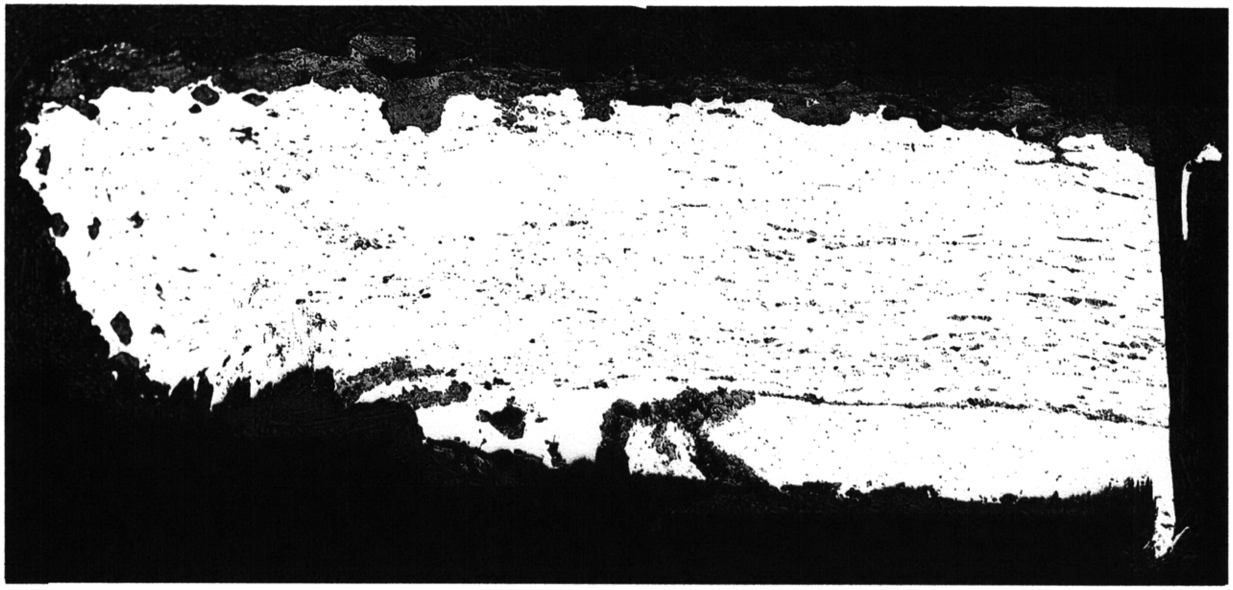


Image Number: Mosaic with MIT 5420_1-1 to 5420_1-3
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 23.vi.2009
Operator: Ismini Papakirillou

Figure 5.62

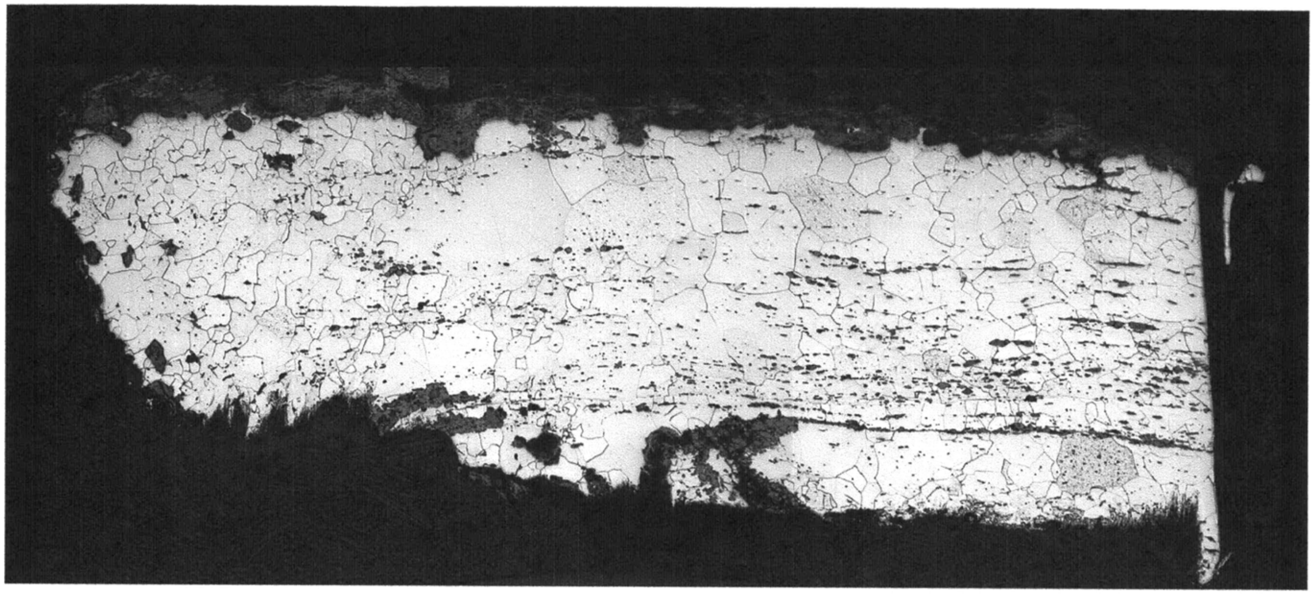


Image Number: Mosaic with MIT 5420_1-9 to 5420_1-10
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.63

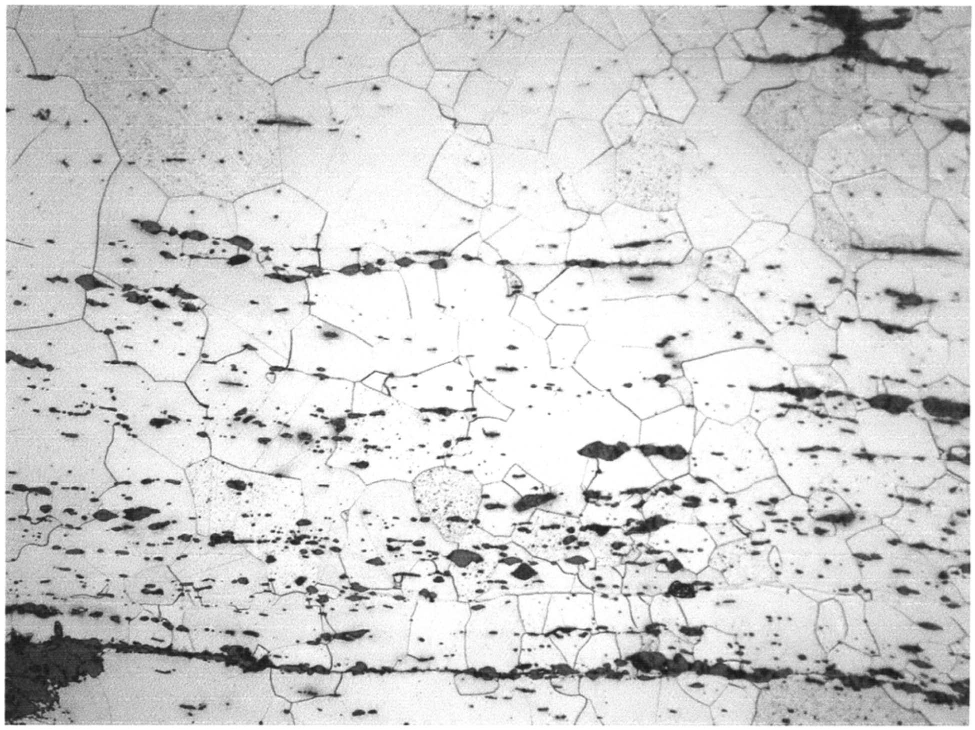


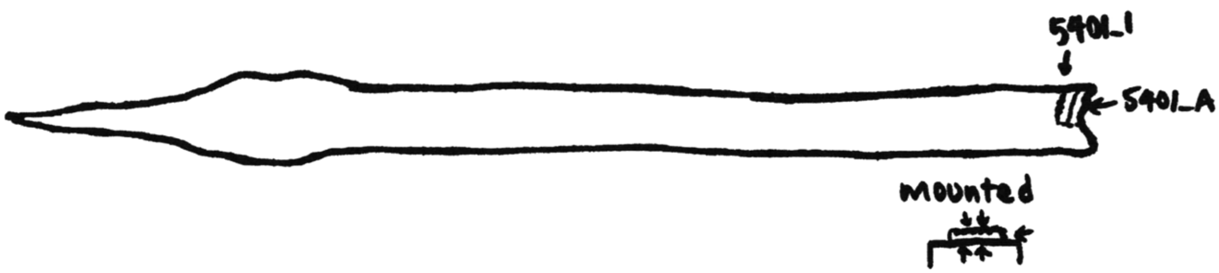
Image Number: MIT 5420_1-11
Microscope: Leica DMLM
Magnification: 100
Etchant: Nital
Description: Iron object
Date: 30.vi.2009
Operator: Ismini Papakirillou

Figure 5.64

MIT 5401

l: 18.10 cm
w: 1.15 cm
weight: 20.89 gr

Sampling



MIT 5401_1 **Sample mounted transversely**
h: 0.14 cm
w: 0.19 cm
l: 1.29 cm

Figure 5.65

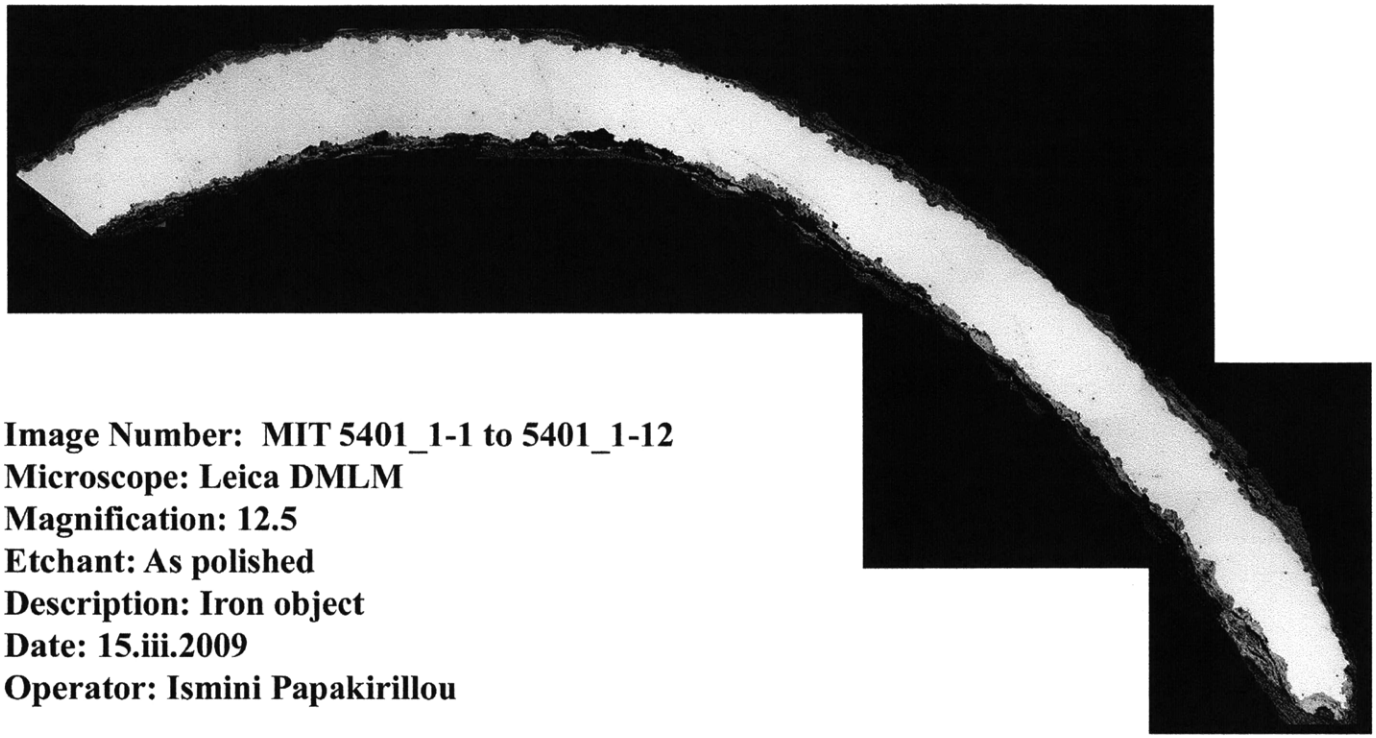


Image Number: MIT 5401_1-1 to 5401_1-12
Microscope: Leica DMLM
Magnification: 12.5
Etchant: As polished
Description: Iron object
Date: 15.iii.2009
Operator: Ismini Papakirillou

Figure 5.66

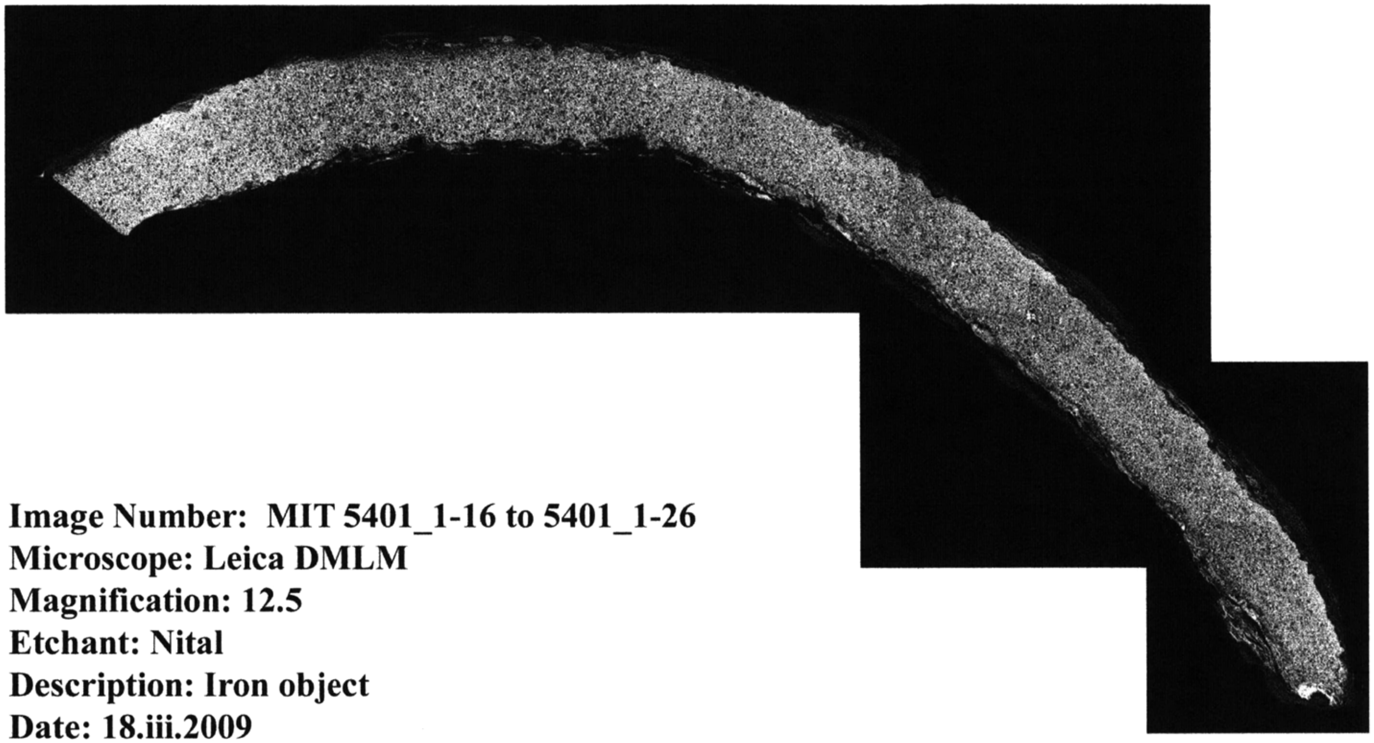


Image Number: MIT 5401_1-16 to 5401_1-26
Microscope: Leica DMLM
Magnification: 12.5
Etchant: Nital
Description: Iron object
Date: 18.iii.2009
Operator: Ismini Papakirillou

Figure 5.67

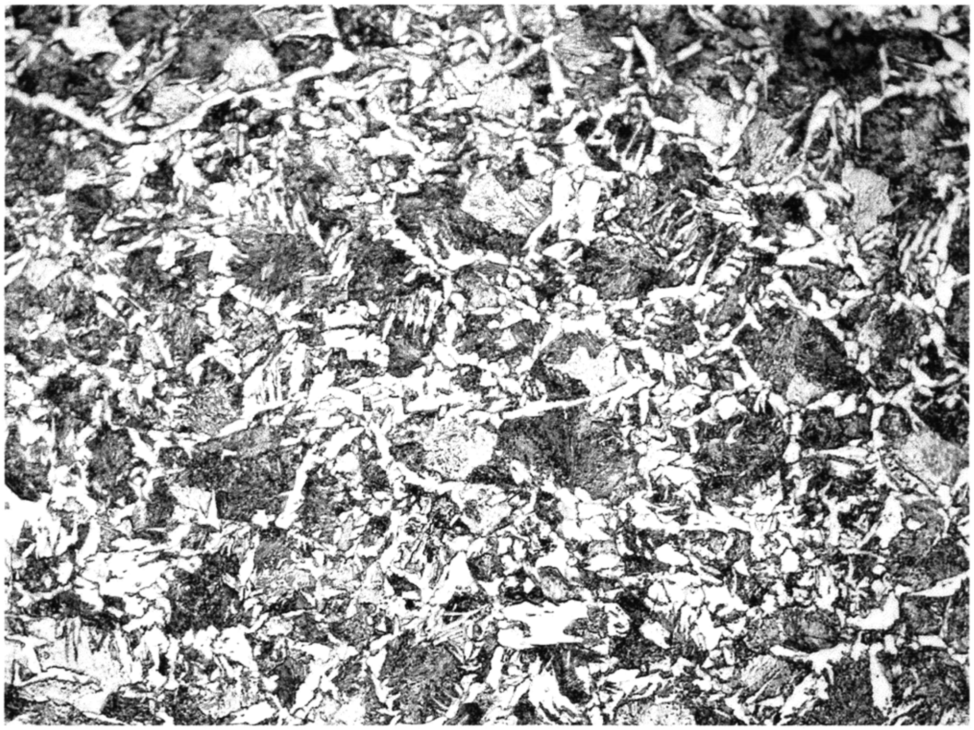


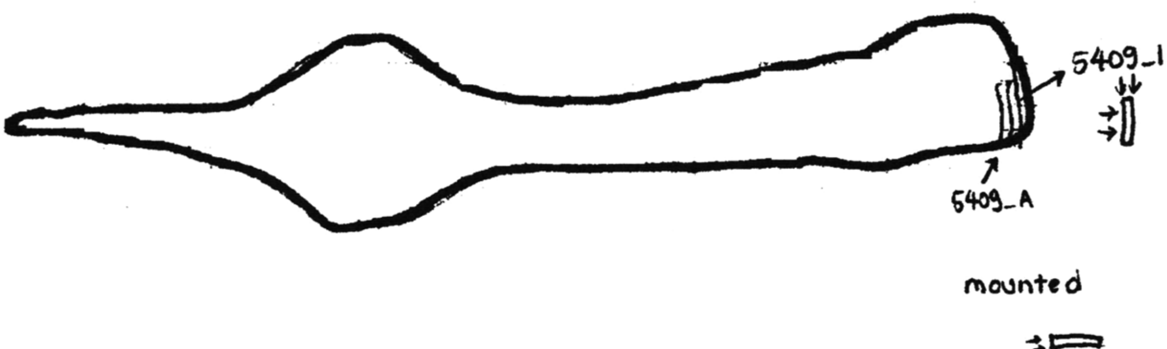
Image Number: MIT 5401_1-15
Microscope: Leica DMLM
Magnification: 200
Etchant: Nital
Description: Iron object
Date: 19.iii.2009
Operator: Ismini Papakirillou

Figure 5.68

MIT 5409

l: 12.41 cm
w: 2.41 cm
weight: 14.65 gr

Sampling



MIT 5410_1
h: 0.17 cm
w: 0.26 cm
l: 0.79 cm

Sample mounted transversely

Figure 5.69

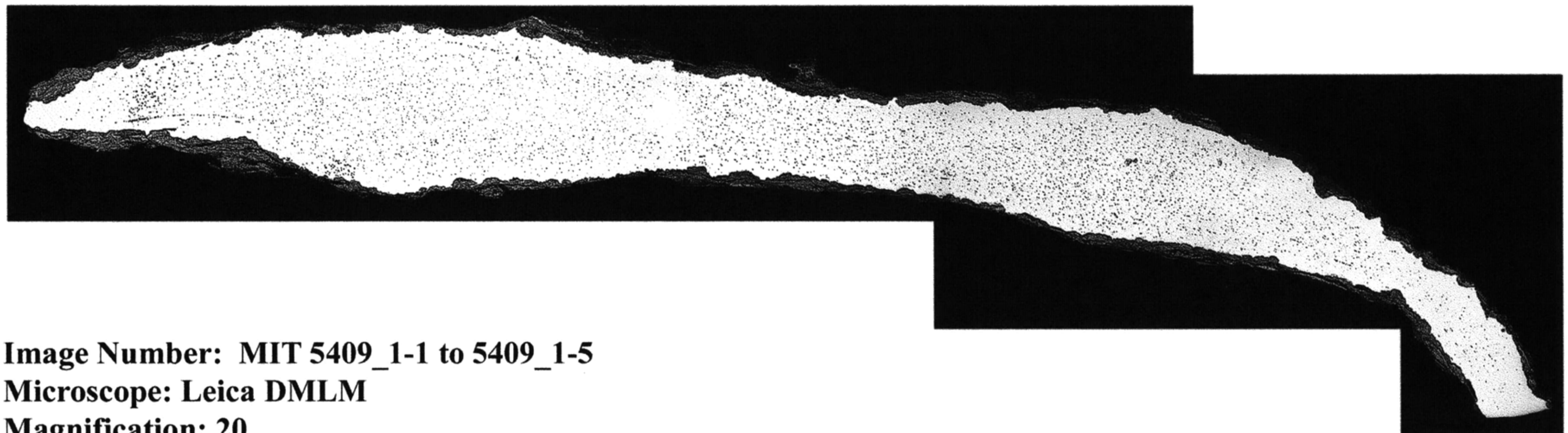


Image Number: MIT 5409_1-1 to 5409_1-5
Microscope: Leica DMLM
Magnification: 20
Etchant: As polished
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.70

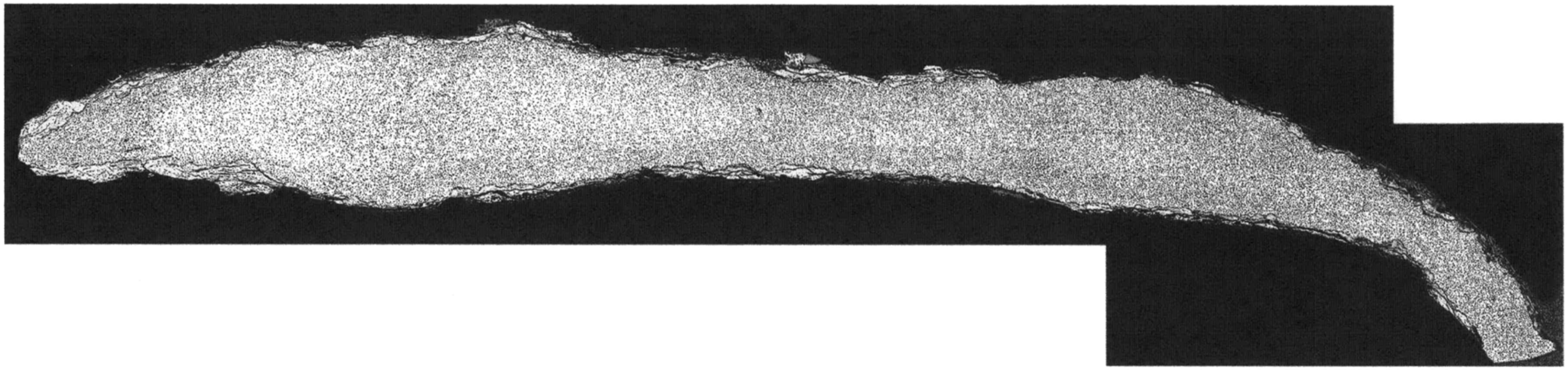


Image Number: MIT 5409_1-7 to 5409_1-12
Microscope: Leica DMLM
Magnification: 20
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.71

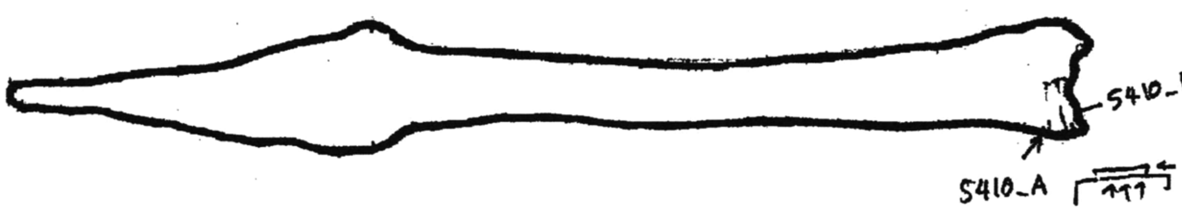
Image Number: MIT 5409_1-19
Microscope: Leica DMLM
Magnification: 100
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.72

MIT 5410

l: 13.69 cm
w: 1.67 cm
weight: 13.18 gr

Sampling



MIT 5410_1 **Sample mounted transversely**
h: 0.17 cm
w: 0.26 cm
l: 0.79 cm

Figure 5.73

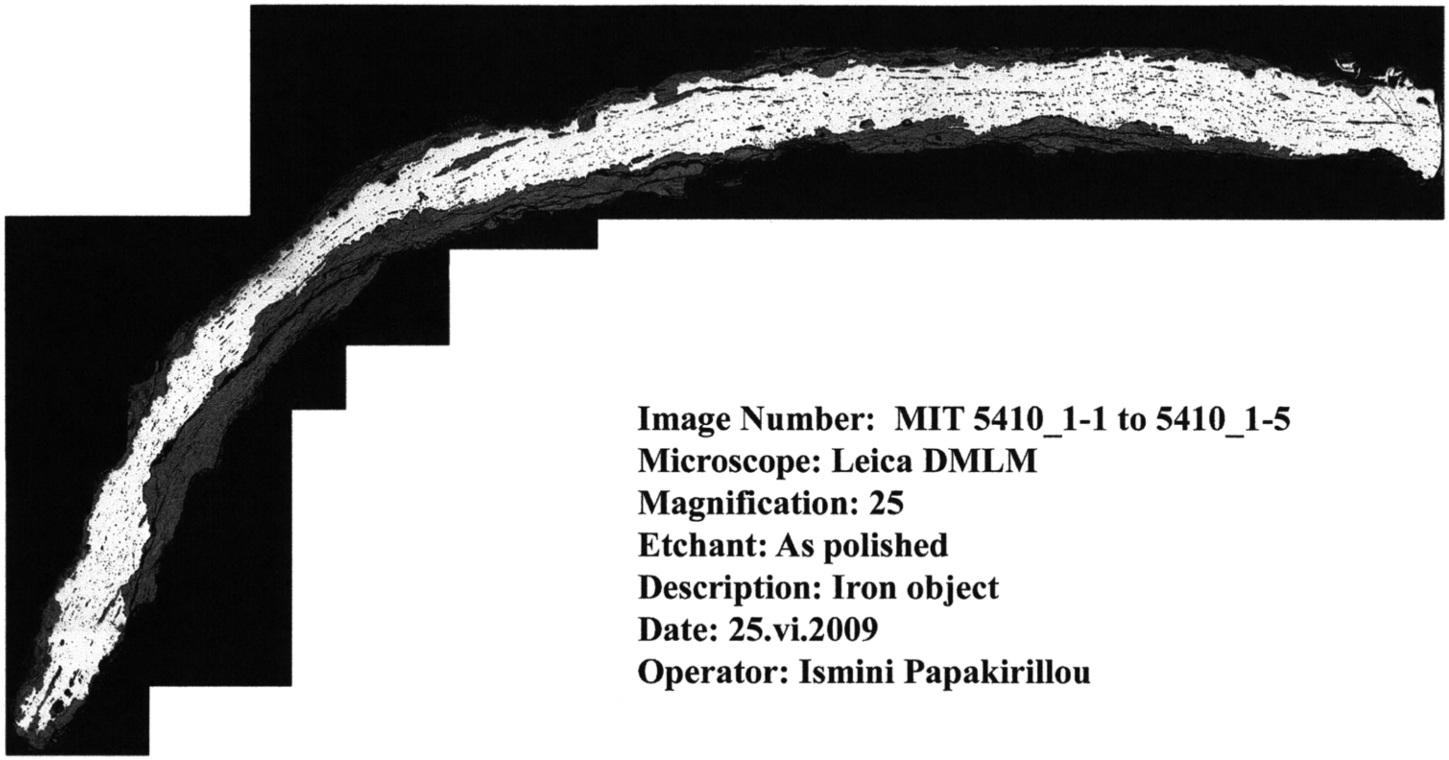


Image Number: MIT 5410_1-1 to 5410_1-5
Microscope: Leica DMLM
Magnification: 25
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.74

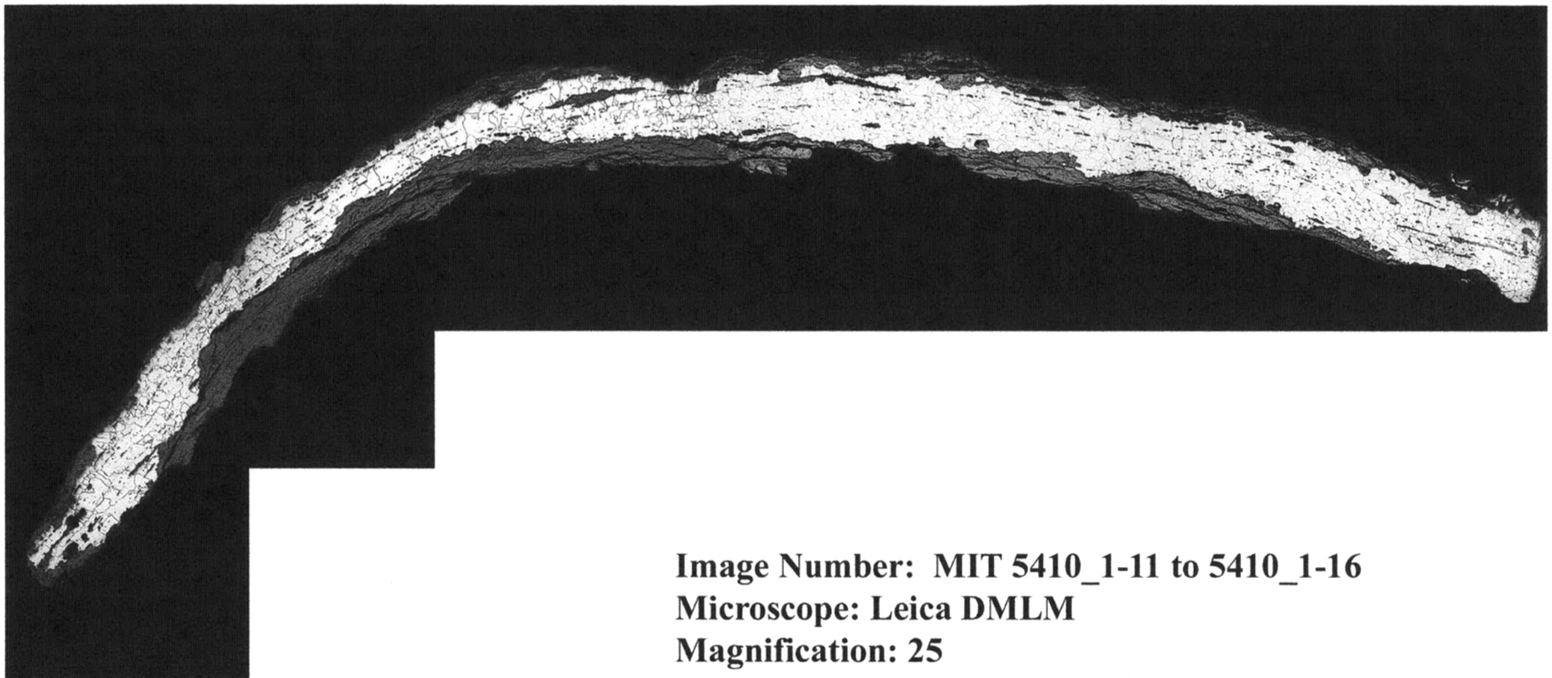


Image Number: MIT 5410_1-11 to 5410_1-16
Microscope: Leica DMLM
Magnification: 25
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.75

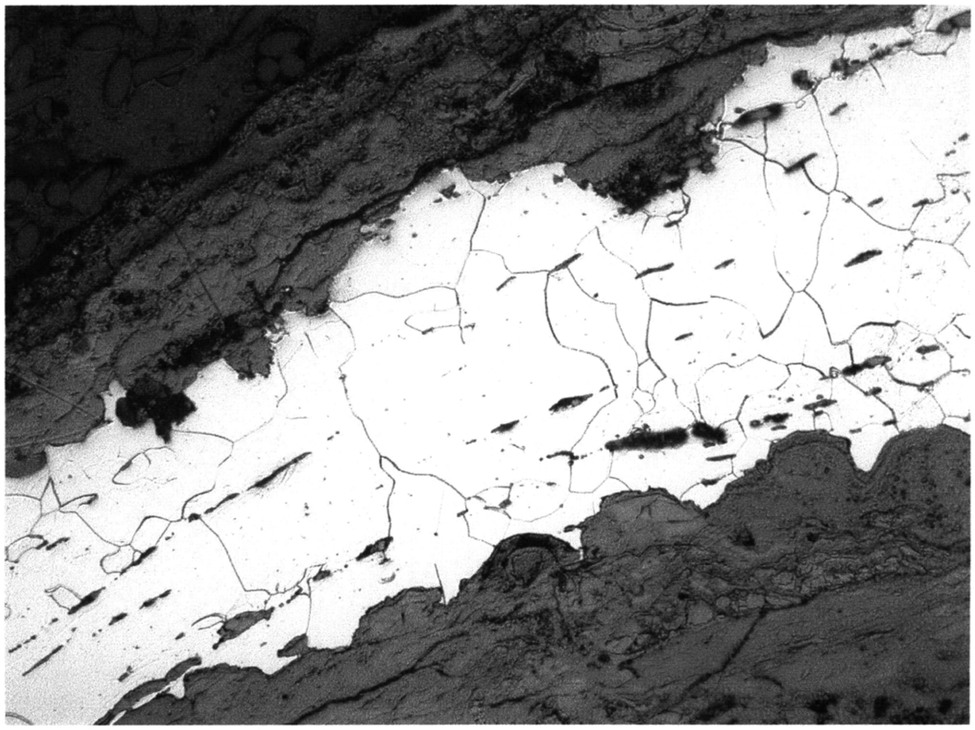


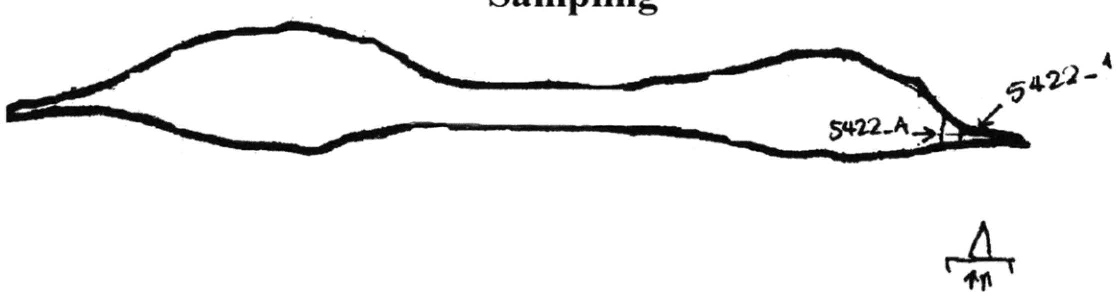
Image Number: MIT 5410_1-19
Microscope: Leica DMLM
Magnification: 200
Etchant: Nital
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.76

MIT 5422

l: 14.04 cm
w: 1.54 cm
weight: 12.12 gr

Sampling



MIT 5422_1 **Sample mounted transversely**

h: 0.23
w: 0.16
l: 0.66

Figure 5.77

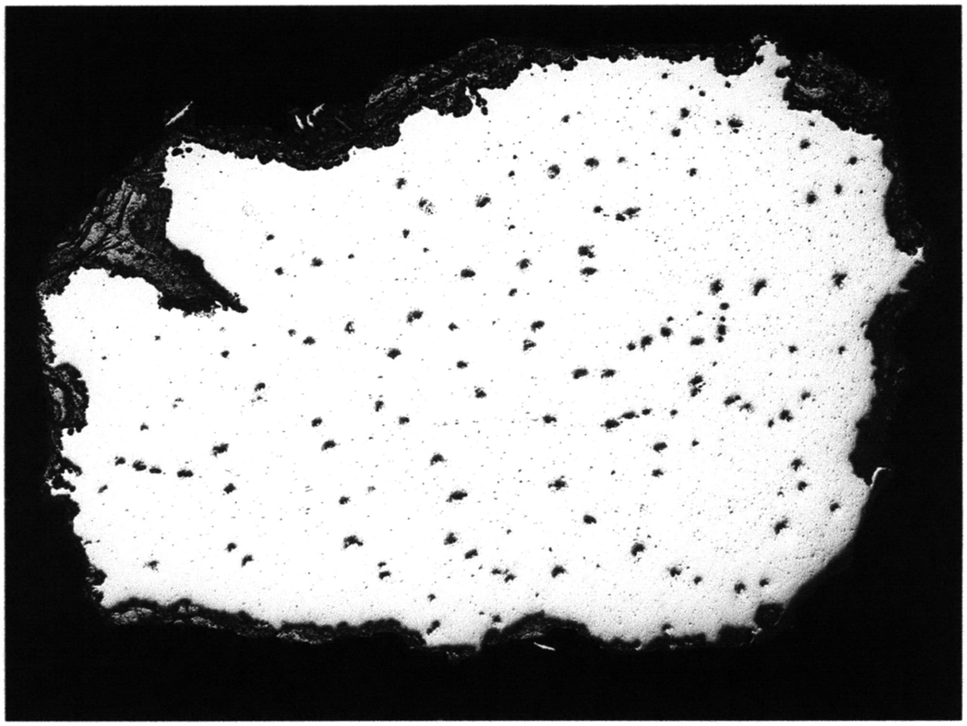


Image Number: Mosaic with MIT 5422_1-1
Microscope: Leica DMLM
Magnification: 50
Etchant: As polished
Description: Iron object
Date: 25.vi.2009
Operator: Ismini Papakirillou

Figure 5.78

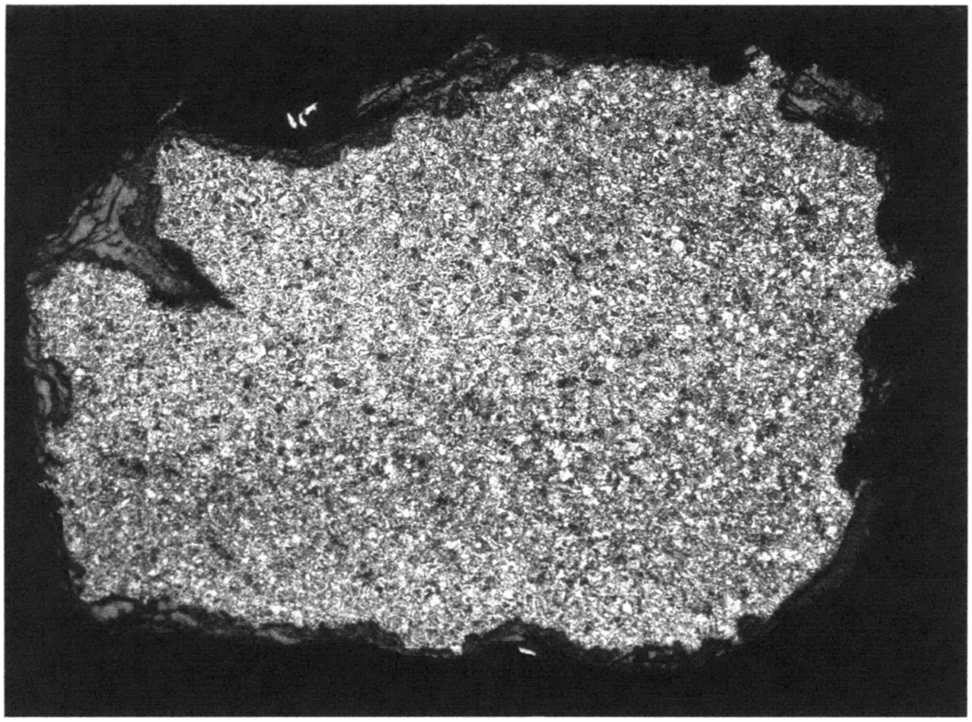


Image Number: Mosaic with MIT 5422_1-4
Microscope: Leica DMLM
Magnification: 50
Etchant: Nital
Description: Iron object
Date: 29.vi.2009
Operator: Ismini Papakirillou

Figure 5.79

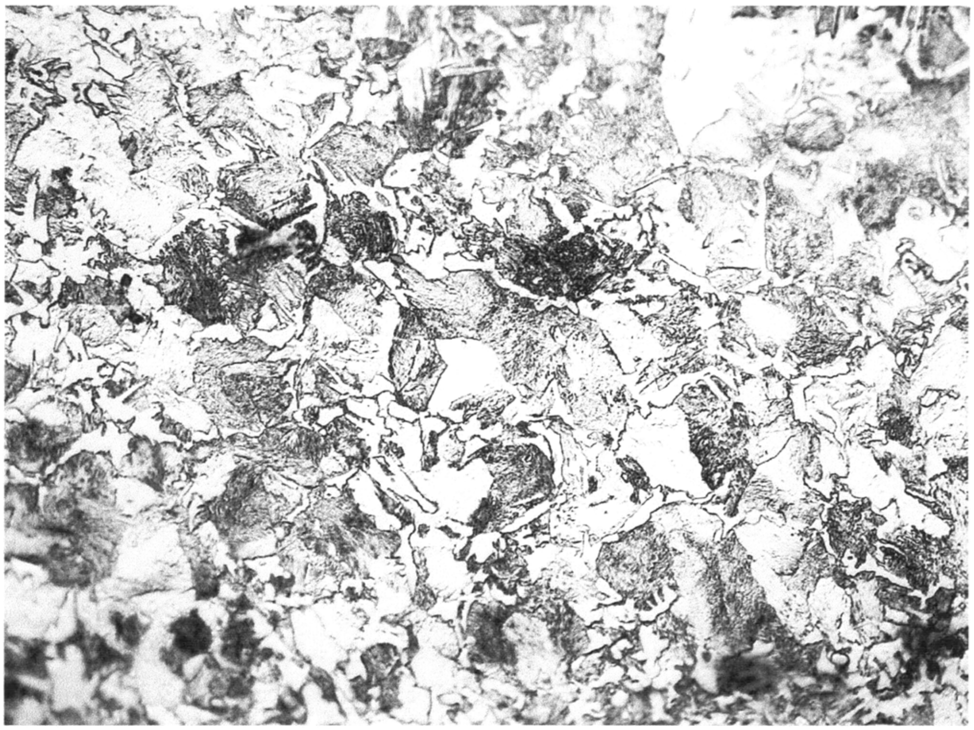
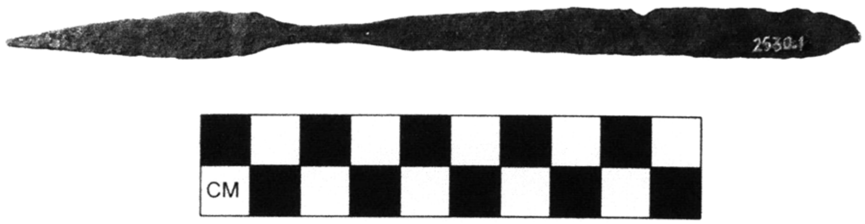


Image Number: MIT 5422_1-6
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 29.vi.2009
Operator: Ismini Papakirillou

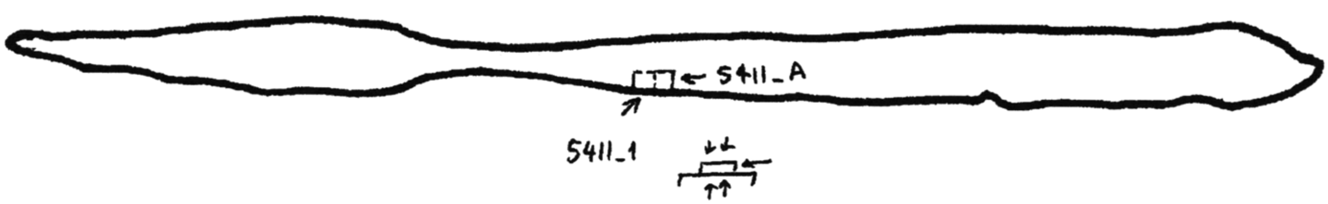
Figure 5.80

MIT 5411



l: 17.22 cm
w: 1.01 cm
weight: 7.82 gr

Sampling



MIT 5411_1
h: 0.33 cm
w: 0.14 cm
l: 0.37 cm

Sample mounted transversely

Figure 5.81

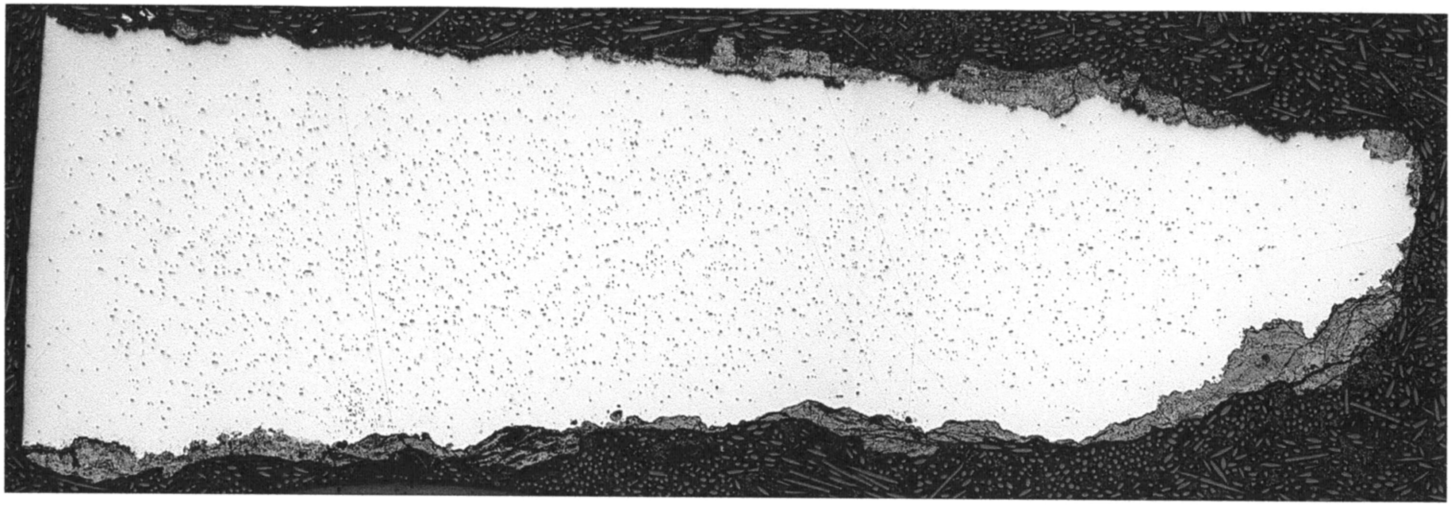


Image Number: Mosaic with MIT 5411_1-1 and 5411_1-2
Microscope: Leica DMLM
Magnification: 45
Etchant: As polished
Description: Iron object
Date: 24.vi.2009
Operator: Ismini Papakirillou

Figure 5.82

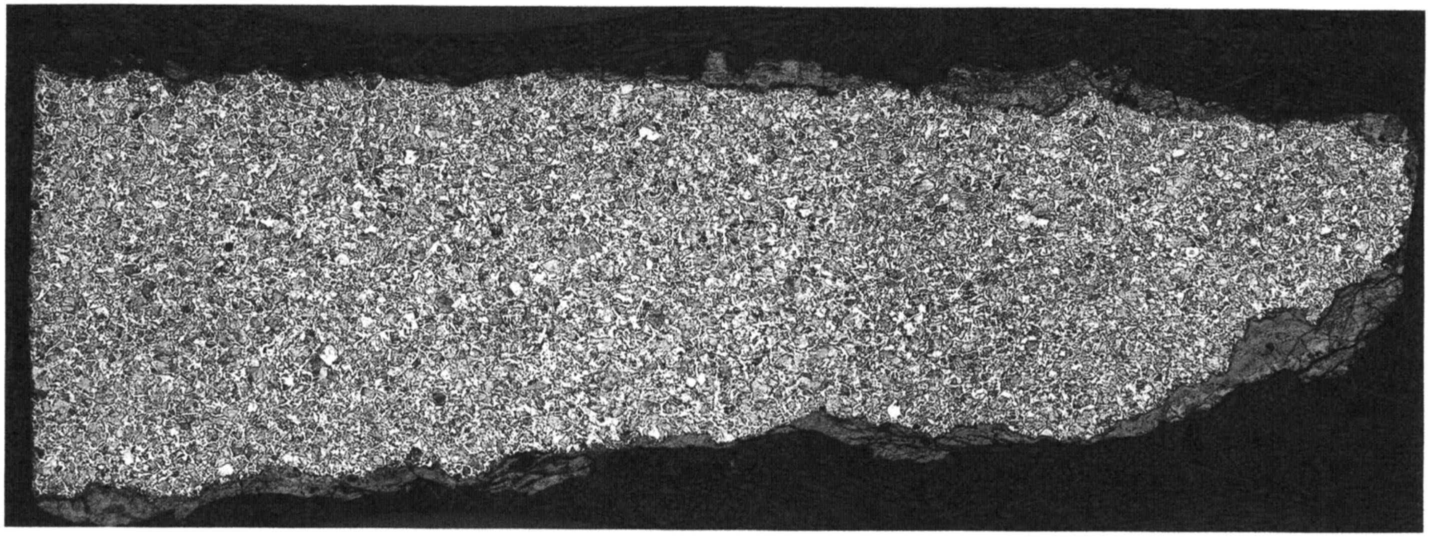


Image Number: Mosaic with MIT 5411_1-6 and 5411_1-7
Microscope: Leica DMLM
Magnification: 45
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.83

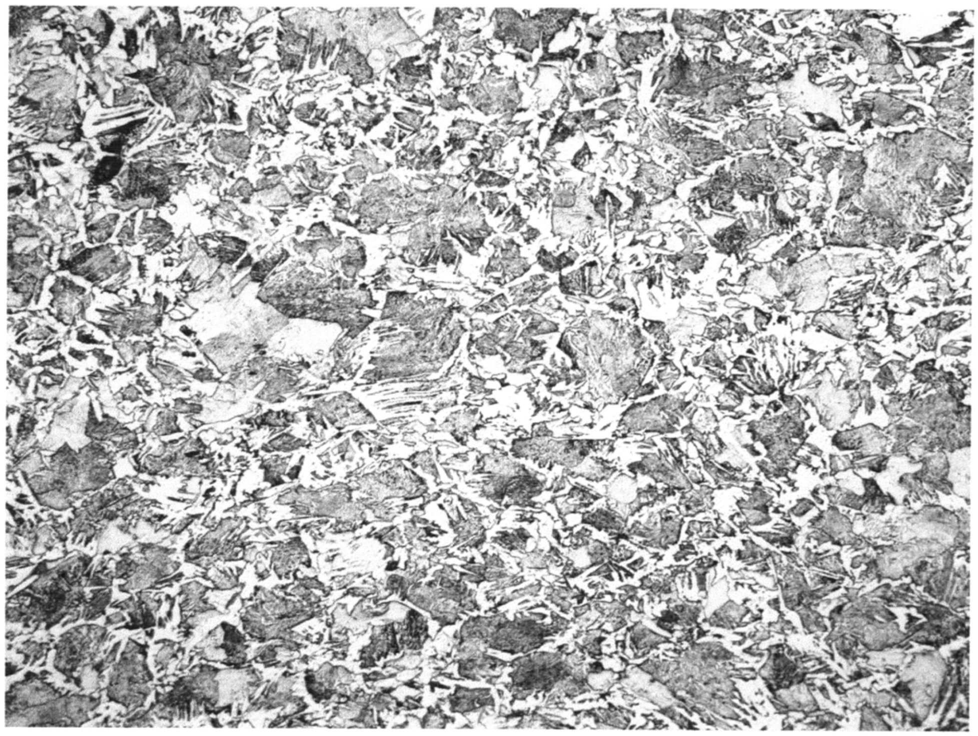


Image Number: MIT 5411_1-7
Microscope: Leica DMLM
Magnification: 200
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.84

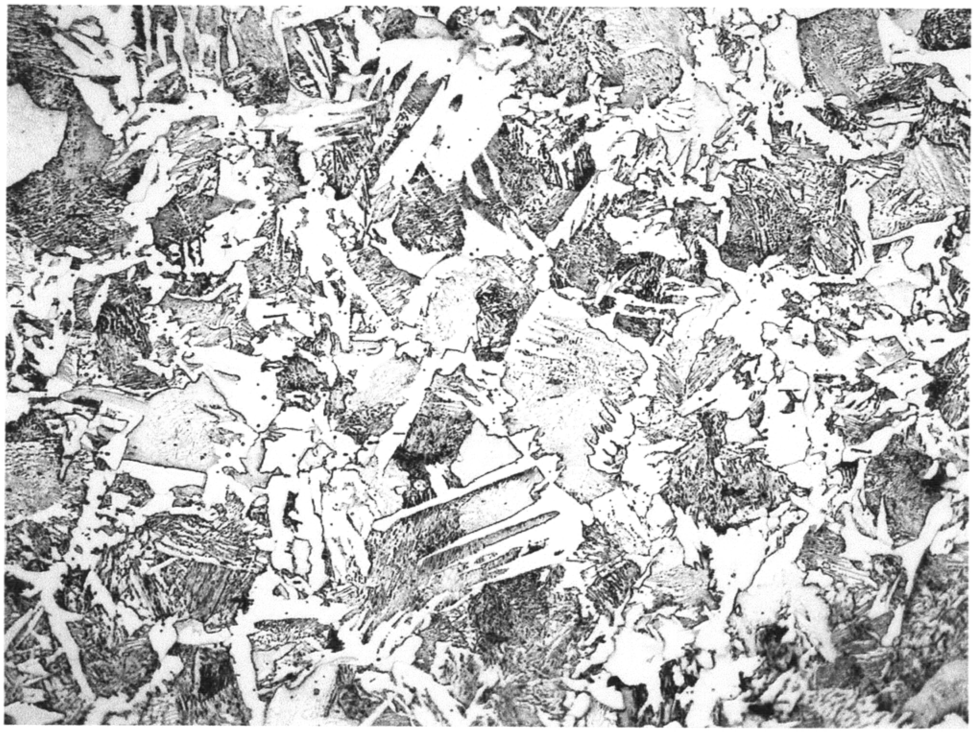


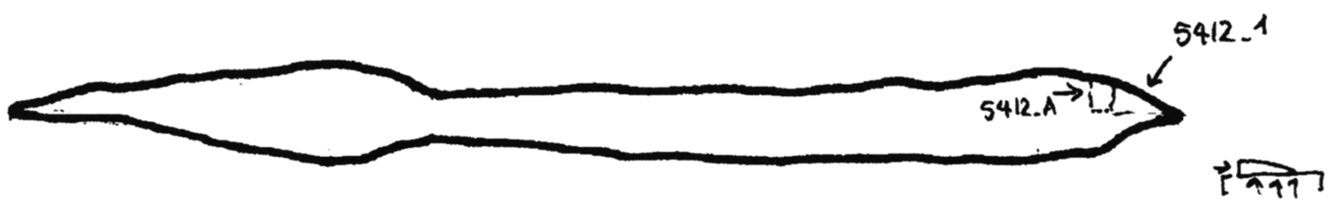
Image Number: MIT 5411_1-10
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.85

MIT 5412

l: 14.45 cm
w: 1.24 cm
weight: 8.28 gr

Sampling



Sample mounted longitudinally

MIT 5412_1
h: 0.27 cm
w: 0.21 cm
l: 0.88 cm

Figure 5.86

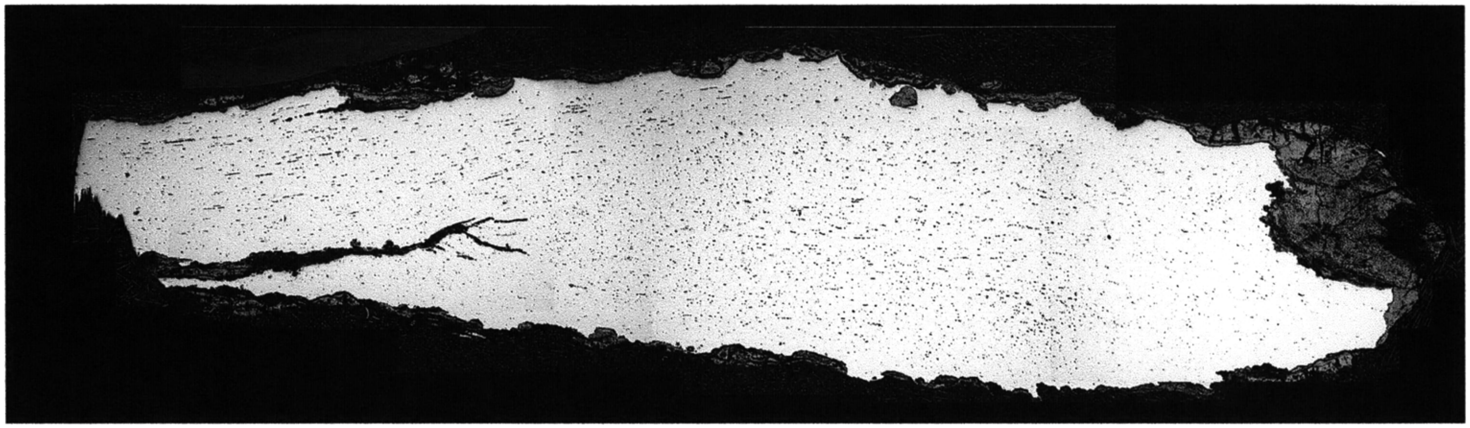


Image Number: Mosaic with MIT 5412_1-1 and 5412_1-9
Microscope: Leica DMLM
Magnification: 20
Etchant: As polished
Description: Iron object
Date: 24.vi.2009
Operator: Ismini Papakirillou

Figure 5.87

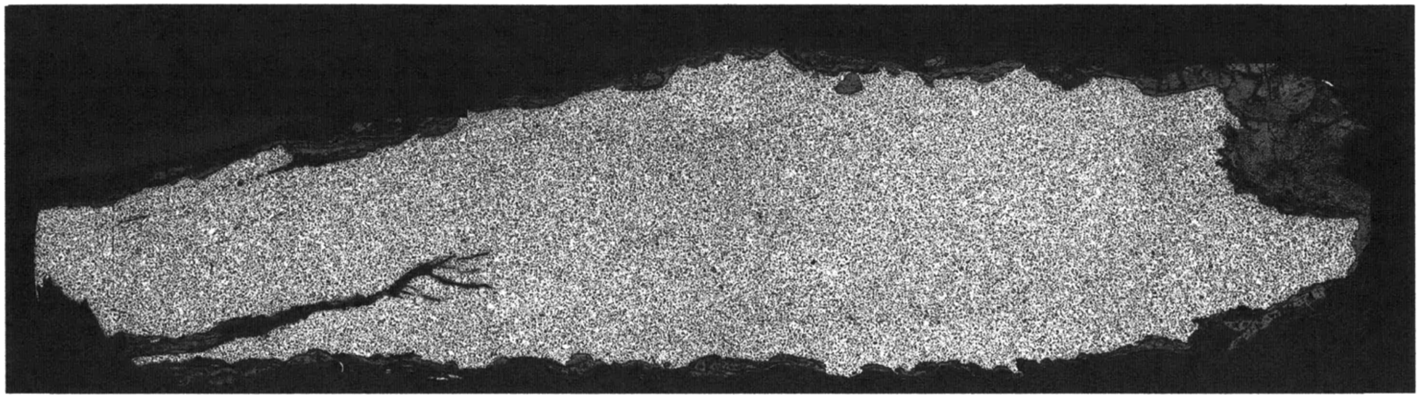


Image Number: Mosaic with MIT 5412_1-10 and 5412_1-16
Microscope: Leica DMLM
Magnification: 20
Etchant: Nital
Description: Iron object
Date: 6.vii.2009
Operator: Ismini Papakirillou

Figure 5.88

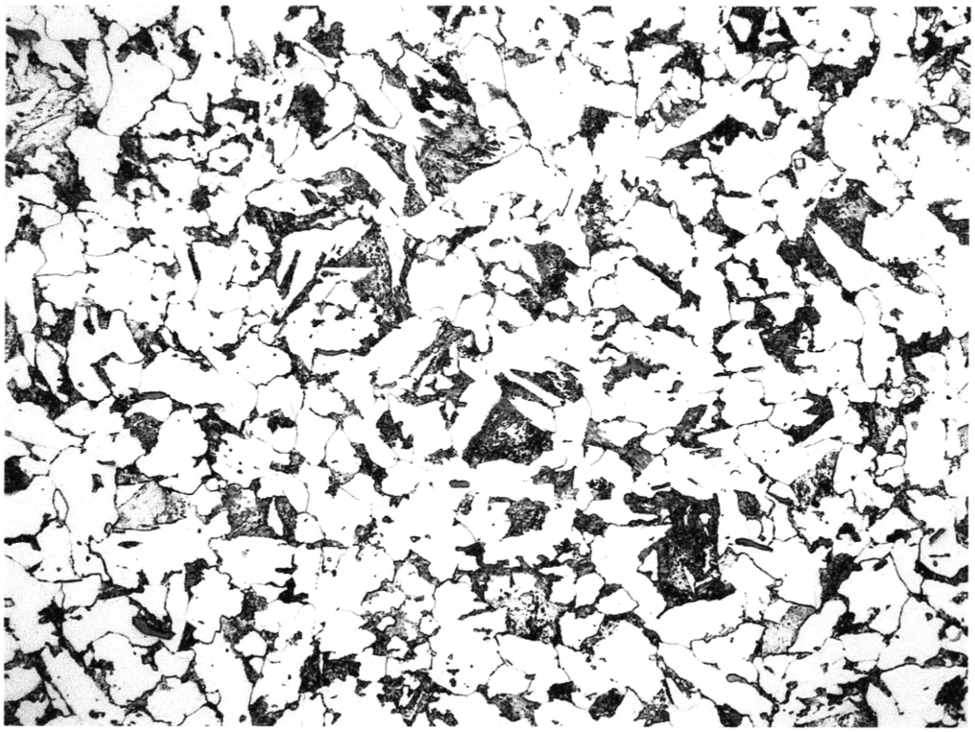


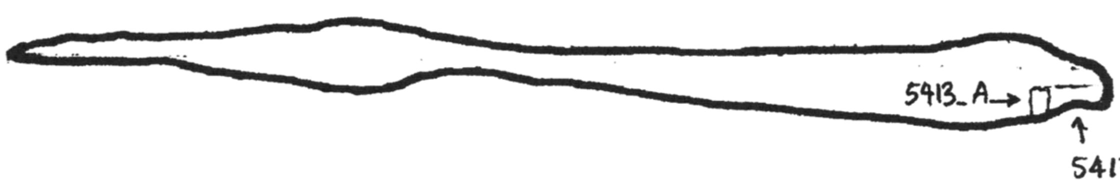
Image Number: MIT 5412_1-19
Microscope: Leica DMLM
Magnification: 500
Etchant: Nital
Description: Iron object
Date: 6.vii.2009
Operator: Ismini Papakirillou

Figure 5.89

MIT 5413

l: 12.84 cm
w: 1.21 cm
weight: 9.09 gr

Sampling



MIT 5413_1 **Sample mounted longitudinally**

h: 0.32 cm
w: 0.25 cm
l: 0.37 cm

Figure 5.90

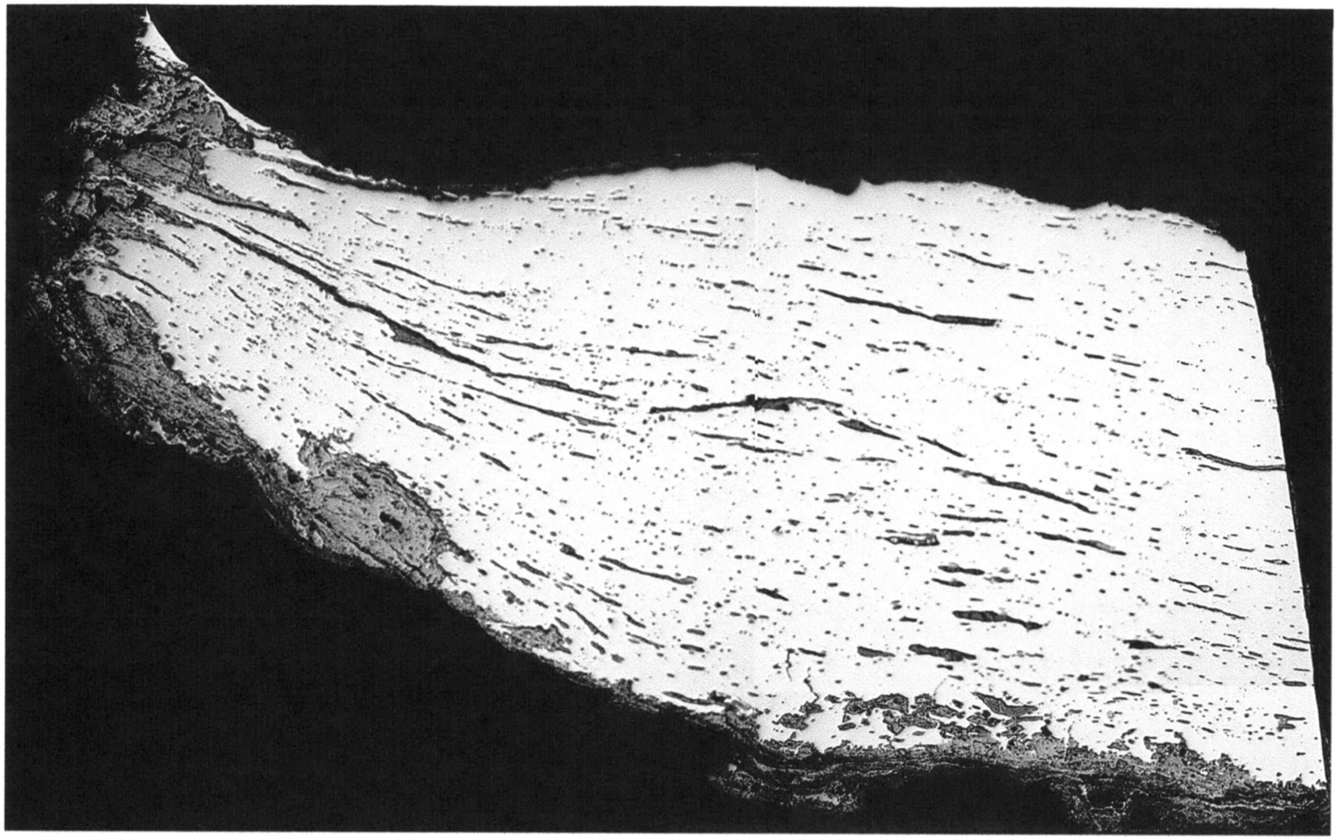


Image Number: Mosaic with MIT 5413_1-1 to 5413_1-5
Microscope: Leica DMLM
Magnification: 40
Etchant: As polished
Description: Iron object
Date: 28.vi.2009
Operator: Ismini Papakirillou

Figure 5.91

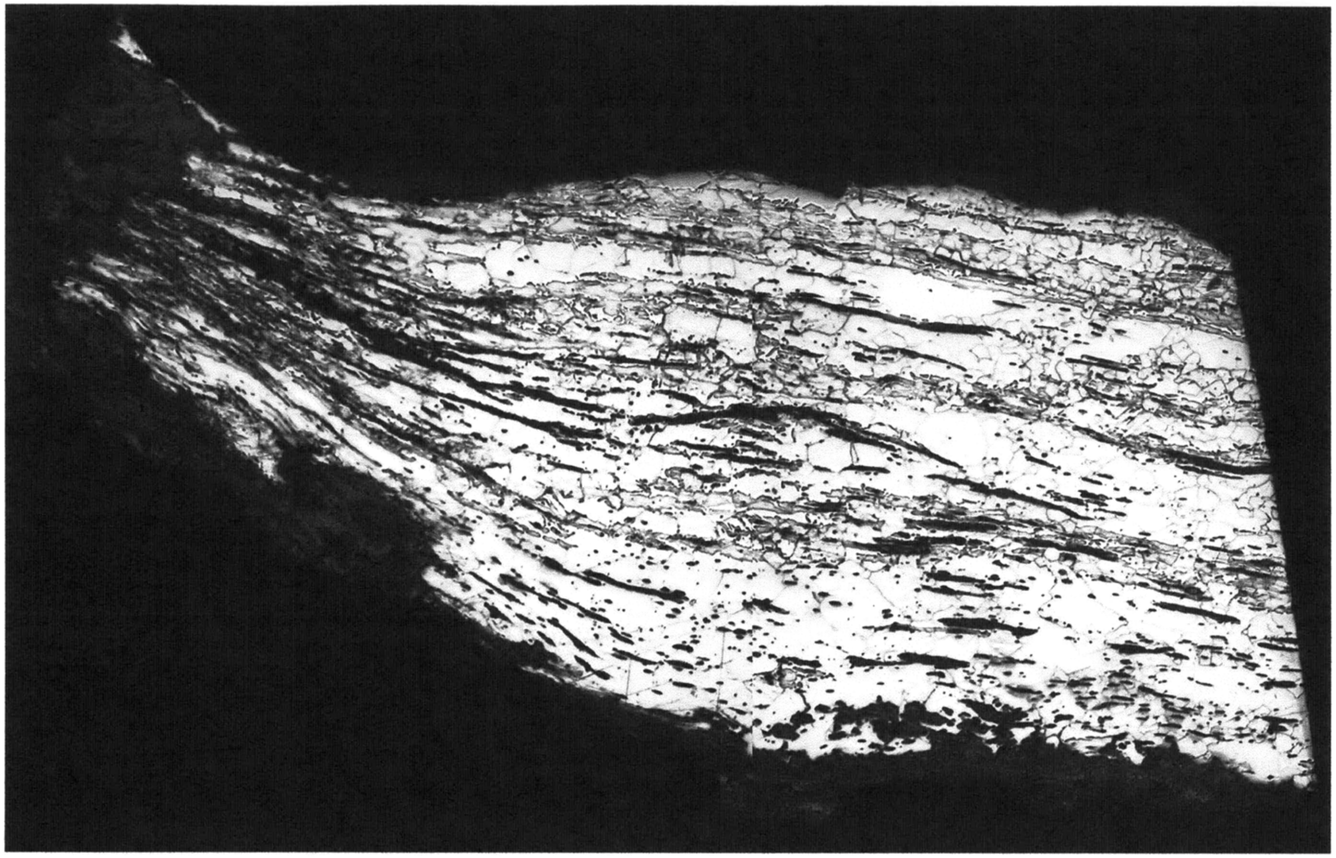
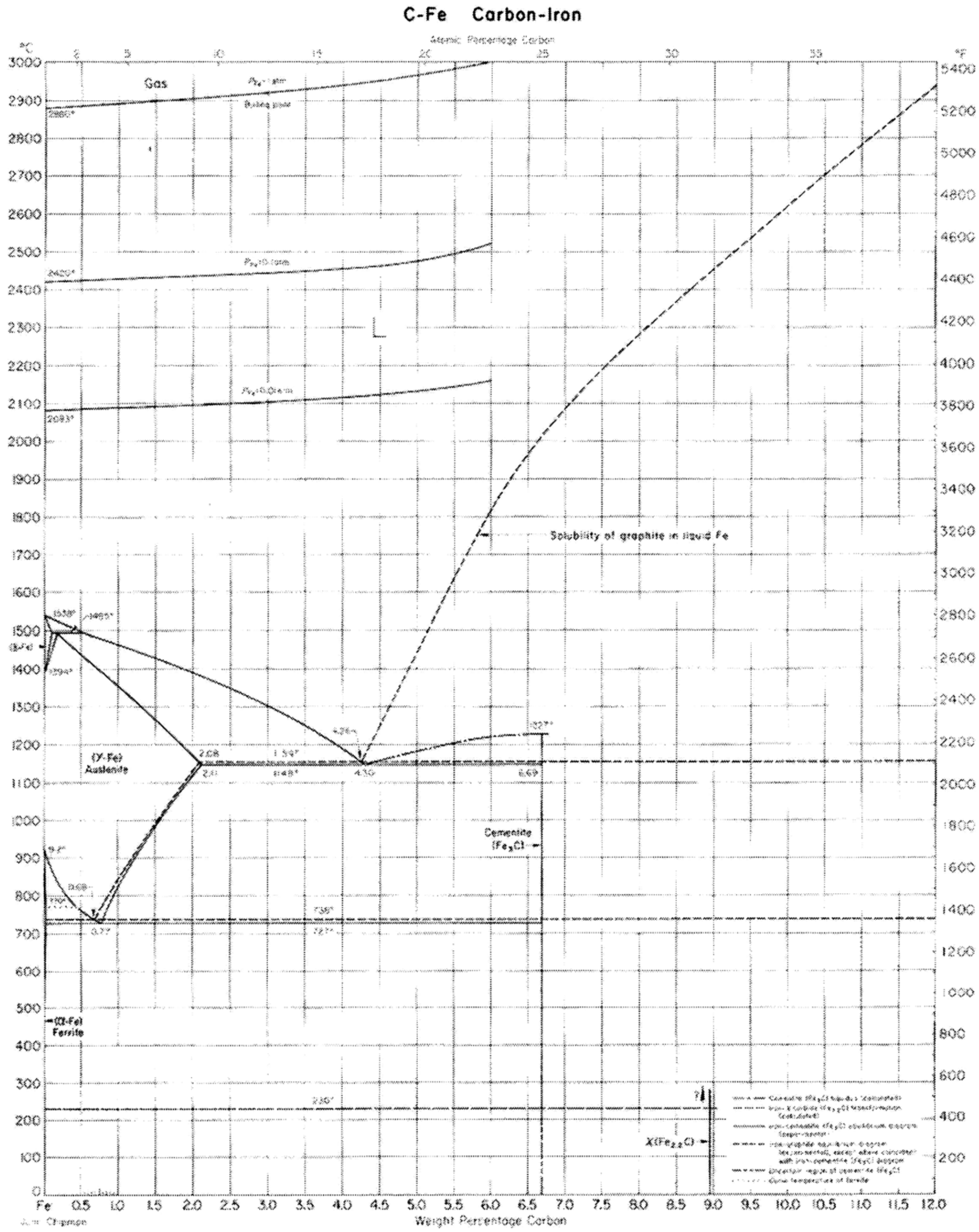


Image Number: Mosaic with MIT 5413_1-11 to 5413_1-16
Microscope: Leica DMLM
Magnification: 40
Etchant: Nital
Description: Iron object
Date: 6.vii.2009
Operator: Ismini Papakirillou

Figure 5.92

Figure 5. 93: Fe-C Phase diagram



(ASM Handbook 1973: 275)

CHAPTER VI: DISCUSSION OF DATA

This chapter will attempt to summarize the analysis of the data discussed in the previous chapter. Starting with the metal used in the manufacture of the objects, I will then discuss the evidence for working on the objects and finally attempt to group the data in a meaningful way.

Metal manufacture

One of the main questions defined in the beginning of this thesis related to the provenance of raw materials used for the manufacturing of these monies. The analysis of the research corpus has lead to a number of conclusions addressing this issue.

Bulk Chemical Analysis

The presence or absence of certain elements in iron can be used as an indicator of the production method used in its manufacture. Trace elements of P, Si and Al are often indicators of a traditional iron bloomery process. These elements are present in the slag produced, small pieces of which are often trapped in the metal. In addition, the absence of certain elements common in industrially produced iron can also point towards more traditional smelting methods. In modern steel, Ni, Cr and Mn are often added to improve the properties of the metal produced. In addition, Ti and V are used in the industrial production of specialist steels (Prof. S.M. Allen, personal communication, April 2009).

All objects were sampled for bulk elemental analysis, using ICP and INAA analysis. The results of the analyses are included in Appendix I. All objects analyzed are made of relatively pure iron. Sample 5412_A has a 1.12 wt. % concentration of Mn, normally associated with industrially produced steel, however the metallographic analysis of this object indicates that it was made from bloom iron, Samples 5413_A and 5416_A have small concentrations of P (>0.5 wt. %). In samples 5409_A, 5410_A, 5419_A and 5421_A, small amounts of SI are present at minor or trace concentration levels (>1.0 wt. %). Both these elements can be directly linked to the presence of slag in the metal. No other elements were present in significant quantities.

The use of bloomery iron was confirmed by examination of the as – polished and etched sections for all the objects of the research corpus. Confirmation was based on a number of factors, outlined below.

Slag inclusions

The presence of slag inclusions in the samples analyzed may provide evidence for the use of raw materials from a traditional bloomery smelt. Study of bloomery slag inclusions often reveals additional information about the smelting process. As discussed in the previous chapter, different crystalline phases in the slags were visible in many of these inclusions. I did not have time to analyze the inclusions with an electron analyzer but that study should be undertaken in the future. Nevertheless, the dendrites present in the slag inclusions of samples (for example sample 5406_1, figs. 5.48-5.49) may be wüstite, as described by C. Smith (Smith 1967a).

In his article on Luristan iron daggers Cyril Smith (1967b) discussed at length different types of inclusions that are typical of bloomery iron slags. These inclusions are often glassy in appearance, indicating a high silica content, and they are produced in the liquid state either from residuals in the ore or from added fluxes. Smith (1967b) identified the following phases in the slag inclusions: mixed wüstite (FeO), fayalite [$(FeO)_2 \bullet SiO_2$ or $2(FeO){\bullet}SiO_2$] and glassy silicate inclusions. Differences in the appearance and size of the slag inclusions are associated with different nucleation rates. It is common for the slag to have one or more dendritic phases that crystallized from the liquid state. The different appearance of slag inclusions can also be a result of the carbon content of the area adjacent to them. In areas of high carbon content, the slag consists of fayalite ($(FeO)_2{\bullet}SiO_2$), which, during cooling crystallizes from the silicate melt in the form of rounded crystals of wüstite (FeO) (Smith 1967b).

Variation in composition

The microstructural composition of the etched sections provides another indication for the use of bloomery iron in the manufacture of the objects in the research corpus. Several samples discussed in Chapter V were noted to be inhomogeneous in composition, with the presence of bands or zones of ferrite and pearlite adjacent to each other. In addition, the carbon content within a single sample can vary, as indicated by the density of iron carbides in the metal microstructure.

This phenomenon of microstructural heterogeneity within a forged iron object was discussed by Smith (1967a) in his Luristan daggers publication. Traditional bloomery furnaces operated in highly carburizing conditions, with the smith having little control over the nature of the smelted bloom. Smith (1967a) describes how an iron object forged from a typical bloom might exhibit zones of varied-carbon content: "the general heterogeneity is entirely of the type that could have originated in the original spongy bloom of iron as it left the reduction furnace, modified with the subsequent shaping of the entire piece and some diffusion of carbon" (Smith 1967a: 37). It is likely that smiths would then combine several different blooms to produce a larger piece of metal. Metallurgical examination of the West African monies shows, however, that this zoning effect was not due to the hammer welding together of several pieces of iron. The slag stringers do not trace interfaces between the different zones of higher and lower carbon content.

Variation in grain size

One of the unusual features noted in several of the money samples is the presence within a single sample of microstructures of differing grain size. A number of samples not only exhibit microstructures that include grains of varying sizes but a clear pattern is present: the finer grain structure is characteristic of areas rich in pearlite, and the coarser grain structure is located in areas with pure ferrite. The explanation for this phenomenon lies in the temperature at which γ-Fe (austenite) nucleates from the melt and the temperature at which the transformation from austenite to (α-Fe + Fe_3C) pearlite occurs. The austenite grains grow through a large temperature drop (~700°C), thus considerable grain growth occurs before the α-Fe (ferrite) – Fe_3C (cementite) transition takes place. The pearlite microstructure is much finer as a result of the low temperature at which this microstructure forms.

The absence of any martensite in the microstructures examined indicates that the metal was not quenched at any point during the forging process.

Fabrication of the objects

Study of the as–polished sections provides valuable information regarding the different manufacturing stages and the ways in which these objects were worked to shape. In certain areas of the microstructure stringers of slag have been broken mechanically during working of the metal to shape the object. This mechanical effect occurs when the stringers are already in the solid state. First, an initial reduction and consolidation of the spongy bloom takes place at high temperature so that the slag – still in a liquid or pasty state is squeezed out and eliminated. Subsequently, the solid slag is deformed and often broken into smaller pieces as the iron is shaped through continuous working at lower temperatures (Smith 1967a).

In addition, the location of these stringers provides valuable information regarding the local direction of metal flow. The elongation and orientation of the stringers follows the flow during forging and shaping (Smith 1967b). For example, samples 5408_1 (fig. 5.57) and 5408_2 (fig. 5.58) were taken adjacent to each other and mounted transversely (5408_1) and longitudinally (5408_2) to demonstrate how the orientation of the slag inclusions reflects the direction of metal flow in response to impact from the forging hammer. The polished sections record the orientation of these inclusions clearly. In the case of money 5408 the slag stringers indicate how the metal was shaped through heavy hammering to form the narrow area adjacent to the blade.

The use of hammer welding is also well documented in these objects. Visual examination and metallographic analysis provided valuable information regarding the use of hammer welding in Liberia group A monies. The polished sections for 5417_1 (fig. 5.29), 5418_1 (fig. 5.34) and 5419_1 (fig 5.37) illustrate these welding lines best. These are high quality welds that indicate considerable experience on the part of the metal smith. The frequent use of hammer welds in Liberia group A monies suggests that these objects were commonly made from multiple pieces of metal, first welded together, and then shaped.

Patterns in the analytical data

The West African monies examined in this thesis were analyzed in groups, following a style typology outlined in Chapter III. In this section I will examine these groupings in light of the analytical findings and check for any patterns that may emerge.

With respect to the bulk chemical data (see Appendix I), no significant differences were noted in the compositions of iron in these groups. Sample (5407_A) is heavily corroded which accounts for the low concentration of iron in the object, (74.5 wt % Fe). No analyses for carbon content were carried out on any of the objects in the study corpus.

Looking at the compositional information provided by the metallographic analysis, I identified three distinct types of microstructure. Seven samples were identified as wrought iron. The primary feature of this microstructure is the presence of ferrite grains. I identified eleven samples as compositionally heterogeneous. Characteristic of bloomery iron, these microstructures include zones of pure ferrite adjacent to zones of ferrite and pearlite grains, the zones varying in volume fraction. I identified four samples as mild steels based on the homogeneous presence of pearlite grains in the microstructure. Table 6.1 summarizes this information, showing that no group–type displays any complete homogeneity with regards to the material used to fashion the monies in that group. Nevertheless, only Cameroon groups C and D contain items made of mild steel, and monies in Cameroon group B are almost all made of low carbon heterogeneous material.

Table 6. 1: Microstructure information by group type

PM NUMBER	MIT NUMBER	GROUP TYPE	MICROSTRUCTURE TYPE
22 2 50 B3616.1	5400	Group A	Low carbon heterogeneous
22 2 50 B3616.2	5414	Group A	Low carbon heterogeneous
22 2 50 B3616.3	5415	Group A	Low carbon heterogeneous
22 2 50 B3616.4	5416	Group A	Wrought iron
22 2 50 B3616.5	5421	Group A	Wrought iron
29 76 50 H1102.2	5399	Group A (L)	Wrought iron
29 76 50 H1102.3	5417	Group A (L)	Low carbon heterogeneous
29 76 50 H1102.4	5418	Group A (L)	Low carbon heterogeneous
20 29 50 B2166.3	5419	Group B	Low carbon heterogeneous
20 29 50 B2166.4	5423	Group B	Low carbon heterogeneous
29 76 50 H1102.5	5398	Group B	Wrought iron
20 29 50 B2166.2	5406	Group B	Low carbon heterogeneous
20 29 50 B2166.3	5407	Group B	Wrought iron
20 29 50 B2166.4	5408	Group B	Low carbon heterogeneous
20 29 50 B2166.5	5420	Group B	Wrought iron
26 1 50 B4273.1	5401	Group C	Mild steel
26 1 50 B4273.2	5409	Group C	Mild steel
26 1 50 B4273.3	5410	Group C	Wrought iron
26 1 50 B4273.4	5422	Group C	Mild steel
37 32 50 2530.1	5411	Group D	Mild steel
37 32 50 2530.2	5412	Group D	Low carbon heterogeneous
37 32 50 2530.3	5413	Group D	Wrought iron

CHAPTER VII: CONCLUSIONS

Both the metallographic and bulk compositional analyses show that all of the West African monies sampled in this study were made from bloomery iron. These results allow us to link these objects to the local systems of metal production. Iron metallurgy was highly developed in the region of study by the late nineteenth century and the smelting of bloomery iron using traditional methods has been well documented (David et al 1989; Miller and van der Merwe 1994; Schmidt 2005; Warnier and Fowler 1979). Ethnographic studies of local iron production provide useful insights regarding the amount of effort, labor time and resources needed to produce bloomery iron (Childs 1991; David et al 1989; DeBarros 1995; Guyer 1986).

The production of these iron monies using locally smelted iron is supported by the ethnographic record. For example, Jane Guyer in her field work discusses these currencies "as locally produced in a village context" (Guyer 1985:2). The analytical results, however, provide no specific indications that these objects were made at a few central locations and then distributed elsewhere or that they were manufactured from the start at the village level. Of particular interest is Liberia Group A, which has a provenance in Liberia. I noted no differences in the metal used to forge the Liberian monies that would distinguish them from the monies of the other groups sampled. The main distinction in Liberia group A monies is in the use of multiple pieces of metal, welded together in their fabrication. The bloomery iron of which they are made is virtually indistinguishable from the iron used in the manufacture of Cameroon monies.

The difference in style is one of the most interesting aspects noted in the iron monies from the region of study. The four different groups studied that originate from Southern Cameroon are only a subset of a much larger group of different types of iron monies used in the region. The various designs used by a number of local ethnic groups represent different interpretations of a common symbolic currency (DeBarros 1995; Guyer 1985; Guyer 2004; Herbert 1984). The prototype for the symbolic currency form was a utilitarian item, an iron spearhead. According to Jane Guyer, the amount of metal used in the manufacture of monies of spearhead shape does not differ considerably from the amount necessary to make the utilitarian tool itself (Guyer 1985). In addition, the use of the bundle form, in which a set number of monies is tied together with binding material, was common to all five groups studied. The unit of value was the bundle of monies rather than the individual items the bundle contained. The Liberian group differs from the other groups in having a distinct twisted feature, longer dimensions and no resemblance to a spearhead.

The variability of form noted in these currencies adds another dimension to the analysis, namely variability in weight. The different money types studied vary in the amount of metal used to make them, yet they were all part of a complex, non-centralized exchange system used by several ethnic groups in the region. In addition, the data I collected regarding the weights of individual monies contained in each of two bundles show great variability even within the same bundle. The weight of each bundle was also examined but these determinations cannot be relied upon due to the poor condition of some of the monies and to missing items in some of these bundles. The one bundle which is preserved intact, from Cameroon group A, demonstrates the considerable amount of metal contained in just one such bundle: 2.9 kilograms.

As discussed above, four of the groups studied are designed based on a spearhead shape. Having established that these monies were made of quality iron and often were the same size as the utilitarian object, a question often asked is whether the monies were at any point used as functional objects. The metallographic analyses provided no evidence that these monies were deliberately treated during their fabrication in order to enhance specific material properties such as strength or hardness. In the case of Cameroon group B, some of the monies contained in the bundle had fully formed sockets, but others were more crudely shaped. For Cameroon groups A, C and D, the monies within each bundle differ greatly in their degree of finish. The symbolic function of the monies, expressed in their shape and in the material from which they are made, is confirmed by the ethnographic record (Guyer 1985; Herbert 2004).

By the late nineteenth century, the main function of these currencies was in bride wealth payments, although they were also used for payment of specialist goods and services (Guyer 1985). Their significance in local societies is emphasized by the considerable amounts of metal used in their fabrication. The fabrication of monies for symbolic use meant the locally produced iron forged to shape them was "taken out of practical use" (Guyer 1985: 4). In addition to the raw material, these iron monies also demanded highly specialized expertise and group labor for their production (Childs 1991; DeBarros 1985; Guyer 1985; Killick 1990). All these features reflect the importance and value assigned to marriage and the notion of bride wealth payments in the region (Guyer 1986).

The use of iron monies provided a means for young men to strengthen their position in their groups through marriage alliances by gaining access to these bundles, the *bikie* (Kingsley 1900). This was not an easy task, but the existence of the monies made it possible for ambitious men who lacked strong support from their lineage to improve their status within the group through polygamy (Guyer 1986). As Jane Guyer writes "there were ways for other men to get a share of the iron produced at the smelt, and to earn it through personal prowess, whether in physical strength and dexterity, intellectual and oratorical gifts, or musical and artistic achievements" (Guyer 1985: 15). The value assigned to these monies was the result of a complex system controlling their supply and distribution. This was achieved by limiting the possibilities of *bikie* re-entering the market place. Only the father of the bride had rights to the marriage payments, and the monies were used only for specialist transactions, as mentioned before (Guyer 1986).

This metallographic study is the first to examine n detail and systematically the method of fabrication of West African iron monies. The results provided by the analyses show that the most important aspects of these monies were the material from which they were made, iron and their form. Even though the form varies somewhat among the different ethnic groups, the process of fabrication was universal across the region. These bundles were used as bride wealth payments and their value was expressed through their design and material. This value was acknowledged and accepted throughout the region, establishing these bundles as a kind of special purpose money for exchange within and between ethnic groups.

Any further inferences regarding the analytical results are hindered by the limited sample data set available. We still have limited knowledge regarding the production and distribution of iron monies, the raw material, among the different ethnic groups in the study region. In addition, further study of these monies in comparison with their utilitarian counterparts would help define the relationships between symbolic and functional use and the nature of the interchanges between them.

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APPENDIX I

Report: A09-3356 (i)

Preliminary Report-ICP
Activation Laboratories

Report Date: 30/07/2009

Analyte Symbol	P	Mass	Final Volume	Si	Al	Cr	Fe	Ni	Pb	Co	Mn	Mo	Ti	V	Cu
Unit Symbol	%	g	ml	%	%	%	%	%	%	%	%	%	%	%	%
Detection Limit	0.005			0.01	0.01	0.01		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Analysis Method	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP
MIT 5406-A	0.324	0.1337	30	0.53	0.1	< 0.01		0.07	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	0.02
MIT 5407-A	0.356	0.0793	20	0.73	0.22	< 0.01		0.07	< 0.01	0.09	0.02	< 0.01	< 0.01	< 0.01	0.04
MIT 5408-A	0.211	0.0534	10	0.67	0.05	< 0.01		0.07	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02
MIT 5409-A	0.054	0.0406	10	1.15	0.04	< 0.01		0.03	< 0.01	0.02	0.73	< 0.01	< 0.01	< 0.01	0.09
MIT 5410-A	0.266	0.0263	10	1.11	0.04	< 0.01		0.02	< 0.01	0.01	0.05	< 0.01	< 0.01	< 0.01	0.08
MIT 5411-A	0.078	0.0553	10	0.65	0.05	< 0.01		0.03	< 0.01	0.02	0.52	< 0.01	< 0.01	< 0.01	0.09
MIT 5412-A	0.149	0.0872	20	0.84	0.09	0.02		0.04	< 0.01	0.02	1.17	< 0.01	< 0.01	< 0.01	0.27
MIT 5413-A	0.533	0.0798	20	0.76	0.07	< 0.01		0.07	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.04
MIT 5414-A	0.013	0.0961	20	0.65	0.07	< 0.01		0.21	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.05
MIT 5415-A	0.04	0.0583	10	0.47	0.09	< 0.01		0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02
MIT 5416-A	0.569	0.1844	40	0.71	0.05	< 0.01		0.04	< 0.01	0.01	0.07	< 0.01	< 0.01	< 0.01	0.06
MIT 5417-A	0.041	0.0741	20	0.72	0.03	< 0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
MIT 5418-A	0.033	0.038	10	1.24	0.04	< 0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
MIT 5419-A	0.042	0.0797	20	1.12	< 0.01	< 0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
MIT 5420-A	0.116	0.0552	10	0.84	0.18	< 0.01		0.15	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.12
MIT 5421-A	0.081	0.0271	10	1.78	0.07	< 0.01		0.12	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03
MIT 5422-A	0.085	0.1164	20	0.73	0.03	0.01		0.04	< 0.01	0.01	0.56	< 0.01	< 0.01	< 0.01	0.07

Chemical Analysis: Results ICP

Report Date: 31/03/2009

Analyte Symbol	Fe	Mn	Ni	Sn	Zn	Pb	Sb	As	Ag	P	Co	Mass	Final Volume
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	g	ml
Detection Limit	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.001	0.005	0.005		
Analysis Method	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP
MIT 5398-A	88.8									0.16		0.059	10
MIT 5399-A	93.4									0.113		0.3803	70
MIT 5400-A	91.2									0.07		0.0549	10
MIT 5401-A	88.7									0.05		0.1661	35

	Si	Cr	V	Ti	Mo	Al	Mn	Pb	Co	Ni	Cu
	%	%	%	%	%	%	%	%	%	%	%
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP	METALS-ICP
MIT 5398-A	0.23	< 0.01	< 0.01	0.02	< 0.01	0.11	< 0.01	< 0.01	< 0.01	0.01	0.04
MIT 5399-A	0.09	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
MIT 5400-A	0.08	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02
MIT 5401-A	0.3	< 0.01	0.01	< 0.01	< 0.01	0.01	0.43	< 0.01	< 0.01	< 0.01	0.12

Chemical Analysis: Results INAA

Report Date: 31/03/2009

Analyte Symbol	Au	Ag	As	Ba	Br	Co	Cr	Cs	Hf	Hg	Ir	Mo	Na	Rb	Sb	Mass
Unit Symbol	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	%	g
Detection Limit	0.1	0.001	0.001	50	0.5	1	5	1	1	1	5	1	0.01	15	0.001	
Analysis Method	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
MIT 5398-A	< 0.1	< 0.001	0.01	< 50	17.7	41	173	< 1	< 1	< 1	< 5	< 1	< 0.01	< 15	< 0.001	0.073
MIT 5399-A	< 0.1	< 0.001	0.001	< 50	3.5	28	60	< 1	< 1	< 1	< 5	< 1	< 0.01	< 15	< 0.001	0.245
MIT 5400-A	0.1	< 0.001	0.001	1450	55.3	84	601	< 1	< 1	< 1	< 5	94	< 0.01	< 15	< 0.001	0.015
MIT 5401-A	0.3	< 0.001	0.048	< 50	7.7	168	138	< 1	< 1	< 1	< 5	< 1	< 0.01	< 15	0.007	0.21

Analyte Symbol	Sc	Se	Sn	Sr	Ta	Th	U	W	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
Unit Symbol	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.1	3	0.01	0.05	0.5	0.2	0.5	1	0.5	3	5	0.1	0.2	0.5	0.2	0.05
Analysis Method	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
MIT 5398-A	2.8	< 3	< 0.01	< 0.05	< 0.5	< 0.2	3.2	< 1	< 0.5	< 3	< 5	0.3	< 0.2	< 0.5	< 0.2	< 0.05
MIT 5399-A	0.2	< 3	< 0.01	< 0.05	< 0.5	< 0.2	< 0.5	6	< 0.5	< 3	< 5	< 0.1	< 0.2	< 0.5	< 0.2	< 0.05
MIT 5400-A	1.6	< 3	< 0.01	< 0.05	< 0.5	< 0.2	< 0.5	< 1	< 0.5	< 3	18	< 0.1	< 0.2	< 0.5	< 0.2	< 0.05
MIT 5401-A	< 0.1	< 3	< 0.01	< 0.05	< 0.5	< 0.2	< 0.5	7	< 0.5	< 3	< 5	< 0.1	< 0.2	< 0.5	< 0.2	< 0.05

APPENDIX II

Scale 1:1

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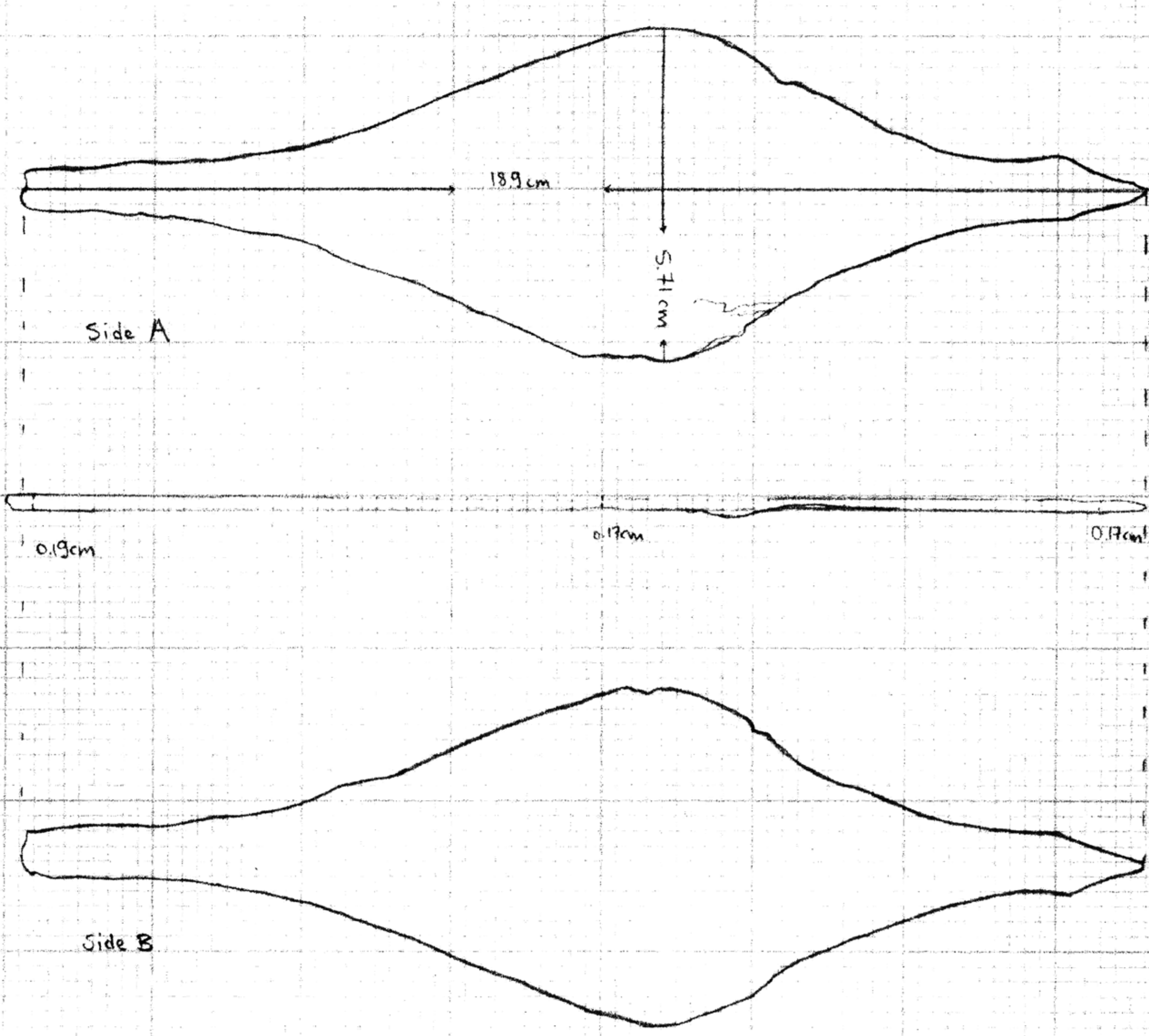
22-2-50/B 3616.
MIT 5400



Scale 1:1

ALL MEASUREMENTS IN CM

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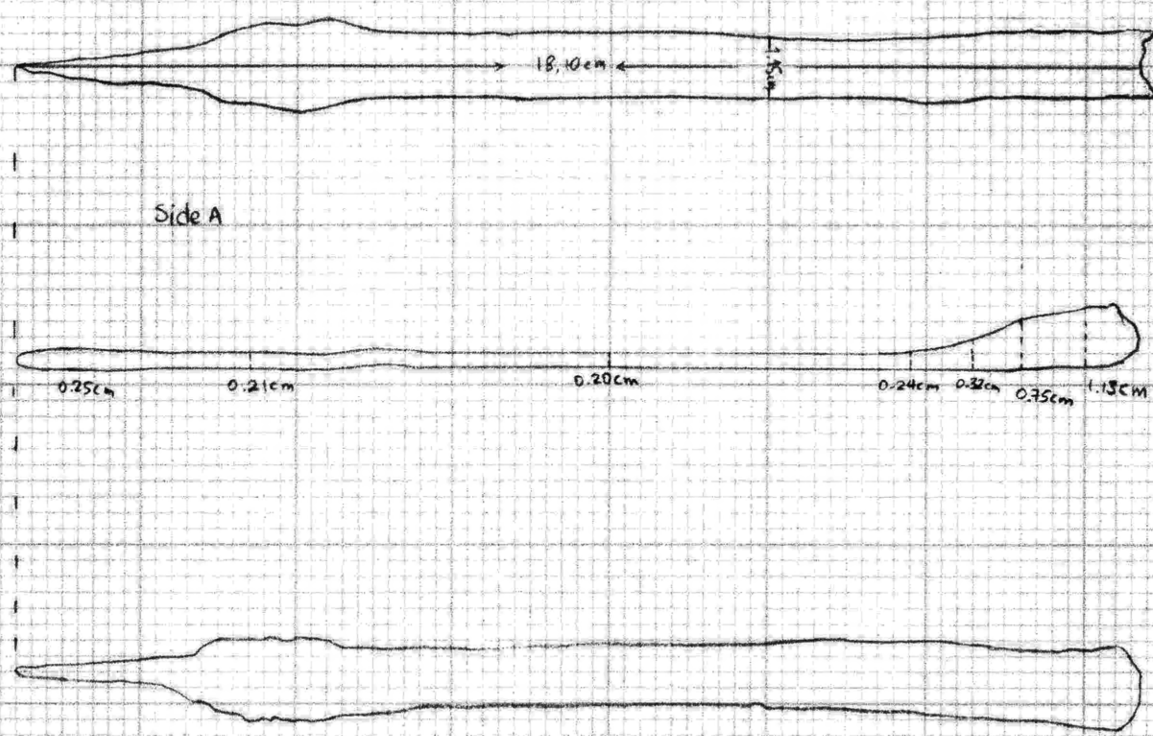
26-1-501 B4273.1
MIT 5401



Side B

ALL MEASUREMENTS IN CM
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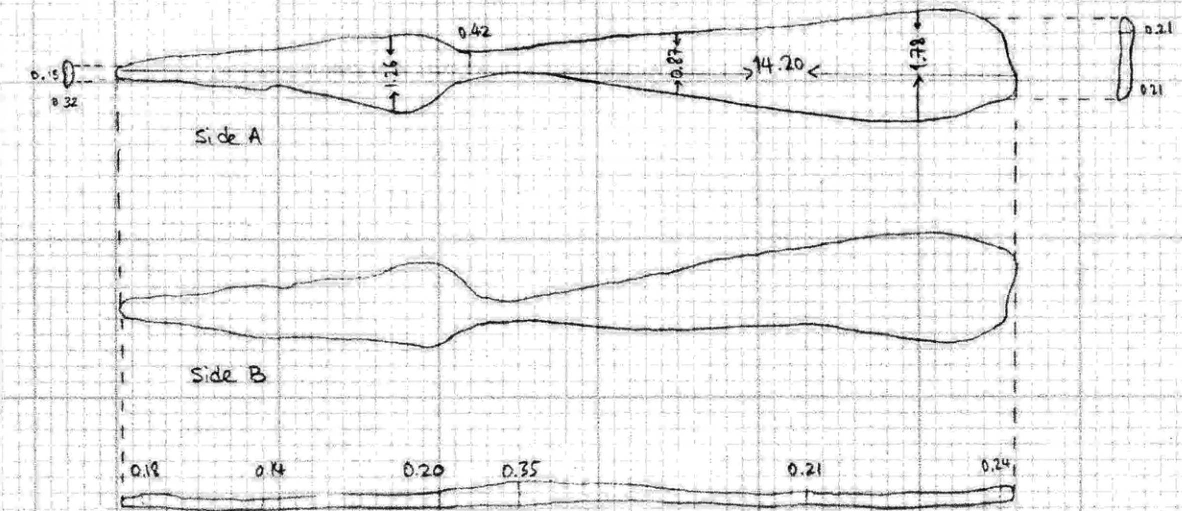
6.20.2009
20-29-50 B2166.2

MIT 5406

Weight 13.80gr.



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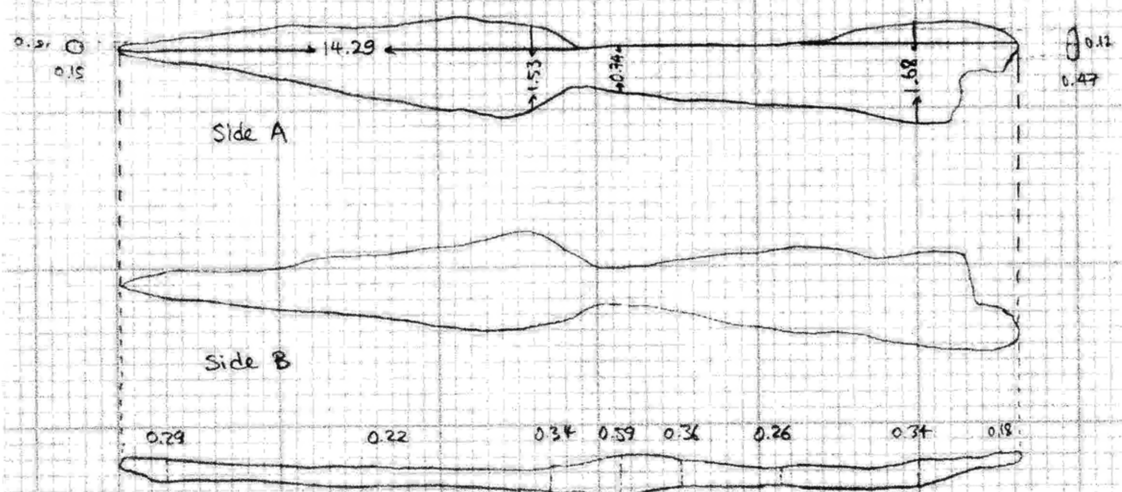
MIT 5407

Weight 15,46 gr.

ALL MEASUREMENTS IN CM
SCALE 1:1



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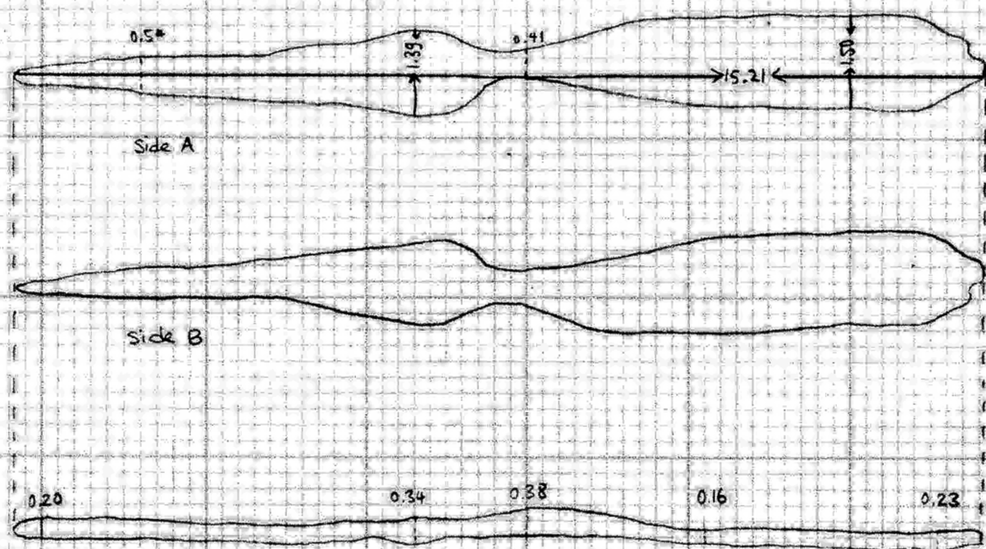
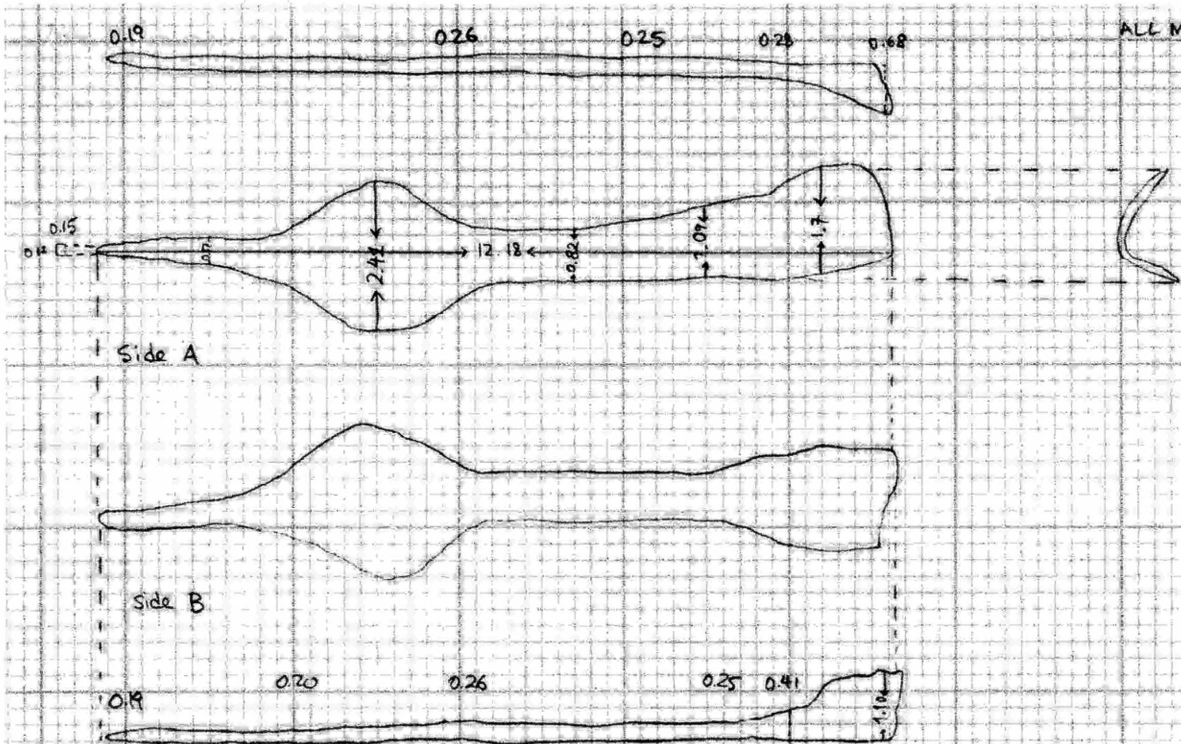
6.20.2009
20.29.50 B2166
MIT S408

Weight 11.90 gr.





ALL MEASUREMENTS IN CM

SCALE 1:1

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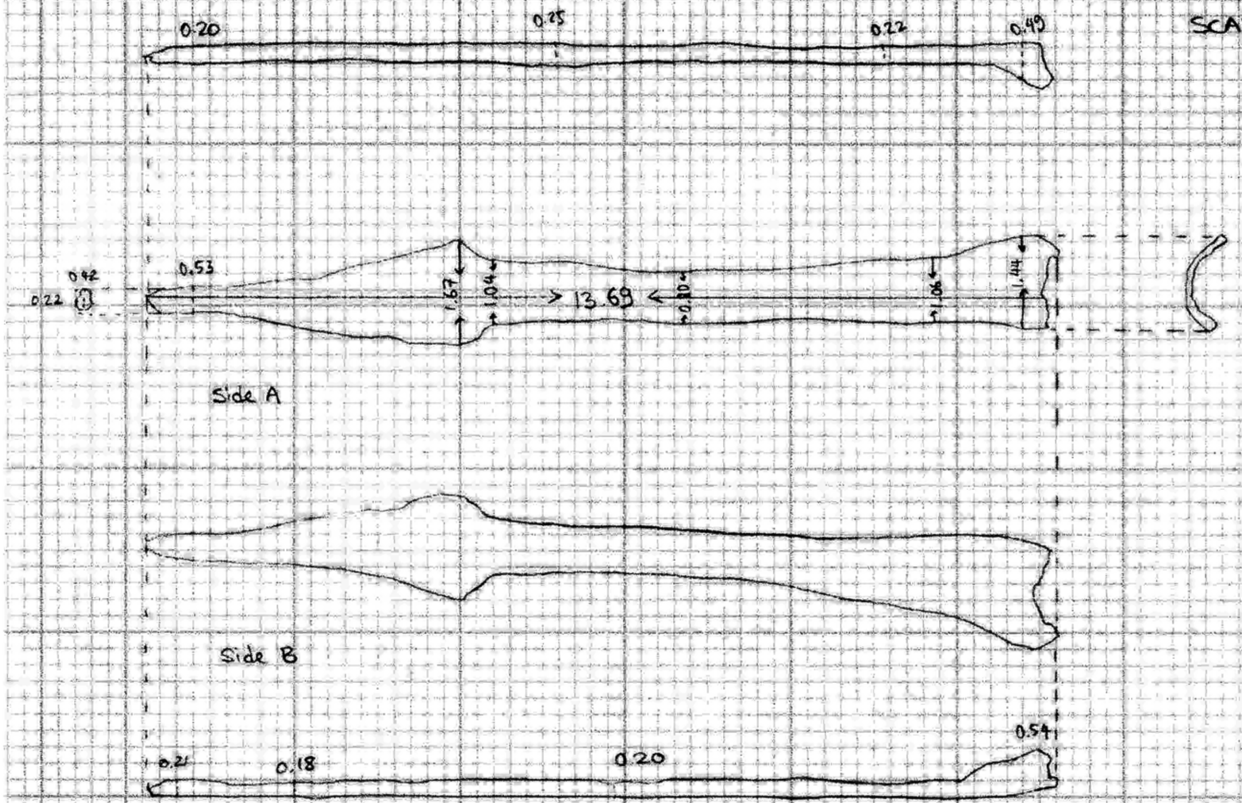
6.20.2009
26.1.50 B4233.2
MIT 5409

Weight: 14.65gr.

ALL MEASUREMENTS IN CM
SCALE 1:1

I. PAPAKIRILLOU
6.20.2009
26-1-50 B 4273.3
MIT 5410

Weight: 13.18 gr.



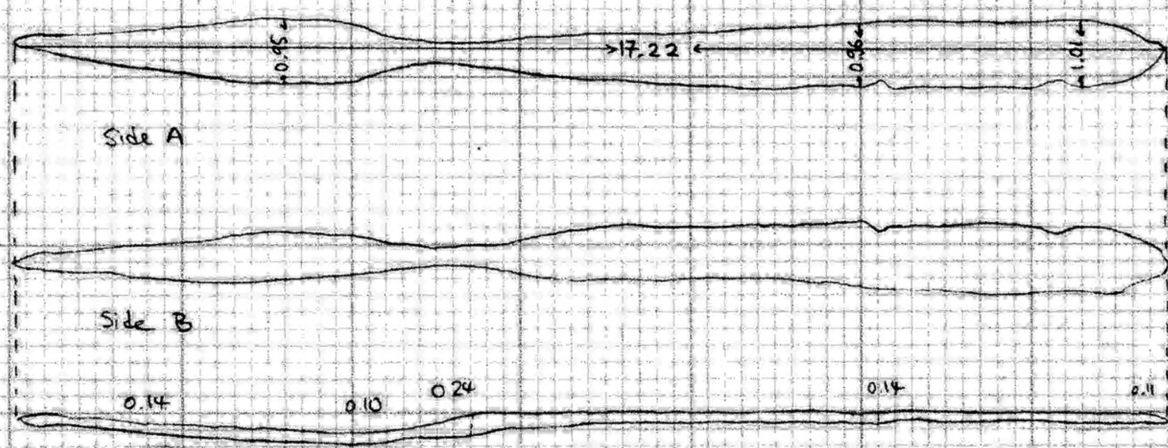
ALL MEASUREMENTS IN CM

SCALE 1:1

6.20.2009

37-32-501 2530

MIT 5411



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SCALE IS 1:1

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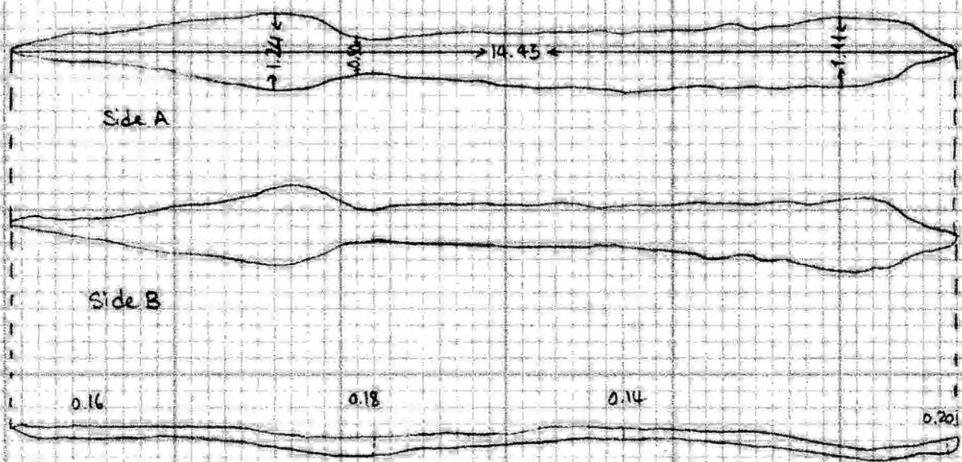
MIT 5412



ALL MEASUREMENTS IN CM

SCALE 1:1

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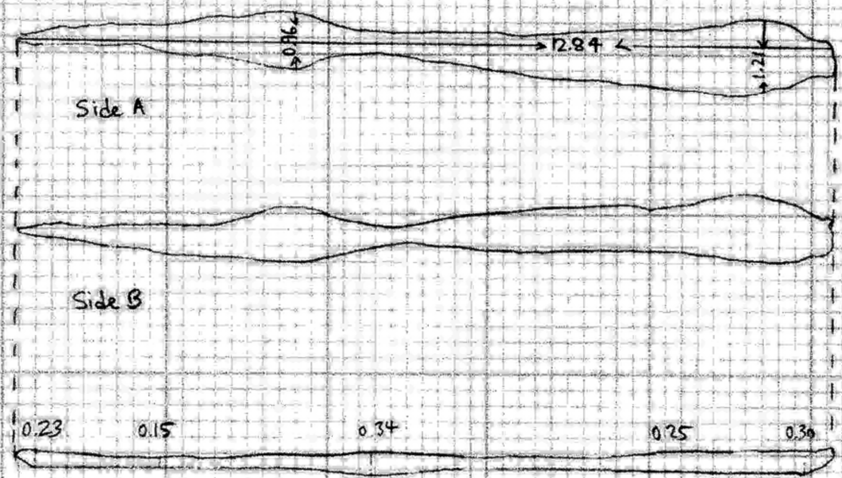
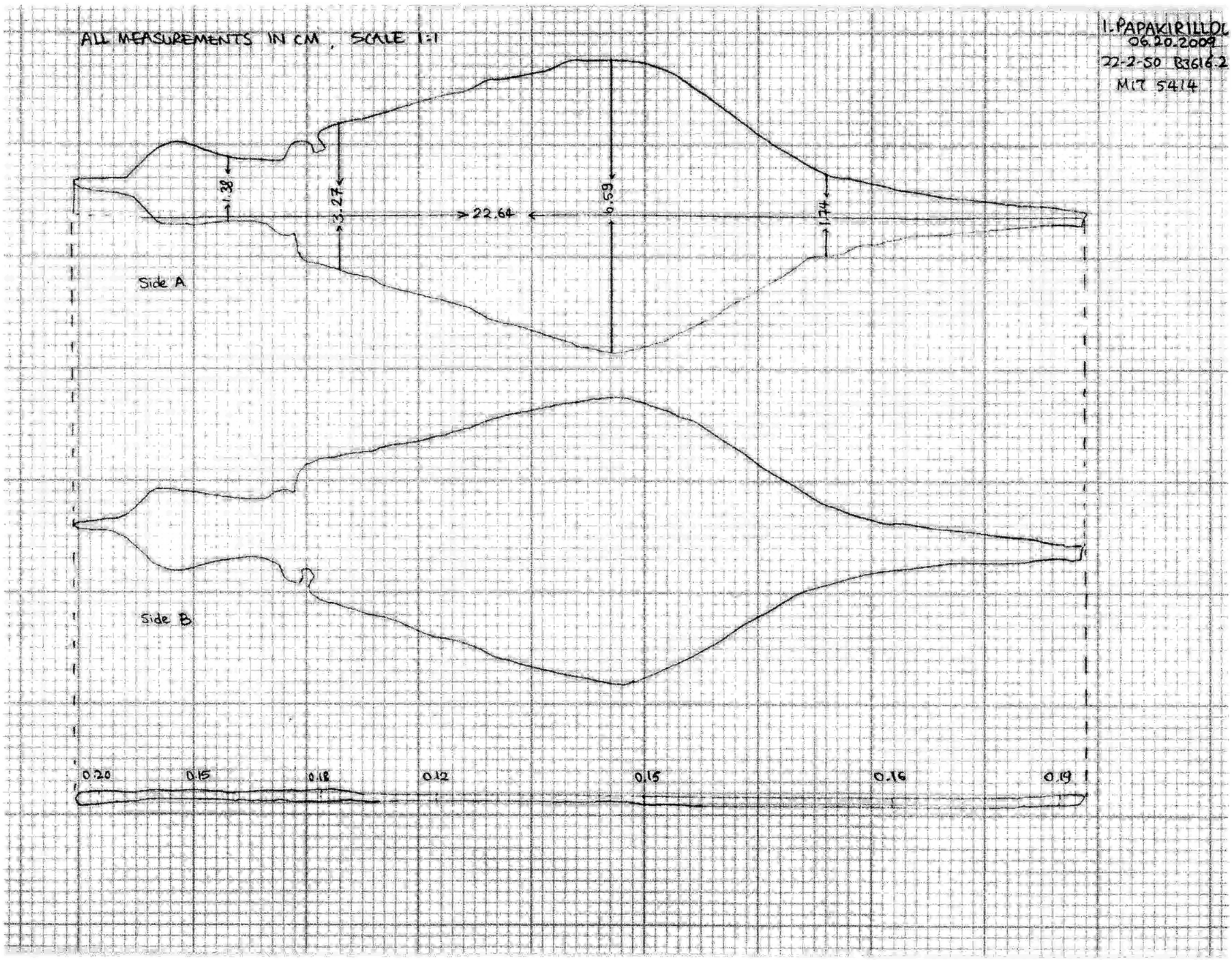
MIT 5413

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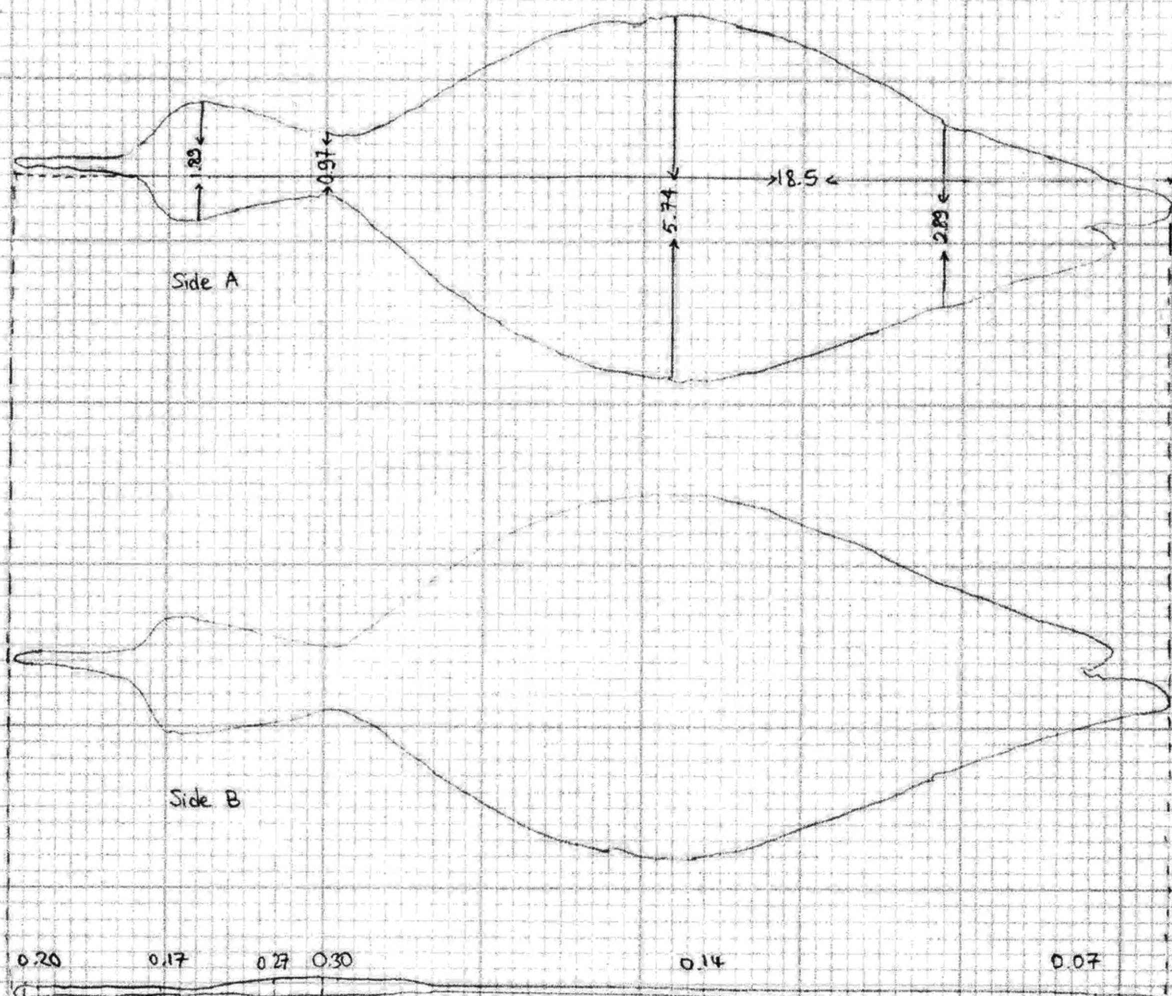
06.20.2009
22-2-50 B3616.2
MIT 5414
1.38
3.27
22.64
6.59
1.74
Side A
Side B
0.20
0.15
0.18
0.12
0.15
0.16
0.19

I.PAPAKIRILLOU
06.20.2009
22-2-50 B3616.3
MΠ 5415

MEASUREMENTS IN CM

SCALE 1:1



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I PAPAKIRILLOU
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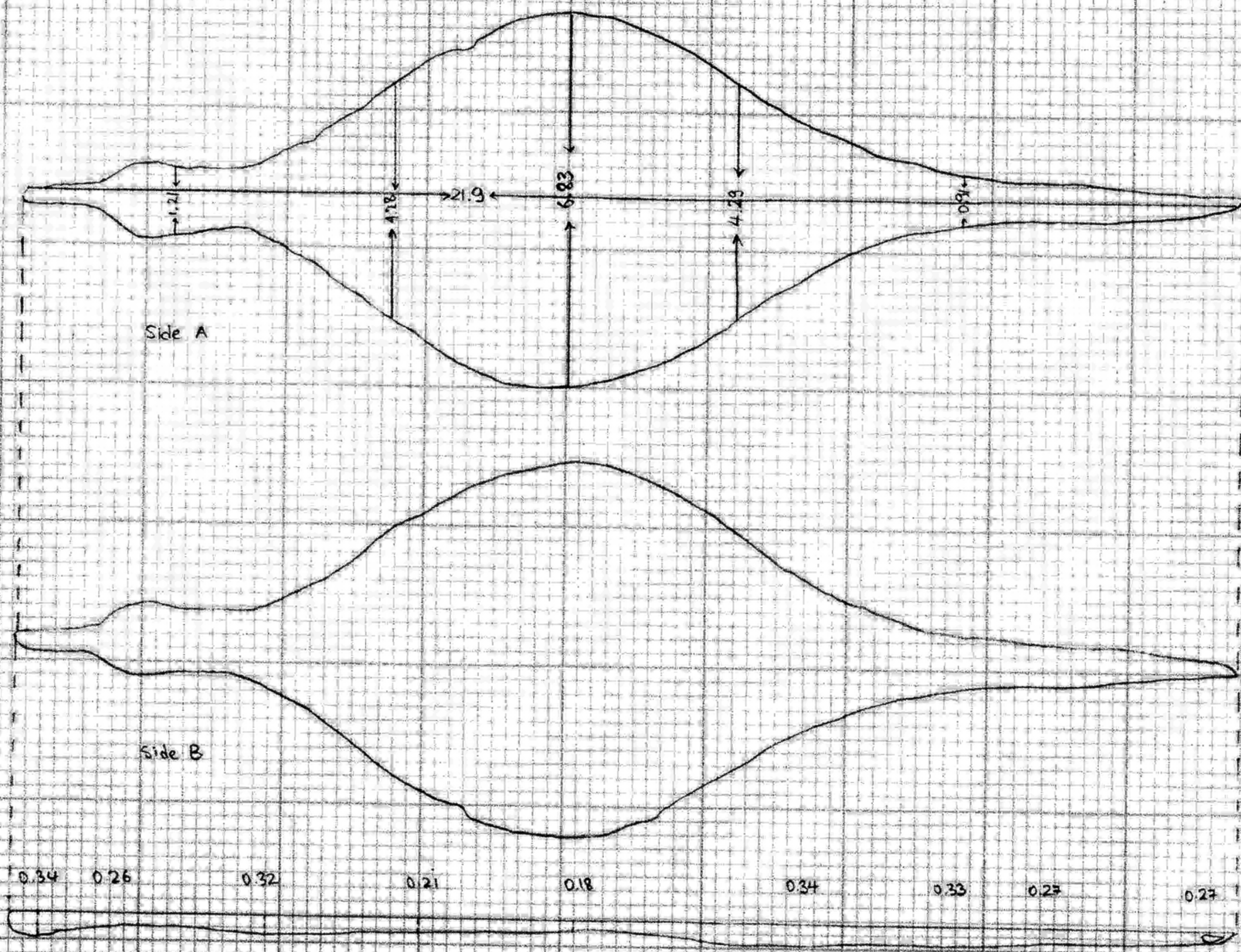
MIT 5416



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29-76-50 H1102.

MIT 547

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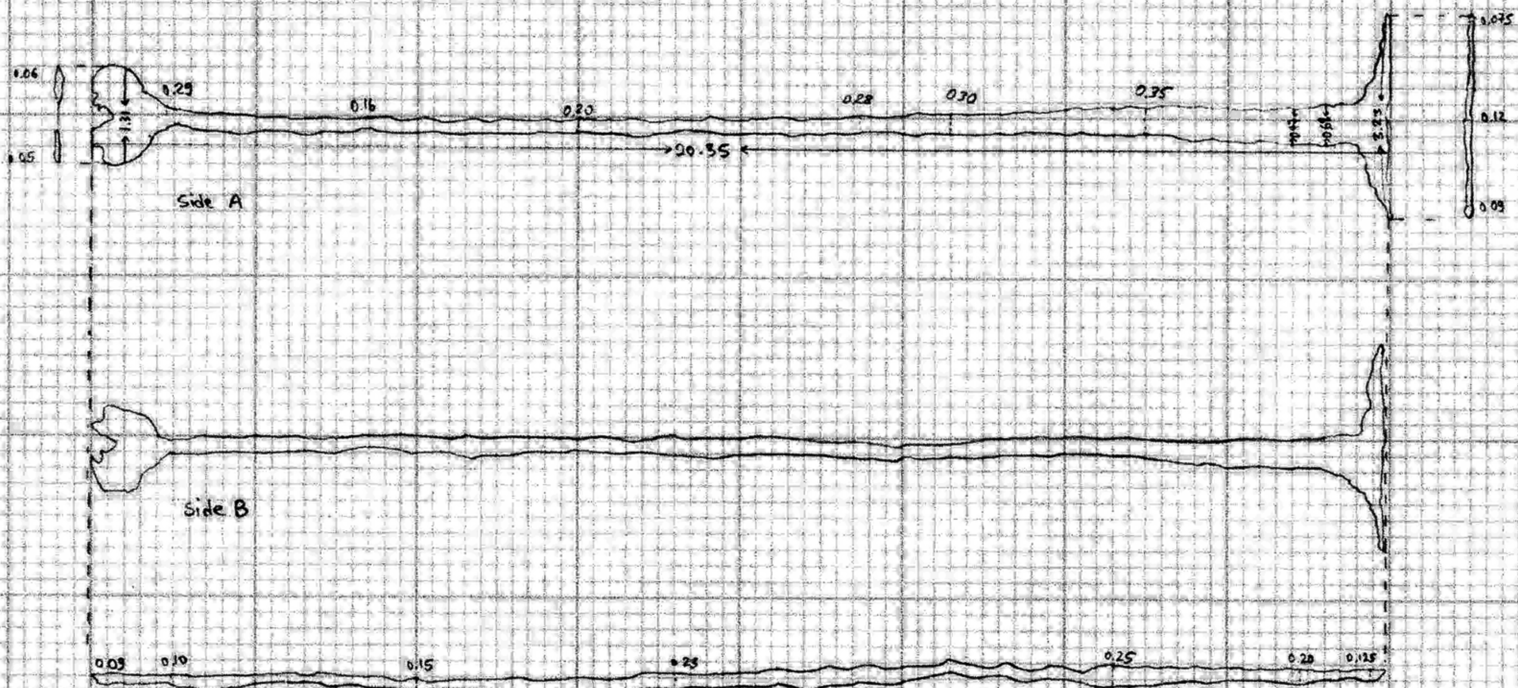

ALL MEASUREMENTS IN CM

SCALE 1:2

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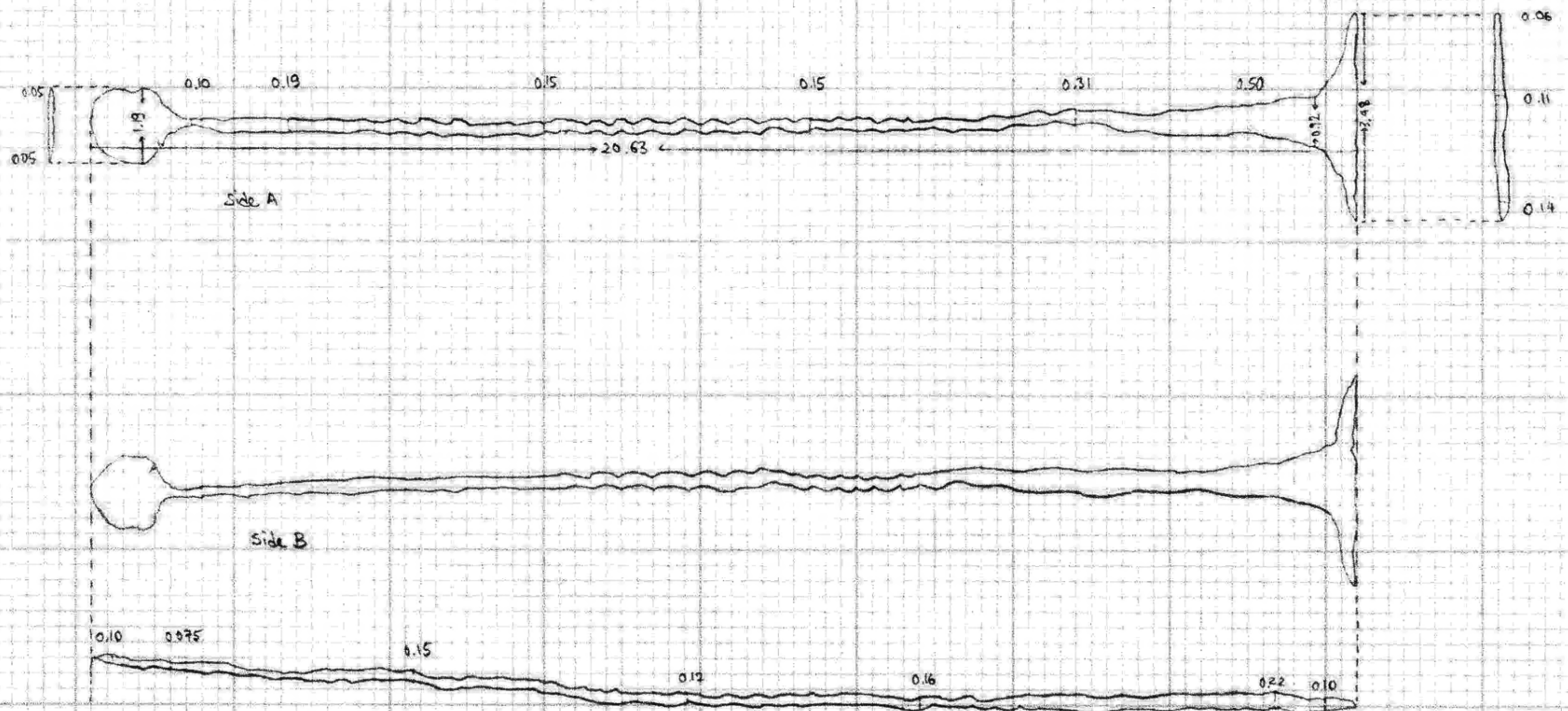
6.21.2009

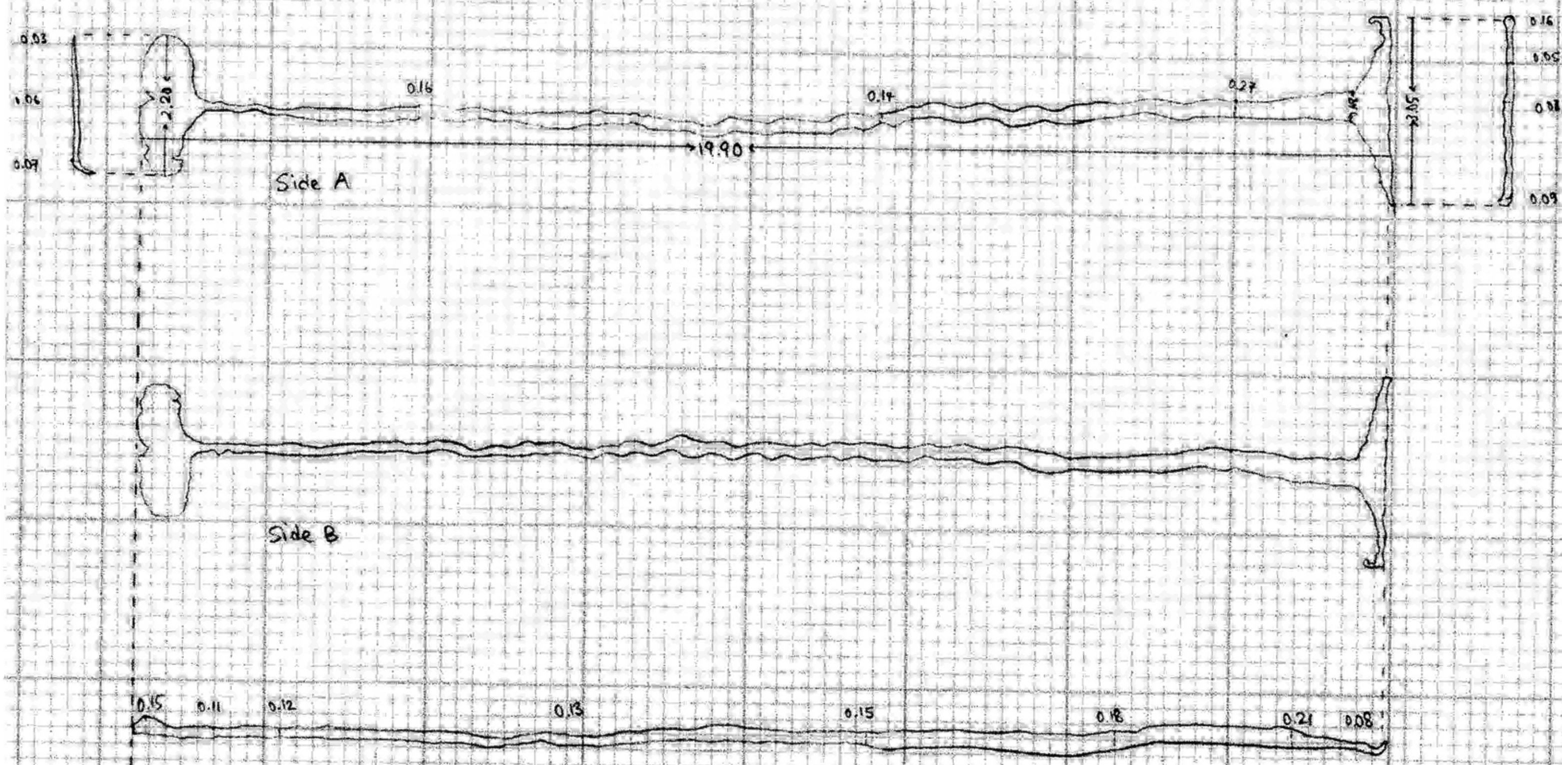
29-76-50 H/102.3
MIT 5418

Weight 35.36gr



ALL MEASUREMENTS IN CM
SCALE 1:2

I.PAPAKIRILLOU
6.21.2009
29-76-50 H1102.4
MIT 5419
Weight 44.01gr



ALL MEASUREMENTS IN CM
SCALE 1:1

I. PAPAKIRILLOU
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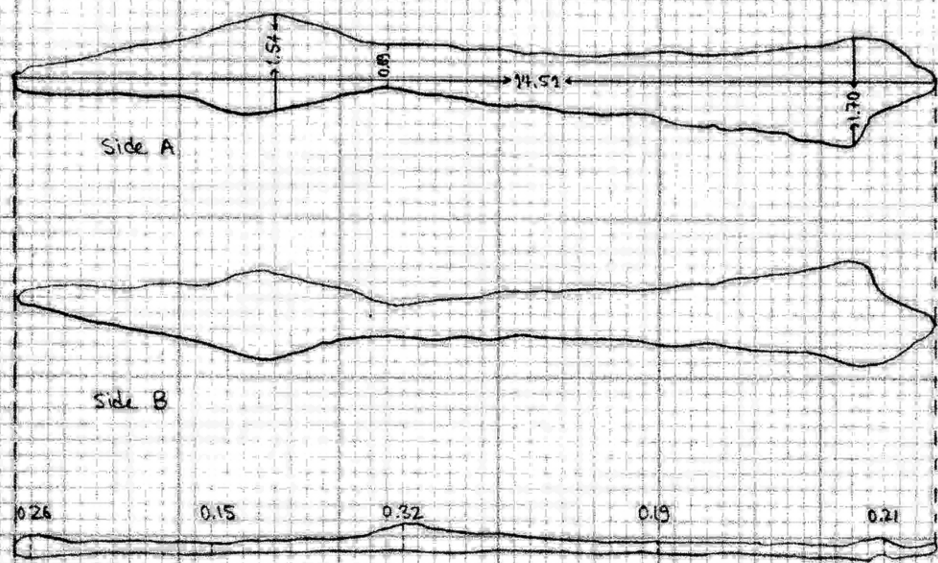
20·29·50 B2166.5
MIT 5420

weight 11.01gr.



ALL MEASUREMENTS IN CM, SCALE 1:1

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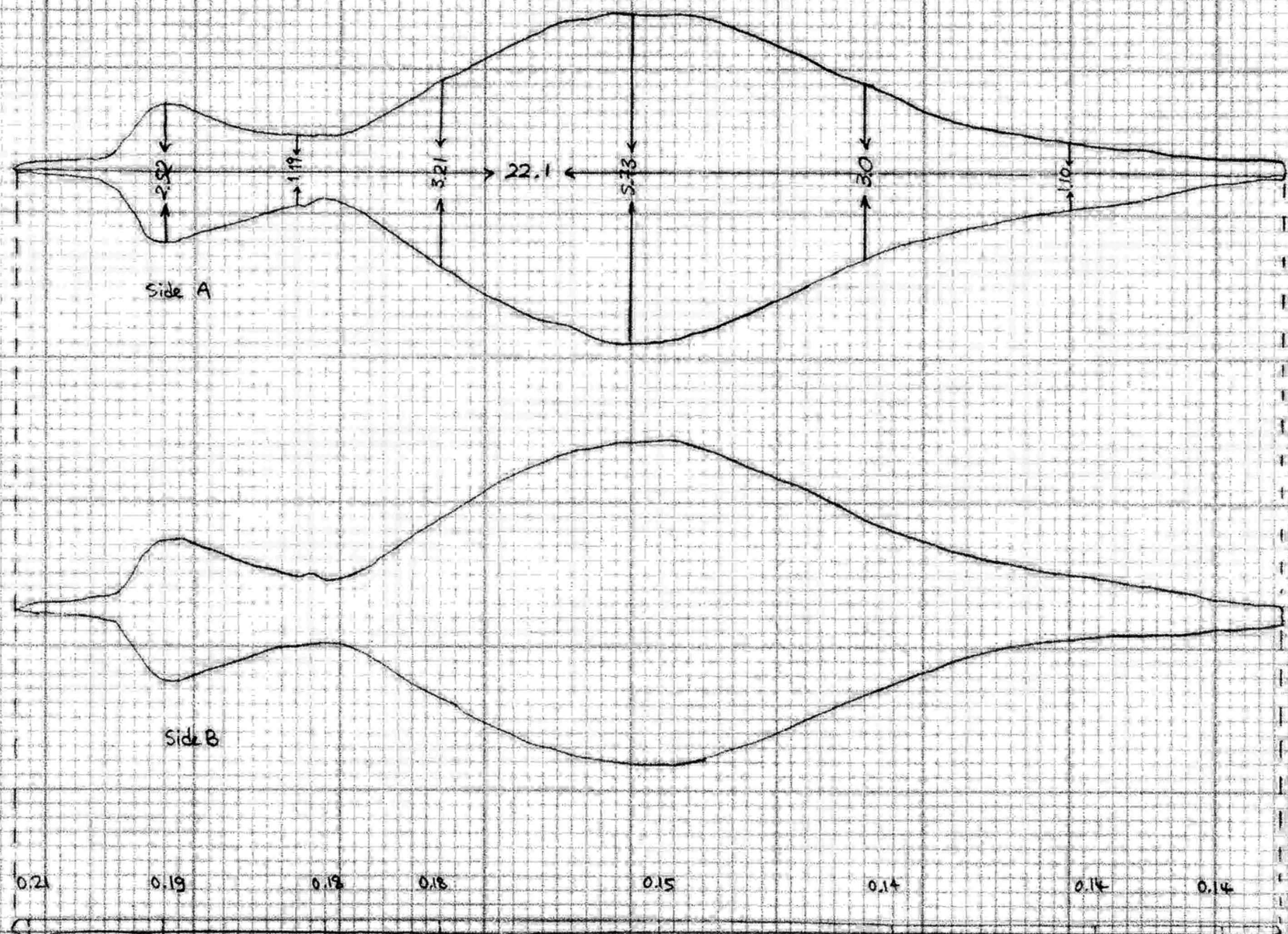
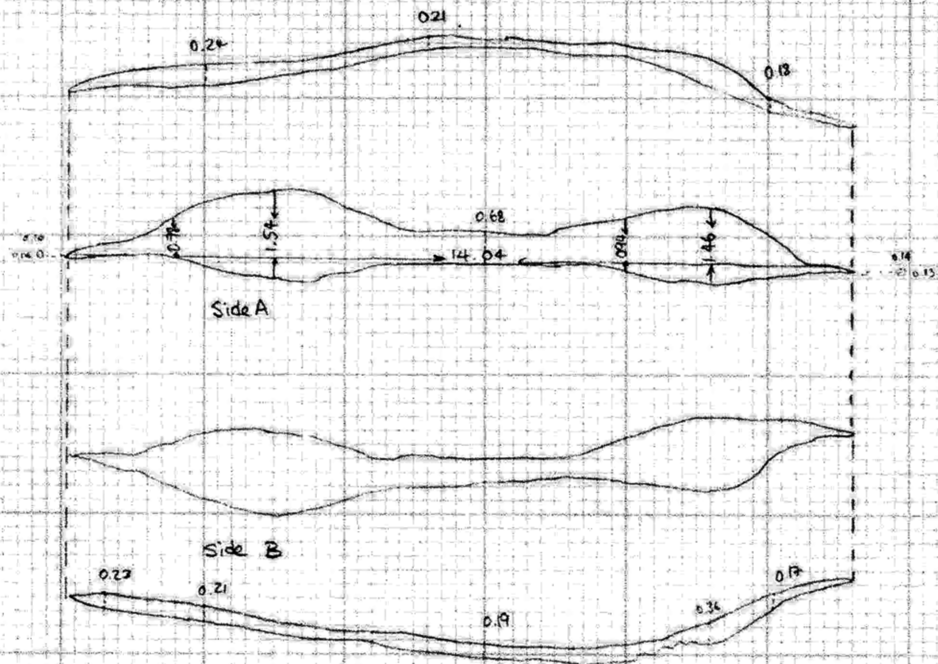
MIT 5421





ALL MEASUREMENTS IN CM

SCALE 1:1

I. PAPAKIRILLOU
6.20.2009

26-1-50 842734

MIT 5422

Weight 12.12gr

ALL MEASUREMENTS IN CM
SCALE 1:2

I.PAPAKIRILLOU
6.21.2009
29-76-50 H1102.5
MIT 5423

Weight 45.18gr