The Materiality of Greek and Roman Curse Tablets

Technological Advances

Edited by
Sofía Torallas Tovar and
Raquel Martín Hernández

with contributions by
Jan N. Bremmer,
Loretta Rossetti,
and Arie Shaus

THE ORIENTAL INSTITUTE OF THE UNIVERSITY OF CHICAGO

THE MATERIALITY OF GREEK AND ROMAN CURSE TABLETS

THE MATERIALITY OF GREEK AND ROMAN CURSE TABLETS

TECHNOLOGICAL ADVANCES

Edited by

Sofía Torallas Tovar and Raquel Martín Hernández

with contributions by

Jan N. Bremmer, Loretta Rossetti, and Arie Shaus

THE ORIENTAL INSTITUTE OF THE UNIVERSITY OF CHICAGO

ISBN: 978-1-61491-082-4

The Oriental Institute, Chicago

Oriental Institute Miscellaneous Publications

Series Editor
Andrew Baumann

with the assistance of
Connie Gundry Tappy

Cover Illustration
Detail of a lead curse tablet written in Latin from Bath (Aquae Sulis), England.
Second to third century CE. Photograph by Mike Peel (www.mikepeel.net) /
CC-BY-SA-4.0 (via Wikimedia Commons).

Cover Design
James M. Slate

Layout
PerfecType, Nashville, TN

Contents

Abbreviations

AIJ	Victor Hoffiller and Balduin Saria, *Antike Inschriften aus Jugoslawien.* Vol. 1, *Noricum und Pannonia Superior.* Amsterdam: Hakkert, 1970
3D	three-dimensional
CMYK	cyan-magenta-yellow-key (color mode)
fig(s).	figure(s)
H-RTI	handheld reflectance transformation imaging
ICOM-CC	International Council of Museums–Committee for Conservation
IL	iron and lead
n.	(foot)note
ppb	parts per billion
ppm	parts per million
RGB	red-green-blue (color mode)
RTI	reflectance transformation imaging
sing.	singular
TM	Trismegistos (database; https://www.trismegistos.org)
UPZ	Ulrich Wilcken, *Urkunden der Ptolemäerzeit (ältere Funde).* 2 vols. Berlin: De Gruyter, 1927

All references to papyri use the *Checklist of Editions of Greek, Latin, Demotic, and Coptic Papyri, Ostraca, and Tablets* at https://papyri.info/docs/checklist. We have given the Trismegistos number for all cited documents for further information.

Introduction: On the Advantages of Material Studies in Magic

Sofía Torallas Tovar and Raquel Martín Hernández

This volume is one of the publications resulting from Curses in Context, a project funded by the Neubauer Collegium for Culture and Society at the University of Chicago.[1] This project assembled scholars to deliberate over the local, chronological, and material contexts of curse tablets in the ancient Mediterranean world.

Curse tablets are small, inscribed metal sheets—usually but not always composed of lead—that are intended to manipulate the actions of other people or animals without their consent. Such tablets have survived from antiquity primarily because of their durable media and because they were often deposited in inaccessible places such as graves, chthonic sanctuaries, and underground bodies of water, including wells, cisterns, and springs. Moreover, the texts that the tablets preserve often give ample insight into the private anxieties, thoughts, and actions of the people who wrote or commissioned them, as well as the names, professions, and social situations of the people whom they curse. Some, for example, are "binding curses," called *katadesmoi* in Greek, which seem to represent a simple form of name magic. These curses aim to restrain rivals in various agonistic venues, such as law courts, contests, or competitions, and do so by manipulating or piercing a series of inscribed names. In many of these binding curses, there is apparently no need for divine help; the performance of the rite is interpreted as an automatic ritual action through which the author's objectives will be fulfilled. Other tablets preserve complex texts that appeal to divinities to intercede for the benefit of the ritual operator or the operator's client. These texts address either gods—normally chthonic gods such as Demeter or Hermes—or the demons of the dead—usually those of erotic purpose—and the tone of these sorts of petitions may be more or less coercive. Other tablets, however, are inscribed with traditional prayers, albeit prayers addressed to chthonic deities asking them to do the binding. Another popular genre of curse tablet that was deposited publicly in sanctuaries asked the god residing in a given sanctuary to bring thieves or slanderers to justice.

Curse tablets have an enduring legacy in the ancient Mediterranean basin, beginning with the earliest Greek examples in the classical period in both Sicily and Athens and surviving via permeation first throughout the Greek-speaking world and later to every corner

1 The principal researchers of this project are Christopher Faraone and Sofía Torallas Tovar, with the collaboration of Richard Gordon and Celia Sánchez Natalías. The project was funded for 2018–21. Four conferences were organized in the framework of this project, and five volumes of proceedings are in production. For further information, visit https://voices.uchicago.edu/cursesincontext/ and https://neubauercollegium.uchicago.edu/research/curses-in-context/.

of the Roman empire. This millennium-old practice offered great opportunities to trace the *longue durée* of what we see as a fairly stable tradition, a process that allows us to focus primarily on the similarities these texts shared over time and between widely distant areas of the ancient Mediterranean world. This approach was dictated primarily by the way these curse tablets were collected and published in the two earliest epigraphic corpora, those of Auguste Audollent and Richard Wünsch,[2] respectively. Later studies composed during the early twentieth century by historians of religion interested in widespread patterns of ritual activity also served as precedents for and influences on our methods.

We should not blame these earlier scholars for their primarily philological and broadly comparative approach, because in most cases the curse tablets published in these early corpora were not excavated under proper archaeological controls, or otherwise appeared on the antiquities market stripped of all historical context. Today this approach seems limited, in part because in the intervening years hundreds of these inscribed lead tablets have been carefully excavated from a variety of contexts: a well in the Kerameikos in Athens (Jordan 1985a), the sanctuary of Demeter and Kore on the Acrocorinth (Faraone and Rife 2007), the fountain of Anna Perenna in Rome (Piranomonte 2005, 2010; Blänsdorf 2010), wells near the hippodromes in Tyre and Caesarea, and a mass crucifixion grave in an urban necropolis on Rhodes. Several sanctuaries in the Western empire bore additional notable deposits, such as those of Isis and the Great Mother in Germany and two important sanctuaries in Great Britain: that of Sulis Minerva in Bath (Tomlin 1988) and that of Mercury at Uley (Tomlin 1993). These relatively recent and ongoing discoveries provide us with detailed information about the archaeological and historical contexts of curse tablets and have allowed or compelled us to think much more carefully about the differences between tablets from different places and centuries. For this reason, our project not only focuses on the texts that curse tablets preserve but in other aspects is also linked with the context and materiality of the objects. We do not merely want to pay closer attention to the texts as they appear to us in all their variants and aberrations[3] but also wish to highlight how these incongruities may connect to their materiality, the nature of their medium, and the archaeological contexts in which they were found.

We are perhaps not the first analysts to pay attention to these matters. In 2009, the conference Contesti Magici, held in Rome, focused on magic in general but with a special focus on archaeology and materiality.[4] Other studies have appeared in recent years with different approaches to the materiality of ritual practice, and especially of magic. Wilburn (2012) emphasizes the importance of the archaeological context in which tablets are found. Houlbrook and Armitage (2015) present a wider geographical and chronological scope, including studies on artifacts connected to magic in ancient and medieval times, from Ireland to Accra. Boschung and Bremmer (2015) pursue an ambitious program to rescue the material contexts of curses from the classical world. Parker and McKie (2018) focus on

2 The earlier collections of curse tablets published by Wünsch (1897) and Audollent (1904) have been augmented by Jordan (1985b, 2000), Tomlin (1988), and Kropp (2008), and Sánchez Natalías (2022). Recent studies on curse tablets include those by Faraone (1991), Versnel (1991, 2010), Gager (1992), Graf (1996, 2005), Ogden (1999), Brodersen (2001), Tremel (2004), Eidinow (2007, 2019), and Edmonds (2019).

3 Cerquiglini 1989 had a great impact especially on medieval philology but also plays a role in the study of ancient texts.

4 The proceedings were published a few years later (Piranomonte and Marco Simón 2012).

materiality and embodied experience of magic in the Roman world. The latest general publication on magic, Frankfurter (2019), devotes a whole section (part 3) to studies attending to archaeology and materiality.

In this concise publication, we have directed our attention toward questions regarding the most technical aspects of studying the materiality of curse tablets: restoration, imaging, and paleography. Each of these aspects generally or historically belongs to a different discipline and scientific domain. They intersect infrequently in academic environments, and hardly any publications exist on technologies related to ancient magic.[5] In addition, we have preferred to isolate these studies in a separate volume for two main reasons: first, publishers in general reject disciplinary combinations of the humanities and science, and second, the volume's availability online allows us to include links to websites.

The papers collected in this volume were presented in 2018 at two conferences concerning curse tablets in the Mediterranean—one in Lonato del Garda, Italy, and the other at the University of Chicago Center in Paris—both as part of the aforementioned Curses in Context project. The three papers are organized in the natural chronological process of studying a lead tablet: restoration, imaging, and paleographical study.

As is the case with many other texts preserved from antiquity and inscribed on fragile materials or exposed to extreme conditions, curse tablets need to undergo special conservation and stabilization processes before they can be properly presented for study. The deciphering and editing of texts incised on metal is particularly complex, and both the toxicity and the fragility of lead documents are good reasons to avoid any possible direct manipulation of the pieces.

The first chapter, by Loretta Rossetti, is devoted to new technologies applied to the unrolling, cleaning, restoration, and conservation of lead tablets. The Arc'Antique Laboratory has recently been commissioned to carry out conservation and restoration work on lead tablets that have either come directly from excavations or are sourced from heritage collections. The laboratory team is examining new technologies for optimizing the process involved in opening tablets that are still either folded or rolled up. In addition, the team has been comparing various cleaning methods and, as well, focusing some of its study on the storage conditions of tablets. After these procedures have been completed, taking high-quality images of the items is an important task to avoid further manipulation of the tablets as much as possible. Different imaging techniques have been evaluated with respect to their efficiency in monitoring cleaning techniques and their potential to assist epigraphists in studying the textual contents.

Recent imaging technologies have provided extremely helpful advances in the study of ancient texts. Multispectral imaging technology, reflectance transformation imaging, polynomial texture mapping, binarization algorithms, and other computational methods increase the legibility of texts incised on lead and other materials. The second chapter, by Raquel Martín Hernández and Arie Shaus, focuses on the technology of binarization algorithms as it is applied to lead tablets and other materials to explore the possibilities of producing automatic facsimiles of original sources from high-quality digital images. The quality of these automatic facsimiles, and their merits and shortcomings, are analyzed.

---

5 But see Rapinesi and Polakova 2012; Viliani and Mauri 2012; or Bevilacqua, Colacicchi, and Giuliani 2012, which touch on restoration and archaeology in a volume on magic in general.

Lead tablets, as artifacts, should then be placed in their context of production. Paleography and archaeology combine in proposing dates for these pieces—the topic of the third chapter, by Sofía Torallas Tovar. The study of paleography and the *mise en page* of the texts on lead tablets, specifically those written in Greek during the period of the Roman Empire, can lead to a better understanding of how scribal techniques were used and applied by scribes whose work seems to bear signs of influence from handbooks or models. We were surprised to discover that despite the available access to several centuries of Greek handwriting on papyri from Hellenistic and Roman Egypt, little effort has been expended to compare these data to writing on lead tablets from the same period or to use these comparanda to gain a better sense of the scribal conventions of the curse tablets or to date them more precisely. This chapter explores the possibility of comparing the paleography of lead tablets to that of papyri by presenting case studies of tablets archaeologically dated and compared to contemporary hands represented on papyrus documents.

We are honored to feature the reflections on materiality by Jan Bremmer that are included as an epilogue to this publication, along with a survey of the latest studies on the topic. The editor of one of the most recent attempts to approach the materiality of magic and its artifacts, Bremmer is also a renowned scholar of ancient texts and rituals.

These essays, which neither are specifically philological nor explicitly address ritual or religious aspects of the practice of cursing, are brought together as a complement and an aid to the study of magic in antiquity. We seek to illuminate the possibilities that various technologies can offer to the study of lead documents by providing better readings of texts, better reconstructions of the original artifacts, and a better evaluation of their material dimension. We hope this volume is one of many with and within which scientists, philologists, archaeologists, and historians can collaborate in understanding "the artifact."

We wish to express our gratitude to the Neubauer Collegium and the University of Chicago for the financial support of our Curses in Context project; to the institutions where the abovementioned conferences were held; to Christopher Faraone, who trusted us with the edition of this volume; to Christopher Woods, former director of the Oriental Institute, who accepted the manuscript of this volume for publication; and to Lucas Binion, who improved the English.

1 The Conservation of Lead Curse Tablets

Loretta Rossetti

Since 1995, the Arc'Antique Laboratory in Nantes, France, has studied the degradation of lead in relation to the element's status as a constituent metal of heritage collection objects.[1] This research was initially commissioned by the Direction des Musées de France, since museums in France had lost a significant number of artifacts made of lead or lead-rich alloys to corrosion. The artifacts had been stored in wooden medal cabinets or cupboards. Since that time, research into corrosion mechanisms and restoration approaches has led to improved conservation methods for these objects and enabled the treatment of many historic and archaeological lead artifacts. Only since 2008, however, when our laboratory was entrusted with a large museum collection comprising a number of engraved lead tablets, have the specific problems of inscribed surfaces been approached in a more targeted way.

LEAD CORROSION

Lead is a metal that has always been justly valued for its corrosion-resistant characteristics. Indeed, it is relatively stable chemically and is less sensitive to both humidity and the presence of certain salts than other metals such as iron or copper-based alloys.

In the open air and in soil, lead and its alloys initially become covered by a layer of oxides. These oxides can then go on to form thicker layers composed most notably of carbonates or other corrosion products, depending on the nature of the environment. These corrosion products are both stable and protective in a neutral or basic environment, as even very ancient artifacts often still come down to us in a good state of conservation.

Conversely, when lead is exposed to volatile organic vapors—for example, acetic, formic, and occasionally propionic acid—the metal displays a high degree of reactivity. In fact, some ligneous species, especially oak, and other materials, such as certain adhesives, plastics, paints, silicone coatings, and papers, give off organic acid vapors that lead to severe corrosion.[2] This very spectacular type of corrosion can cause the complete disappearance of artifacts, because the resulting corrosion products combine a large volume with low adherence (Degrigny 1997).

1 Unless otherwise specified, all photographs were taken by Jean-Gabriel Aubert, Carl Colonnier, and Loretta Rossetti from Grand Patrimoine de Loire Atlantique–Arc'Antique.

2 For more details on the materials that can cause lead corrosion, see Tétreault 1999, 2003.

CORROSION WITH EXPOSURE TO ORGANIC VAPORS

The hypothesis is that when lead carbonates are exposed to organic acid vapors, they are initially transformed into highly soluble lead acetates. These carbonate rapidly because of carbon dioxide in the air and give rise to a large quantity of new lead carbonates. Cracks running through the entire thickness of lead carbonates allow acetic acid to come into contact with the metal. The cycle of this corrosive process remains active until the metal has completely disappeared. As corrosion products lack permanent adherence, they become detached from the surface, eventually reducing the metal artifact to a mass of white dust (fig. 1.1). The determining factor that governs these corrosion mechanisms is the concentration of acetic acid: the higher the concentration of acetic acid present, the greater the corrosion progresses in enclosed, unaired spaces, such as glass display cases or storage cabinets.

Emissions of acetic acid increase with temperature, and these vapors become increasingly damaging in conditions of high humidity, leading to an increased condensation of acetic acid on the metal. At this point, any information present on the surfaces (engraved information in particular) tends to disappear. Sadly, this phenomenon was observed on a significant number of heritage collection artifacts that had been kept in wooden cupboards or metal cabinets. Organic vapors—which may become concentrated when drawers are rarely opened—brought about the total degradation of artifacts (fig. 1.2).

Stratigraphic observations carried out on certain lead tablets preserved in the National Library of France both indicated the location of corrosion products within them and assessed the negative effects of their development on the artifacts. We can observe white corrosion products, freshly formed within the metal core, corresponding exactly to the cracks running through the outer layers of the corrosion products (figs. 1.3 and 1.4). It seems that organic vapors released by the constituent wood of the medal cabinets were able to get to the metal core through cracks in the corrosion products formed during the burial period, resulting in the formation of new corrosion products. In the case presented in figure 1.3,

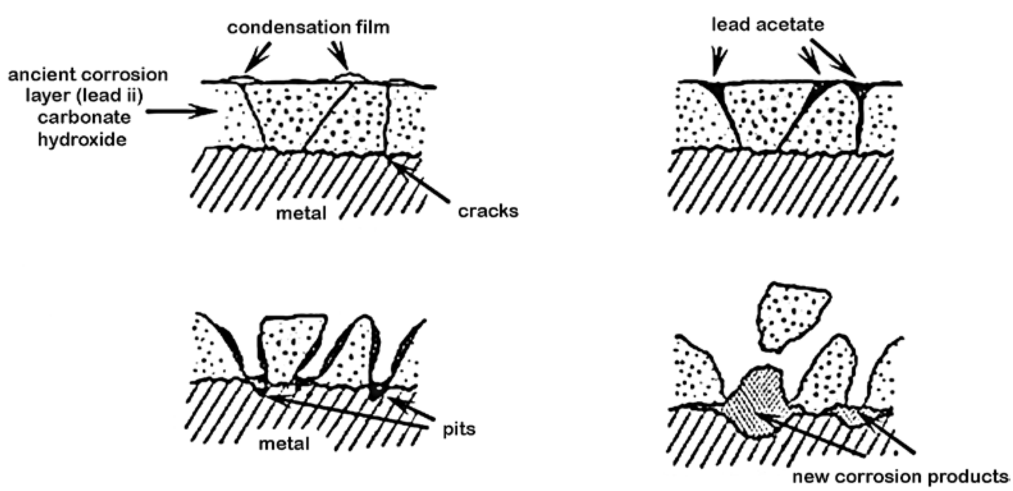


Figure 1.1. Hypothesis of lead corrosion mechanism when exposed to acetic acid.

Figure 1.2. State of degradation of lead tablets conserved in a museum cabinet.

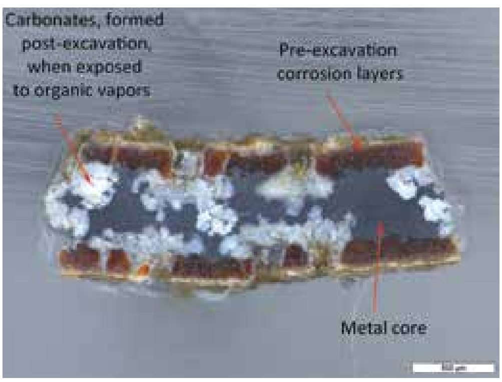


Figure 1.3. Stratigraphic cross section of a tablet fragment. White corrosion products newly formed within the central metal core are visible.

Figure 1.4. Stratigraphic cross section of a tablet fragment. Here the metal has been almost completely transformed into corrosion products.

the development of new lead carbonates within the metal has led to a reduction in the mechanical properties of the latter, thereby resulting in an overall fragility of the tablet itself. In the case of figure 1.4, corrosion has completely transformed the residual metal, causing the fragmentation of the tablet and no doubt a corresponding loss of information.

The effect of organic acids on newly excavated lead is less frequently observed. But this phenomenon may be exemplified by the corrosion typically found on the bottom of sarcophagi or the exterior of reliquaries exposed to body decomposition liquids (figs. 1.5 and 1.6).

Figure 1.5. Example of preferential degradation at the base of a seventeenth-century lead sarcophagus due to the action of body decomposition fluids.

Figure 1.6. Example of the punctual (perforating) degradation of the wall of a sixteenth-century lead reliquary that contained an embalmed heart.

PREVENTIVE CONSERVATION OF LEAD IN HERITAGE COLLECTIONS

A study carried out between 2009 and 2011 by the Arc'Antique laboratory and two Parisian museums sought to check for the presence of organic vapors in storage and exhibition rooms.[3] To evaluate the presence of acetic acid, Dräger® colorimetric tubes specifically designed for acetic acid proved useful in occasional spot measurements but gave reliable values only for quantities greater than 1 ppm. Quantities of only about 100 ppb may be sufficient to jeopardize the preservation of lead artifacts (figs. 1.7 and 1.8).

To obtain more accurate results, other methods of detecting organic vapors were also used.[4] Eliminating the source of pollution by moving objects to an environment free from organic vapors remains the optimal solution; metal cabinets are preferred to wooden cabinets. When this solution is not possible, emissions can be limited by ensuring that exhibit cases and drawers are sufficiently ventilated or feature adsorbents. Since installing an efficient ventilation system at the storage location can be a significant investment, the use of adsorbents provides a good alternative.

Our tests, which were conducted using a modified zeolite adsorbent together with a colored indicator, gave promising results, but additional studies must be carried out before these sensors are systematically implemented. In particular, the lifespan of the sensors should be evaluated and possible interferents, such as moisture, identified. Applying a protective coating to artifacts could also provide a possible solution, but we remain cautious about the potential risks associated with the aging of these coatings.

---

3 Between 2009 and 2011, Arc'Antique conducted a research program called PPb (Prevention of Risks Associated with Lead in Conservation–Restoration: From Restoration Workshop to Museum), funded by the Ministry of Culture and in collaboration with two museums—the Museum of Arts and Crafts of Paris and the National Archaeology Museum of Saint-Germain-en-Laye—together with specialists in health and safety: the Institute of Industrial and Environmental Hygiene–Environmental and Occupational Health Safety team and the National Conservatory of Arts and Crafts of Angers, associated with the Toxicology Laboratory of the University of Pharmacology of Nantes. This research program was based on three pillars: the evaluation of lead-related health risks, the protection of lead objects, and preventive conservation.

4 The Getty Conservation Institute has published a comprehensive book summarizing the research findings (Grzywacz 2006). The British Museum has published a database of materials Oddy tests; see https://britishmuseum.iro.bl.uk/concern/books/102da8e4-8a79-4d94-adec-00226ee8ed60?locale=en.

Figure 1.7. Dräger tubes specifically for acetic acid and pump to draw out air. The upper tube shows negative for acetic acid, while the lower shows positive (indicator turns yellow).

Figure 1.8. Measuring the presence of acetic acid in a museum drawer.

ISSUES SPECIFIC TO ENGRAVED LEAD SURFACES

The above explanation of lead corrosion aims to outline the difficulties encountered by conservationists in the treatment of lead curse tablets. Useful information is located on the surface of these artifacts to a depth of just a few millimeters, corresponding to the depth of engravings. In the case of a well-preserved or new tablet, the edges of the engravings remain sharp, either still metallic or only lightly covered by a veil of corrosion products. Conversely, in the case of corroded tablets, engravings are preserved inside strata of corrosion products that may be very friable or powdery. Revealing significant markings involves performing the critical act of preserving or removing a particular corrosion product from a surface ravaged by cracks and crevices of a similar size to that of the actual engravings (figs. 1.9 and 1.10).

Figure 1.9. Macroscopic view of engravings on new lead facsimile.

Figure 1.10. Macroscopic view of engravings on a corroded tablet.

CLEANING

On a newly excavated tablet or one that already forms part of a heritage collection, cleaning often reveals incisions that are hidden under a layer of corrosion products or dirt. To quantify the impact of this action on inscriptions, both mechanical and chemical cleaning methods were compared. We selected certain processes commonly used in restoration laboratories, such as the complexing of aqueous or acid solutions, as well as mechanical methods, such as microsandblasting with glass microbeads or vegetable abrasive.[5] Measurements of roughness were carried out using microtopography on the surfaces before and after cleaning: the results of this research were presented at the International Council of Museums–Committee for Conservation (ICOM-CC) Metals Working Group, held September 2–6, 2019, in Neuchâtel, Switzerland. Initial results show that microsandblasting carried out at very low pressure with a vegetable abrasive is the best treatment for preserving engravings (figs. 1.11 and 1.12).

Figure 1.11. Tablet before cleaning.

Figure 1.12. Tablet after partly chemical, partly mechanical cleaning.

5 We did so in successive research projects from 2015 to present.

OPENING THE TABLETS

During rituals, tablets were generally folded or rolled up and sometimes pierced by nails (fig. 1.13). To access the texts that are usually preserved on the internal surfaces, metal sheets must first be unfolded. Recent tests with the aim of reading these closed tablet surfaces have yielded promising results[6] but are not yet widely used, and they are not always conclusive. Indeed, since lead is a radiopaque metal, commonly used investigative means such as radiography or tomography do not reveal such fine details as incisions on lead surfaces.

As previously mentioned, when a given lead tablet arrives on the restorer's lab bench, its state of corrosion will vary enormously. The greater the degree of corrosion, the more the metal will have lost its mechanical characteristics of ductility and malleability. Opening the tablet requires exerting force on its fragile structure—force that may result in cracking or even breakage.

In our laboratory prior to 2018, newly excavated tablets were systematically opened at room temperature, under binoculars, using small metal and wooden tools. We were able to observe that the metal of tablets that were still mainly metallic was weakened around folded areas, and tablets generally broke at these junctures (figs. 1.14 and 1.15). To maintain fragment cohesion, it is sometimes necessary to apply Japanese paper to external surfaces during the opening process.

Tablets found in wetland areas or that otherwise might contain residues of an organic nature are preferably opened at room temperature. For example, a tablet found inside a well and preserved in the water bore no inscription but contained a small bundle of fibrous residue preserved within the folded metal. Analysis of the residue revealed the presence of human and animal hair, as well as plant residue (figs. 1.16–1.18).[7] Among the identified

Figure 1.13. Examples of tablets before opening. Photo courtesy Carl Pause, Clemens Sels Museum Neuss (Goedecker-Ciolek, Pause, and Scholz 2016).

6 See the video at https://www.youtube.com/watch?v=ZJHggC0IsC8.

7 The identification of dander was carried out with the help of L. Laquay and P. Charlier from the team of medical anthropology and forensic medicine (University of Versailles Saint-Quentin-en-Yvelines, Paris Descartes University) and C. Moulherat of the Musée du Quai Branly. Plant residue was analyzed by Marlu Kühn, Integrative Prehistoric und Scientific Archaeology, University of Basel, Switzerland.

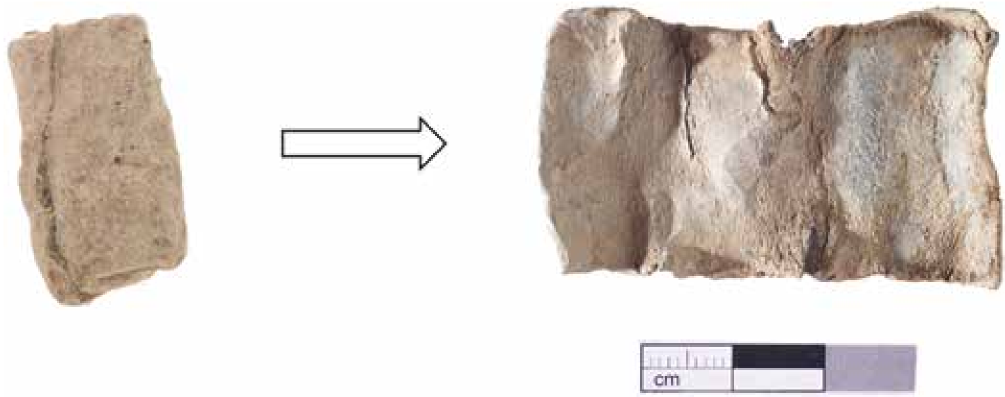


Figure 1.14. Example of a relatively well-preserved tablet.
Left: Before opening. *Right:* Internal surface after opening.

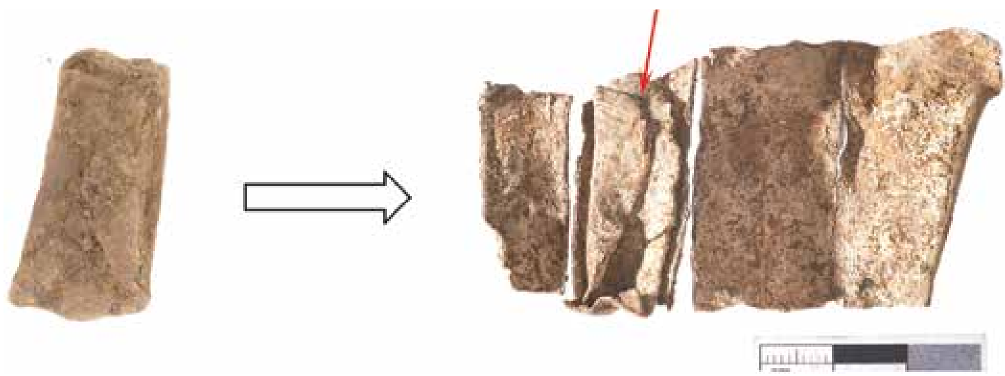


Figure 1.15. Example of a partially mineralized tablet. *Left:* Before opening.
Right: Internal surface after opening. Breakage along the fold lines and the presence of another small sheet inside the tablet are observable.

carpological residue were gramineous plants, fragments of husks (probably cereals), and fruits and grasses (grains of *Rhinanthus* and clover).

To overcome the issue of tablets deteriorating as a result of their being opened, in 2018 the laboratory began a research program to optimize document-opening parameters. We focused primarily on the influence of temperature by evaluating variations in microhardness and granular structure both in new lead (pure lead and lead–tin alloys) and in newly excavated archaeological tablets.

In new lead, the act of rolling and folding does not appreciably modify microhardness. However, microhardness tends to increase slightly as a result of heating. Adding 1 to 5 percent of tin to the lead increases the microhardness of the material. The microhardness of corroded archaeological lead is generally higher than that of newer lead. In general, the more corroded the lead, the higher its degree of microhardness and the more heterogeneous its microstructure.

Figure 1.16. Phases of the opening of a tablet found in a waterlogged environment (a well). Note the fibrous residue found inside the folded metal.

Figure 1.17. Residue, insufficiently complete for identification, but possibly a feather. Photo courtesy M. Kühn.

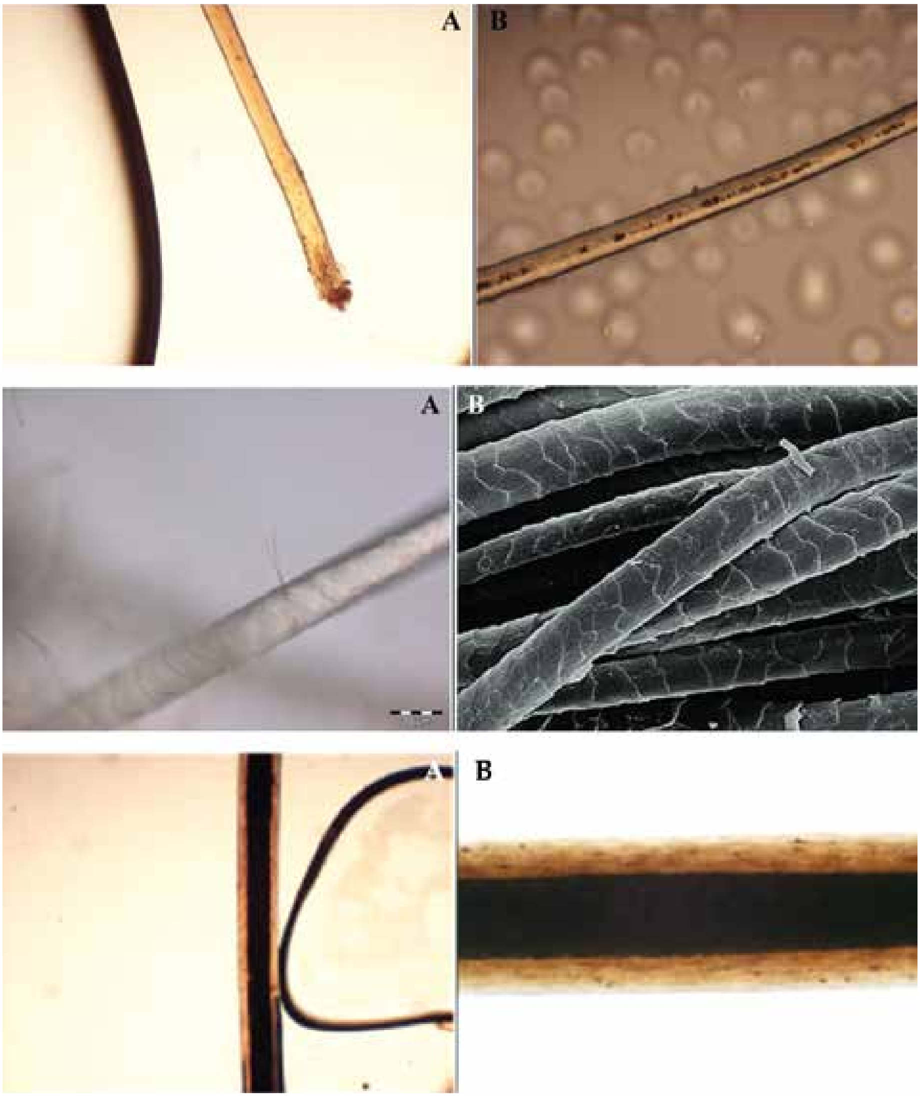


Figure 1.18. Human, ovine, and canine dander. Photo courtesy P. Charlier and C. Moulherat.

Thicker grain boundaries (probably due to intergranular corrosion) cause the material to lose cohesion (fig. 1.19). In archaeological lead, an increase in temperature has short-term effects on microhardness, which at first tends to increase before returning to its initial value after only a few hours. On the other hand, an increase in temperature causes a decrease in the size of the grains in the material, which in turn leads to increased fracture toughness. This property could prevent the propagation of cracks that occur during the opening process. Temperature values of 50, 70, and 90 degrees centigrade were tested.

Based on these results, a first protocol has been established for the opening of tablets. After heating them for twenty-four to forty-eight hours, tablets are removed from the heat, and efforts are made to open them within a very short time frame, before the lead cools again and is no longer malleable. Any further efforts to open the tablets at this point would result in damage to them. This procedure can be repeated until opening is complete (figs. 1.20–1.22). This sort of research remains ongoing and does not currently allow us to define a standard procedure with a precise heating time and temperature corresponding to the state of degradation of the tablet. Unfortunately, a certain degree of fracturing will inevitably occur on severely mineralized tablets.

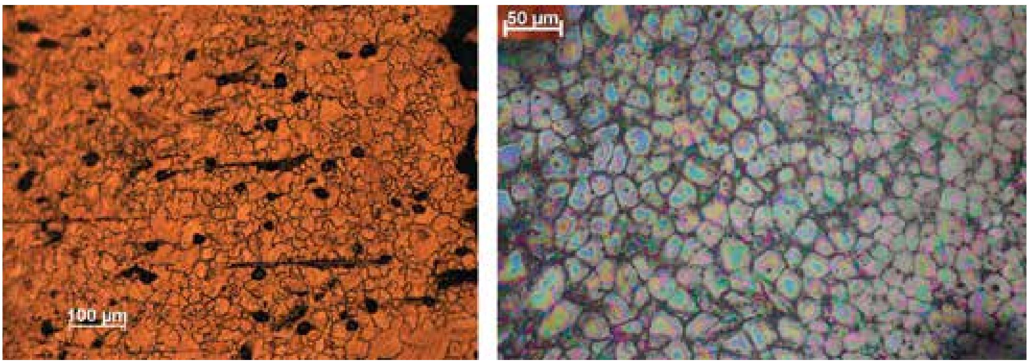


Figure 1.19. *Left:* Microstructure of pure new lead. *Right:* Microstructure of archaeological lead.

Figure 1.20. An archaeological tablet placed between two infrared lamps. The height and distance of the lamps enables approximate object temperature to be determined. The process is carried out in close proximity to binoculars to avoid a drop in temperature when the artifact is moved.

Figure 1.21. Checking the temperature.

Figure 1.22. Opening the tablet under binoculars using small metal and wooden tools.

MEASURES TO PRESERVE THE INTEGRITY OF ARTIFACTS

Another issue concerns the degree of fragmentation and overall fragility of certain tablets. Indeed, when a tablet remains fragmented, restorers can join fragments only if they are certain that the junctions fit together. Collages can then be made using reversible resins and reinforced by gluing pieces of Japanese paper to the back using a reversible glue (figs. 1.23 and 1.24).

If matches are inapparent due to worn edges or missing elements, an accurate collage may not be possible. Two solutions may then be envisaged: (1) working with an epigraphist to assist in recomposing and/or (2) determining suitable storage for the fragments. Our experience with the first solution has been extremely positive (figs. 1.25 and 1.26), but such help may not always be feasible within the time frame allotted for restoration.

Figure 1.23. The obverse of a fragmented tablet.

Figure 1.24. The back of the same tablet. The collages of fragments were consolidated by applying Japanese paper.

Figure 1.25. Celia Sánchez Natalías, epigraphist, at work in the laboratory.

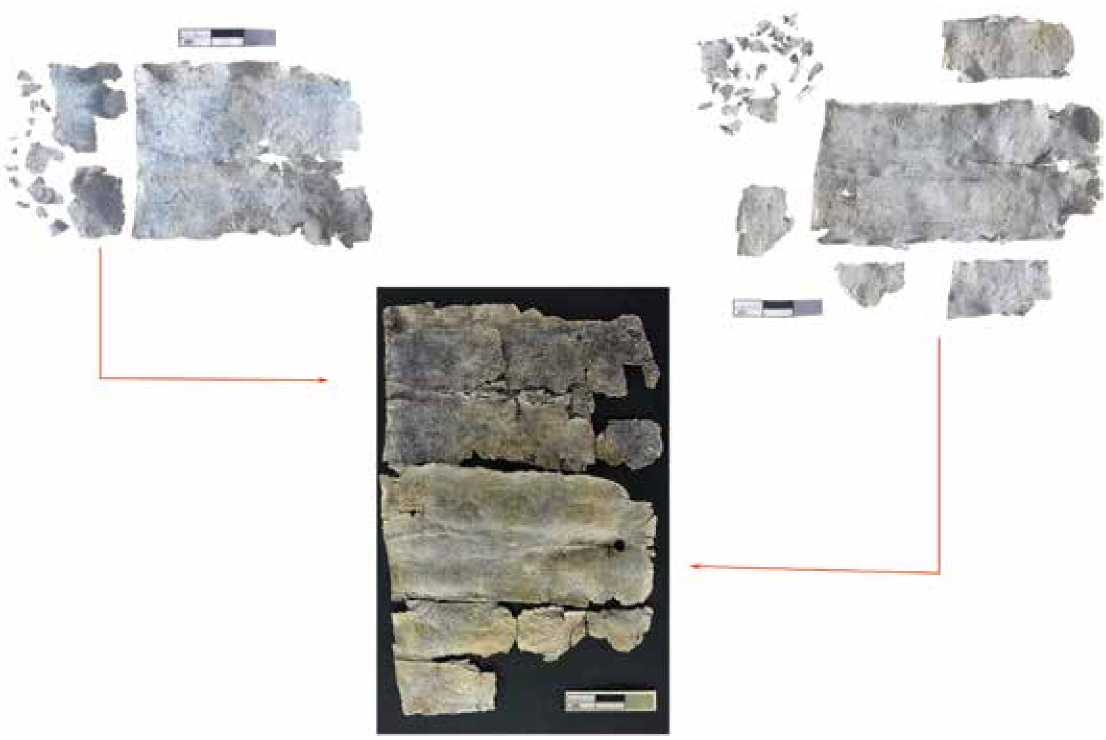


Figure 1.26. Suggestion for reassembling two tablets referenced under two numbers after study revealed that the text continued across the different fragments.

When only storing the fragments is feasible, putting them in a sachet risks fragmenting them still further. Even storing fragments in a box should be avoided if they are liable to slide around each time the box is moved. Of first priority is using inert materials (which do not release organic acid components) for storage. With this purpose in mind, we conducted aging tests on certain packaging materials to determine which one was the most suitable for lead storage. Recommendations for the use of certain materials are also given in the literature (see n. 2 above).

Our studies found no single hard-and-fast solution. Generally, it is important to provide a rigid support, such as corrugated polypropylene, on which the fragments can be placed to avoid having to handle them directly. They can be contained in repositionable foam (e.g., by attaching them with pins; see fig. 1.27). In extreme cases, using reversible methods we opted to affix very small fragments to Japanese paper, which in turn was placed on a rigid support (figs. 1.28 and 1.29).

Our research questions enabled the development of new supports, leading to an overall improvement in the packaging of tablets (fig. 1.30). We also tested ways of producing suitable support materials for severely distorted tablets. The first tests of this sort consisted in taking a direct imprint of the reverse (fig. 1.31), but this procedure proved unsatisfactory because stress to the artifacts became too great.

Instead, it is preferable to take photogrammetry shots to make 3D prints of supports (figs. 1.32–1.36). This procedure is much less aggressive, since there is no direct contact with the surface of the tablet, and the resulting support is perfectly shaped to fit the surface's irregularities. But since no aging test of the resins used in 3D printing has yet been carried out, moldings in neutral resin[8] are made of the 3D printed supports as a precaution.

After our tests, certain difficulties still persisted, such as storing tablets inscribed on both sides that may also be fragmented.

Figure 1.27. Example of storing a series of small, noncontiguous fragments on a corrugated polypropylene tray, held in place by foam pinned to the support.

8 The resin used for 3D printing that gave the best results was polylactic acid. To copy 3D supports, we used polyurethane, polyester, or epoxy resins.

Figure 1.28. Severely degraded tablets with inscriptions.

Figure 1.29. Collages of fragments affixed to pieces of Japanese paper, then placed on rigid corrugated polypropylene.

Figure 1.30. *a:* Storage box made from sheets of corrugated polypropylene and polyethylene foam, sealed with polyester tape. *b–c:* Tablet held in place by polyethylene foam cut to fit around the tablet's shape and supported by a small, corrugated polypropylene tray. *d–f:* Tablet turned out onto a sheet of foam for inspection of the reverse.

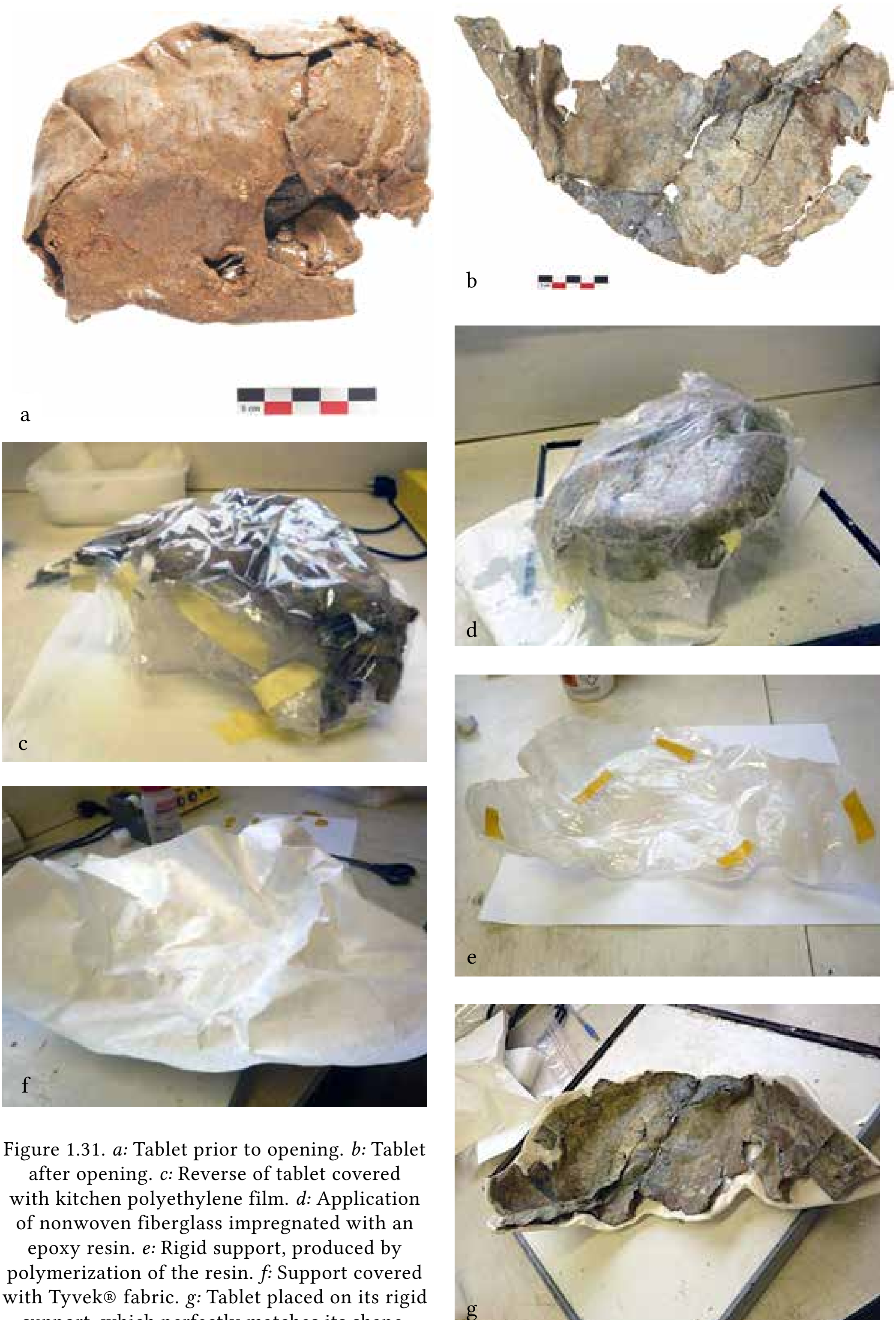


Figure 1.31. *a:* Tablet prior to opening. *b:* Tablet after opening. *c:* Reverse of tablet covered with kitchen polyethylene film. *d:* Application of nonwoven fiberglass impregnated with an epoxy resin. *e:* Rigid support, produced by polymerization of the resin. *f:* Support covered with Tyvek® fabric. *g:* Tablet placed on its rigid support, which perfectly matches its shape.

Figure 1.32. Shooting the back of a tablet by photogrammetry.

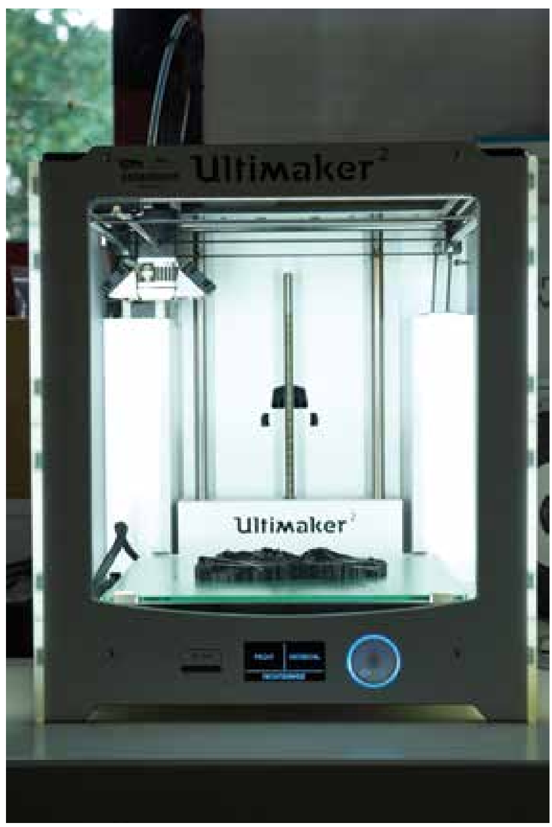


Figure 1.33. 3D printing of support.

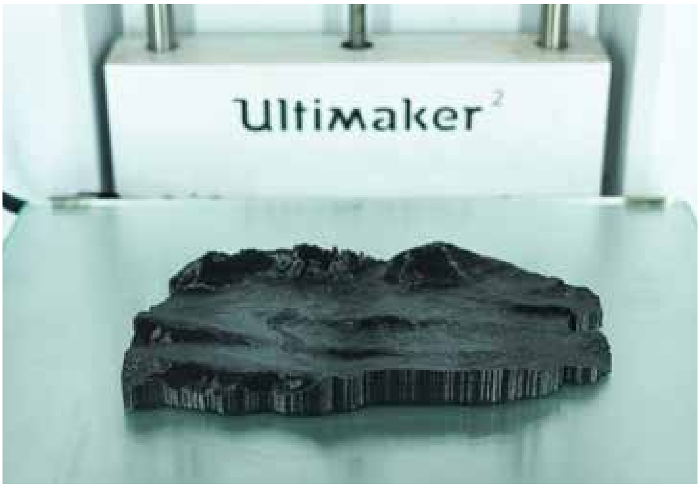


Figure 1.34. Resulting support.

Figure 1.35. Tablet on its 3D support.

Figure 1.36. Tablet on polyurethane resin support, slightly larger than the original 3D support to allow the artifact to be handled without touching its edges.

LONG-TERM CONSERVATION OF INFORMATION

Our main priority as restorers is to ensure the material conservation of artifacts while at the same time conserving any information that may be preserved on them. In the case of fragile artifacts such as tablets, however, it is advisable for such information to be conserved separately, apart from the artifact itself. Data can be studied without direct, or even remote, manipulation of objects. This approach is of particular interest if images can accurately reproduce engravings without any loss of detail.

We therefore extended our study to the comparison of different imaging techniques.[9] Among those tested were a series of photographic techniques—conventional photo, Z compression, open light, dense correlation photogrammetry, reflectance transformation imaging (RTI)—in addition to others, such as radiography, structured-light scanning, hyperspectral camera use, tomography, and microtopography. The results of these tests were presented to a group of French epigraphists during a study day at the laboratory in October 2016. At the end of the day, the three most convincing techniques for the study of engraved texts were selected: RTI,[10] structured-light scanning, and open light.[11] In specific cases, microtopography can also be useful to highlight details (analyzed area 1–2cm^2; Mélard 2016). The first two techniques—RTI and structured-light scanning—require visualization of the results on a computer and enable the modification of incident light parameters on the surface being analyzed. Open light is a relatively simple and rapid technique that gives very detailed images on paper prints; it can be useful for graphic views or as a basis for drawings.

REFLECTANCE TRANSFORMATION IMAGING

RTI (fig. 1.37) offers the following advantages and disadvantages:

	Advantages	**Disadvantages**
Data acquisition	No specialist assistance required—simple process and installation	Basic technical knowledge of phototography
	Relatively fast	Occasional problems in reassembling images
		Difficult when tablets are not flat
Viewing	Choice of light source position	On screen—requires relevant software
	On screen—free, easy-to-use software	
	Possible to print out view	

9 See also chapter 2 in this volume.

10 For further details on RTI, see http://culturalheritageimaging.org/Technologies/RTI/.

11 Karl Colonnier served as the photographer. Open light combines two existing photographic techniques: open flash and light painting. Like light painting, open light requires working in total darkness, if possible. It involves opening the camera shutter for a given time and lighting the whole object/subject with a 360-degree grazing light.

Figure 1.37. Photographers taking freehand photos of a tablet from different angles. Shooting can be automated with the help of a dome.

STRUCTURED-LIGHT SCANNING

Structured-light scanning (figs. 1.38–1.41) offers the following advantages and disadvantages:

	Advantages	**Disadvantages**
Data acquisition	Relatively fast for entire surface	Cutting-edge equipment, qualified operator—specialized private companies or research laboratories
	Possible to take measurements	Relatively fast acquisition, but data exploitation required
	Some manipulation of the artifact necessary if the metal is folded for acquisition of hard-to-reach places	
	Possible to print out a high-definition 3D resin model	
Viewing	On screen—high-definition 3D model	Better on screen, but files are very large
	Possible to print out view on paper, as required	Familiarity with software required
		Computer with a good graphics board required

Figure 1.38. Acquisition of images using scanner with fringe projection.

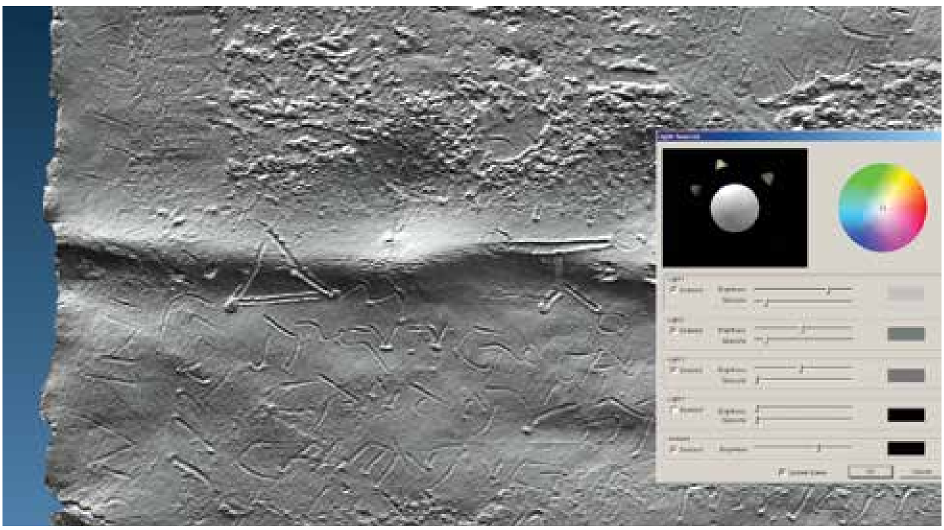


Figure 1.39. 3D rendering of tablet surface as viewed on screen (interface of viewing software).

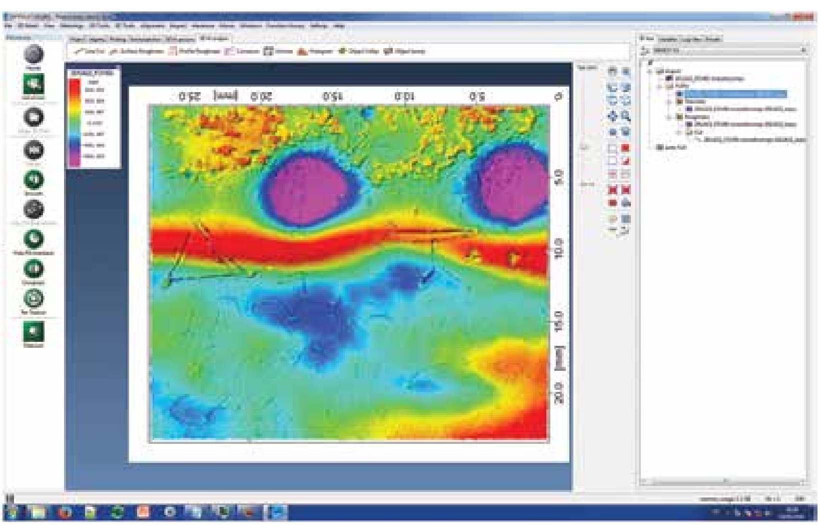


Figure 1.40. Topography of a tablet's surface with coding of altitudes in false colors (screenshot).

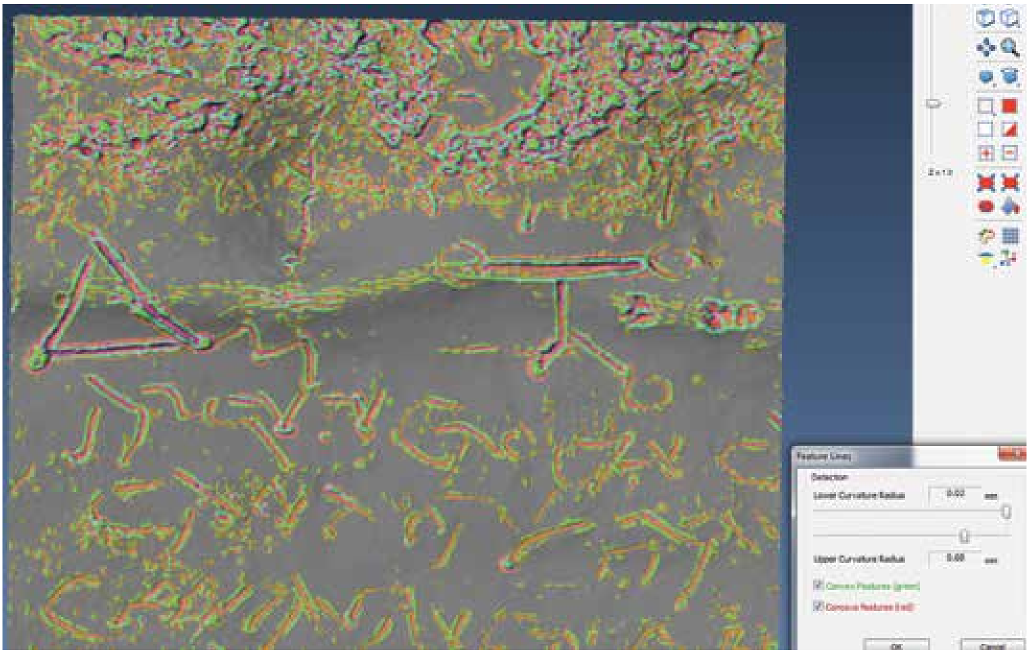


Figure 1.41. Same area as in figure 1.40 with all curvatures highlighted (screenshot).

OPEN LIGHT

Open light (figs. 1.42 and 1.43) offers the following advantages and disadvantages:

	Advantages	**Disadvantages**
Data acquisition	No specialist assistance required—simple process and installation (camera, tripod, light source required)	Basic technical knowledge
	Immediate result	Total darkness required
	Good readability of details	
Viewing	Better on screen (possibility of enlargements)	
	Paper printing—better definition than traditional photography (useful to base drawings on)	

Figure 1.42. *Top:* Classic photographic view of engraved surface. *Bottom:* Detail.

Figure 1.43. *Top:* View of same surface with open light. *Bottom:* Detail.

MICROTOPOGRAPHY

Microtopography (figs. 1.44 and 1.45) offers the following advantages and disadvantages:

	Advantages	**Disadvantages**
Data acquisition	High definition of details	Cutting-edge equipment, qualified operator—limited availability
	Possibility of taking accurate measurements	Slow data acquisition
		Not suitable for overall view
Viewing	On screen—high-definition 3D model	On screen
	Possible to print out view on paper, as required	Printed paper screenshot (low resolution)
		Expert interpretation required

Figure 1.44. Imaging by microtopography.

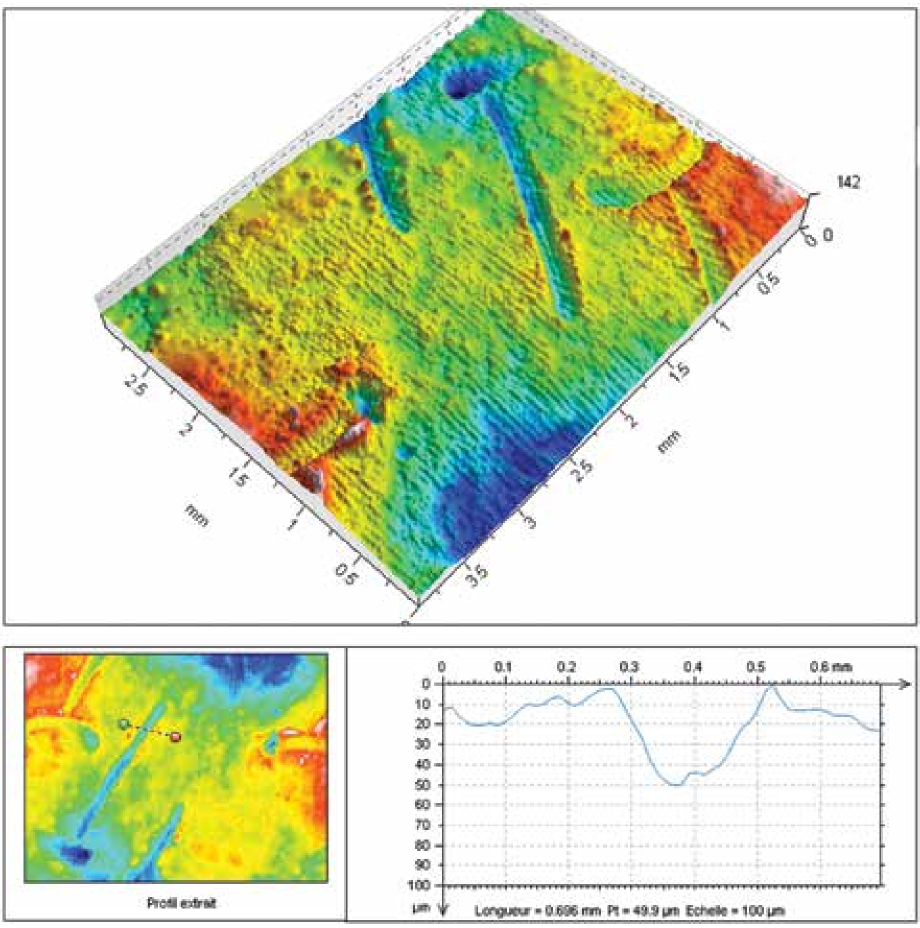


Figure 1.45. Study of surface and profile of engravings.

CONCLUSIONS

Our work as conservators and restorers on such particular artifacts as lead curse tablets has led to the emergence of a range of issues that invite investigation. These problems concern not only the nature of their constituent material but also their function as a support for sensitive information.

Far from being exhaustive, this chapter addresses merely a few among the plethora of problems one may encounter in handling these artifacts and outlines the state of just one body of current, collective knowledge. First, we emphasized the importance of preserving lead objects in an environment free from organic acid vapors. This precaution is of prime importance for the long-term preservation of artifacts, which would otherwise deteriorate dramatically to a point where they no longer exist. The proper storage of tablets is therefore a sensitive point. Neutral materials should be used for packaging, and artifacts should always be handled carefully and placed on suitable—preferably rigid—supports. The opening of rolled tablets was the subject of a first study aimed at optimizing operational parameters. In these delicate experiments, the state of mineralization of the metal is a determining factor. The more degraded the artifact, the greater the loss of the characteristics of malleability that are typical of the metallic state. This loss can lead to the formation of cracks or even fractures during the opening process. According to our current state of knowledge, if rolled tablets are not from a waterlogged environment or are likely to contain organic residue, then heating them improves their resistance to the pressure applied when they are opened. Any prying open must be carefully controlled so that it stops as soon as resistance becomes apparent. The artifact must then be reheated for a sufficient amount of time to homogenize the material. The opening process, therefore, consists of alternating periods of heating with gradual efforts to pry the tablet open. This ongoing part of our research requires still further studies and tests.

We also discussed the problem of the recomposition of fragmented pieces and emphasized the limitations caused by the loss of clear junctions between fragments that prevents the restorer from carrying out a collage. In these cases, collaboration with an epigraphist can be a great help. In any case, it is necessary to store fragments carefully to avoid their further fragmentation.

Focusing on the problems related to reading engraved surfaces and the long-term preservation of their data led us to explore imaging techniques. Several techniques were tested, and the results of each were submitted to French epigraphists. Three techniques were selected for the study and reproduction of engraved texts onto paper: RTI, structured-light scanning, and open light. In addition, microtopography was found to be useful for highly accurate surveys of very localized areas (1–2 cm^2), such as studying a particular letter or evaluating cleaning techniques.

2 New Technologies for Tracing Magical Texts and Drawings: Experience with Automatic Binarization Algorithms

Raquel Martín Hernández and Arie Shaus

Many issues faced by paleographers and philologists in their study of the materiality of the objects at hand might provide obstacles that can literally make or break our ability to interact with a given text. The essays in this book show how new technologies are significantly helping in the tasks of deciphering, understanding, and restoring ancient texts written on different materials.

Philological editions of ancient texts, and articles in which ancient artifacts are studied, sometimes require facsimiles of the discussed finds: tablets, gemstones, and papyri. The facsimiles are especially important for certain objects when a normal photograph cannot fully capture or elucidate the writing (e.g., texts written on metal lamellae). In these and other cases, as we explore below, the production of facsimiles provides a great tool in the advancement of interacting with and understanding texts.

In this chapter we examine some possible methods of producing facsimiles of ancient objects, specifically those that have been studied within the projects led by Christopher A. Faraone and Sofía Torallas Tovar at the University of Chicago. These projects focus on Greco-Egyptian magical formularies and curse tablets written in Greek and Latin. Here we make an initial assessment of the material particularities of individual fragments and then describe different methods that can be used to produce black-and-white facsimiles of these artifacts. Finally, we explore the possibility of using automatic binarization algorithms and analyze the results obtained across different materials.

FRAMEWORK

The University of Chicago's Transmission of Magical Knowledge in Antiquity: The Papyrus Magical Handbooks in Context[1] is an ambitious project aiming to reedit, translate, and study the preserved magical formularies of Greco-Roman Egypt (first century BCE to fifth century CE). One of the primary goals of the project is to focus on the materiality of the papyri. The study includes not only the texts but also magical drawings that appear within the texts—mainly figural representations of gods and demons, victims, and magical

1 The project, directed by Christopher A. Faraone and Sofía Torallas Tovar, has been funded by the Neubauer Collegium for Culture and Society. See https://papyrusmagicalhandbook.wordpress.com.

symbols. These images will be integrated with the edited texts in black-and-white facsimiles, placed in the same position in which they appear in the original document. In this way, the reader will have a clear picture of the layout of the text without having to turn to the image of the papyrus itself, which is sometimes difficult to access. This project proposes a promising new methodology that looks to provide a more accurate understanding of the peculiarities of these specific texts and their transmission.[2]

On the other hand, the project Curses in Context, also funded by the Neubauer Collegium for Culture and Society, aims at a more intensive and contextualized study of ancient curse tablets written in Greek and Latin. Texts written on lead are usually edited without using a photograph of the tablet, mainly because normal captures do not provide a sufficient contrast of light and shadow to allow the reader to examine the document thoroughly. Sometimes, however, the edited text is accompanied by a drawing or a black-and-white facsimile. In the past, drawings by hand were the only option. This technique, though extremely useful, is not within the reach of everyone's artistic abilities. In addition, such facsimiles usually involve a higher degree of inaccuracy because they are often biased by the text-editor's interpretation.[3] Today, the use of high-resolution photographs and technological advances in facsimile production can better meet the demands of production and enhance the reliability of these drawings. Furthermore, the use of automatic binarization algorithms allows us to produce facsimiles of great precision after only a brief investment of time.

Depending on the scholar's degree of intervention in the creation of the facsimile, the techniques employed can be categorized as manual, semiautomatic, and automatic. As we point out below, all of these techniques have their respective advantages and disadvantages. In addition, the effectiveness of automatic binarization algorithms depends on the material on which the text was written.

MATERIALITY OF MAGICAL TEXTS AND PROBLEMS OF LEGIBILITY

Papyrus is probably the material surface that offers the least number of issues for facsimile creation, thanks to the high contrast between the black ink and the papyrus's light-yellow fibers. In most cases, the ink is well fixed to the fibers and clearly legible, unless superficial problems are present—for example, carbonization of the papyrus,[4] deterioration of the surface by external agents, or instability of the ink itself. Subsequently, given the papyri we are working on (mainly Greco-Egyptian magical formularies), infrared, multispectral, or reflectance transformation imaging (RTI) captures[5] are not normally required.

2 The first volume of the project has been published; see Faraone and Torallas Tovar 2022.

3 For an analysis of the degree of interpretation, see Shaus, Finkelstein, and Piasetzky 2010.

4 On the use of new technologies employed to read carbonized or deteriorated papyri, see, e.g., Kleve and Del Mastro 2000; Chabries, Booras, and Bearman 2003; Bülow-Jacobsen 2008; Bay et al. 2010; Macfarlane 2010; Alexopoulou et al. 2013; Kotoula and Earl 2015; and Janko 2016.

5 On RTI, see Earl et al. 2011; https://culturalheritageimaging.org; and chapter 1 in this volume.

In antiquity, potsherds were commonly used as writing material for private use and are particularly linked to aggressive magic, according to the procedures preserved in formularies and the content of the actual curses themselves (Martín Hernández and Torallas Tovar 2014b). Texts and drawings produced on potsherds (resulting in "ostraca," sing. "ostracon") were usually made with ink, since it adheres well to the surface of earthenware, though not quite as well as to papyrus. In the case of ostraca that have been exposed to deleterious external agents, the ink is often erased and the reading more challenging.

In cases where the surface of the ostracon has been effaced and the text is practically illegible, both infrared and multispectral photography may be useful (Bearman and Christens-Barry 2009; Faigenbaum et al. 2012, 2014; Sober et al. 2014). A successful capture of the object using these techniques with the added assistance of photo-retouching programs may offer a high-quality image that reveals more than the naked human eye can see (Faigenbaum-Golovin et al. 2017; Mendel-Geberovich et al. 2017).

Finally, in antiquity, metals—particularly lead—comprised the most common surfaces on which curse tablets were produced. The ductility of lead, together with its low economic cost and the multiple ritual analogies that were established between its color and coldness, made it the ideal material to carry out such aggressive ritual acts. The tablets were usually very thin and of small dimensions. Texts, symbols, and images were engraved with very sharp objects and are sometimes very small. To complicate matters, the tablets were often folded, pierced by nails, or deposited in bodies of water. Consequently, the small size of the text, the folding marks, the holes, and the degenerating effects of external agents on the tablet can turn the reading process into a significant ordeal. In such cases, new imaging technologies may offer great help for reading the texts.[6]

THE CREATION OF FACSIMILES OF MAGICAL TEXTS AND THE PROMISE OF NEW TECHNOLOGIES

MANUAL FACSIMILES

Publications of magical texts from antiquity often include black-and-white drawings or a high-quality image of the text to provide the reader with a clear image with which the proposed readings can be collated.[7] This provision is especially important for texts with magical images. Older editions of these texts, however, usually did not include such images (e.g., Wessely 1893; Audollent 1904),[8] though in some cases the edited texts were accompanied by freehand drawings (e.g., Kenyon 1893; Wünsch 1898). For example, the corpus of Greek Magical Papyri (*Papyri Graecae Magicae*), edited in 1928 (Preisendanz 1928–31), does not make any attempt at introducing high-quality drawings. Only some of the magical symbols were sporadically drawn in freehand and included in the publication. Small black-and-white photographs of some of the drawings of the papyri were included at the

6 See chapter 3 in this volume.

7 Bülow-Jacobsen 2020.

8 The drawings by Audollent, not included in his edition of the curse tablets, have been recently published in Németh 2013.

end of each volume. The publication itself included only a description of the drawing (either in the edited text or in its critical apparatus). The English translation of this corpus by Hans Dieter Betz, published in 1986, made an effort to supplement the texts with their corresponding images by including freehand drawings.

Computer image-editing software, such as Adobe Photoshop or Adobe Illustrator, may be extremely useful in creating accurate facsimiles. Producing "manual" facsimiles using these programs is an easy task, as the scholar needs only a high-quality digital image of the text, an image-editing program, a drawing tablet,[9] and a steady hand. With the image open in Adobe Photoshop, a new layer must be added to the image. The letters and drawings of the original inscription may be tracked in this new layer by using a different color for better contrast of parts of the image or text that are already tracked. When the work is complete, the background image is removed and the tracked layer saved. Changing the tracking color to black results in a black-and-white facsimile.

Recently, applications ("apps") developed for tablet computers have been improved, and now there exist convenient tools for performing the task of facsimile creation. Adobe apps such as Adobe Sketch, Adobe Draw, and Astropad[10] are all interesting choices. These apps make it possible to trace drawings by using a digital pen directly on one's screen, thus facilitating great precision.

All these manual processes can provide accurate facsimiles. Still, they require spending a great deal of time on deciphering strange symbols and complicated drawings, especially when the text is long or contains additions, as is usually the case in our projects.

SEMIAUTOMATIC FACSIMILES

Image-editing programs provide sophisticated tools that assist in editing images and producing semiautomatic facsimiles. Using contrast manipulation, color correction, noise removal, and mechanisms to separate the foreground from the background, a provisional facsimile can be created in relatively little time. These kinds of tools work well for black text written on papyrus and potsherds but are more difficult to apply with good results on other materials, such as lead. In this case, RTI images and viewers are of great help. This approach offers a good alternative to manual facsimiles, but the user must be aware of the possible loss of information during the process, since the writing is sometimes faded and can be completely lost when using color correction.

AUTOMATIC BINARIZATION ALGORITHMS

In projects such as the ones we are referring to—projects in which large numbers of facsimiles must be produced—alternatives that make the work both easier and faster without losing accuracy must be investigated. For that reason, we have explored the advantages of using automatic binarization algorithms. These methods allow for very fast, automatic production of black-and-white (binarized) versions of digital images. Often, such binarized

9 If only a personal computer is available, see Shaus et al. 2016.

10 This app uses the tablet as though it were a drawing tablet. The program is available and fully supported for use on Windows and Mac.

images are used as a first step toward further image-processing and text analysis tasks, such as optical character recognition, text digitization, and identification and comparison of scribes (Faigenbaum-Golovin et al. 2016, 2020; Shaus et al. 2020), but they can also be used alone for publication purposes.

Binarization algorithms (for a survey and examples, see Shaus, Turkel, and Piasetsky 2012) are performed on grayscale digital images. If several channels are present in the image, as in RGB (red-green-blue) images, they are usually averaged in advance on a per-pixel basis. Automatic binarization algorithms can be roughly divided into the two most common types: global and local.

Global algorithms partition the image into foreground (black) and background by setting a single binarization threshold for the whole image based on a certain logic. For example, if colors from 0 (black) to 255 (white) are present, an algorithm may set a threshold to 100, turning all the pixels with values 0–100 into 0 and pixels with values 101–255 into 255. The threshold can be predetermined or chosen by a method that takes into account the image's specific information; the most common such algorithm was suggested by Nobuyuki Otsu (1979).

Local algorithms are another, slightly more sophisticated option for producing a binarization. Typically, a binarization threshold would be computed for each pixel in the image individually based on its surrounding pixels—a "sliding window." The size of the window is important and may greatly influence the binarization results; a window size is typically chosen based on the resolution of the image, the size of the characters or drawings, and the distance between the lines. Local algorithms propose a natural technique of dealing with issues such as differential preservation of ink or uneven illumination of the artifact, though at the cost of higher computational burden and lack of "whole image" information when calculating the local thresholds. Numerous local binarization methods have been suggested, the most prominent being those by Wayne Niblack (1986) and Jaako Jari Sauvola (Sauvola and Pietikainen 2000).

Noting the promising results that such algorithms have offered for texts written on potsherds (Shaus, Turkel, and Piasetsky 2012), we began a collaboration and applied the various algorithms to texts written on other materials, such as papyrus, parchment, and metal. In addition, we tested the algorithms on drawings and symbols, frequently featured on documents.

EXPERIMENTS

EXPERIMENTAL SETTING

We developed a program allowing for the fast creation of several binarizations for each document, a program to be utilized and evaluated by the paleographer. The following algorithms were applied: predetermined threshold values of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, and 240; Otsu automatic global threshold selection algorithm; Niblack local threshold selection algorithm with half-window sizes of 50, 100, 150, 200, and 250 pixels; Sauvola local threshold selection algorithm with half-window sizes of 50, 100, 150, 200, and 250 pixels (the real window is of the size 2 × half + 1 pixels).

AUTOMATIC FACSIMILES OF MAGICAL TEXTS ON OSTRACA

Unsurprisingly, the program produces quite good black-and-white binarizations for texts and images written on potsherds. Here we have chosen an aggressive Coptic magical text (edition in Martín Hernández and Torallas Tovar 2014a) to demonstrate the automatic facsimile created by the algorithm. For an example of the program's run, see figure 2.1; for results, see figure 2.2.

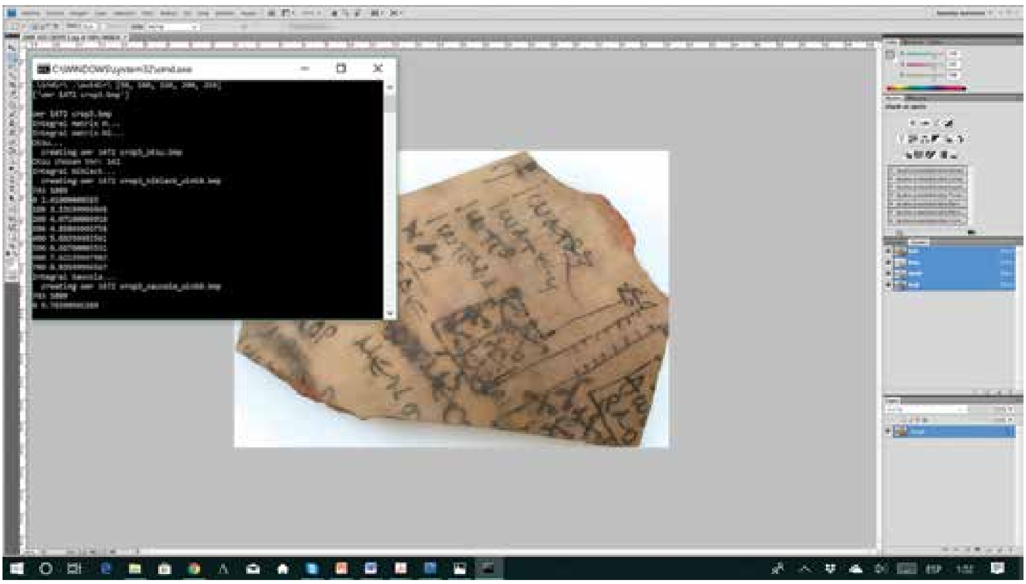


Figure 2.1. Capture of the original image of the piece and the program's run. Image ©Abadía de Montserrat.

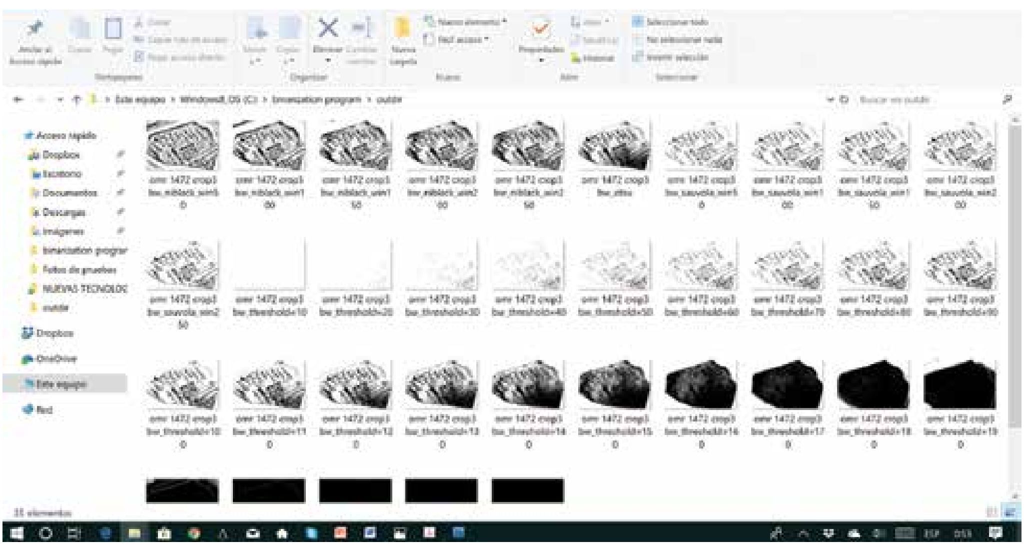


Figure 2.2. Example of results provided by the automatic binarization algorithm.

Some problems with shading on the edges due to the curved surface were detected. Such issues can be resolved by combining two or three resulting binarizations in Photoshop or another image-editing program to obtain an accurate image of the whole artifact. With just some slight adjustments using the editing tools, a rather accurate facsimile can be produced in a short time, as exemplified in figure 2.3.

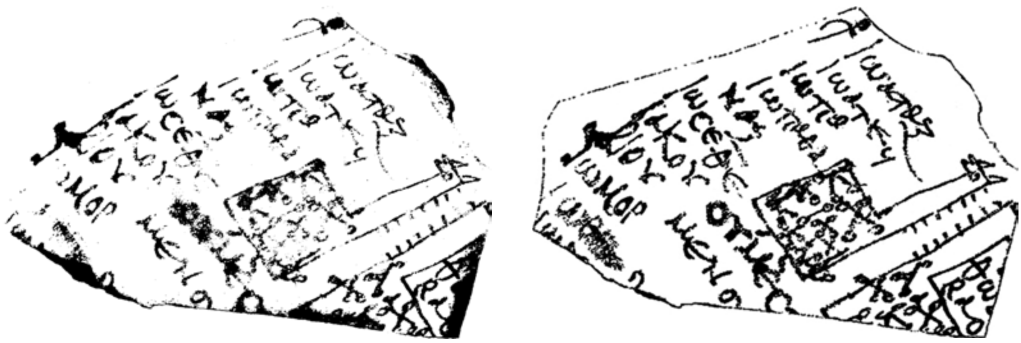


Figure 2.3. Example of binarization and facsimile creation of a Coptic magical text. *Left:* The best image produced by automatic binarization (sauvola_win50). *Right:* The final product—a combination of different images produced by the program with a little image retouching in Photoshop.

AUTOMATIC FACSIMILES OF MAGICAL TEXTS ON PAPYRUS AND PARCHMENT

The program produced a less efficient binarization with papyrus than it did with potsherds, mainly because the surface of papyrus presents more shades, and its color scheme is larger than that on ostraca. Using a multispectral or infrared capture of the object, however, could certainly improve the outcome. The results of the first tests were promising but, again, not as distinct as the results obtained with ostraca. One of the issues is that if one saves the image of the papyrus in the CMYK (cyan-magenta-yellow-key) color mode instead of RGB, the algorithm produces a binarization in which the colors are inverted: the ink is in white and the papyrus surface is in black. To produce a more accurate black-and-white facsimile, only a color inversion is needed. Some minor retouching and a bit of erasing reduces the difference between the automatic facsimile and the manual facsimile. An example of the result can be seen in figure 2.4.

The binarizations for texts written on parchment are similar to those on papyrus. Depending, however, on the preservation of the ink and the thinness of the parchment, which can make the ink on the back visible on the front (a "bleed-through" effect), the results are very different. The use of infrared or multispectral images can be of great help in the most difficult cases. An example of the result is shown in figure 2.5.

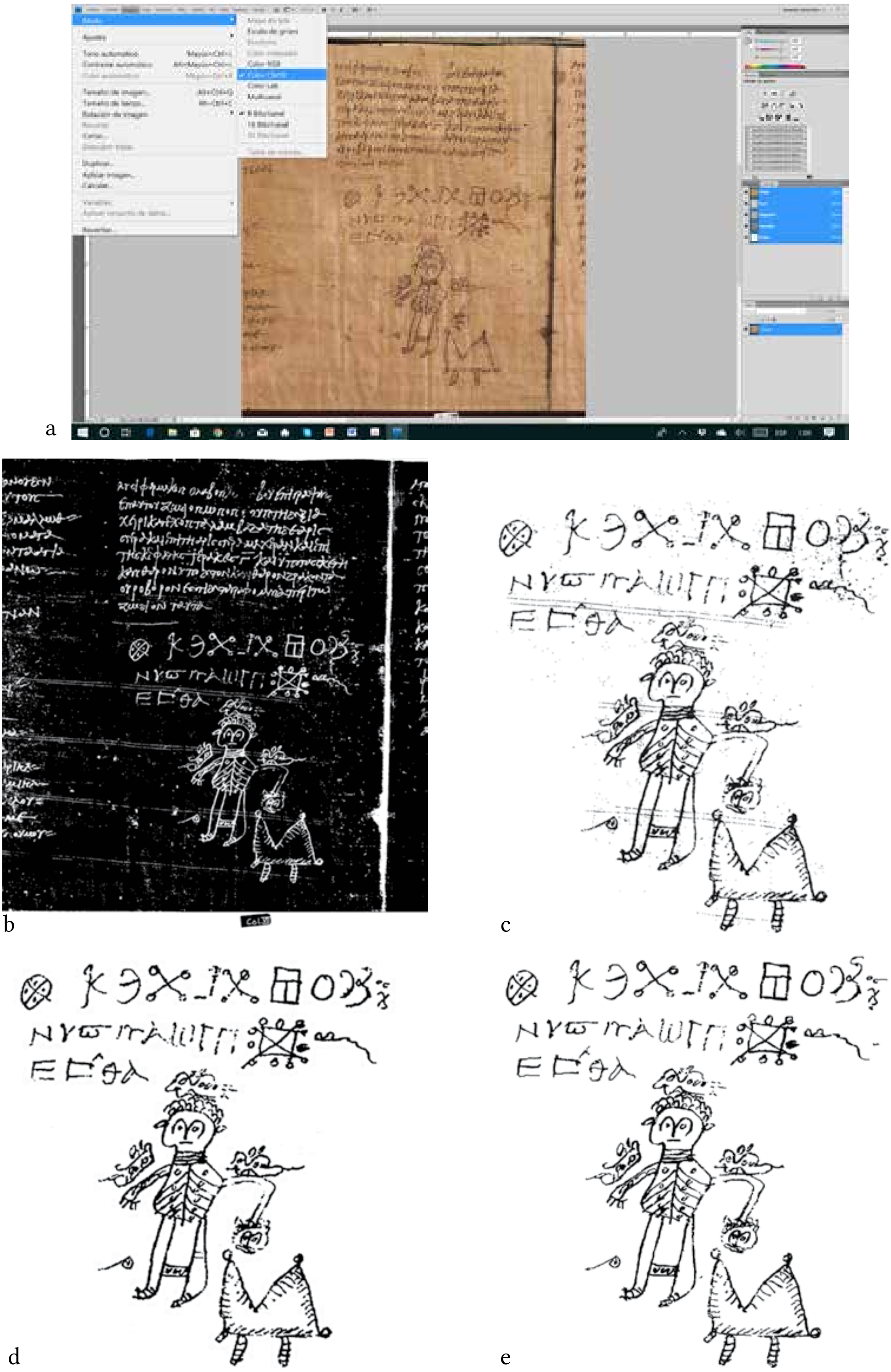
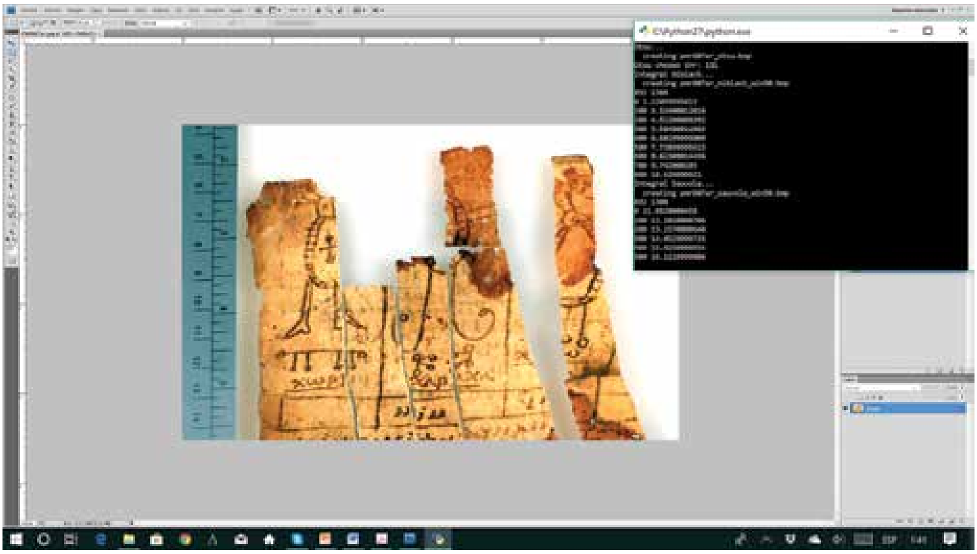
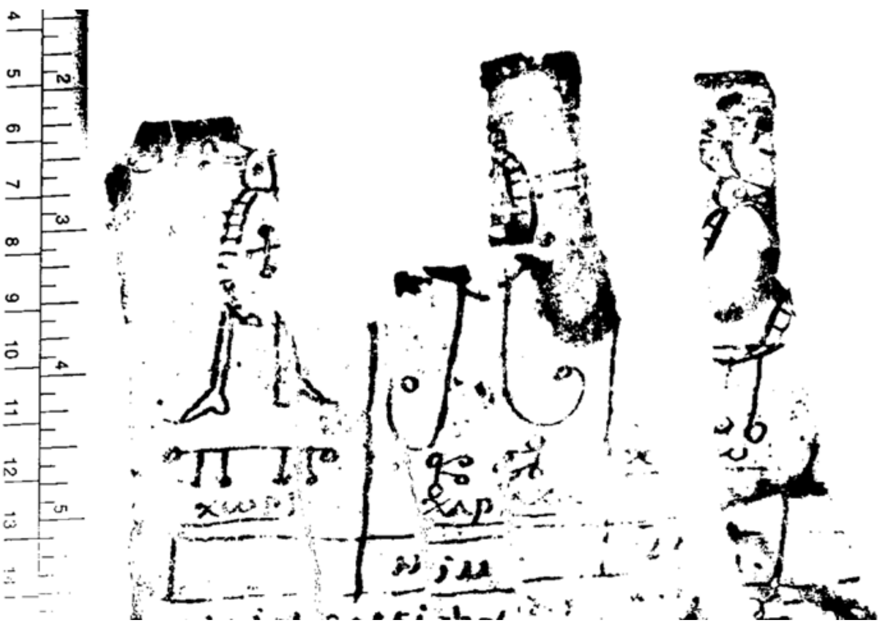


Figure 2.4. Example of binarization and facsimile creation with papyrus: P.Oslo I 1, © University of Oslo. *a:* Saving the image in CMYK mode. *b:* Result obtained by the algorithm (threshold at grayscale value of 150). *c:* Inversion of colors. *d:* Retouched automatic facsimile. *e:* Manual facsimile.



a



b

Figure 2.5. Example of binarization and facsimile creation with parchment.
a: Magical texts on parchment. P.Monts.Roca inv. 607a ©Abadía de Montserrat.
b: Automatic binarization (Sauvola algorithm with half-window size of 50 pixels).

AUTOMATIC FACSIMILES OF MAGICAL TEXTS ON METAL (LEAD)

Texts written on lead are typically the most challenging. Without an RTI image of the artifact, the results are very poor. Even with an RTI capture present, producing a facsimile of the whole object is difficult, mainly because of problems in its preservation, irregularities of its surface, and the visibility of its incisions.

An RTI image is created from multiple digital photographs taken from a stationary camera position. Every photograph is taken with light projected from a different direction using a lighting dome (in RTI) or a handheld flash (in H-RTI). This technique has greatly improved the visibility of texts written on lead using viewers of RTI images such as RTIViewer.[11] RTI viewers offer binarized images that, contingent on the light, can make the text more or less visible depending on the part of the surface on which the text is written. This technique may offer good visibility of specific artifacts, especially those where the contrast between light and shadow is greater. Tests with our program were performed to see how well the binarization algorithms work with RTI images of lead curse tablets, but unfortunately the results were poor.

FURTHER STEPS

Several future avenues of research can be proposed:

- All the binarizations may benefit from automatic speckle removal (for details, see Shaus, Turkel, and Piasetzky 2012), which can offer further improvement of processing speed.
- More sophisticated overall improvement may be achieved by using sparse methods in the binarization process (for an example, see Shaus et al. 2013).
- If specific characters or minor details require reconstruction, the use of a semi-automatic stroke reconstruction algorithm (see Sober and Levin 2017) may be advised.
- A combination of 3D scanning and pattern recognition algorithms can be beneficial for incised texts (for an example, see Rothacker et al. 2015).
- For documents written in ink, a hardware-based binarization can be attempted (see Shaus et al. 2019).

CONCLUSIONS

Given the great advances in technology that are easily accessible to scholars and the great ease of obtaining high-quality images of ancient texts, it is vitally important that philological editions take advantage of these advances to offer a more complete presentation of the texts. Increasingly, editions of ancient texts tend to take into account the data provided by the material study as well as other features generally left aside in past studies, when scholars were mainly interested in providing only an accurate reading of the text. In projects such as those described above, which aim to offer an edition as faithful to the original as

11 This free and open-source program is accessible at https://culturalheritageimaging.org/What_We_Offer/Downloads/.

possible, the production of facsimiles to be included in the published edition of the text is of vital importance. This study explores the possibilities of using automatic binarization algorithms to reach that goal. Such algorithms provide great help in creating accurate black-and-white images in record time, and their effectiveness has been shown for texts on papyrus, parchment, and potsherds. The results for engraved texts, especially on metal, are not as promising at the moment, but some ideas and desiderata have been suggested here. The results and proposals we have presented constitute the first steps in the effort to achieve, in the future, equal effectiveness in the binarization of ancient texts in metal.

3 Paleography of the Curse Tablets: Dating a Document on Lead

Sofía Torallas Tovar

One of the main aims of the discipline of paleography is to authenticate and date ancient texts by analyzing their handwriting. This method works only when it is based on comparisons with a large number of examples that have exact dates or somewhat sure dates—the wider the sample, the better. While there is a strong paleographical tradition for both medieval Greek manuscripts and Greek papyri—a tradition that goes back several centuries—there is no general study of the documents written on metal. It makes sense that these disciplines remain separate, since they present different materiality as well as extensive chronological gaps, but the isolation in which they have traditionally developed does not allow a flow of information that can be mutually useful.

Thus far, inscriptions on lead tablets have been subject to only partial comparisons and have yet to undergo a general study. There are indeed paleographical considerations in the publications of lead inscriptions, but usually these publications aim to give an approximate date for such inscriptions without truly considering the problem holistically. Any useful parallels that are adduced for comparison are made, in general, with local epigraphy.[1] The study of these very difficult texts is mainly concerned with establishing a text, and the shapes of letters are important only as a means of distinguishing one from another.

It is also important to consider that none of the known inscriptions on lead contains an explicit date, so all dating is based on archaeological context and eventually prosopography. These methods of dating are imprecise and provide only estimates. However, these estimated dates provide space for a systematic analysis of handwriting.

In this chapter, I explore the possibility of comparing the paleography of lead tablets with that of papyri, examine the problems and methodologies that arise through both lenses, and use a few case studies to evaluate the results.[2] The larger project aims to (1) produce a catalog of images that is geographically and chronologically organized and is more or less reliably based on archaeological criteria; (2) establish some common styles or

1 Kirchner 1935 and Kern 1913 have been and still are invaluable repertories for comparison, as are Tracy 1990 and 2003, in the identification of hands in Attic inscriptions.

2 I do not mean that it has never been done. In fact, there is an example in Jordan and Curbera 2008, 137–38. In Curbera, Sierra Delage, and Velázquez 1999, 280, there is even an attempt at comparison with papyri. What has not yet been done is a survey full enough to provide a tool for identifying styles or for dating hands.

models, while taking a few caveats into account; and then (3) test the possibility of using paleographical studies of other materials, primarily papyrus, as a means of comparison.

THE CORPUS

The corpus of curse tablets is composed mainly of documents written on lead (Kiyanrad et al. 2015)—albeit occasionally on other metals and even ostraca[3]—with a stylus or a nail and intended to manipulate the actions of other people or animals without their consent. There are, to date, thousands of examples of such tablets, mostly inscribed in the Greek language and ranging from the fifth century BCE to at least the sixth century CE. Their geographical distribution covers nearly the entirety of the Mediterranean region and greater Europe.[4]

This basic description of the corpus elucidates the primary obstacles to pursuing this project: the wide distribution of these texts can produce geographical variation, and the chronological span brings the paleographical study of documents into two disciplines: epigraphy for the earliest examples, and papyrology for the latest ones. I offer five methodological considerations about the specific peculiarities of this corpus: materiality, literacy, special writing, genre, and imaging. Among these five, the materiality[5] and the imaging of the lead tablets present especially serious hindrances to their analysis and comparison with parallels.

MATERIALITY

When scripts incised on metal are compared with scripts written with ink and calamus on a soft surface, it becomes clear that the "inscribing" techniques produce very different results. Writing with a calamus or reed pen gives the scribe flexibility and allows rounded strokes and cursive writing. Incision with a stylus on hard material, such as metal, on the other hand, restricts mobility and the execution of strokes, with the result that special traits of styles and models are obscured.[6] Lead, especially when warmed, may be an exception. It seems to be an easy material on which to inscribe with a stylus.[7] In general, however, different materiality gives expectedly different results in the production of cursive writing, where ligatures and connected strokes in letters depend on how the scribe manipulates the writing instrument within the material constraints of both the surface and the pen.

3 As with letters, other materials were also used: curses are attested on ostraca, limestone, talc, papyrus, and gemstone. Some are even written with ink on metal—for example, Ägyptisches Museum, Berlin 13412 (Jordan 1985b, 190, no. 160).

4 For a survey, see Ogden 1999.

5 On the materiality of curse tablets, see Curbera 2015.

6 Jordan (1985a, 212) is reticent to compare with papyri based precisely on the material execution of the writing.

7 For an example of rounded strokes on metal, see Faraone and Rife 2007.

LITERACY

My second consideration, literacy, is an important factor in the evaluation of scribal practice.[8] The lower the literacy of the scribe, the more irregular the hand becomes, and consequently the less carefully it follows those patterns or models of writing that can allow for precise dating and the identification of hands. But this factor affects all kinds of documents, on soft or hard surfaces, inscribed or incised. Since this is not specifically the case for lead inscriptions, these exemplars need to be excluded from the study.

SPECIAL WRITING

One must also take a few peculiarities of magical texts into account when studying the paleography of curse tablets. Scribes often purposefully altered the appearance of the text by using special characters, reverse writing, boustrophedon, and similar textual modifications (Ogden 1999, 29–30; Faraone 1991, 8, 12).[9] Although these modifications may be advantageous since they can potentially be dated,[10] they also pose a disadvantage in that deformations can obscure the style or model of the handwriting.

GENRE

There is a general tendency in the study of textual corpora to segregate texts by genre (including documentary or "paraliterary" genres). This makes the most sense when the object of study is exclusively textual, as in the case of biblical papyri, Christian letters, magical handbooks, administrative documents, and legal documents, to give some examples. The materiality of these documents is often but not necessarily connected to the genre of the texts. Most documentary papyri are written in cursive hands, though not always, while literary texts, especially high-quality books written by professional scribes, use formal hands. But this observation is only a general rule of thumb. One finds literary texts written in cursive, slow, or very formal hands, and the same can be said about most genres. For this reason, a paleographical survey of curse tablets should include other documents written on lead to obtain as wide a sample as possible, including, if feasible, dated documents.

The use of lead in the Mediterranean goes back to the eighth century BCE and may even extend to the Late Bronze Age (Payne 2015, 106 n. 188).[11] As a by-product of the extraction of silver, lead was abundant in areas where silver was mined and was a cheap and widely used material. For example, until the Hellenistic and Roman periods, lead was frequently used for letters (Sarri 2017, 53–56; Ceccarelli 2013, appendix 1; Eidinow and Taylor 2010). The body of letters composed on lead provides invaluable parallels to the earliest curse tablets.

8 On literacy and magical texts, see Ogden 1999, 57–58.

9 On retrograde writing and its varieties in curses on lead, see Jordan and Rotroff 1999, 150. On deformation of writings, see also Curbera and Jordan 1998, 31–32, 34–35.

10 Curbera and Jordan (1996, 48 n. 15) discuss the need for a full study of "*charaktêres*" (cf. Mastrocinque 2012b; Gordon 2014).

11 I thank the anonymous reviewer for this reference.

Other documents, such as those of the more than 4,000-piece corpus of oracular tablets from Dodona (Dakaris, Vokotopoulou, and Christidis 2013), from the fifth century BCE to the destruction of the sanctuary in 167 BCE, provide a rich source of information. Although the archaeological exploration of the site, which started at the end of the nineteenth century and continued into the mid-twentieth, is inadequate for use in precise dating, the great number of documents recovered provide a uniform corpus with which to work.[12] Additionally, two large cavalry archives from the fourth to third century BCE, excavated in the Kerameikos in Athens and at the Dipylon gate, also provide archaeologically dated parallels (Posner 1974). The Kerameikos lots, discarded in a well, can be dated stratigraphically thanks to the pottery excavated in the two layers in which the lead inscriptions were eventually found.

IMAGING

Incised writing on lead does not provide enough contrast with the surface to allow adequate imaging for study. Personal examination of documents should, of course, never be replaced by imaging, but the advancing quality of images offers ever-closer matches to this experience. In the past few years, we have witnessed an increase in the digital resources and technologies applied to philology, especially in terms of improving the quality of digital imaging. These developments mostly concern documents written in ink. In the case of incised documents, particularly metal inscriptions, technological advancement in terms of access and quality of images remains in its developmental stages.

Traditionally, lead documents have been published with line drawings, if any. Since the documents are difficult to read and photograph, the line drawings involve an added level of interpretation by the editor, and the reader cannot check the original because of the limitations of photography mentioned above. Fortunately, imaging of these lead tablets is progressing. In general, there have been important developments in multispectral imaging for papyrus documents, manuscripts, and inscriptions. Similarly, reflectance transformation imaging (RTI) technology produces a combination of images of the object taken with circular lighting.[13] Moreover, current automatic binarization programs and RTI photography can produce much better and more accurate drawings. Scholars at the University of Tel Aviv have recently applied this binarization to ostraca texts dating to the Second Temple period, and some of their results are impressive—especially those that restore incomplete handwritten characters.[14] These binarization algorithms produce black-and-white facsimiles of texts written on ostraca and metal surfaces—great aids for epigraphers because they provide clear images in high contrast, with the possibility of retouching the facsimiles later. Both technologies in combination produce more reliable images of the inscription, images that are less subject to the interpretation of the epigrapher. The result is not only improved textual legibility and interpretative ability but also a more accurate observation of the quality of the script.

12 The corpus is not completely homogeneous, however, in that the inscriptions present different dialectal traits due to the fact that most documents were written by travelers.

13 See chapters 1 and 2.

14 See chapter 2.

COMPARISON WITH THE PAPYRI: ARCHAEOLOGY AND PALEOGRAPHY

Having discussed the foregoing considerations about the corpus, the question remains whether papyri can be used as comparanda to hands on lead. Excluding slow hands and those that purposefully deform or alter the shapes of letters with the intention of having some magical effect, a paleographical study of hands inscribed on lead and a survey of archaeologically dated examples would provide a useful tool. The project should, of course, include as many examples as possible, but in this chapter I focus only on the possibilities of comparison with hands on papyrus by discussing four case studies based on lead tablets that have been found in controlled archaeological contexts.

I have already mentioned the challenges of achieving this comparison. From the point of view of the material execution of the handwriting, the results of the process of writing and the process of inscription will necessarily be different. Nevertheless, certain features of both processes can be compared. After all, when the same scribe writes on different media, the model in his or her head remains the same, and we should be able to identify some features of that model.

The question of geographical variation of the script or scribal practice would further argue against the possibility of comparison. Crisci (1996), for example, explored such geographical variation in a series of writing samples produced outside Egypt. The topic is quite complex. He demonstrated some geographical cohesion in hands from the fourth to the third century BCE and observed some homogeneity in hands from even later, in the Roman period. But he also considered some examples of writing produced in areas not connected to the main cultural networks. In interconnected areas, cultural homogeneity generated common models of writing, while isolated areas presented some specific evolutions and the influence of other scripts. We must suppose that writing styles and models of hands emanated from a limited number of focal points. Places such as Alexandria and Athens were cultural and administrative centers whence both formal literary styles and chancellery styles must have expanded to the rest of the Mediterranean. Examination of the hands of lead tablets needs to take this factor into account.[15]

The paleography of the papyri has been widely studied, and today there are plenty of tools for doing so. Basic handbooks and catalogs for both literary and cursive hands include, for example, those by Roberts (1956), Cavallo (1967), Seider (1967–70), Turner (1987), Cavallo and Maehler (1987, 2008), and Harrauer (2010), and the PapPal project (https://pappal.info) has proven to be a great aid in finding dated parallels to hands from the Ptolemaic to the Late Roman periods. The large number of administrative documents and the more-or-less linear evolution of documentary hands allow for quite accurate dating of documents. Although literary hands are more difficult to date because of conservativism and less dynamic evolution of the models (Orsini 2018; Nongbri 2018), the considerable

15 Recent scientific work on the materials provides further data to consider when dealing with the geographical origin of the inscriptions. A recent article, "Lead Isotope Analysis in Magic Artifacts from the Berlin Museums" (Vogl et al. 2018), presents an analysis with interesting results about pieces from Egypt containing isotopes from Laurion in Greece. There is not much that can be firmly concluded from these results, as they can really only attest to the fact that the material was imported from Greece, though not necessarily by the scribe. But such mobility needs to be considered in the case of many of the items we are discussing here.

number of examples allows for rather accurate dates even of literary hands. Administrative documents written on papyrus, for example, often contain a specific date, and the reuse of some papyri can provide a terminus with some reliability based on the date found in the administrative text on the side opposite that of the literary text.[16]

CASE STUDIES

Archaeology usually provides excellent chronological information, though it needs to be used with prudence. Often, materials come from dumps where subsequent building activity may have disturbed the stratigraphy, and sometimes materials dating from a later period can be found together with materials from an earlier one. In the case of curse tablets, moreover, the ancient practice of digging and hiding the documents, or throwing them into wells or tombs, adds a reason to consider the stratigraphical information with caution. Below I present four case studies in which the archaeological information combined with paleography can establish a somewhat reliable date.

THE ATHENIAN AGORA

An excellent corpus for the comparative work proposed here is that of the curse tablets from the Athenian Agora. Jordan (1985a) provides a map and chronological table of the site's eight wells and their stratigraphy, with Well I firmly dated to the late fourth to early third century BCE and Well VIII to the third to fifth century CE. The texts (around thirty curse tablets) found in Well V (located in C18:2) can be archaeologically dated to two to four decades between the middle of the first to the beginning of the third century CE, though Jordan himself was reluctant to date these documents using paleography:

> As for the date of Well V's tablets, the well itself was in use from the second half of the first through the first half of the third century of our era. I am reluctant to try to assign, on the basis of the handwriting on the tablets, any closer date than "late Roman", for the only reliably dated bodies of handwriting of the period are on papyrus and pottery. Writing on lead is generally less cursive than writing on these other materials, as if writing on lead was a slower process [Jordan 1985a, 212].

I have chosen Jordan's tablet 9 (Inv. no. IL 952, pl. 67; see fig. 3.1), a curse against Juliana and Polynikos that paleographically can be dated to about the third century CE, and compared it to three other third-century papyri that present a similar clear hand containing separated letters and few ligatures. In this way, the shapes of the letters and the *ductus* with which they were written can be compared with the strokes on lead.

As shown in figure 3.2, I have used (a) P.Oxy. XX 2341 (208 CE; TM 22213), (b) P.Oxy. XLI 2997 (214 CE; TM 16544), and (c) P.Oxy. XLII 3055 (285 CE; TM 16450) as comparanda. Although there are rounded strokes in some letter shapes in the papyri that do not have parallels on the lead tablet, I believe that in general the hands have common features in

16 Turner (1954, 102–6), however, has proven that there is no rule for the number of years that may pass between the use of recto and verso. He offers a list of documents in which the difference ranges between one month and several years—even a case where the gap reaches two hundred years. But when considered as a whole, the average time amounts to between two and four decades.

Figure 3.1. Curse against Juliana and Polynikos (from Jordan 1985a, pl. 67).

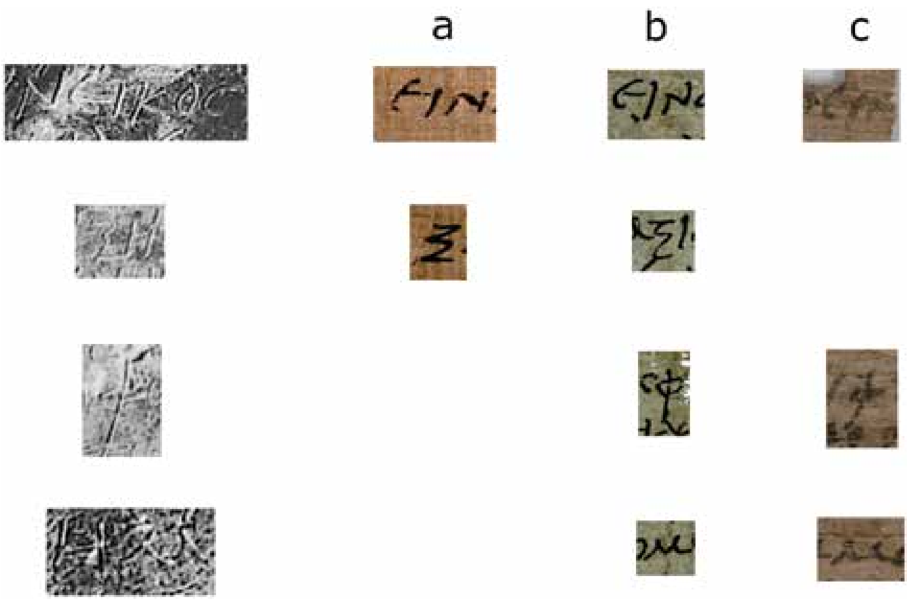


Figure 3.2. Comparison of Jordan's tablet 9 with P.Oxy. XX 2341, XLI 2997, and XLII 3055.

some shapes and sizes, even ligatures. For example, observe the rounded *epsilon* followed by an *iota* contained between the notional lines; the *phi* with a similar proportion and flat head, especially in (c); and the three-stroke *mu*. A full study of the texts from the eight wells could provide a basis we might use to confirm the archaeological date and basic evolution of the script in a closed sample.

I now compare the handwriting of the curse against Juliana and Polynikos with a piece lacking a clear archaeological provenience, namely, a curse tablet from Sisak in Pannonia (fig. 3.3) that is reported to have been found in September 1898 in the bed of the river Kulpa or Kupa (ancient Colapis). Curbera and Jordan (1996, 46; *AIJ* 526: Hoffiller 1938) propose a third-century CE date of origin based on the shapes of the letters: "The letter-forms seem to suggest the third century of our era." A comparison with (a) P.Oxy. XXII 2341 (208 CE) shows some similarities in the shapes of some letters, while at the same time some divergences—such as the *mu* in four strokes—that can be explained by the material constraints of using a stylus (fig. 3.4). But observe the pointy shape of *alpha*.

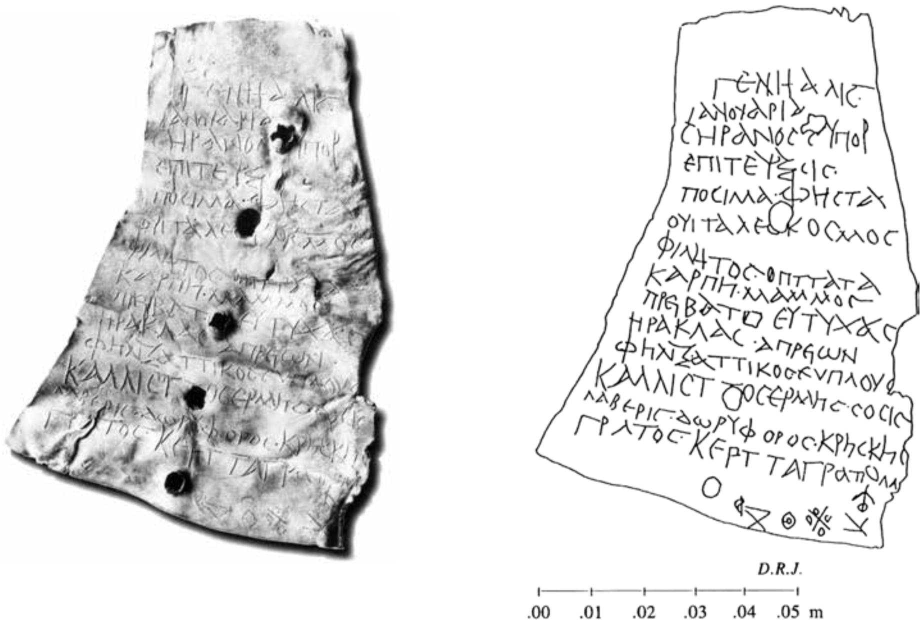


Figure 3.3. Curse tablet from Pannonia (from Curbera and Jordan 1996, 46, pl. 3).

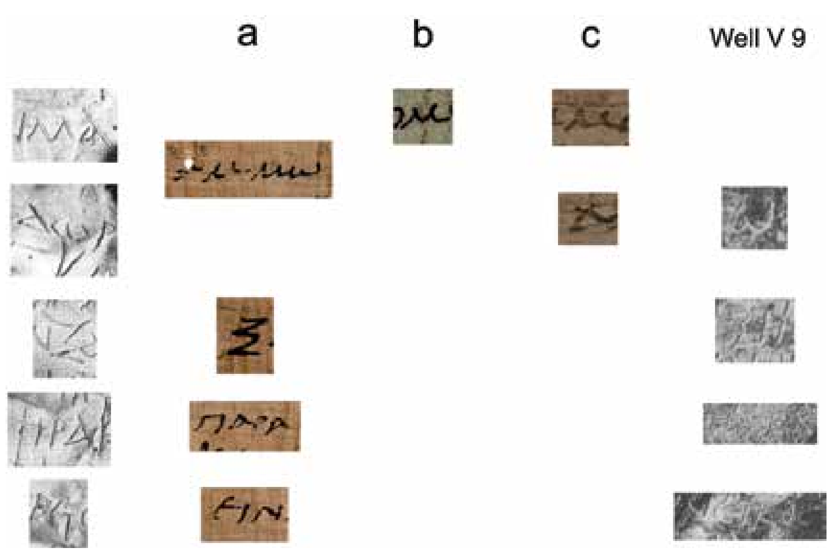


Figure 3.4: Comparison with (*a*) P.Oxy. XXII 2341, (*b*) XL 2997, (*c*) XLII 3055, and Well V, no. 9.

CHYTRIDION FROM THE AREOPAGUS, ATHENS

My second example comes from a curse tablet found inside a small pot (Jordan and Rotroff 1999, 147–54), a *chytridion*, in the Areopagus in Athens (Agora inv. P. 27880; figs. 3.5 and 3.6). The typology of the pot can be dated within a span of less than a century—about 325 to 250 BCE. The only paleographical reference to the shape of the letters in the publication of this document notes the inconsistency in the use of lunate *sigma* and four-stroke *sigma* (Jordan and Rotroff 1999, 150).[17]

Comparison with papyri of this date reveals some parallels in the shapes of letters and general *ductus* of the writing. I propose a comparison with the curse of Artemisia (UPZ I 1, TM 65797), dated to the end of the fourth century, as well as a document from

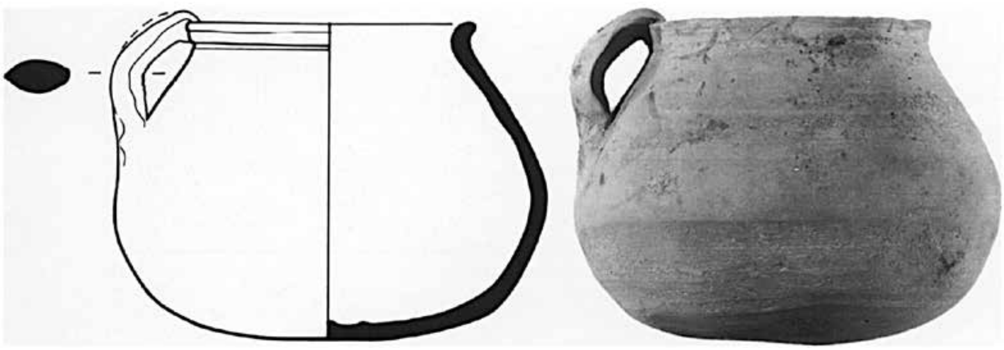


Figure 3.5. Chytridion from the Areopagus in Athens (from Jordan and Rotroff 1999, 149).

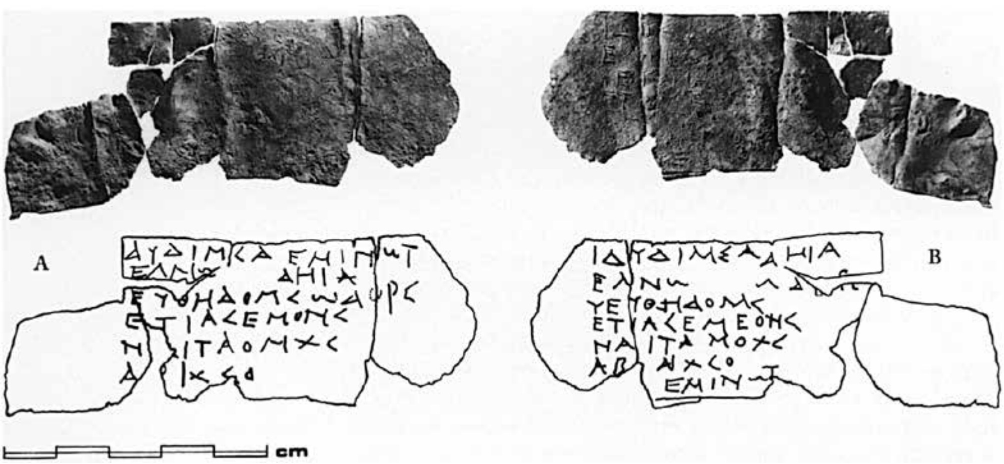


Figure 3.6. Athens Agora inv. P. 27880 (from Jordan and Rotroff 1999, 151).

17 For coverage on inconsistencies within the same document during this transitional period, see the Köln Sappho papyrus (P.Köln XI 429 + 430), which presents the contrast between the square and rounded *epsilon*, a transformation from the epigraphic uncial (Cavallo and Maehler 2008, 36–37).

the Zenon archive (P.Cair. Zenon I 59002, TM 2293), dated to 260 BCE (see fig. 3.7). At the end of the fourth or beginning of the third century BCE, some letter-shapes still show inconsistency, especially those of the *epsilon* and *sigma*, evolving from their epigraphic shapes into the rounded forms we find thereafter.

Comparable with UPZ I 1 are the shape and size of *theta* and *omicron*, in contrast with larger and wider square letters; *omega* in line 7 of the B face; the four-stroke *epsilon*; and *mu* in three strokes with the medial stroke raised above the baseline. The Zenon papyrus offers an example of a hand from the latter part of the archaeological period assigned to the pot. The contrast of wider and narrower letters—especially the size of the *omicron*, the wide *mu* in three strokes with a central curved stroke, the triangular *alpha*, and the wide *eta*, among others—are good elements of comparison.

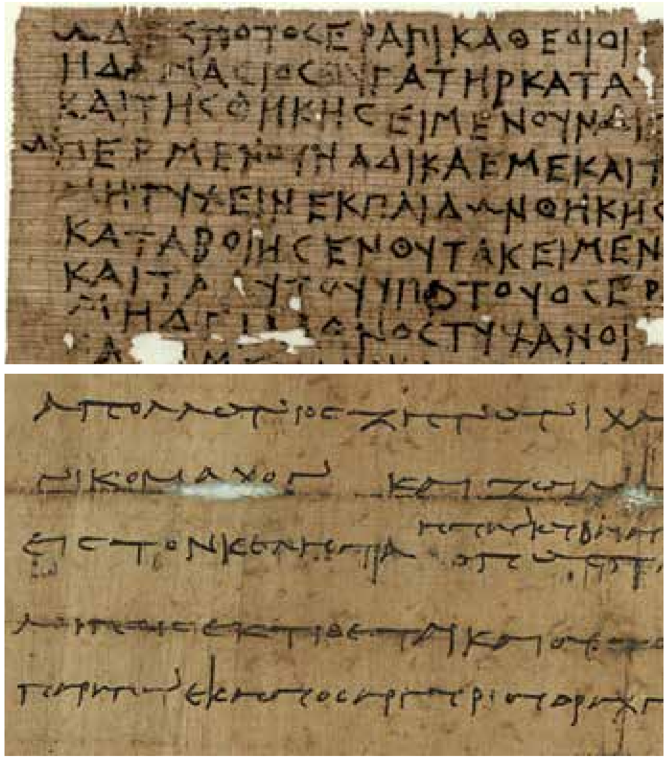


Figure 3.7. *Top:* The curse of Artemisia (UPZ I 1). *Bottom:* P.Cair.Zen. I 59002.

CURSE FROM JERUSALEM

My third case study is a juridical curse from Jerusalem with a firm dating from an archaeological site where the *terminus post quem* is 285 CE (based on a coin) and the *terminus ante quem* is 363 CE, the collapse and destruction of the building. Within this relatively short time span, paleography can provide further specification. I have chosen for comparison (a) P.Cair.Isid. 3A (TM 10359, 299 CE), (b) P.Sakaon 34 (TM 13052, 321 CE), and (c) P.Oxy. XLIV 3178 (TM 15942, 248). Certain combinations of letters, shown in figure 3.8, give a first glimpse of the parallel. The dating according to this comparison confirms the archaeological date and perhaps fine-tunes it to the end of the third or beginning of the fourth century CE. Observe, especially, the ligatures of both *epsilon–iota* and *alpha–iota*, with the slight slant to the right and the downward projection of the *iota*, and the shape of the *omega*, which continues with a stroke after the second belly. The h-shaped *eta* and its position vis-à-vis the preceding *tau* are also comparable in both documents.

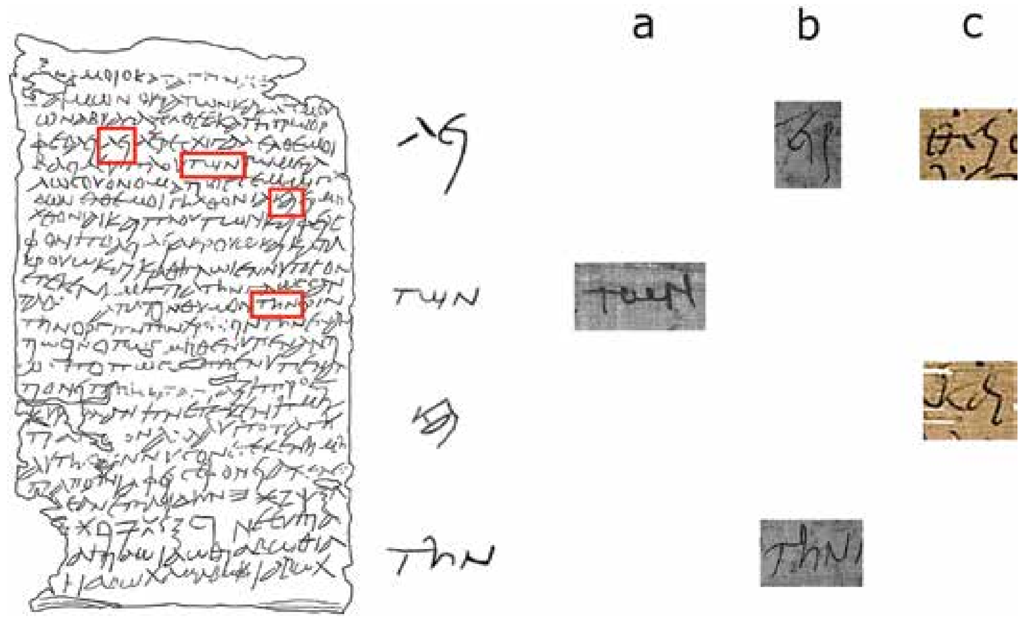


Figure 3.8. Juridical curse from Jerusalem and comparison with (*a*) P.Cair. Isid. 3A, (*b*) P.Sakaon 34, and (*c*) P.Oxy. XLIV 3178. From Ben Ami, Tchekhanovets, and Daniel 2013, 231.

CURSE TABLET FROM WEST CRIMEA

The fourth example is a curse tablet from West Crimea (fig. 3.9). I have chosen this piece not only because it has a somewhat reliable archaeological context but also because even though the text is written in reverse and with backwards letters (i.e., from right to left and with the letters flipped horizontally), enough paleographical features can be confirmed to assign the piece to the expected date. Although it was found by chance in 2012, the survey projects conducted in the area between 2007 and 2013 prove that virtually all rural sites in the area emerged around 360 BCE, after all of northwestern Crimea became dependent on Chersonesos, and abruptly ceased to exist around 270 BCE. Stolba, the editor, believes that the "lettering of inscriptions" suggests the second half of this time span (ca. 320–270 BCE) as their likely date. A comparison to materials on papyrus confirms this dating, as Stolba describes:

> Palaeography: A lunate sigma is used throughout the text, but is executed in two different ways: as a semi-circle scratched in a single stroke (lines 2 and 5), or as a curve capped with a slanting bar added by an additional touch of the stylus (2, 3, 5). A sigma at the start of line 7 was perhaps also intended to be executed in the latter manner, but, owing to slipping of the hand, acquired a squared shape resembling a four-barred sigma. Omicrons are small, also showing two different manners of execution: a single, sometimes unclosed, loop and two, occasionally also non-joining, semi-circles. Xi (1) is without the centre upright. The use of an archaisized chi (3) in the form of an upright cross is exceptional, and, to my knowledge, unparalleled in the fourth-century inscriptions of Chersonesos. We find it, however, on several ostraka from the north-east

sector of the city, where it has been thought to confirm their fifth-century B.C. date. Our late example demonstrates once again that the use of palaeography as a sole dating tool requires great caution [Stolba 2016, 281–82].

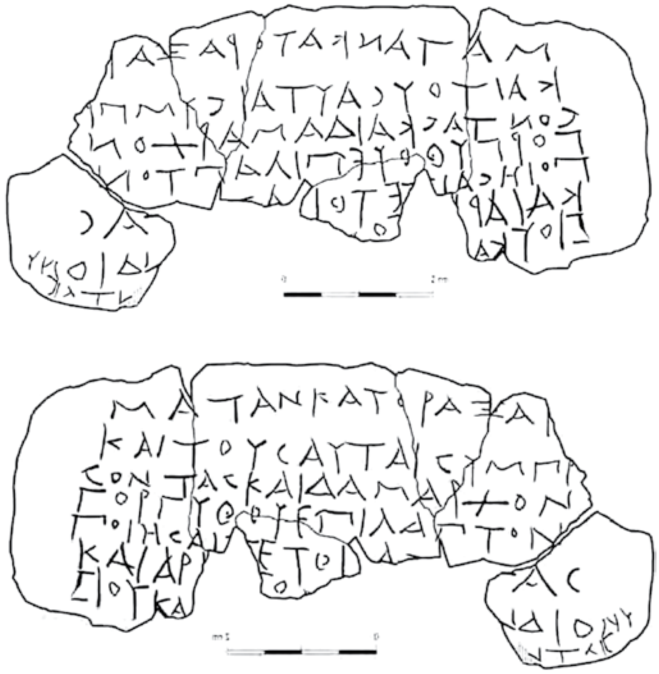


Figure 3.9. Curse tablet from West Crimea; from Stolba 2016, 282. *Top:* Actual. *Bottom:* Flipped.

Fine-tuning is difficult when dealing with an inscription in which the shapes of the letters have been purposefully deformed, but I believe that by flipping the drawing of the text over, one can safely compare this inscription with papyri from the late fourth or early third centuries (see fig. 3.7 above), considering the contrast between the wider and narrower letters (*mu* vs. *omicron*) and the shapes of *alpha* and *kappa*. Observe in the lead tablet the *pi* with a shorter right-hand vertical stroke, the epigraphic *xi* in three strokes, the turned *chi*, and dotted *theta*, which are epigraphic traits that still appear in early third-century papyri.

CONCLUSIONS

The challenges posed by the corpus of lead inscriptions range from the purely material to the purely circumstantial. Although the production of writing on lead tablets is radically different from the use of ink on a soft surface, the model underlying the executed shapes of letters was probably the same. A thorough study of the shapes of letters, the disposition of each letter on the notional lines, and their relationship to each other (either in terms of ligatures or the contrast in shape and module) can be systematically studied and helpfully compared to the examples on papyrus. The geographical distribution of the lead inscriptions presents an additional problem, though one faces similar problems with the corpus of papyri despite the fact that no one seems to question the geographical origin of the scribe when dealing with the hand. In short, geographical context can be considered but does not hinder the comparison given that some kind of scribal *koiné* existed among the Greek-speaking population in the Mediterranean basin, not to mention the mobility of scribes and artifacts. Lead tablets present many peculiarities but also share many features with other forms of textual production. Perhaps I am optimistic, but I believe that a paleography of the lead tablets (of which curse tablets are undoubtedly the most extensive corpus in terms of number, chronology, and geography) is possible, and a comparison of them with other corpora of texts, in particular the papyri and ostraca from Egypt, should prove a useful endeavor for various types of interdisciplinary research.

Epilogue: Modern Technology and Ancient Curse Tablets

Jan N. Bremmer

With this small but substantial *libellus*, Sofía Torallas Tovar and Raquel Martín Hernández initiate, as it were, a new phase in the study of ancient magic.[1] Admittedly, the modern study of magic is hardly much older than a good century. But in this period, we can clearly distinguish different stages. Around 1900, modern research starts with the collection of magical texts and their publication in corpora such as the well-known ones by Richard Wünsch (1869–1915) and Auguste Audollent (1864–1943) (Wünsch 1897, 1898, 1900, 1907; Audollent 1904),[2] many of which will be restudied and republished in a new *Corpus defixionum Atticarum*, in preparation by Jaime Curbera; the edition of the magical papyri by Karl Preisendanz (1883–1968) also still belongs to this period (Preisendanz 1928–31).[3] It is not by chance that we see these publications emerge around 1900, as that was the time of the big projects in German *Wissenschaft* driven by the great scholars of the era, such as Theodor Mommsen (1817–1903), Adolf von Harnack (1851–1930), and Ulrich Wilamowitz von Moellendorff (1848–1931) (see Rebenich 2021, 73–98, 402–7).

A second wave of interest began in the mid-1980s, when David Jordan (1942–2018) published a new survey of Greek *defixiones*,[4] and an *équipe* around Hans Dieter Betz issued a translation of the Greek magical papyri (Jordan 1985b; Betz 1986, to be read with the still-useful review by Brashear 1998). These and other contemporary editions and translations have caused a tsunami of monographs, translations, and proceedings of conferences on magic,[5] which shows no sign of abating.[6] Given the available corpora, it is unsurprising

1 For this epilogue, I draw freely on my "Preface: The Materiality of Magic" (in Boschung and Bremmer 2015, 7–19, and Bremmer 2019), with substantial additions and updates. I am most grateful to Charlotte von Schelling for her kind correction of my English.

2 For Wünsch, see Hepding 1915; Kroll 1916–18 (with bibliography). For Audollent, see Németh 2013, 15–22; https://www.persee.fr/authority/385772 (online publications accessed August 3, 2022).

3 For Preisendanz, see the brief biography by the University of Heidelberg library at https://www.ub.uni-heidelberg.de/wir/geschichte/preisendanz.html (accessed August 3, 2022), which is conspicuously silent about his Nazi past. For the Chicago project to reedit and retranslate the magical papyri, see https://papyrusmagicalhandbook.wordpress.com (accessed August 3, 2022); the project's first volume has been published (Faraone and Torallas Tovar 2022).

4 For a brief obituary of David Jordan, see http://www.cig-icg.gr/content/david-jordan-13-2-1942-–-9-9-2018-former-director-canadian-institute; for a full bibliography, see Rocca and Bevilacqua 2020, 3–21.

5 For good bibliographies, see Moreau and Turpin 2000, 4:7–159; Calvo Martínez 2001; Fabrini 2006; and Gordon and Marco Simón 2010, 1–4.

6 From the most recent studies, I single out Stratton and Kalleres 2014; Suárez de la Torre, Blanco, and Chronopoulou 2015; Frenschkowski 2016; Reif 2016; Costantini 2019b; Edmonds 2019; and Frankfurter 2019.

that most of the subsequent publications concentrated on the Greek rather than the Latin world. And indeed, the Greek world is clearly overrepresented in the best general studies of ancient magic, which appeared in the initial wake of the renewed interest (Graf 1997; Dickie 2001; see also, somewhat later, Carastro 2006 and Collins 2008). In fact, not until 2010 did a collective volume appear that concentrated exclusively on the Latin West (Gordon and Marco Simón 2010; note also Mastrocinque 2012a).

It is hardly surprising that the study of magic has also been affected by the digital revolution. A promising project is the password-protected *Thesaurus Defixionum Magdeburgensis*,[7] and there are digital corpora of the curses in Roman Britain (see Tomlin 1988, and n. 18 below) and the Levant,[8] of the magical gems,[9] of the vocabulary of the Greek magical papyri,[10] and of Coptic magical papyri and their bibliographies.[11] An extensive database of papyri with religious, ritual, magical, and divinatory texts is being developed by colleagues in Leuven, but unfortunately access is limited by the hefty subscription price.[12] It is obvious that in this respect we are still at an initial stage, but digital databases will undoubtedly change the field in the coming years, just as the *Thesaurus Linguae Graecae* has revolutionized the study of ancient Greek literature.

The studies of the past four decades have not only enlarged our knowledge of magical texts in general and of *defixiones* in particular but also enabled the study of the various aspects of magic. A number of contributions have elucidated the definition of magic and its postulated difference from religion, as well as the relevant Greek and Roman vocabulary.[13] Other contributions have concentrated on editions of texts and their categorizations, on the person of the magician, and on the social practices connected with magic.[14] It is evident, though, that in general these studies had little or no interest in the drawings and layout of the magical papyri or the actual shape and material of the curse tablets. This lack of interest can easily be demonstrated by the indices of Fritz Graf's and Matthew Dickie's books. Neither index contains the *lemmata* "book" (cf. Bremmer 2015), "*charaktêres*" (Gordon 2012; Martín Hernández 2012; Dijkstra 2015), "gem" (Gordon 2011; Dasen and Nagy 2019; Edreffy, Nagy, and Spier 2019), "*ostraka*" (Martín Hernández and Torallas Tovar 2014b), "ring" (Suárez de la Torre 2019), or "voodoo doll" (Ball 2019). "Figurines" receive

7 The Thesaurus Defixionum (TheDefix) database at the University of Hamburg (https://www.geschichte.uni-hamburg.de/arbeitsbereiche/alte-geschichte/digitalisierung/thedefix.html, accessed September 18, 2022) has replaced the earlier Thesaurus Defixionum Magdeburgensis (TheDeMa) online resource (http://www.ges.ovgu.de/Lehrst%C3%BChle+und+Fachgebiete/Ehemaliger+Lehrstuhl+f%C3%BCr+Alte+Geschichte/Forschung+und+Projekte/TheDeMa/zur+Datenbank.html).

8 For this resource, see https://papyri.uni-koeln.de/magica-levantina/index.html (registration required, accessed August 3, 2022).

9 The Campbell Bonner Magical Gems Database is located at http://cbd.mfab.hu (accessed August 3, 2022).

10 For this resource, see http://dge.cchs.csic.es/lmpg/ (accessed August 16, 2019).

11 For this resource, see http://www.coptic-magic.phil.uni-wuerzburg.de/index.php/bibliography (accessed August 3, 2022).

12 For this resource, see https://www.trismegistos.org/magic/ (accessed August 3, 2022).

13 On magic and religion, see Bremmer 2008, 347–52; Dufault 2016. On Greek vocabulary, see Bremmer 2008, 235–48; Otto 2011, 143–218, which hardly advances on earlier studies despite its length. On Latin, see Rives 2010; Costantini 2019a.

14 See the bibliographies in the recent publications listed in my footnotes.

mention by Graf but not by Dickie, who, on the other hand, pays more attention to amulets, which have now been exemplarily studied by Christopher A. Faraone (2018).

Given these omissions, it was only to be expected that the so-called "material turn" would eventually inspire classical scholars to direct their attention to the material aspects of magic—in particular, of the curse tablets and the magical papyri. And indeed, in 2012 there appeared a book studying the archaeological contexts of magical practices in Roman Egypt, Cyprus, and Spain; and in the same year a conference was organized in Cologne on the materiality of magic—a conference that cast its net even wider by encompassing the ancient world, the ancient Near East included, and by concentrating on such objects as curse tablets, figurines, grimoires, and phylacteries (Wilburn 2012; Boschung and Bremmer 2015).[15] The recent blockbuster on ancient magic has followed this trend, containing a substantial section on the materials of ancient magic (Frankfurter 2019, 279–602), and the new study of iconography of magic is part of the same development (Martín Hernández 2022). It is in the context of this material turn, which I see as the third phase in the study of ancient magic, that I would locate the publication of the present collection of studies on the materiality of the Greek and Roman curse tablets.[16]

Curse tablets, often engraved on lead, become visible first in Sicily in the late sixth century BCE, where, under influence from the Carthaginians, such tablets probably originated in Selinous, with its very mixed population (Willi 2008, 317–21; Bremmer 2010, 17–18 = 2019 reprint, 129; Campedelli 2019). From there they spread in two directions. To begin, they went east, to mainland Greece, where they came to Athens in the fifth century. In Attica, the lead of the Laurion silver mines was widely available and indeed also widely used for curse tablets, as modern isotope analysis shows (Vogl et al. 2018). But the curse tablets did not stop there and can be found even in Olbia (Belousov 2018). Rather later, in the second half of the fourth century BCE, they went northward and entered the Oscan world (Murano 2013; McDonald 2015, 133–66), first in the coastal cities, with their mixed Greek–Oscan populations. From there, they started to appear in the Latin world in the second century BCE, probably via Pompeii, before spreading farther northward with the expansion of the Roman empire,[17] where they have been found in Gaul (Gordon and Marco Simón 2010, 2 n. 8), but also in Britain, notably in Bath (Tomlin 1988),[18] Spain (Faraone 2018), Switzerland (Frei-Stolba et al. 2015), ancient Germany (see most recently Blänsdorf 2012 [translated into English by Veale 2017], 2019, 2020), and Pannonia (see most recently Barta 2009, 2012, 2015).

This *libellus* demonstrates that new technological approaches can greatly help in better preserving and reading the discovered and excavated *defixiones*. Loretta Rosetti's contribution shows how complicated these procedures can be. Fortunately, many curse tablets were discovered in a waterlogged environment so that the writing on them has been

15 It is noteworthy that another book appeared in 2015 with the same title as that by Boschung and Bremmer—namely, Houlbrook and Armitage 2015, thus confirming the trend of interest in the material side of magic.

16 For full surveys, see Riess 2012, 164–234, to be added to the references in Eidinow 2019.

17 For their geographical and chronological spread, see Urbanovà 2014.

18 For other studies of *defixiones* by Tomlin, see his bibliography in Sánchez Natalías 2019, 29–35; Sánchez Natalías has recently published a sylloge of the *defixiones* from the Roman West in two volumes (Sánchez Natalías 2022).

preserved (see Eidinow 2019, 366; Stroszeck 2019b); in fact, dozens of new curse tablets have recently been discovered in a well in the Athenian Kerameikos (Stroszeck 2019a). Depending on the environment,[19] the tablets' states of corrosion can vary enormously, so opening the artifacts has to be done very carefully—all the more so, obviously, as tablets are more vulnerable at the junctures of the folded areas. Introducing a protocol in these cases, as Rosetti describes, is a very sensible approach. But this task seems to present only the beginning of other problems, as proper storage requires further attention and the quest for space free from organic acid vapors.

Imaging constitutes one way to improve our reading of the often very difficult-to-decipher curse tablets. Raquel Martín and Arie Shaus show that binarization algorithms can help improve the drawings' visibility. This fairly new method seems to have become increasingly popular in historical research, for it manages to lessen the effects of physical noise, such as specks and stains (Martins de Almeida et al. 2018; Sulaiman, Khairuddin, and Nasrudin 2019), making this approach quite promising for further research in papyri, parchments, and ostraca.

Only when we have taken all the necessary measures to preserve, store, and decipher the various texts can we begin the dating process. As Sofía Torallas Tovar argues, a systematic analysis of the handwriting on the lead tablets compared with that on the papyri and ostraca can help date the curse tablets with greater certainty than is possible when only the finds' stratigraphy or prosopography are considered.

All in all, these fine contributions suggest that a new future awaits the study of the *defixiones*, a future in which not only their meanings and mentalities but also their materialities will play an important role. In this respect, the present *libellus* illustrates the exciting technological possibilities of the digital age, which surely will surprise us with many new discoveries in the years to come.

19 For the findings in sanctuaries, see Graf (2019), who also convincingly questions the distinction between *defixiones* and prayers for justice, as proposed by Henk Versnel, most recently in Versnel 2009. For new findings in a grave, see Lamont 2021.

Bibliography

Alexopoulou, Athina A., Agathi-Anthoula Kaminaria, Athanasios Panagopoulos, and Egert Pöhlmann

2013 "Multispectral Documentation and Image Processing Analysis of the Papyrus of Tomb II at Daphne, Greece." *Journal of Archaeological Science* 40, no. 2: 1242–49.

Audollent, Auguste

1904 *Defixionum tabellae quotquot innotuerunt: tam in Graecis Orientis quam in totius Occidentis partibus praeter Atticas in Corpore inscriptionum atticarum editas.* Paris: Fontemoing. Reprint, Frankfurt: Minerva, 1967.

Ball, Amanda C.

2019 "A New Typology of Magic Dolls." PhD diss., University of North Carolina at Chapel Hill. Accessed August 3, 2022. https://cdr.lib.unc.edu/concern/dissertations/c247dx31j.

Barta, Andrea

2009 "The Language of Latin Curse Tablets from Pannonia: A New Curse Tablet from Aquincum." *Acta Antiqua Academiae Scientiarum Hungaricae* 49: 23–29.

2012 "*Milites magistratusque*: A New Curse Tablet from Savaria." *Acta Classica Universitatis Scientiarum Debreceniensis* 48: 167–73.

2015 "*Ito Pater, Eracura* and the Messenger: A Preliminary Report on a New Curse Tablet from Aquincum." *Acta Classica Universitatis Scientiarum Debreceniensis* 51: 101–13.

Bay, Stephen, Roger Thomas Macfarlane, Thomas A. Wayment, and Gregory Bearman

2010 "Multi-spectral Imaging vs. Monospectral Infrared Imaging." *Zeitschrift für Papyrologie und Epigraphik* 173: 211–17.

Bearman, Gregory, and William A. Christens-Barry

2009 "Spectral Imaging of Ostraca." *PalArch's Journal of Archaeology of Egypt/Egyptology* 6, no. 7: 1–20.

Belousov, Alexey V.

2018 "To Bind Your Enemies: Some Specific Features of Olbian Defixiones in the General Context of Greek Magic." In *Violence in Prehistory and Antiquity / Die Gewalt in der Vorgeschichte und im Altertum*, edited by Eduard Nemeth, 153–77. Kaiserslautern/Mehlingen: Parthenon.

Ben Ami, Doron, Yana Tchekhanovets, and Robert Walter Daniel

2013 "A Juridical Curse from a Roman Mansion in the City of David." *Zeitschrift für Papyrologie und Epigraphik* 186: 227–36.

Betz, Hans-Dieter, ed.

1986 *The Greek Magical Papyri in Translation.* Chicago: University of Chicago Press. Reprint, 1992.

Bevilacqua, Gabriela, Olimpia Colacicchi, and Maria Rita Giuliani

2012 "Tracce di ousia in una defixio dalla Via Ostiense: Un lavoro multidisciplinare." In *Contesti magici / Contextos mágicos*, edited by Marina Piranomonte and Francisco Marco Simón, 229–36. Rome: De Luca.

Blänsdorf, Jürgen

2010 "The Text from the Fons Annae Perennae." In *Magical Practice in the Latin West: Papers from the International Conference Held at the University of Zaragoza, 30 Sept.–1 Oct. 2005*, edited by Richard Gordon and Francisco Marco Simón, 215–44. Religions in the Graeco-Roman World 168. Leiden: Brill.

2012 *Die Defixionum tabellae des Mainzer Isis- und Mater-Magna-Heiligtums, Mainz*. See S. Veale, 2017.

2019 "Die Verfluchungstäfelchen aus dem Kohortenkastell *Abusina* / Eining: *Defixionum tabellae Abusinenses* (DT Abusina)." *Bayerische Vorgeschichtsblätter* 84: 229–42.

2020 "Pathetic Lament on a Defixion Tablet from Abusina (near Eining, Danube)." In *Gift of a Book: Studi in memoria di David Jordan,* edited by Giovanna Rocca and Gabriella Bevilacqua, 97–102. Alessandria: Edizioni dell'Orso.

Boschung, Dietrich, and Jan N. Bremmer, eds.

2015 *The Materiality of Magic*. Paderborn: Fink.

Brashear, William M.

1998 "'*Botokudenphilologie*' Vindicated." *International Journal of the Classical Tradition* 5, no. 1: 66–79.

Bremmer, Jan N.

2008 *Greek Religion and Culture, the Bible and the Ancient Near East*. Leiden: Brill.

2010 "*Manteis*, Magic, Mysteries and Mythography: Messy Margins of *Polis* Religion?" *Kernos* 23: 13–35. Reprinted in J. N. Bremmer, *The World of Greek Religion and Mythology: Collected Essays II*, 125–46. Tübingen: Mohr Siebeck, 2019.

2015 "From Books with Magic to Magical Books in Ancient Greece and Rome." In *The Materiality of Magic*, edited by Dietrich Boschung and Jan N. Bremmer, 241–69. Paderborn: Fink.

2019 "Magic, Magician: II. Greco-Roman Antiquity." In *Encyclopedia of the Bible and Its Reception*, edited by C. M. Furey, M. Constance, S. L. McKenzie, T. C. Römer, J. Schröter, B. D. Walfish, and E. Ziolkowski, 17:437–40. Berlin: De Gruyter.

Brodersen, Kai

2001 "Briefe in die Unterwelt: Religiöse Kommunikation auf griechischen Fluchtafeln." In *Gebet und Fluch, Zeichen und Traum: Aspekte religiöser Kommunikation in der Antike*, 57–68. Münster: Lit Verlag Hopf.

Bülow-Jacobsen, Adam

2008 "Infra-red Photography of Ostraca and Papyri." *Zeitschrift für Papyrologie und Epigraphik* 165: 175–85.

2020 "Photography of Papyri and Ostraca." In *Using Ostraca in the Ancient World: New Discoveries and Methodologies*, edited by Clementina Caputo and Julia Lougovaya, 59–86. Berlin: De Gruyter.

Calvo Martínez, José Luis

2001 "Cien años de investigación sobre la magia antigua." *MHNH: Revista Internacional de Investigación sobre Magia y Astrología Antiguas* 1: 7–60.

Campedelli, Camilla

2019 "Ancient Greek Magical Practices in Sicily and Southern Italy: A New Research Project." In *Litterae Magicae: Studies in Honour of Roger S. O. Tomlin*, edited by Celia Sánchez Natalías, 151–58. MHNH Supplements 2. Zaragoza: Pórtico.

Carastro, Marcello

2006 *La cité des mages: Penser la magie en Grèce ancienne*. Grenoble: J. Millon.

Cavallo, Guglielmo

1967 *Ricerche sulla maiuscula biblica*. Studi e Testi di Papirologia 2. Florence: Le Monnier.

Cavallo, Guglielmo, and Herwin Maehler

1987 *Greek Bookhands of the Early Byzantine Period*. Bulletin of the Institute of Classical Studies Supplements 47. London: Institute of Classical Studies.

2008 *Hellenistic Bookhands*. Berlin: De Gruyter.

Ceccarelli, Paola

2013 *Ancient Greek Letter Writing: A Cultural History* (600 BC–150 BC). Oxford: Oxford University Press.

Cerquiglini, Bernard

1989 *Éloge de la variante: Histoire critique de la philologie*. Paris: Seuil.

Chabries, Douglas M., Steven W. Booras, and Gregory H. Bearman

2003 "Imaging the Past: Recent Applications of Multispectral Imaging Technology to Deciphering Manuscripts." *Antiquity* 77, no. 296: 359–72.

Collins, Derek

2008 *Magic in the Ancient Greek World*. Oxford: Blackwell.

Costantini, Leonardo

2019a "Exploring the Semantic Complexity of the *voces mediae*: *Magus*, *magicus*, and *magia*." In *Lemmata Linguistica Latina*, vol. 1, *Words and Sounds*, edited by Nigel Holmes, Marijke Ottink, Josine Schrickx, and Maria Selig, 21–35. Berlin: De Gruyter.

2019b *Magic in Apuleius' Apologia: Understanding the Carges and the Forensic Strategies in Apuleius' Speech*. Berlin: De Gruyter.

Crisci, Edoardo

1996 *Scrivere greco fuori d'Egitto: Ricerche sui manoscritti greco-orientali di origine non egiziana dal IV secolo a.C. all'VII d.C.* Florence: Edizioni Gonnelli.

Curbera, Jaime B.

2015 "From the Magician's Workshop: Notes on the Materiality of Greek Curse Tablets." In *The Materiality of Magic*, edited by Dietrich Boschung and Jan N. Bremmer, 97–122. Paderborn: Fink.

Curbera, Jaime B., and David R. Jordan

1996 "A Curse Tablet from Pannonia Superior." *Tyche* 11: 45–50, with pl. 3.

1998 "Curse Tablets from Mytilene." *Phoenix* 52: 31–41.

Curbera, Jaime B., Marta Sierra Delage, and Isabel Velázquez

1999 "A Bilingual Curse Tablet from Barchín del Hoyo (Cuenca, Spain)." *Zeitschrift für Papyrologie und Epigraphik* 125: 279–83.

Dakaris, Sotiris, Julia Vokotopoulou, and Anasthasios Phoibos Christidis, eds.

2013 *Τα Χρηστήρια ελάσματα της Δοδώνης*. 2 vols. Archaeological Society at Athens Library 285–86. Athens: Archaeological Society at Athens.

Dasen, Véronique, and Árpád M. Nagy

2019 "Gems." In *Guide to the Study of Ancient Magic*, edited by David Frankfurter, 406–45. Leiden: Brill.

Degrigny, Christian

1997 *Étude de la dégradation des objets en plomb dans les collections publiques et détermination des moyens de les stabiliser et de les conserver à long terme*. Nantes: Arc'Antique.

Dickie, Matthew W.

2001 *Magic and Magicians in the Greco-Roman World*. London: Routledge.

Dijkstra, Jitse

2015 "The Interplay between Image and Text on Greek Amulets Containing Christian Elements from Late Antique Egypt." In *The Materiality of Magic*, edited by Dietrich Boschung and Jan N. Bremmer, 271–92. Padeborn: Fink.

Dufault, Olivier

2016 "Problems Related to the Use of the Category of Magic in the Writing of Greek and Roman History." *Distant Worlds Journal* 1: 173–85.

Earl, Graeme P., Philip J. Basford, Alexander S. Bischoff, Alan Bowman, Charles Crowther, Jacob Dahl, Michael Hodgson, Eleni Kotoula, Kirk Martinez, Hembo Pagi, and Kathryn E. Piquette

2011 "Reflectance Transformation Imaging Systems for Ancient Documentary Artefacts." In *Electronic Visualisation and the Arts*, edited by Jonathan P. Bowen, Stuart Dunn, and Kia Ng, 147–54. Accessed August 3, 2022. https://eprints.soton.ac.uk/204531/.

Edmonds, Radcliffe G., III

2019 *Drawing Down the Moon: Magic in the Ancient Greco-Roman World*. Princeton: Princeton University Press.

Edreffy, Kata, Árpad M. Nagy, and Jeffrey Spier, eds.

2019 *Magical Gems in Their Contexts: Proceedings of the International Workshop Held in the Museum of Fine Arts, Budapest, 16–18 February 2012*. Rome: L'Erma di Bretschneider.

Eidinow, Esther

2007 *Oracles, Curses, and Risk among the Ancient Greeks*. Oxford: Oxford University Press.

2019 "Binding Spells on Tablets and Papyri." In *Guide to the Study of Ancient Magic*, edited by David Frankfurter, 351–87. Leiden: Brill.

Eidinow, Esther, and Claire Taylor

2010 "Lead-Letter Days: Writing, Communication and Crisis in the Ancient Greek World." *Classical Quarterly* 60, no. 1: 30–62.

Fabrini, Pierangiolo

2006 *Magica antiqua: Indice e guida a una bibliografía informatica*. Pisa: Edizioni ETS.

Faigenbaum, Shira, Barak Sober, Israel Finkelstein, Murray Moinester, Eli Piasetzky, Arie Shaus, and Michael Cordonsky

2014 "Multispectral Imaging of Two Hieratic Inscriptions from Qubur el-Walaydah." *Ägypten und Levante* 24: 349–53.

Faigenbaum, Shira, Barak Sober, Arie Shaus, Murray Moinester, Eli Piasetzky, Gregory Bearman, Michael Cordonsky, and Israel Finkelstein

2012 "Multispectral Images of Ostraca: Acquisition and Analysis." *Journal of Archaeological Science* 39, no. 12: 3581–90.

Faigenbaum-Golovin, Shira, Anat Mendel-Geberovich, Arie Shaus, Barak Sober, Michael Cordonsky, David Levin, Murray Moinester, Benjamin Sass, Eli Turkel, Eli Piasetzky, and Israel Finkelstein

2017 "Multispectral Imaging Reveals Biblical-Period Inscription Unnoticed for Half a Century." *PLOS One* 12, no. 6: e0178400.

Faigenbaum-Golovin, Shira, Arie Shaus, Barak Sober, David Levin, Nadav Na'aman, Benjamin Sass, Eli Turkel, Eli Piasetzky, and Israel Finkelstein

2016 "Algorithmic Handwriting Analysis of Judah's Military Correspondence Sheds Light on Composition of Biblical Texts." *Proceedings of the National Academy of Sciences* 113, no. 17: 4664–69.

Faigenbaum-Golovin, Shira, Arie Shaus, Barak Sober, Eli Turkel, Eli Piasetzky, and Israel Finkelstein

2020 "Algorithmic Handwriting Analysis of the Samaria Inscriptions Illuminates Bureaucratic Apparatus in Biblical Israel." *PLOS One* 15, no. 1: e0227452.

Faraone, Christopher A.

1991 "The Agonistic Context of Early Greek Binding Spells." In *Magika Hiera: Ancient Greek Magic and Religion*, edited by Christopher A. Faraone and Dirk Obbink, 3–32. Oxford: Oxford University Press.

2018 *The Transformation of Greek Amulets in Roman Imperial Times*. Philadelphia: University of Pennsylvania Press.

Faraone, Christopher A., and Joseph L. Rife

2007 "A Greek Curse against a Thief from the Koutsongila Cemetery at Roman Kenchreai." *Zeitschrift für Papyrologie und Epigraphik* 160: 141–57.

Faraone, Christopher A., and Sofía Torallas Tovar, eds.

2022 *Greek and Egyptian Magical Formularies: Text and Translation, Vol. 1*. Berkeley: California Classical Studies.

Frankfurter, David, ed.

2019 *Guide to the Study of Ancient Magic*. Leiden: Brill.

Frei-Stolba, Regula, Pirmin Koch, Hans Lieb, and Regula Ackermann

2015 "Eine neue Fluchtafel aus Kempraten (Kt. St. Gallen / CH)." In *Lesen und Schreiben in den römischen Provinzen*, edited by Markus Scholz and Marietta Horster, 113–22. Mainz: Verlag des Römisch-Germanischen Zentralmuseums.

Frenschkowski, Marco

2016 *Magie im antiken Christentum*. Stuttgart: Hiersemann.

Gager, John G.

1992 *Curse Tablets and Binding Spells from the Ancient World*. Oxford: Oxford University Press.

Goedecker-Ciolek, Roswitha, Carl Pause, and Markus Scholz

2016 "Verschwundene Verwünschungen: Zwei römische Fluchtafeln aus Neuss." In *Novaesium 2016: Neusser Jahrbuch für Kunst, Kultur und Geschichte*, 337–42. Neuss: Neusser Stadtarchiv.

Gordon, Richard

2011 "Archaeologies of Magical Gems." In *Gems of Heaven*, edited by Chris Entwistle and Noel Adams, 39–49. London: British Museum.

2012 "Memory and Authority in the Magical Papyri." In *Historical and Religious Memory in the Ancient World*, edited by Beate Dignas and R. R. R. Smith, 145–80. Oxford: Oxford University Press.

2014 "Charakteres between Antiquity and Renaissance: Transmission and Re-invention." In *Les savoirs magiques et leur transmission de l'Antiquité à la Renaissance: Magie, savoirs et religion dans le monde byzantin*, edited by Véronique Dasen and Jean-Michel Spieser, 253–300. Micrologus' Library 60. Florence: Sismel and Galluzzo.

Gordon, Richard, and Francisco Marco Simón, eds.

2010 *Magical Practice in the Latin West: Papers from the International Conference Held at the University of Zaragoza, 30 Sept.–1st Oct. 2005.* Religions in the Graeco-Roman World 168. Leiden: Brill.

Graf, Fritz

1996 *Gottesnähe und Schadenzauber*. Munich: C. H. Beck.

1997 *Magic in the Ancient World.* Cambridge, MA: Harvard University Press.

2005 "Fluch und Verwünschung." *Thesaurus Cultus et Rituum Antiquorum* 3: 247–70.

2019 "Lead Invocations in Greek Sanctuaries." In *Griechische Heiligtümer als Handlungsorte: Zur Multifunktionalität supralokaler Heiligtümer von der frühen Archaik bis in die römische Kaiserzeit*, edited by Klaus Freitag and Matthias Haake, 75–86. Stuttgart: Franz Steiner.

Grzywacz, Cecily M.

2006 *Monitoring for Gaseous Pollutants in Museum Environments.* Tools for Conservation. Los Angeles: Getty Conservation Institute.

Harrauer, Hermann

2010 *Handbuch der griechischen Paläographie.* 2 vols. Stuttgart: Anton Hiersemann.

Hepding, Hugo

1915 "Richard Wünsch." *Hessische Blätter für Volkskunde* 14: 136–43.

Hoffiller, V. B. Saria

1938 *Antike Inschriften aus Jugoslawien.* Vol. 1, *Noricum und Pannonia Superior.* Zagreb: Pelikan.

Houlbrook, Ceri, and Natalie Armitage, eds.

2015 *The Materiality of Magic: An Artifactual Investigation into Ritual Practices and Popular Beliefs.* Oxford: Oxbow.

Janko, Richard

2016 "Parmenides in the Derveni Papyrus: New Images for a New Edition." *Zeitschrift für Papyrologie und Epigraphik* 200: 3–23.

Jordan, David R.

1985a "Defixiones from a Well Near the Southwest Corner of the Athenian Agora." *Hesperia* 54, no. 3: 205–55.

1985b "A Survey of Greek Defixiones Not Included in the Special Corpora." *Greek, Roman and Byzantine Studies* 26, no. 2: 151–97.

2000 "New Curse Tablets (1985–2000)." *Greek, Roman and Byzantine Studies* 41: 5–46.

Jordan, David R., and Jaime B. Curbera

2008 "A Lead Curse Tablet in the National Archaeological Museum, Athens." *Zeitschrift für Papyrologie und Epigraphik* 166: 135–50.

Jordan, David R., and Susan I. Rotroff

1999 "A Curse in a Chytridion: A Contribution to the Study of Athenian Pyres." *Hesperia* 68, no. 2: 147–54.

Kenyon, Frederic George

1893 *Greek Papyri in the British Museum: Catalogue with Texts.* Vol. 1. London. Oxford University Press.

Kern, Otto

1913 *Inscriptiones graecae.* Bonn: A. Marcus and E. Weber.

Kirchner, Johannes

1935 *Imagines inscriptionum atticarum: Ein Bilderatlas epigraphischer Denkmäler Attikas.* Berlin: Gebr. Mann.

Kiyanrad, Sarah, Julia Lougovaya, Antonia Sarri, and Kai Trampedach

2015 "Metall." in *Materiale Textkulturen: Konzepte–Materialien–Praktiken*, edited by Thomas Meier, Michael R. Ott, and Rebeca Sauer, 293–306. Materiale Textkulturen 1. Berlin: De Gruyter.

Kleve, Knut, and Gianluca Del Mastro

2000 "Il PHerc. 1533: Zenone Sidonio *A Cratero*." *Cronache Ercolanesi* 30: 149–56.

Kotoula, Eleni, and Graeme Earl

2015 "Digital Research Strategies for Ancient Papyri: A Case Study on Mounted Fragments of the Derveni Papyrus." In *CAA2014—21st Century Archaeology: Concepts, Methods and Tools. Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology*, edited by François Giligny, François Djindjian, Lauren Costa, Paola Moscati, and Sandrine Robert, 145–54. Oxford: Archaeopress.

Kroll, Wilhelm

1916–18 "Richard Wünsch." *Biographisches Jahrbuch für die Altertumswissenschaft* 38: 1–11.

Kropp, Amina

2008 *Defixiones: Ein aktuelles Corpus lateinischer Fluchtafeln.* Speyer: Kartoffeldruck-Verlag.

Lamont, Jessica

2021 "Crafting Curses in Classical Athens: A New Cache of Hexametric *Katadesmoi.*" *Classical Antiquity* 40: 76–117.

Macfarlane, Roger T.

2010 "P.Herc. 817 from Facsimiles to MSI: A Case for Practical Verification." In *Proceedings of the Twenty-Fifth International Congress of Papyrology, Ann Arbor, July 29–August 4, 2007*, edited by Traianos Gagos, 455–62. American Studies in Papyrology. Ann Arbor: Scholarly Publishing Office, University of Michigan Library.

Martín Hernández, Raquel

2012 "Reading Magical Drawings in the Greek Magical Papyri." In *Actes du 26e Congrès international de papyrologie Genève, 16–21 août 2010*, edited by Paul Schubert, 491–98. Geneva: Droz.

Martín Hernández, Raquel, ed.

2022 *The Iconography of Magic: Images of Power and the Power of Images in Ancient and Late Antique Magic*. Leuven: Peeters.

Martín Hernández, Raquel, and Sofía Torallas Tovar

2014a "A Magical Spell on an Ostracon at the Abbey of Montserrat." *Zeitschrift für Papyrologie und Epigraphik* 189: 175–84.

2014b "The Use of the Ostracon in Magical Practice in Late Antique Egypt: Magical Handbooks vs. Material Evidence." *Studi e Materiali di Storia delle Religioni* 80: 780–800.

Martins de Almeida, Marcos, Rafael Dueire Lins, Rodrigo Bernardino, Darlisson Jesus, and Bruno Lima

2018 "A New Binarization Algorithm for Historical Documents." *Journal of Imaging* 4, no. 27. Accessed August 3, 2022. https://www.mdpi.com/2313-433X/4/2/27/htm.

Mastrocinque, Attilio

2012a "A Cartography of Defixiones in the Western Roman Empire." In *Contesti magici / Contextos mágicos*, edited by Marina Piranomonte and Francisco Marco Simón, 123–33. Rome: De Luca.

2012b "Les *charaktêres*, formes des dieux d'après les papyri et les gemmes magiques." In *La raison des signes: Présages, rites, destins dans les sociétés de la méditerranée ancienne*, edited by Stella Georgoudi, Renée Koch Piettre, and Francis Schmidt, 537–46. Religions in the Graeco-Roman World 174. Leiden: Brill.

McDonald, Katherine

2015 *Oscan in Southern Italy and Sicily*. Cambridge: Cambridge University Press.

Mélard, Nicolas

2016 "Imaging Techniques for Microanalysis of Paleolithic Mobiliary Art." *Journal of Archeological Science: Reports* 10: 903–9.

Mendel-Geberovich, Anat, Arie Shaus, Shira Faigenbaum-Golovin, Barak Sober, Michael Cordonsky, Eli Piasetzky, and Israel Finkelstein

2017 "A Brand New Old Inscription: Arad Ostracon 16 Rediscovered via Multispectral Imaging." *Bulletin of the American Schools of Oriental Research* 378: 113–25.

Moreau, Alain, and Jean-Claude Turpin, with the collaboration of Pascale Brillet

2000 *La Magie: Actes du colloque international de Montpellier 25–27 mars 1999*. Vol. 1, *Du monde babylonien au monde hellénistique*. Vol. 2, *La magie dans l'antiquité grecque tardive: Les mythes*. Vol. 3, *Du monde latin au monde contemporain*. Vol. 4, *Bibliographie générale*. Montpellier: Université Paul Valéry.

Murano, Francesca

2013 *Le tabellae defixionum osche: Ricerche sulle lingue di frammentaria attestazione*. Rome: Fabrizio Serra.

Németh, György

2013 *Supplementum Audollentianum*. Hungarian Polis Studies 20. Budapest: University of Debrecen, Department of Ancient History.

Niblack, Wayne

1986 *An Introduction to Digital Image Processing*. New Jersey: Prentice-Hall.

Nongbri, Brent

2018 *God's Library: The Archaeology of the Earliest Christian Manuscripts.* New Haven: Yale University Press.

Ogden, Daniel

1999 "Binding Spells: Curse Tablets and Voodoo Dolls in the Greek and Roman Worlds." In *Witchcraft and Magic in Europe: Ancient Greece and Rome*, edited by Bengt Ankarloo and Stuart Clark, 1–90. Philadelphia: University of Pennsylvania Press.

Orsini, Pasquale

2018 *Studies on Greek and Coptic Majuscule Scripts and Books*. Berlin: De Gruyter.

Otsu, Nobuyuki

1979 "A Threshold Selection Method from Gray-Level Histograms." *IEEE Transactions on Systems, Man, and Cybernetics* 9, no. 1: 62–66.

Otto, Bernd-Christian

2011 *Magie: Rezeptions- und diskursgeschichtliche Analysen von der Antike bis zur Neuzeit.* Religionsgeschichtliche Versuche und Vorarbeiten 57. Berlin: De Gruyter.

Parker, Adam, and Stuart McKie

2018 *Material Approaches to Roman Magic: Occult Objects and Supernatural Substances.* Oxford: Oxbow.

Payne, Annick

2015 *Schrift und Schriftlichkeit: Die anatolische Hieroglyphenschrift.* Wiesbaden: Harrassowitz.

Piranomonte, Marina

2005 "La fontana sacra di Anna Perenna a Piazza Euclide: Tra religione e magia." *MHNH: Revista Internacional de Investigación sobre Magia y Astrología Antiguas* 5: 87–104.

2010 "Religion and Magic at Rome: The Fountain of Anna Perenna." In *Magical Practice in the Latin West: Papers from the International Conference Held at the University of Zaragoza, 30 Sept.–1 Oct. 2005*, edited by Richard Gordon and Francisco Marco Simón, 191–213. Religions in the Graeco-Roman World 168. Leiden: Brill.

Piranomonte, Marina, and Francisco Marco Simón, eds.

2012 *Contesti magici / Contextos mágicos.* Rome: De Luca.

Posner, Ernst

1974 "The Athenian Cavalry Archives of the Fourth and Third Centuries B.C." *American Archivist* 37, no. 4: 579–82.

Preisendanz, Karl

1928–31 *Papyri graecae magicae: Die griechischen Zauberpapyri.* 2 vols. Leipzig: Teubner. Revised edition by A. Henrichs, Stuttgart: Teubner, 1973–74.

Rapinesi, Ida Anna, and Jarmila Polakova

2012 "La conservazione dei materiali magici del santuario di Anna Perenna: Il restauro." In *Contesti magici / Contextos mágicos*, edited by Marina Piranomonte and Francisco Marco Simón, 175–82. Rome: De Luca.

Rebenich, Stefan

2021 *Die Deutschen und ihre Antike.* Stuttgart: Klett Cotta.

Reif, Matthias

2016 *De arte magorum: Erklärung und Deutung ausgewählter Hexenszenen bei Theokrit, Vergil, Horaz, Ovid, Seneca und Lucan unter Berücksichtigung des Ritualaufbaus und der Relation zu den Zauberpapyri.* Göttingen: Vandenhoeck & Ruprecht.

Riess, Werner

2012 *Performing Interpersonal Violence: Court, Curse, and Comedy in Fourth-Century* BCE *Athens.* Berlin: De Gruyter.

Rives, James B.

2010 "*Magus* and Its Cognates in Classical Latin." In *Magical Practice in the Latin West: Papers from the International Conference Held at the University of Zaragoza, 30 Sept.–1 Oct. 2005*, edited by Richard Gordon and Francisco Marco Simón, 53–77. Religions in the Graeco-Roman World 168. Leiden: Brill.

Roberts, Colin H.

1956 *Greek Literary Hands: 350* BC–AD *400.* Oxford: Clarendon Press.

Rocca, Giovanna, and Gabriella Bevilacqua, eds.

2020 *Gift of a Book: Studi in memoria di David Jordan.* Alessandria: Edizioni dell'Orso.

Rothacker, Leonard, Denis Fisseler, Gerfrid Müller, Frank Weichert, and Gerfrid Fink

2015 "Retrieving Cuneiform Structures in a Segmentation-Free Word Spotting Framework." In *Proceedings of the 3rd International Workshop on Historical Document Imaging and Processing*, edited by Bertrand Coüasnon, Volker Märgner, Volkmar Frinken, and Bill Barrett, 129–36. New York: Association for Computing Machinery.

Sánchez Natalías, Celia

2022 *Sylloge of Defixiones from the Roman West: A Comprehensive Collection of Curse Tablets from the Fourth Century* BCE *to the Fifth Century* CE. 2 vols. Oxford: BAR International Series.

Sánchez Natalías, Celia, ed.

2019 *Litterae Magicae: Studies in Honour of Roger S. O. Tomlin.* MHNH Supplements 2. Zaragoza: Pórtico.

Sarri, Anna

2017 *Material Aspects of Letter Writing in the Graeco-Roman World.* Berlin: De Gruyter.

Sauvola, Jaako Jari, and Matti Pietikainen

2000 "Adaptive Document Image Binarization." *Pattern Recognition* 33, no. 2: 225–36.

Seider, Richard

1967–70 *Paläographie der griechischen Papyri.* Stuttgart: Hiersemann.

Shaus, Arie, Israel Finkelstein, and Eli Piasetzky

2010 "Bypassing the Eye of the Beholder: Automated Ostraca Facsimile Evaluation." *Maarav* 17, no. 1: 7–20.

Shaus, Arie, Yana Gerber, Shira Faigenbaum-Golovin, Barak Sober, Eli Piasetzky, and Israel Finkelstein

2020 "Forensic Document Examination and Algorithmic Handwriting Analysis of Judahite Biblical Period Inscriptions Reveal Significant Literacy Level." *PLOS One* 15, no. 9: e0237962.

Shaus, Arie, Barak Sober, Shira Faigenbaum-Golovin, Anat Mendel-Geberovich, Eli Piasetzky, and Eli Turkel

2016 "Facsimile Creation: Review of Algorithmic Approaches." In *Alphabets, Texts and Artefacts in the Ancient Near East: Studies Presented to Benjamin Sass*, edited by Israel Finkelstein, Christian Robin, and Thomas Römer, 474–88. Paris: Van Dieren.

Shaus, Arie, Barak Sober, Eli Turkel, and Eli Piasetzky

2013 "Improving Binarization via Sparse Methods." In *Recent Progress in Graphonomics: Learn from the Past; Proceedings of the 16th International Graphonomics Society Conference (IGS 2013),* edited by Masaki Nakagawa, Marcus Liwicki, and Bilan Zhu, 163–66. Tokyo: Tokyo University of Agriculture and Technology Press.

Shaus, Arie, Barak Sober, Omer Tzang, Zvi Ioffe, Ori Cheshnovsky, Israel Finkelstein, and Eli Piasetzky

2019 "Raman Binary Mapping of Iron Age Ostracon in Unknown Material Composition and High Fluorescence Setting—a Proof of Concept." *Archaeometry* 61, no. 2: 459–69.

Shaus, Arie, Eli Turkel, and Eli Piasetzky

2012 "Binarization of First Temple Period Inscriptions—Performance of Existing Algorithms and a New Registration Based Scheme." In *Proceedings of the 13th International Conference on Frontiers in Handwriting Recognition (ICFHR 2012)*, 645–50. Los Alamitos, CA: IEEE Computer Society.

Sober, Barak, Shira Faigenbaum-Golovin, Itzhaq Beit-Arieh, Israel Finkelstein, Murray Moinester, Eli Piasetzky, and Arie Shaus

2014 "Multispectral Imaging as a Tool for Enhancing the Reading of Ostraca." *Palestine Exploration Quarterly* 146, no. 3: 185–97.

Sober, Barak, and David Levin

2017 "Computer Aided Restoration of Handwritten Character Strokes." *Computer-Aided Design* 89: 12–24.

Stolba, Vladimir F.

2016 "Two Hellenistic Defixiones from West Crimea." *Greek, Roman, and Byzantine Studies* 56: 263–92.

Stratton, Kimberly B., and Dayna S. Kalleres

2014 *Daughters of Hecate: Women and Magic in the Ancient World.* Oxford: Oxford University Press.

Stroszeck, Jutta

2019a "Athen, Griechenland. Kerameikos. Archäologischer Kontext von Fluchtafeln: Brunnen B 34." *E-Forschungsberichte des DAI* 2019, no. 2: 97–102.

2019b "Unterweltsvorstellungen und die Fundorte von Fluchtafeln im Kerameikos." In *Griechische Nekropolen: Neue Forschungen und Funde,* edited by Heidi Frielinghaus, Jutta Stroszeck, and Panos Valavanis, 337–76. Möhnesee: Bibliopolis.

Suárez de la Torre, Emilio

2019 "The Use of Rings in the Greek Magical Papyri." In *Litterae Magicae: Studies in Honour of Roger S. O. Tomlin*, edited by Celia Sánchez Natalías, 211–32. MHNH Supplements 2. Zaragoza: Pórtico.

Suárez de la Torre, Emilio, Miriam Blanco, and Eleni Chronopoulou, eds.

2015 *Los papiros mágicos griegos: Entre lo sublime y lo cotidiano.* Madrid: Clásicos Dykinson.

Sulaiman, Alaa, Omar Khairuddin, and Mohammad F. Nasrudin

2019 "Degraded Historical Document Binarization: A Review on Issues, Challenges, Techniques, and Future Directions." *Journal of Imaging* 5, no. 48. Accessed August 3, 2022. https://www.mdpi.com/2313-433X/5/4/48/htm.

Tétreault, Jean

1999 *Coatings for Display and Storage in Museums.* CCI Technical Bulletin 21. Ottowa: Canadian Conservation Institute.

2003 *Airborne Pollutants in Museums, Galleries and Archives.* Ottawa: Canadian Conservation Institute.

Tomlin, Roger S.O.

1988 "Tabellae Sulis: Roman Inscribed Tablets of Tin and Lead from the Sacred Spring at Bath. Part 4 (the Curse-Tablets)." In *The Temple of Sulis Minerva at Bath*, vol. 2, *Finds from the Sacred Spring*, edited by B. Cunliffe, 59–277. Oxford: Oxford University School of Archaeology.

1993 "The Inscribed Lead Tablets: An Interim Report." In *The Uley Shrines: Excavation of a Ritual Complex on West Hill, Uley, Gloucestershire: 1977–9*, edited by Ann Woodward and Peter Leach, 112–30. London: English Heritage.

Tracy, Stephen V.

1990 *Attic Letter-Cutters of 229 to 86* B.C. Berkeley: University of California Press.

2003 *Athens and Macedon: Attic Letter-Cutters of 300 to 229* B.C. Berkeley: University of California Press.

Tremel, Jan

2004 *Magica agonistica: Fluchtafeln im antiken Sport.* Hildesheim: Weidmann.

Turner, Eric G.

1954 "Recto and Verso." *Journal of Egyptian Archaeology* 40: 102–6.

1987 *Greek Manuscripts of the Ancient World.* 2nd ed. revised and enlarged by P. J. Parsons. Bulletin of the Institute of Classical Studies Supplements 46. London: Institute of Classical Studies.

Urbanovà, Daniela

2014 "Die lateinischen tabellae defixionum, der Usus und die Spezifika auf dem Gebiet des Imperium Romanum." In *Actes du X*e *colloque international sur le latin vulgaire et tardif*, edited by Piella Molinelli, Pierluigi Cuzzolin, and Chiara Fedriani, 1047–98. Bergamo: Sestante Edizioni.

Veale, S., trans.

2017 "Defixiones and the Temple Locus: The Power of Place in the Curse Tablets at Mainz." *Magic, Ritual, and Witchcraft* 12: 279–313 (= Blänsdorf 2012).

Versnel, Henk

1991 "Beyond Cursing: The Appeal for Justice in Judicial Prayers." In *Magika Hiera: Ancient Greek Magic and Religion*, edited by Christopher A. Faraone and Dirk Obbink, 60–106. Oxford: Oxford University Press.

2009 *Fluch und Gebet.* Berlin: De Gruyter.

2010 "Prayers for Justice, East and West: New Finds and Publications since 1990." In *Magical Practice in the Latin West: Papers from the International Conference Held at the University of Zaragoza, 30 Sept.–1 Oct. 2005*, edited by Richard Gordon and Francisco Marco Simón, 275–354. Religions in the Graeco-Roman World 168. Leiden: Brill.

Viliani, Rosa Maria, and Roberto Mauri

2012 "La conservazione dei materiali magici del santuario di Anna Perenna: La documentazione attraverso tecniche digitali." In *Contesti magici / Contextos mágicos*, edited by Marina Piranomonte and Francisco Marco Simón, 183–92. Rome: De Luca.

Vogl, Jochen, Martin Rosner, Jaime Curbera, Uwe Peltz, and Burkhan Peplinski

2018 "Lead Isotope Analysis in Magic Artefacts from the Berlin Museums." *Archaeological and Anthropological Sciences* 10, no. 5: 1111–27.

Wessely, Carl

1893 *Neue griechische Zauberpapyri.* Denkschriften der kaiserlichen Akademie der Wissenschaften in Wien. Philosophisch-historische Classe 42/2. Vienna: F. Tempsky.

Wilburn, Andrew

2012 *Materia Magica: The Archeology of Magic in Roman Egypt, Cyprus and Spain.* Ann Arbor: University of Michigan Press.

Willi, Andreas

2008 *Sikelismos: Sprache, Literatur und Gesellschaft im griechischen Sizilien (8.–5. Jh. v. Chr.).* Basel: Schwabe.

Wünsch, Richard

1897 *Defixionum Tabellae Appendix.* Vol. 3, Pt. 3 of *Inscriptiones Atticae: Supplementum Inscriptionum Atticarum*, edited by A. L. Oikonomides. Berlin: Reimer. Reprint, Chicago: Ares, 1976.

1898 *Sethianische Verfluchungstafeln aus Rom.* Leipzig: Teubner.

1900 "Neue Fluchtafeln." *Rheinisches Museum* 55: 62–85, 232–71.

1907 *Antike Fluchtafeln.* Bonn: De Gruyter. Reprint, 1912.

Contributors

Jan N. Bremmer
University of Groningen
j.n.bremmer@rug.nl

Raquel Martín Hernández
Universidad Complutense, Madrid
raquelma@ucm.es

Loretta Rossetti
Laboratoire Arc'Antique, Nantes
Loretta.rossetti@loire-atlantique.fr

Arie Shaus
Harvard Medical School, Tel Aviv University
ashaus@post.tau.ac.il

Sofía Torallas Tovar
University of Chicago
sofiat@uchicago.edu

The study of ancient curse tablets (*defixiones* or *defixionum tabellae*) throughout the twentieth century was based almost exclusively on the texts they contained, leaving aside, as less interesting, the analysis of the materiality of the magical artifacts on which the texts were written. The curse tablets, which were inscribed and subsequently deposited during rituals for aggressive purposes, present important material characteristics and states of preservation that deserve to be part of the analysis to which they are normally subjected. This volume contains essays on important aspects related to the materiality of lead tablets: conservation and restoration, multispectral photography, computational image processing, and paleographic analysis. The material approach to the study of the tablets in recent years is put in context in an epilogue.

ORIENTAL INSTITUTE
THE UNIVERSITY OF CHICAGO