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STEFANO PULGA

Conservation Practices on Archaeological Excavations

PRINCIPLES AND METHODS

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Corrado Pedelì
Stefano Pulga

Translated by Erik Risser

The Getty Conservation Institute
Los Angeles

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The Getty Conservation Institute works to advance conservation practice in the visual arts, broadly interpreted to include objects, collections, architecture, and sites. It serves the conservation community through scientific research, education and training, model field projects, and the broad dissemination of the results of both its own work and the work of others in the field. And in all its endeavors, it focuses on the creation and dissemination of knowledge that will benefit professionals and organizations responsible for the conservation of the world's cultural heritage.

This book was originally published in Italian in 2002 by Edizioni del Giglio, Florence, Italy. It was created as a consequence of a training course taught by the authors and organized and funded by the Museo Internazionale delle Ceramiche (MIC), in Faenza, Italy. The course was developed through the hard work and dedication of Anna Maria Lega, who at the time was the coordinator of the MIC's department of conservation and today is assistant director of the Istituto Statale d'Arte G. Ballardini in Faenza. The authors owe Anna Maria a great debt of gratitude for her enthusiastic support of this project from its inception.

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Contents

Appendixes

Foreword to the English-Language Edition

If archaeological excavation is by its very nature destructive while conservation is concerned with preventing damage and slowing deterioration, it should come as no surprise that the two disciplines have sometimes been at odds. Conservators have been viewed as impediments to progress, archaeologists as solely concerned with making new discoveries. The past several years, however, have witnessed progress, with professionals from both disciplines attempting to address seemingly conflicting goals and objectives. These efforts, along with advances in both conservation and archaeology, have led to a greater appreciation of the value of working together and the knowledge that results.

In this new environment of collaboration, it is critical that field archaeologists and conservators have the tools necessary to work side by side as they investigate *and* preserve the material record of the past. We see this publication, *Conservation Practices on Archaeological Excavations: Principles and Methods*, as one such tool.

The Getty Conservation Institute has long been engaged in the conservation of archaeological sites. Our activities have included research into conservation materials and tools, training programs for in situ conservation, and specialist colloquia on reburial, shelters, and site management. We have also sponsored—and published the proceedings of—international conferences on this subject.

We were, therefore, intrigued when Erik Risser, associate conservator at the J. Paul Getty Museum, brought *Pratiche conservative sullo scavo archeologico,* by Corrado Pedelì and Stefano Pulga, to our attention and offered to translate the work into English. Erik, who has worked extensively as an on-site conservator on excavations around the world, has been using the Italian edition for many years to help archaeologists and conservators cultivate a shared understanding of common goals and best practices.

We thank Erik for the time and expertise that went into the thoughtful translation of this valuable book. We are grateful to Jerry Podany, head of the antiquities conservation department at the J. Paul Getty Museum, for allowing Erik the time to devote to this important project. We would also like to express our appreciation to the authors, Corrado Pedelì and Stefano Pulga, for sharing their work and allowing us to communicate their ideas in English.

We hope this book will serve archaeologists, conservators, site managers, and students as a manual to bolster best practices on excavations, ensuring that archaeological finds—from small objects to monumental architectural features—are appropriately protected.

Timothy P. Whalen
Director
Getty Conservation Institute

Foreword

It is with great pleasure that I write a foreword to this book. Problems related to the conservation of excavated finds are of the utmost relevance today. It was such problems that convinced me as an archaeologist, over twenty years ago, that I needed to have a knowledge of the principles and techniques of conservation. My formal training as an archaeologist—as for most archaeologists in those days—made no mention of conservation. So the topic of this book is of great personal interest. I wish that at that time I had had access to this valuable compendium of information and advice.

The relationship between excavation and conservation has been a difficult one. It has often been seen, wrongly, as bringing together a research discipline (archaeology) and a "caring" profession (conservation, with all those parallels with the medical profession that we know so well). According to this view, still held in some quarters, the archaeologist is interested only in research, believing that conservation is someone else's task, and, not surprisingly, the conservator—charged with remedying postexcavation deterioration that the finds have suffered—takes a poor view of the archaeologists and their field procedures.

Fortunately, this polarization of views is recognized increasingly as a travesty of the reality. Excavation and conservation must be seen as two complementary aspects of an integrated approach to investigating and preserving the material record of the past. Several indicators encourage the view that real progress has been made: the number of conservators who have trained first in archaeology; the number of archaeologists who recognize that long-term preservation (and understanding) of the past is in fact what their profession is about; the number of university-level programs in archaeological conservation; the number of sessions at archaeological conferences that now include papers, even whole sessions, devoted to conservation; and so on.

So are there grounds for optimism for the future relationship between excavation and conservation? I would say, cautiously, yes. There is still much to be achieved. It is one thing for archaeologists and conservators increasingly to recognize that they need each other. It is another to recognize that they speak the same language and have the same understanding of ethics, materials, deterioration processes, and solutions that meet the demands of investigation, conservation, and public display. Books such as this will go a long way toward establishing that dialogue and common language.

In closing, I have to comment that both authors, at a certain time in their careers, benefited from advanced professional training at ICCROM. Perhaps, as I hope, this experience contributed to the broad understanding and appreciation for conservation shown in their book. ICCROM also produced many years ago publications on archaeological conservation (*Conservation on Archaeological Excavations,* 1984; and *Preventive Measures during Excavation and Site Protection,* 1986). It remains a topic of central interest to ICCROM. Meanwhile, the authors have produced an updated and concise guide to the principles and methods of archaeological field conservation. I hope it reaches the wide audience that it deserves.

Nicholas Stanley Price
Director-General, ICCROM

Introduction

It could be said that archaeology and conservation tread paths that often run parallel but seldom converge. The long-standing emphasis in archaeology on the excavation and removal of objects, in fact, frequently ignores the basic principles of conservation. Yet it is often initial conservation in the field that determines the long-term survival and intelligibility of both movable objects and fixed features. Indeed, by ensuring the survival of artifacts and the wealth of information they contain, conservation plays an essential role in enriching our understanding of recovered material culture.

This book is intended to facilitate the harmonious collaboration between the two sides of this essential relationship, by serving as a user-friendly guide to conservation practices on archaeological excavations. It is intended particularly for professionals who work directly with recovered artifacts, materials, and immovable features, for it is they who, consciously or unconsciously, are most likely to influence the preservation of these elements. We do not, therefore, discuss conservation in and of itself; our intention, rather, is to highlight the specific needs of conservation in an archaeological context, thereby acknowledging the legitimate objectives of both disciplines, along with the beneficial role each can play for the other when collaboration takes place in a climate of mutual understanding and respect. The book's primary objective is to further our understanding of the impact that archaeological, logistical, managerial, and scientific issues can have on recovered materials—whether objects or fixed features—and to illuminate how the challenges arising from this interaction can be successfully resolved.

The subject matter of this book is also relevant to other disciplines commonly affiliated with archaeological excavation whose purviews are related to the study or guardianship of recovered materials. Some of the matters discussed, for example, may be of interest to scientists, project managers, and professional conservators, including those who work primarily not in the field but in laboratories and other controlled environments. The approach throughout combines theoretical concerns with hands-on advice; the authors hope that practitioners and students of both archaeology and conservation may find a useful interface between the precepts of academic theory and the demands of practical reality.

To this end, in the following chapters the different stages of the process of archaeological excavation have been reinterpreted, with each presented in light of the particular conservation challenges—both theoretical and practical—most directly related to it. Such an approach allows us to range across the full spectrum of relevant issues, from initial treatment options to the problems associated with preserving excavated features and sites. The opening chapter presents a general overview of archaeological methodology and conservation practices. Chapter 2 initiates a discussion of environmental factors as they relate to alteration and deterioration of newly excavated materials; chapter 3 focuses on the types of materials most frequently recovered. Then follows a chapter on the process known as *messa in luce*, during which an object or feature is "brought to light," or progressively revealed, during the course of excavation. Chapters 2 through 4 are written to be intelligible to readers who may lack significant technical or scientific training; together they constitute a concise presentation of the interrelationship of soil and archaeological materials, illuminating the chemical and physical response of materials both to natural conditions and to human activities. We hope that this will help establish guidelines sufficient to allow the recognition of different material types. This in turn should make it easier to interpret their conservation needs, and to decide on a course of conservation compatible with archaeological activities and objectives.

Similar concerns inform the chapters that follow. There is an examination of different forms of shelters and coverings that can be used during excavation as well as between seasons or campaigns. Two chapters on the use of biocides and consolidants, along with their accompanying appendixes, are based on countless years of experience and aimed specifically at conservators. Other chapters deal with more practical interventions, including stabilization, immobilization, and containment, as they relate both to materials in situ and to those to be removed or block-lifted; these discussions are intended to present solutions that involve relatively simple techniques and easy-to-find tools and materials and that may not necessarily require a conservator to implement them. In chapter 11 the stages of exposing or unearthing archaeological materials are considered in relation to the conservation question of preliminary cleaning; this allows us to identify the critical features of each of these important activities, clarify their points of reciprocal influence, identify potential conflicts, and suggest possible practical solutions, thereby facilitating a seamless continuity from archaeology to conservation. Proper packing and labeling are also treated in some detail, to emphasize the importance of the management and storage of archaeological materials as a critical component of their recovery and survivability. Finally, generous space is devoted to possible solutions for medium- and long-term preservation, such as reburial of features and the capping and repointing of masonry.

Throughout we set aside most general theories, broad assumptions, and rigid emphases on exclusive areas of competency in favor of a simple, inclusive, and pragmatic approach that is realistically applicable in the field. This is true not only for systematic excavations but also—and even more emphatically—for situations involving the need for rescue or emergency excavations, the frequency and constraints of which are growing ever greater, to the detriment of both ethical practice and archaeological remains themselves.

It is our belief that meaningful results can be obtained by focusing on the specific conservation needs of material heritage, whether or not it is to be excavated. For us the concern is, and should remain, methodology. There is no overriding benefit to archaeologists or conservators—or, for that matter, to recovered materials—when the priorities of one discipline are advanced at the expense of the other. Both professions ultimately aim to achieve the same objective: to understand and preserve the past through the material record. We hope that this book can serve as a referential framework for the proper planning and budgeting of both archaeological and conservation activities, which are—or should be—inextricably linked.

Finally, it is perhaps fitting that the introduction to a book very much concerned with methodology should say something about the method of its own composition. All that has been written in the following pages is based in the authors' personal experiences, acquired in the field over many years. These experiences were examined critically against the published findings and concerns of professionals of differing nationalities who deal directly with issues concerning the conservation of archaeological remains. There followed the task of adapting the ethical principles and operational practices of conservation generally to the specific realities of Italian archaeology. This, from the very beginning, was the primary objective, for it obliged us to examine the problems common to excavations from a range of perspectives and to propose solutions of maximum flexibility.

The result is a book that has been written in a spirit of close and fruitful collaboration. Each chapter attempts to merge the authors' knowledge and experiences in such a way as to arrive at a common understanding. We have tried our best to make every sentence useful to those who seek to understand the conservation issues that characterize archaeological excavations and who are willing to attempt to resolve them.

Excavation and Conservation

Conservation during and after Excavation

There is the reasonable expectation on every archaeological excavation that portions of the material record will be recovered, whether artifacts or structural remains, that will ultimately inform our knowledge of human activity and history.[1] Accordingly, it is fair to assume that the stratigraphy from which these remains will be unearthed will also be recovered (the "levels of occupation" that typically contain information crucial to interpretation). These stratigraphic layers will need to be documented in a comprehensive manner that can be summarized as follows (without any attempt to be exhaustive):

- Identification of the stratigraphic layer or level
- Identification of the chronological relationship between the different stratigraphic layers
- Documentation of the stratigraphic sequence
- Collection, documentation, and registration of the materials recovered from the stratigraphic level

This form of documentation requires the gradual and systematic removal of superimposed stratigraphic layers to reveal progressively lower archaeological levels and highlights the destruction and irreversibility intrinsic to archaeological excavation. Planning prior to and during excavation activities is very important in order to reduce the number of potential variables that can lead to the loss of information before it can be documented, analyzed, or understood. Paramount in planning is the inclusion of conservation measures by anticipating the types and nature of remains that may be recovered and the equipment and materials necessary to guarantee their preservation.

For small or so-called movable artifacts or features, in situ conservation measures may be limited or of short duration as such objects can be removed to a controlled environment such as a laboratory or storage facility more conducive to their preservation. Large or fixed features, such as masonry or floors, cannot be removed and therefore must be treated from the moment of discovery and ultimately incorporated into a long-term in situ conservation program.

With this said, large and immovable features as well as small artifacts in the area of excavation should be considered together in a holistic conservation program. To this end, one of the objectives of conservation as applied to archaeological excavation should be to limit the potential loss of information when an object or a feature is separated, physically or conceptually, from its context. When this is done, a more precise and systematic collection of information that can be preserved for future generations is more likely. If more preventive measures were applied on a greater scale and from the macroperspective of the site, rather than the microscale of the recovered artifact, intensive or interventionist conservation treatments would be less necessary, or at least less expensive, after excavation activities had concluded.

"Archaeological conservation" should therefore be conceived as including both movable and immovable heritage. The tendency to date, however, has been to treat them separately. This distinction is often continued in the decontextualized display of objects within a museum, to the detriment of the site. In contrast to the conservation of artifacts, conservation of a site rarely involves planning for its long-term preservation or presentation.

Conservation during Excavation

From the first moment of discovery archaeological remains undergo a rapid and intense process of alteration and/or deterioration from exposure to new conditions of light, temperature, and relative humidity (see chap. 4). The specific response of an archaeological material depends primarily on its intrinsic chemical and physical properties and how these have been affected by the forces it has been exposed to within the burial environment. Much of this is discussed more fully in later chapters, but here we want to point out that knowing that this shock associated with a new environment is unavoidable, those responsible for the excavation should plan ahead and develop procedures aimed at minimizing the impact of these factors during excavation. Of course, controlling the climate is not feasible, especially on outdoor excavations, so greater attention should be paid to selecting the right time to fully unearth sensitive archaeological materials in order to minimize the potential for environmental shock and, even before this, implementing appropriate systems of shelter or protection and having the appropriate materials on hand to deal with any eventuality.

Excavation is rarely complete at the end of just one season. The issues of protecting in situ features or remains between excavation campaigns should thus also be considered, planned for, and, if needed, financed. Virtually every choice related to the whole or partial protection of an excavated site is ultimately the result of a compromise between archaeologists and conservators. Ideally this compromise should be in favor of the basic principles of preventive conservation, but this is not always the case. For this reason, it is useful to evaluate the pros and cons of implementing preventive conservation measures well beforehand instead of near the end of an excavation season, a critical moment when preventive conservation measures are often seen as an extra burden in terms of work and funds. Underestimating the need for preventive measures will almost always result in some form of physical and mechanical deterioration, to the detriment of the preserved archaeological artifacts, features, and stratigraphy, leading to a loss of information and context.

Another issue that may arise during the course of an excavation is the differing professional responsibilities and objectives of archaeologists and conservators. Usually conservators want to remove fragile or sensitive archaeological objects as soon as possible to avoid further deterioration. Archaeologists, on the other hand, want to know the context of the object and its relation to other artifacts or remains and thus do not want it removed too quickly. The outcome in these instances can be negative if appropriate measures to ensure stability are not implemented in a timely manner. Here too a compromise is often necessary, one that takes into account the needs of the archaeologist in association with those of the archaeological material to ensure its stability and preservation. As with all the previously mentioned issues, the planning and coordination of operations is of fundamental importance, as is mutual respect for professional competencies.

Conservation after Excavation

At the end of most excavations there are typically two different types of interventions carried out, depending on the fate of the site itself: *preventive* (active maintenance, e.g., drainage, covers) and *therapeutic* (to reduce the rate of deterioration).

Because, realistically, few sites have medium- to long-term conservation measures implemented to ensure their preservation, it is widely accepted that the best option for the conservation of small or movable artifacts and features is their removal to a laboratory or storage facility. With respect to the sites themselves, some will inevitably be destroyed or disturbed by construction or development, and others, without the potential or significance for visitation, will be reburied to ensure their preservation. Very few sites are considered important enough to be fully preserved and have full measures carried out for their long-term preservation and presentation. In any case, no excavated site should be abandoned and left to inevitable deterioration and ruin.

It is important to fully evaluate the resources necessary to partially or fully preserve a site, in both practical and financial terms. Conservation, once undertaken, is not static but rather is an ongoing and active commitment that must be carried out full-time. Sufficient funds and personnel must be available to undertake regular and extraordinary maintenance, environmental monitoring, and, if possible, some form of climate control dealing with light and temperature (this can be in the form of shelters), not to mention security of some sort to prevent vandalism or theft.

Factors That Characterize and Influence Archaeological Excavations

At the moment of excavation at least two objectives are crucial:

- Definition and systematic documentation of the relationship between the archaeological finds and their spatial and stratigraphic context
- Avoidance of further deterioration or loss of fragile or highly degraded archaeological materials that are chemically and physically unstable

These two priorities, one archaeological and the other conservation driven, are often downplayed or disregarded because of administrative or logistical factors. These factors include the following:

- *Site typology and archaeological relevance*, for example, necropolis, urban or rural settlement, monument, road, dump
- *Type of excavation*, for example, academic training program, professional excavation, rescue excavation, explorative excavation, recovery

A site's typology, its potential archaeological relevance, and the type of excavation often overwhelmingly define the goals of excavation and, by extension, the priorities. The very methodology by which excavation is to be undertaken will be directly influenced by these factors, as will the organization of responsibilities and activities, including those regarding personnel, budget, and allotted time.

The decision to *preserve* a site will determine, first and most important, the type and extent of conservation measures undertaken to effect its presentation and accessibility. The perceived significance of the site as a whole or a particular feature of it will influence the type and extent of conservation intervention carried out in the excavated areas, the creation of shelters and/or protective structures, and the preservation of movable artifacts or features in situ, as well as the development and financing of a maintenance plan.

The decision to *temporarily or permanently rebury* a site will determine the necessary minimum level of documentation, as well as the types of possible consolidative structural interventions to be applied to deteriorated or at-risk features, and the implementation of various stabilizing and protective measures aimed at counteracting the deleterious effects of natural (rain, groundwater, and the weight of soil) and anthropological (foot or vehicular traffic) phenomena.

The inevitability of the *destruction of a site* due to development or other causes will determine the more meticulous and definitive level of necessary documentation with respect to the previous two options and the possible removal of large or immovable archaeological features (e.g., mosaic floors, frescoed walls, renderings) that otherwise would be irreparably lost.

The following factors can have a profound influence on the nature of the excavation:

- *Site location and climatic conditions:* if outdoors whether in an urban area or in the countryside and if indoors whether within a building or a naturally protected area such as a cave; the days, weeks, and/or months that are financially and, in terms of seasonal weather, climatically feasible for archaeological excavation to take place (i.e., a short time in areas of the world with severe winters and most of the year in areas that are temperate and thus more conducive to outdoor work)
- *Material factors:* topography of the terrain to be excavated and its soil composition, as well as the nature and state of preservation of the finds
- *General logistics:* distance of the site from the base of operations (where people are fed and housed and where recovered materials are worked on and stored); transportation (whether the site is reached by foot, car, or other means); work schedule (number of hours per day and number of days per week); organization of meals (where the major meals of the day are taken, whether exclusively at the excavation house or on the site or some combination of the two); basic sanitation and health conditions conducive to minimizing illness and days missed due to sickness
- *Technological logistics:* availability of basic services (running water, electricity, heat, etc.), temporary or permanent structures for housing personnel and for dealing with recovered materials (tents, houses, laboratories, warehouses); security (alarm systems or security personnel, communication systems); availability of equipment and supplies for archaeological and conservation operations; proper drainage of rainwater
- *Bureaucratic factors:* permits for excavation (whether determined by a bid contract or outside or independent funding); agreements and issues involving multidisciplinary competencies common to excavation (whether overseen by a university or administrative body or a private company)
- *Shareholder involvement:* promotion of the significance of the excavation to local and regional populations as a reflection of their heritage and as having potential political or economic benefits associated with tourism or visitation to a site to foster a sense of connection to and responsibility for the site and its excavation
- *Safety issues and regulations:* adherence to and implementation of accepted and regulated safety measures pertaining to working conditions, safety, operation of equipment, and building codes associated with the various professional competencies common to excavations
- *Time available for completion of work:* the time necessary to undertake all the disciplinary operations associated with excavation, not just the excavation itself
- *Professional factors:* number of professionals, whether part of the administrative structure of the excavation or as outside contractors, and the level of professional training associated with each (e.g., excavators may be part of a training program, while the architects or conservators are professionals)
- *Human (and psychological) factors:* the individual character of the personnel involved with excavation activities, their collective or individual professionalism and organizational skills, their level of interest and involvement, as well as their reasons for involvement (academic, moral, financial, etc.)
- *Other factors:* unexpected events, such as weather or illness; external pressures such as financial, emotional, or outside circumstances

- *Economic factors:* limited or nonexistent financing for active or preventive conservation measures (most archaeologists prefer to direct as many of their resources as possible to actual excavation rather than to fund related activities such as conservation)
- *Time factors:* possible conflict between objectives of archaeologists and constraints imposed by budgetary imperatives, especially in such projects as public works in which archaeological remains are deemed insignificant or the project (e.g., construction of roads, subways, underground parking structures) is deemed of high value or priority
- *Interdisciplinary collaboration and cooperation:* the rare case in which conservation priorities are given precedence over archaeological activities, when some or a substantial portion of the funding of an excavation is used to slow or delay actual excavation

Certain inherent, or "natural," factors cannot be changed or modified in any way. These include the geographic location and archaeological relevance of a site, its topography and soil composition, and the condition of its finds and features. Most of the remaining factors—the available budget, general logistics (housing, transportation, work schedule), and human issues (professionalism and motivation)—are adaptable and can be changed or improved. With respect to conservation, it is possible to intervene in some technical-logistical factors, for example, bureaucratic ones and public and political opinion. From a technical point of view, attention to the organization and coordination of activities, the associated personnel and their professional competency, and, ultimately, personal safety should be a priority.

Conservation Activities on an Excavation

In 1991 English Heritage published volume 2 of *Management of Archaeological Projects* (MAP2), which provides clear guidelines for planning and organizing archaeological projects and emphatically underlines the importance of calculating potential conservation needs on any excavation (Andrews 1991). In 1994 the Institute of Field Archaeologists affirmed that any professionally coordinated archaeological excavation, including its eventual publication, must involve conservation.

It is interesting to note that both of these initiatives originated from the discipline of archaeology. MAP2 in particular defines *conservation* as an integral part of the archaeological process, starting with the act of excavation, continuing through the period of study and interpretation, and concluding with publication of the final report. British archaeology, in its approach and management, has always been considered a model by archaeologists around the world. Even most conservation professionals who deal with conservation and preservation issues in the field consider the British model exemplary, albeit one in which local regulations and/or realities may necessitate an adjustment in its practices and implementation. This is, in fact, the main intent of the present volume: to make conservation activities applicable to general archaeological problems and to underscore why it is paramount to include preventive and conservation measures from the very beginning of planning operations and actual excavation.

What Necessitates Conservation Measures

Ethical and conservation principles were set forth by the UNESCO General Assembly at its December 5, 1956, meeting in New Delhi in the "Recommendation on International Principles Applicable to Archaeological Excavations 1" (see Appendix 1). The so-called Restoration Charters were initiated in 1932 by the Consiglio Superiore per le Antichità e Belle Arti (IT) and reelaborated in 1972 by the Italian Ministry of Education. And on May 12, 1983, the ICCROM General Assembly in Rome issued guidelines in its Twelfth Session report.

It is useful to recognize the practical realities of many or all the professional disciplines associated with the recovery, study, and preservation of archaeological and historical materials (independent of their typology or actual or associated value) in relation to these governing documents. Despite their long existence, reconfirmation, and further definition, many of the practices stated in these documents are often flouted or simply disregarded. The loose interpretation of the signifier "rescue excavation" or "explorative excavation" subverts the principles of these documents. Today, at the beginning of the third millennium, where this is the case archaeology and conservation are commonly perceived not as instruments to recover, understand, and preserve "human cultural patrimony" but as inevitable and obligatory impediments to modernization. The ability of archaeologists and conservators to influence the time frame of development and construction is often negligible. Instead excavation is subordinated to the will and desires of developers, architects, engineers, and politicians. This is in complete contradiction to the principles, perhaps idealistic but nonetheless logical and sound, defined in the charters of half a century ago.

It is striking that the above-mentioned documents give a great deal of attention to small, movable artifacts and materials but do not mention immovable structures and features in situ. These structures and features should be given the same attention and consideration, as they often provide the functional, architectural, and urban contexts for all movable objects. Unfortunately, once the small artifacts have been removed, fixed features are typically disregarded and left to certain and often rapid decline. Full or partial preservation of a site (for presentation and interpretation) is rare, as is reburial. Once abandoned, a feature is exposed to atmospheric conditions and biological attack, leading to unfettered alteration and loss in a matter of a few years. Even when full documentation of the archaeological context has been conducted, the physical loss of this context is usually ignored.

There are essentially three principal causes of the demise and loss of archaeological features: bureaucracy, insufficient planning, and climate. Of the three, it is certainly easier to ameliorate the negative aspects of climatic conditions that those of bureaucracy. Climate responds to dynamics dictated by the laws of basic physics, which are scientifically exact and verifiable. The same cannot be said of bureaucracy. Insufficient planning can be overcome, especially if an interdisciplinary approach is practiced. As enshrined in the charters, this has been identified as being indispensable but as yet is not a widespread reality.

RELIABILITY OF INFORMATION

An altered or deteriorated artifact may become an unreliable or misleading document for classification and, more generally, for the understanding of historical or archaeological context. Most archaeological artifacts contain a good amount of significant information within their constituent materials. The preservation of this information is linked directly to the intrinsic chemical and physical properties of the material and its stability and condition at the time of excavation. Conservation measures undertaken in the field during excavation can actually help slow any potential alteration or deterioration and the definitive loss of information.

CONTINGENT FACTORS

The following may be regarded as contingent factors:

- The increasing frequency of "emergency" or "rescue" excavations relative to "systematic" ones
- The decrease in funding for both archaeological excavations and conservation, long-term preservation, and maintenance
- The postponement of the systematic study of archaeological finds and their context

Emergency excavations are an ever-increasing reality that produce an inevitable confrontation between compressed deadlines and scarcity of means, personnel, and funds. Such circumstances are typically set in motion by those who decide the fate of heritage on paper according to the need to offer a token gesture to preservation. This gesture puts archaeological procedures and conservation practices and their principles to the test. In such situations, a momentary delay is sufficient to witness an act of almost complete destruction by an excavating machine whose use and permission to proceed were decided by the same authorities charged with making decisions on cultural activities.

As long as there is not a greater common awareness or a more positive valuation of archaeological heritage, a strategy that is more pragmatic and less philosophical or theoretically ethical will be necessary. If archaeology has to deal increasingly with the pressures and realities of development, where rules and rhythms are dictated by the cost of labor and materials, then applied conservation techniques may also need to be adapted to aid archaeological practice.

The Nature of Conservation Interventions

Beyond the various criteria or terms that might be used to define the nature of conservation activities in the field, perhaps the most appropriate is that they should be complementary to archaeological activities (fig. 1.1). Assuming that proper archaeological methodology is followed, conservation measures should become an integral part of excavation and material recovery, one that supports archaeological activities by providing prompt technical assistance to prevent deterioration of any recovered materials or, in the worst instance, limits loss of its inherent informational value. Conservation measures undertaken ethically should act in unison of purpose with excavation and, in so doing, avoid many of the potential logistical issues mentioned above.

In order to be accepted and integrated into archaeological practice, conservation activities should be underpinned by these guiding principles:

- They should not be at odds with the basic methodologies of excavation. That is to say, an artifact or material should not be removed for conservation reasons when this might compromise the understanding of the archaeological stratigraphy without full and proper

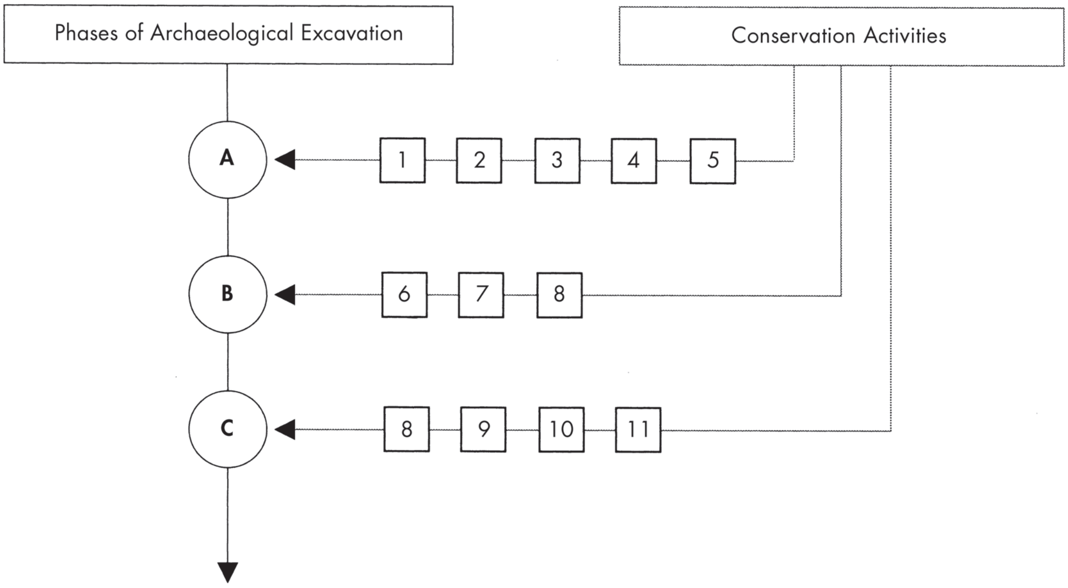


Figure 1.1 The correlation of conservation activities with archaeological excavation.

documentation or before conferring with the archaeologist responsible.
- They should operate in association and synergy with all other excavation activities.
- They should be undertaken in an expedient and efficient manner so as to not excessively interrupt or unduly delay excavation.
- They should not impede but rather foster and contribute to further study and understanding.
- They should not impede or otherwise compromise future conservation interventions.
- In the absence of a conservator in the field, some basic and remedial operations can be undertaken by knowledgeable and appropriately trained excavators.
- They should be noninvasive.
- They should be as fully reversible as possible.
- They should be preventive as well as conservative.
- They should always be documented fully.
- They should use easily obtained and maintained equipment.
- They should be cost-effective.
- They should be well planned and organized.

If these basic principles are not respected, any materials treated in an urgent or rescue situation could easily be subjected to further deterioration and any later interventions jeopardized or complicated. The goal of intervention should be to stabilize or maintain the condition of the object so as to preserve its material significance and informational value. Fortunately, most of these principles can be adhered to without recourse to extraordinary measures. Common sense and sufficient planning, coupled with goodwill, basic training and skills, and a modest budget to acquire simple equipment, are usually enough to ensure a positive outcome.

Planning for Conservation

Conservation activities should be conceived during the planning phase of an excavation. This will ensure greater integration and appropriate prioritization of activities and funding. Planning should be undertaken by an interdisciplinary group that consists at the very least of a director of field operations (archaeologist), a director of scientific activities (geophysicist or archaeometrist), and a conservator. The inclusion of sponsors as other sources of revenue is also common if grants are not sufficient (Pedelì and Pulga 2000).

In the case of rescue or emergency excavations, planning translates into a predetermined set of rules and actions that encompasses the majority of plausible eventualities and minimizes risks. For systematic excavations, planning involves organizing all facets of an interdisciplinary effort in order to extract the maximum amount of information. Most bureaucratic systems that use a bidding process to decide who will undertake excavation do not allow for accurate technical or scientific planning, let alone recognize or encompass conservation activities (De Gattis 2001). Aside from their negative influence on the quality of work in general and the archaeological outcome in

Figure 1.2 Typical bad situation during excavation due to inadequate planning. Archaeological features have been covered with polyethylene sheeting while waiting for a temporary shelter to be constructed. In the meantime, rain has flooded much of the excavated area, and the materials to be used to construct the shelter have been placed directly on top of the archaeological features. Many potentially harmful situations can be avoided with proper realistic planning of the time and sequence of activities.

particular, many bureaucratic practices do not even consider the conservation needs or the potential for the preservation of recovered materials, whether movable or immovable.

A proposal of the Department of Cultural Heritage of the Aosta Valley (Italy) that was carried out initially in 2000 and 2001 and continues today provides that all bids for archaeological contracts include a technical and scientific plan for the recovery and preservation of finds (Pedelì 2002). Another proposal by the same service and under examination at the time of writing calls for the production of a "plan for intervention and conservation" for any emergency excavation in the region, as these, by their very nature, rarely have a preliminary plan. Both of these proposals assume common goals for all the disciplines involved toward a singular objective: greater knowledge about and protection of cultural heritage.

In order for these proposals to work in a broader sense, they must involve on the part of the planners:

- Understanding the region in question and its terrain (likely locations of sites according to natural features and terrain)
- Understanding the basic climatic and seasonal conditions of the region in question (mean seasonal temperature, highs and lows, number of days with subzero and near-zero temperatures, average seasonal precipitation, orientation of sites in relation to the sun and primary winds, and, if possible, groundwater levels)
- Understanding the location of natural and human resources (sources for materials such as stone, wood, and water; businesses specializing in building and art supplies; presence of professional archaeologists, conservators, and general technicians)

- Understanding and anticipating the types of materials, and the nature of their manufacture, likely to be encountered during excavation (i.e., the excavation of a Roman site might reveal mosaics or floors in opus signinum, which would not be likely materials encountered on a prehistoric site)
- Understanding the professional competencies involved in an excavation and putting in place a well-organized structure of cooperation and communication between them, coupled with an awareness of conservation issues related to proper caretaking of movable and immovable materials, including having the basic equipment and materials on hand to undertake common conservation treatments and preventive measures, as well as a defined set of actions relating to unearthing, protection, conservation, and removal

Proper planning will truly bear fruit only if the overall operational budget includes the expenses related to protective covers and structures and their maintenance during excavation operations and between campaigns. It would be frustrating, not to mention potentially destructive, to have to interrupt excavation for any number of reasons without adequate protection for the excavated area. The most common recourse in these instances is the use of plastic sheeting to cover large areas; however, plastic tends to puddle and collect rainwater, creating stresses on the materials beneath it and creating a microenvironment that traps moisture and invites biological growth.

The fact that rescue and emergency excavations are now fairly common does not mean that planning principles are inapplicable or superfluous. Instead, they are of the greatest importance to avoid delayed reaction times or decision making in crucial moments because of the temporary unavailability of conservation professionals (Pedelì and Pulga 2000). A general knowledge and understanding of the basic principles and issues of in situ conservation is fundamental to anyone involved in archaeological excavation.

First Aid Operational Unit

Definition and Function

If archaeological materials are distinct from other materials because of the very nature of their manufacture, interment, and survival, then it is equally true that materials originating from excavations have specific conservation issues pertaining to the nature of their recovery. These issues, in turn, require particular conservation skills that are somewhat different from those necessary for the treatment of materials from nonarchaeological contexts and, because they are on-site, in laboratories. A particular sensibility and familiarity is essential. One of the major issues facing conservation on-site is the lack of recognized value of this distinct skill set, which often means that adequately employed and compensated professionals are rarely engaged. Therefore, based on personal experiences, and corroborated by professionals involved in excavations in other parts of the world, we have developed in the Autonomous Region of the Aosta Valley an alternative solution: a first aid operational unit (FAOU), composed of individuals with an affinity for the issues specific to archaeological recovery and in situ preservation.

As conceived, an FAOU is ideally suited for local and regional development and construction surveys and rescue archaeology operations. However, because all forms of excavation involve the recovery of material artifacts, an FAOU can also be seen as a basic model that can be adapted to all types of archaeological projects. As such, its function is to work in concert with archaeologists and conservators to perform the more standard and remedial aspects of both activities, freeing them to focus their energies on larger, more complicated, intensive, or specialized undertakings. Such units are already a reality in England but are still lacking in many places where, more than ever, they would be an invaluable component of the excavation process.

Hypothetical Profile of an FAOU

An FAOU can consist of one or more persons who do not necessarily have to be archaeologists or conservators, although these would be preferred professional backgrounds, even if they may present a slight bias in their approach. It is important to note that the concept of the FAOU was not developed to replace conservators or to undertake the primary and final interventions on artifacts or a site. The very name "first aid operational unit" was chosen for its neutral terminology, in the belief that it would help distinguish the roles of the operational unit members from the responsibilities of the archaeologist or conservator (Carandini 2000; Barker 1981).

If properly trained and instructed, experienced and competent individuals could undertake certain tasks that require no specific specialization, ostensibly filling the philosophical void between archaeologists and conservators and providing methodological continuity between the two professions. For example, as a medium-term strategy, specific personnel could be instructed on the basic notions of excavation techniques, climatic and environmental factors, and their deleterious effects on different types of materials. Building on this, they could be trained in specific methods for unearthing sensitive materials, as well as their lifting, packing, and transit. In addition, they could evaluate the condition of recovered materials and their susceptibility to environmental factors and ongoing excavation activities, as well as the potential repercussions of different forms of action (leaving in situ vs. removal, etc.). Moreover, they could assess the ongoing state of preservation and undertake basic preventive measures (stabilization, protection, packing) without turning to more direct and intensive forms of interventions that would affect or alter the properties of a material and that are better performed by a professional conservator. Recently there have been several courses on this subject funded by ICCROM and the European Community in Serbia, Albania, and Jordan.

In cases involving urgent intervention there is little to no room for experimentation, and the necessary materials and equipment must be readily available. In this respect, experience gained in the field and objective analysis of the achieved results are fundamental. In this light an experienced FAOU can be seen as a potentially vital link between the realities of archaeological excavations and the requirements for long-term preservation of both movable and immovable heritage. If this link is weak or nonexistent, recovered archaeological materials will undoubtedly be adversely affected, and perhaps too deteriorated to conserve or to provide reliable information.

Duties and Responsibilities

In agreement with the archaeologist directing excavation activities or with the department or entity overseeing operations, the FAOU as conceived could and perhaps should undertake and oversee certain duties:

- Participate in the preliminary planning of the excavation
- Define the parameters of their responsibilities and conservation and preventive procedures therein
- Have the necessary materials and equipment to undertake the prescribed conservation and preventive actions
- Be involved with site activities from the beginning
- Monitor the condition of artifacts and features in situ and those that have been packed and readied for transport
- Assess that the prescribed work is being properly implemented and, if needed, undertake specific measures to respond to the situation
- Adjust prescribed activities to evolving situations when unforeseen or unexpected problems are encountered
- Document all activities, whether conservation or preventive, with forms compatible with the procedures of archaeologists and conservators, complete with photographs and illustrations suitable for incorporation into a final report
- Interface with archaeologists, conservators, and all other professionals or specialists involved in excavation
- Interface with those responsible for the management of the storage facilities of the materials removed from excavation
- Follow all rules and regulations regarding safety

In addition, an institutional FAOU could:

- Have a budget that allows for the procurement of the necessary basic annual equipment and materials, as well as any specific supplies particular to the type of impending excavation
- Locate and purchase the materials needed for the regular maintenance inherent in long-term preservation
- Give presentations on the techniques and materials of intervention to new personnel prior to excavation
- Control spending of portions of the budget

ENDNOTE

1 This chapter is based on Stanley Price 1995.

Environmental Issues

The Soil

In archaeology, soil is viewed primarily as a historical source to be investigated for its material record of past human activities and events in the form of artifacts and features and of ecological alteration, such as plant domestication and farming. From the perspective of conservation, soil is understood as a physical, chemical, and biological system that interacts with the materials it contains (i.e., archaeological finds).[1] The nature of soil varies greatly and is dependent on several concomitant factors: geologic location, geomorphology, composition and stratigraphy, depth, temperature, water content, chemical composition, and pH. The state of preservation of buried materials depends on their specific nature and that of the enveloping soil and on the interaction between these two factors.

It is useful to have a basic knowledge of the type of soil(s) to be excavated in order to ascertain the probability of preservation of common archaeological materials. This, in turn, makes it possible to predict an object's potential state of preservation and/or life expectancy and, by extension, can help in planning for the appropriate materials, chemicals, and equipment in the event of its recovery.

Soil matrix is most commonly composed of four primary types of particles: sand, loam, silt, and clay. These are often present in distinct layers, one on top of the other, or they can be mixed together. The specific soil composition is further dependent on water percolation and drainage, vaporous gas filtration, dissolved mineral components, and the presence of organic matter.

Sandy soils are permeable to atmospheric gases and easily percolated by and drained of water. Clay soils, on the other hand, absorb and retain large quantities of water and are much more impermeable to atmospheric gases such as oxygen, carbon dioxide (CO_2), and sulfur dioxide (SO_2). From a theoretical standpoint one of the worst burial conditions for the conservation of archaeological objects is a combination of sandy surface layers coupled with a humid outdoor climate. In such a case, water vapor and oxygen have the ability to continually interact with each other and with the materials buried within the sandy strata. This can lead eventually to the deterioration of the materials through oxidation and hydrolysis. Hydrolysis can lead to the leaching of various crucial components within a material or, once water is removed, dehydration, which can set up repeated wetting and drying cycles that exacerbate corrosion in metals and swelling and shrinkage in some organic materials. Clay or bog layers, on the other hand, can provide an environment that is conducive to the preservation of many organic materials. In these cases, water penetrates the soil and fills the great majority of hollows or air spaces, blocking access of environmental gases and in particular oxygen. Favorable preservative conditions can also be found within dry sandy layers occurring in a dry outdoor climate, such as the desert(s), or where a dry sandy layer is below a clay layer that acts as an impermeable layer to moisture and gases.

Water plays a fundamental part in the physical, chemical, and biological equilibrium within soil and the environment as a whole. It can trigger and be part of chemical reactions, acting as a solvent or as the vehicle that introduces dissolved substances; and through humidification or saturation it can instigate physical phenomena such as expansion/contraction of organic materials or the solution/dissolution of salts, as well as create an environment that is sympathetic to biological growth. Given the complexity of the many deterioration phenomena involving moisture, it is best to defer to later discussions in this book (and see bibliography).

The pH of soil is normally between 5 and 9 (from slightly acid to slightly alkaline). In extreme cases it can be between 2 and 11.[2] Soil pH can vary considerably because of the introduction of new basic ions from sources such as rain that can introduce hydrogen (H^+), which, combined with environmental carbon dioxide (CO_2), forms carbonic acid (CO_3), or of roots and microorganisms that create CO_2, which, in the presence of moisture, increases soil acidity (pH 1–6). Soils rich in alkaline ions (Na^+, K^+) or alkaline earth ions (Ca^{2+}, Mg^{2+}) are commonly basic (pH 8–14). When there is an increase or decrease in basic or alkaline ions the chemistry of the soil and the object it contains also changes, forming new salts and altering the pH value toward neutral (pH 7). Certain archaeological materials survive better and for longer periods in acidic soils (e.g., leather, keratin-based textiles, or fabrics like silk or wool); others are better preserved in alkaline soils (e.g., iron, bone, wood, and cellulose-based textiles or fabrics like cotton). In general, however, it is neutral soils that preserve the largest amount of archaeological materials.

Temperature directly influences the rate of chemical reaction. Theoretically for every 10°C increase in temperature, the rate of reaction is believed to double. The rate of deterioration may be similarly affected, doubling at 20°C as compared to 10°C. Both temperature and oxygen levels tend to decrease with greater depth. This seems to indicate that there is a greater probability of better and longer preservation of materials in the deeper layers of soil.

The Buried Object or Feature

While buried, archaeological materials are inevitably subjected to many chemical, physical, and biological phenomena of alteration and deterioration that not only change their appearance but also alter their very nature. The manner in which these phenomena occur and the changes they create are dependent on the structure and composition of the archaeological object or feature, as well as the surrounding soil's oxygen, water, and pH levels (see above). In general, the lower the level of oxygen and water and the closer to neutral the pH, the greater the probability of preservation of the object.

Alteration phenomena occur quickly and intensely during the initial period of interment. Subsequently the object gradually reaches what is often defined as a state of equilibrium with the surrounding burial environment, wherein chemical, physical, and biological interactions between the object and the soil continue but at a much reduced and less aggressive rate. Each material type reaches its own state of equilibrium at the expense of its original properties and characteristics. This can take multiple forms, including chemical enrichment through the absorption of compounds dissolved in the soil (soluble salts and pollutants carried by moisture) and/or chemical depletion of constituents due to hydrolysis, dissolution and leaching, structural changes (expansion, contraction, cracking, disaggregation, etc.), or corrosion (metals and glass). Any or all of these phenomena may produce changes in appearance (shape, color, size) and weight. Certain materials deteriorate but remain in some form of preservation, generally altered in appearance and

Table 2.1 Materials with the Possibility of Preservation (related to hypothetical and generalized burial environment)

H_2O: damp or wet soil **O_2: present**			**H_2O: waterlogged soil** **O_2: limited or absent**		
Acidic pH (1–5)	**Neutral pH** (slightly acidic/ basic) (6–8)	**Alkaline pH** (9–14)	**Acidic pH** (1–5)	**Neutral pH** (slightly acidic/ basic) (6–8)	**Alkaline pH** (9–14)
Gold, silver, and their alloys Roman glass Shale Amber Porcelain Stoneware Glazed ceramic	Gold, silver, copper, lead, tin, zinc, and their alloys Limestone Marble All ceramics Glass Bone Shale	Gold, silver, copper, lead, and their alloys Iron Bone Limestone Alabaster Marble Unglazed ceramics	Gold, silver, and alloys Shale Wood Leather Keratin, horn Amber Jet Porcelain Stoneware Earthenware Textiles (silk, wool, proteinic fibers)	Gold, silver, copper, lead, tin, zinc, and their alloys Shale Limestone Alabaster Marble Amber Jet Glass Wood Leather Textiles Horn Bone All ceramics Iron	Gold, silver, copper, tin, zinc, lead, and their alloys Shale Limestone Alabaster Marble Amber Jet Bone Wood Leather Textiles (vegetable fibers, linen, flax hemp) Iron

Source: Watkinson and Neal 1998.

Table 2.2 Materials with Little Possibility of Preservation (related to hypothetical and generalized burial environment)

H_2O: damp or wet soil **O_2: present**			**H_2O: waterlogged soil** **O_2: limited or absent**		
Acidic pH (1–5)	**Neutral pH** (slightly acidic/ basic) (6–8)	**Alkaline pH** (9–14)	**Acidic pH** (1–5)	**Neutral pH** (slightly acidic/ basic) (6–8)	**Alkaline pH** (9–14)
Copper, lead, tin, zinc, and their alloys Iron Wood Leather Horn Textiles Bone Limestone Alabaster Low-fired ceramics Medieval glass	Tin, zinc, and their alloys Textiles Wood Leather Horn Alabaster Limestone	Tin, zinc, and their alloys Textiles Wood Leather Horn Alabaster Limestone	Lead, tin, zinc, and their alloys Textiles (vegetable fibers) Bone Glass Terracotta Limestone Alabaster		Lead, tin, and their alloys Textiles (proteinic fibers) Horn Glass

Source: Watkinson and Neal 1998.

structure. Other materials deteriorate altogether and leave little to no trace on excavation.

Although the specific processes that cause alteration and deterioration are still not fully understood, it is possible to construct a fairly detailed account of the reactions and events affecting the different types of materials. Tables 2.1 and 2.2 give a basic outline of the theoretical relationship between a specific burial environment and material type and the probability of preservation. Both tables refer to northern European soil types, especially British, and differ from tables for dry sites found in the international literature (Sease 1992).

The Burial Environment

The main environmental parameters that have a significant effect on archaeological objects and features, both interred and excavated, are temperature (T) and relative humidity (RH). These are significant because they are fundamentally linked while being highly variable and cyclical and can change in intensity and frequency.

Temperature

The concept of temperature is relative. In physical terms it is related to the action of infrared radiation (IR). There are numerous measurement systems for temperature: the Celsius scale (°C), the Fahrenheit scale (°F), and the Kelvin scale (°K). Conventionally the Celsius scale is used as the scientific and international standard in Europe, taking its points of reference from the freezing point of water (0°C) and its boiling point (100°C).

Temperature is significant because it affects many physical-chemical phenomena important to the preservation of archaeological materials:

- All chemical reactions are accelerated by an increase in temperature.
- Heat causes expansion of materials; conversely, cooling causes contraction (with the single exception of water).
- Biological growth, such as bacteria and plants, is supported by certain temperature ranges.
- Temperature directly affects the relative humidity of the air and, by extension, the state of equilibrium of archaeological materials and their surrounding environment.

Absolute Humidity and Relative Humidity

The gaseous mixture known as air may contain certain amounts of water in the form of vapor. The amount of potential water vapor in the air is dependent on its temperature. The warmer the air, the greater the amount of water vapor it can contain. Hygrometers are used to measure the actual amount of water vapor in the air and are based on what is known as the saturation line, which is the amount of water vapor contained in the air as a function of its temperature. The maximum amount of water vapor that the air contains at a given temperature is known as the absolute humidity (AH). Both the saturation line and the absolute humidity are expressed in grams of moisture per cubic meter (g/m^3) of air. Above any point on the saturation line, air is not able to absorb or contain any more water vapor, causing any excess moisture to come out of the gaseous state into its liquid form as condensation.

Below the saturation line, air does not always contain the maximum amount of moisture possible. This is measured with reference to the saturation line and is better known as the relative humidity (RH). For example, as shown in the psychrometric chart (fig. 2.1), a single cubic meter of air at 10°C can hold up to 10.5 grams of water vapor. If, however, this cubic meter of air contains only 5 grams of water vapor, then the amount of water vapor present is 50% relative to the saturation line for this quantity of air. Accordingly, for this example, the relative humidity would be 50%. Relative humidity is therefore the percentage of saturation for a given volume of air at a given temperature and is expressed as a percent.

All psychrometric charts used to measure humidity give three parameters:

- Temperature (T), expressed in °C
- Absolute humidity (AH), expressed in g/m^3
- Relative humidity (RH), expressed as a %

Knowing two parameters will always allow the third to be calculated.

Dynamics and Effects of Climate

Clearly, then, there is a very close correlation between temperature and humidity. Air temperature is directly related to the presence of infrared radiation and will therefore be directly proportional to the intensity and duration of solar radiation (daylight). Thus temperature variations will be greatest on clear sunny days and at their minimum on cloudy or overcast days. Absolute humidity is closely linked to precipitation and evaporation from bodies of water (rivers, streams, lakes, oceans) and the ground.

Psychrometric chart: With two parameters you can always calculate the third parameter

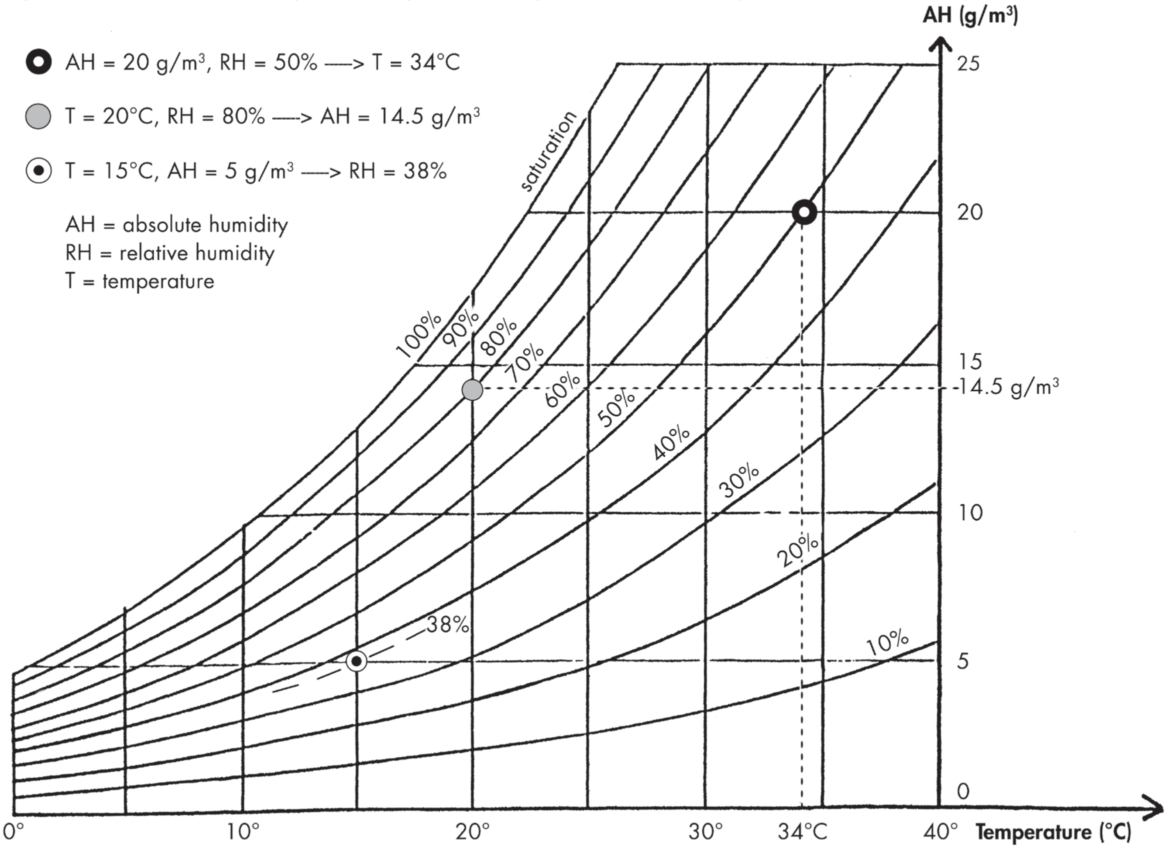


Figure 2.1

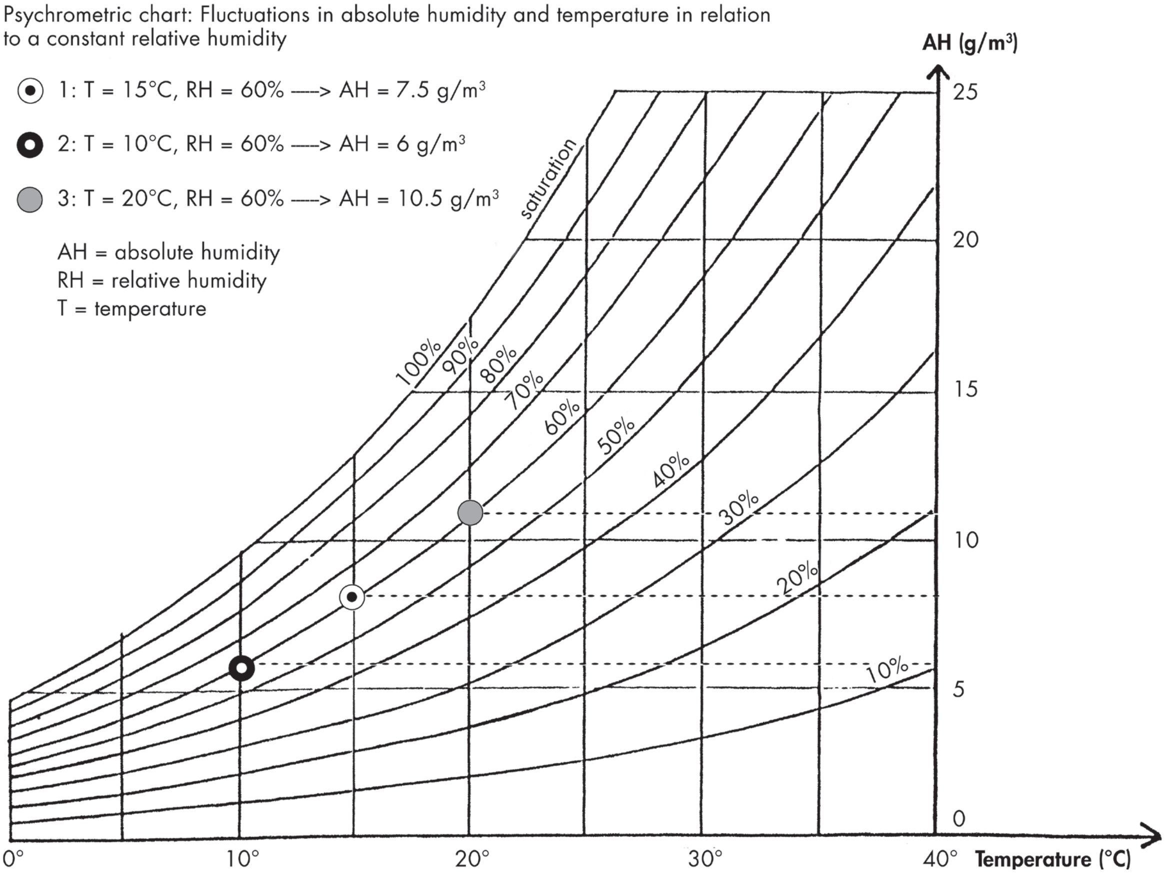


Figure 2.2

Relative humidity is a correlation of both temperature and absolute humidity. To illustrate this correlation, the same value of absolute humidity can have a high relative humidity at a low temperature or a very low relative humidity at a higher temperature (fig. 2.2). In the natural environment the changes in temperature and relative humidity are continuous and cyclical. Limiting the effects of these variations is of paramount importance for the conservation of objects that have remained interred for centuries under stable (nonfluctuating) temperature and moisture levels.

Natural cycles of temperature and relative humidity variation can be of very long duration (glaciation/deglaciation), long duration (seasonal), short duration (days), or very short duration (weather events such as storms). Seasonal changes are slow and progressive, which can allow materials and objects to slowly adjust and find their equilibrium without substantial ill effects. Short-term and rapid environmental changes do not permit objects and materials sufficient time to find their equilibrium and therefore result in greater damage.

By considering some of the most common weather patterns (clear, overcast, rain) it is possible to understand that external climate can be devastating to archaeological materials. In good weather conditions the temperature and relative humidity cycle rapidly about every twelve hours, with temperature increases and subsequent decreases in relative humidity during daylight hours, followed by lower temperatures and higher relative humidity in the evening and into the night. This is, of course, somewhat theoretical given that there is a significant difference, depending on distance from the equator, in the hours of daylight in summer and winter. All the same, this still holds true as a cycle, and in their attempt to reach natural equilibrium with the ambient moisture levels all archaeological materials will lose moisture during the lower relative humidity phase of the cycle and absorb moisture during the higher relative humidity phase.

If the weather is overcast or cloudy, variations in temperature tend to be less severe. Likewise, variations in relative humidity tend to be less pronounced, which means the theoretical danger to archaeological materials is also somewhat diminished.

In the case of rain or snow, archaeological materials would be in direct contact with moisture, in the liquid or solid state, and absorption of water would be rapid. This in turn would cause an increase in volume in some materials, while all would be subject to mechanical forces as water moves over their surfaces. Given that rain is eventually followed by sun or winds, the gradual evaporation or sudden loss of water from saturated archaeological materials can produce or provoke many common deterioration mechanisms, such as salt crystallization or structural expansion and contraction phenomena. If precipitation occurs in the winter, sudden drops in temperature are possible and could lead to the deterioration of objects or materials as water freezes within their porous structures. All the climatic eventualities mentioned in this paragraph lead to the irrefutable conclusion that most archaeological materials directly exposed to wet weather will suffer some form of deterioration.

Starting from this conclusion, it is clear that archaeological materials must be considered in relation to their previous, current, and future environments and protected from the moment of their excavation (see chap. 6). This seems self-explanatory for fragile, sensitive, or deteriorated materials but equally holds true for stable materials. Accordingly, it is important to understand that an ideal environment for archaeological materials' preservation is not and cannot be an absolute concept but rather is based on their individual condition and specific physical-chemical characteristics.

In summary, given the dynamics of climate and weather, especially those typical of most open-air excavations, it is important to understand and to take into account the various deterioration mechanisms these can cause so as to be able to quickly intervene to limit their effect on the preservation of a number of different materials.

Messa in luce: Principles and Conservation Issues

The criteria under which archaeological objects or structural features are unearthed—or "brought to light"[3]—are closely linked to the methodology of archaeological excavation. The basic principle of excavation is the systematic removal of superimposed earthen layers. In physical terms this translates into the progressive removal of soil in the horizontal and the vertical, beginning from the top and working toward the bottom. Soil is removed in both directions simultaneously within the limits of the interpreted archaeological layer or stratum. This process is repeated for each successive layer (fig. 2.3).

From the moment of exposure, minutes, hours, days, weeks, or even months may pass before the full excavation and removal of an object or recovery of an archaeological feature. Objects can remain in this state of transition for various reasons, including the excavation of surrounding or adjacent areas or the completion of graphic documentation. During this period, the partially excavated object is constantly exposed to an environment that is different from that of interment. Some objects or features, especially those that are large or vertical, such as walls or large pots, can simultaneously occupy two different environments. In these instances both the subsoil and the external climate are acting on the object. If the subsoil is wet or damp, this can favor the migration of soluble salts to the unearthed portion of the object by means of capillary action, channeling moisture from the soil to areas in contact with the air and provoking evaporation.

From the perspective of conservation, the moment of exposure, whether partial or whole, is one of the most traumatic for any type of archaeological find regardless of its nature and whether it was originally created for external or internal use. After centuries of adaptation to and permanence in subsoil climatic conditions, the object is subjected to sudden disruption of its established physicochemical state of equilibrium. From the first minutes after unearthing the adjustment to the new environmental parameters can cause strong chemical and physical stresses within the object, leading inevitably to alteration, possible deterioration, and potentially complete loss.

Features or objects intended to remain in situ face further risk of deterioration, especially if no form of covering or adequate localized protection is afforded the excavated area (see chap. 6). Any such archaeological finds are confronted with a different and more variable climate than that of interment, and one can reasonably expect:

- The significant presence of oxygen
- Temperature variation, seasonal (most pronounced during the warm seasons), daily (transitions from day to night), and sudden (storms)
- Relative humidity fluctuations subject to temperature changes
- Moisture-level fluctuations: times of extreme wet (rainfall, snowfall, flooding, etc.) to extreme dry (summer months, windy days, drought, etc.)
- The presence of gaseous pollutants (CO_2 and SO_2)
- The presence of light radiation in three forms: visible, IR, and ultraviolet (UV)

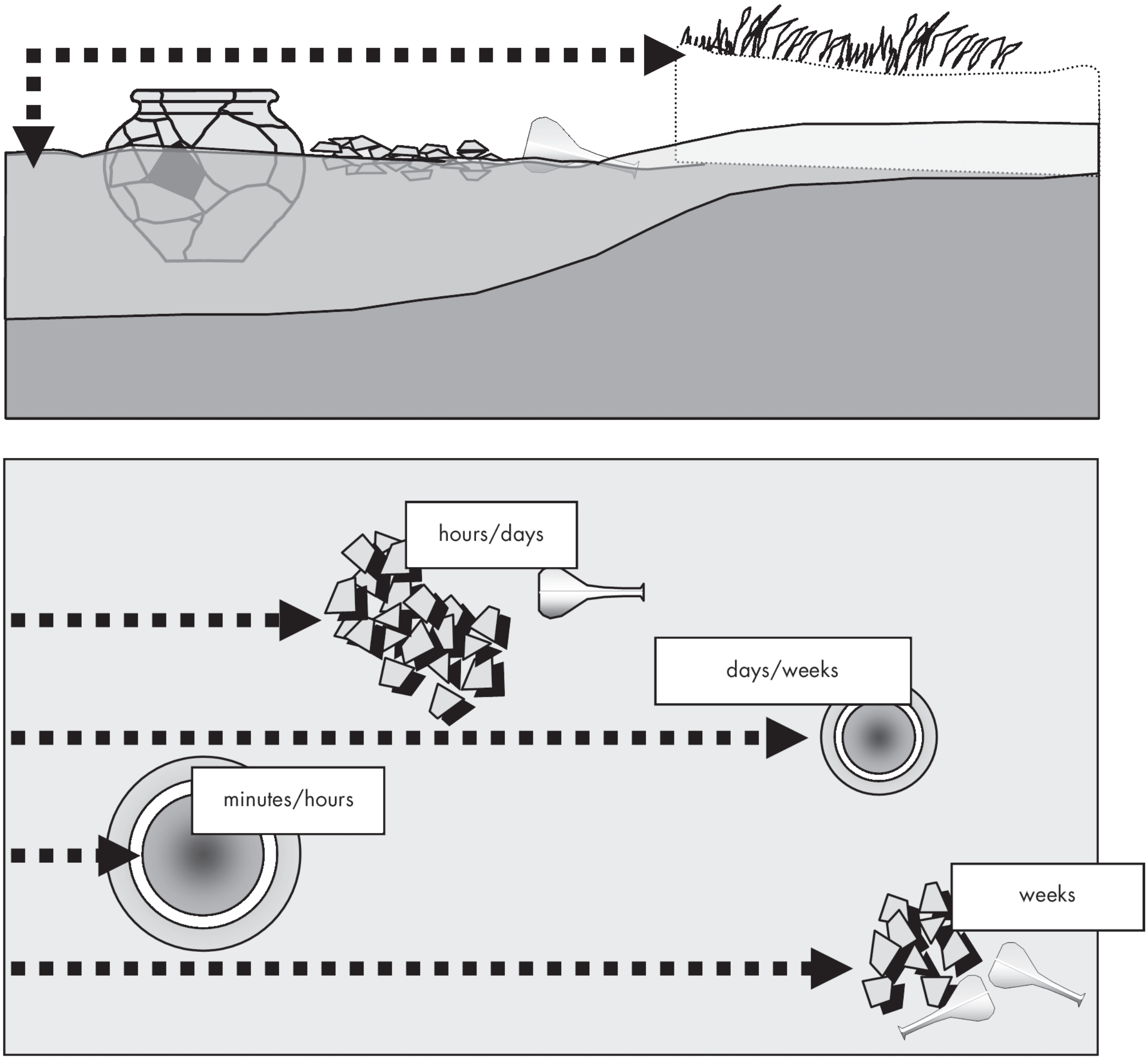


Figure 2.3 Sectional and overhead diagram of the various phases of unearthing during excavation.

In general, all these phenomena reactivate and accelerate deterioration mechanisms such as biodeterioration and corrosion and precipitate the rapid drying of materials recovered wet or moist, potentially causing structural weakening.

Theoretically since oxygen and relative humidity are the main sources of deterioration phenomena they should both be eliminated to guarantee conservation (Thomson 1986). In reality, however, preventing oxygen from interacting with objects on-site is practically impossible, and affecting temperature can also prove very difficult. For these practical reasons climate control in situ is usually limited to protecting objects or features from direct exposure to sunlight, rain, or wind. It is relatively easy to prepare simple systems of protection against direct sun, wind, and rain. Protecting objects from fluctuations in relative humidity, on the other hand, is far more difficult; objects will be affected from within minutes of their unearthing, even when sheltered or in temporary storage.

Changes in relative humidity cause archaeological metals and glass to undergo chemical changes, whose effects are manifested through corrosion, which makes these materials gradually more sensitive to further humidity fluctuations (see chap. 3). The corrosion of ferrous metals, although extremely slow within the burial environment, begins within a matter of minutes after excavation in ambient relative humidity levels exceeding 35 to 40%. This level of relative humidity is considered relatively dry at many latitudes but is harmful to ferrous metals, potentially provoking the creation of small brownish liquid droplets that are the telltale sign of the reactivation of corrosion of the remaining metal.

The same humidity level (40% RH) also causes serious damage to water-saturated materials, whether organic or inorganic. For example, in the case of saturated wood or leather a rapid loss of moisture leads to significant dimensional variations and distortions within a few hours and can ultimately cause the complete structural collapse of the object. In certain types of low-fire ceramics a rapid loss of moisture can produce expansion/contraction forces that result in the microfissuring or cracking of the ceramic fabric, detachment of ceramic or vitreous slips, and much more. (See chap. 3.)

Other than the archaeological objects and materials themselves, certain substances contained within their structure as contaminants are also susceptible to fluctuations in relative humidity. Of primary importance in this category are soluble salts, absorbed by the object during burial. Once the object is unearthed, salts acclimatize to environmental humidity levels by either losing or gaining water from the air, causing a cycle of deliquescence and crystallization of the salt crystals, together with migration into the porous structure of the archaeological remains. Porous materials are especially affected, in particular, ceramics and stone, which can have disaggregation and efflorescence at the microstructural level of their pores.

The conservation issues of excavated materials associated with climatic fluctuations do not cease after the object has been removed from the soil. Almost all the factors mentioned in the previous paragraphs must be factored into the later handling of objects, especially packing (see chap. 12) and on-site storage (see chap. 14).

Despite the multiple conservation issues inherent in the ambient environment and the varying effects these can have on archaeological materials, most objects will respond to such forces in a predictable manner (see chap. 4). This predictability is an advantage, allowing for a number of preventive measures to be planned and prepared prior to excavation. Even so, all conservation efforts can prove to be in vain if appropriate measures and steps are not undertaken after the completion of excavation and materials are consigned to storage or for treatment.

ENDNOTES

1 This chapter is based on Bergeron and Remillard 1991; and Watkinson and Neal 1998.

2 pH is a measurement scale, from 1 to 14, based on the concentration of hydrogen ions (H^+). Low pH values indicate a predominance of acid, high values a predominance of base. A pH of 7 is neutral; and the farther from 7 the number, the greater the acidity or alkalinity.

3 The Italian expression *messa in luce* means literally "to bring to light." In English, "initial exposure" or "unearthing" best expresses its meaning in this context. The term is used here to refer to the operation or moment in which an object or feature is brought to light or progressively revealed during the course of excavation by removal of the surrounding soil.

Properties and Deterioration of Archaeological Materials

The term *deterioration* (synonymous with *damage* or *degradation*) signifies a modification of the original material resulting in a negative impact on its properties with relation to its ultimate preservation and conservation. *Alteration*, on the other hand, refers to a modification of the original material that does not specifically involve a negative change or deterioration of its properties with respect to its preservation (Commissione NorMal 1991).

Overview

The materials that constitute archaeological finds are, like all the materials on Earth, classifiable into two principal chemical categories: inorganic and organic.[1] For both basic types of materials it is useful to list some of the general physical characteristics that influence their properties. Inorganic materials come from the mineral world (e.g., stones, ceramics, metals) and have the following general characteristics:

- They generally do not burn when heated.
- They are generally not light sensitive.
- Microorganisms do not usually proliferate on them; when present, there is generally little serious consequence to the material.
- Some stones and ceramics are porous and during burial can absorb water and salts dissolved in water through capillary action. Once excavated and exposed to a new ambient environment, the salts present in the pores of the material may begin to release or absorb moisture from the air. This can, in turn, cause repeated crystallization of the salts and weaken the mechanical strength of the structure of porous materials.
- Metals and glass are nonporous but are subject to chemical changes (corrosion) that can transform them into mineralized salts. These mineral salts themselves can be either soluble or insoluble and are always sensitive to ambient moisture or humidity.

Organic materials come from the plant and animal world (e.g., wood, cotton, wool, bone, ivory, leather) and have the following basic characteristics:

- They generally burn when heated.
- They are sensitive to light.
- In conditions of high relative humidity, greater than 65% RH, with no ventilation or light, they can host microorganisms that grow at their expense by using them as a source of nutrients. This leads to profound changes and weakening of their structure and appearance.
- They are generally hygroscopic (i.e., they attract water) and quickly absorb or release moisture, which can cause dimensional changes.
- They tend to keep their relative humidity in equilibrium with the environment. If they are drier than the ambient air, they tend to absorb moisture, increasing in both weight and volume. If they are wetter than the ambient air, they tend to lose moisture, decreasing in weight and volume.

For a classification of individual material types, see Appendix 2.

Materials Common to Structures

Any immovable structure, whether a wall or a floor, is made up of two main categories of materials: aggregates and binders. Aggregates do not take part chemically in the creation of the final product. Examples are stones, bricks, sand, and tesserae. Binders are those materials that once employed undergo chemical and physical changes that come to define the mechanical characteristics of the final product, such as hardness, rigidity, and resistance to weathering and environmental factors.

A fundamental distinction between binders is based on their reaction with water. An *aerial* binder is defined as any substance that, whether damp or wet, hardens on contact with air and once hardened remains generally sensitive to moisture or water. A *hydraulic* binder is any substance that hardens in contact with water and once hardened is resistant to moisture. Both types are obtained from heating naturally formed rocks to very high temperatures, transforming them into substances that readily react with water (hydraulic binders) or with carbon dioxide present in the environment (aerial binders). These reactions give rise to the formation of mineral crystals that develop considerable adhesive strength between themselves and any aggregates they are in contact with.

Masonry walls and floor coverings held together with or made from aerial binders, especially *lime* and *clay*, are common among recovered archaeological structures. More rarely features can be composed entirely of or held together with *gypsum plaster*,[2] the only true hydraulic binder known in antiquity. Lime mortars tend to survive well in moist or wet environments, whereas clay- or gypsum-based mortars do not and if preserved at the moment of excavation probably have lost much of their structural cohesion and continue to be held together primarily by the moisture present in the soil. Once drying begins these mortars deteriorate rapidly, while lime mortars will remain relatively stable. The physical and chemical properties of each of these types of binders are explored more fully below.

Clays

PROPERTIES

Various minerals diffused in the natural world and accumulated in large natural deposits by alluvial or fluvial action are classified as clays. The two primary clay minerals are silicon dioxide or silica (SiO_2) and aluminum oxide or alumina (Al_2O_3). At the molecular level both minerals demonstrate a basic structural foundation of platelet-like units. By virtue of this structure, clay particles have a lamellar shape.

Clays swell when mixed with a small quantity of water and become cohesive and plastic, which allows them to be easily modeled and manipulated and to retain a given shape. Plasticity and cohesion are both linked to the presence of a thin film of water between the lamellar particles. This aqueous film permits the particles to slide past one another and at the same time provides the adhesion between the particles that keeps the clay mass together.

Clays lose some of their volume during drying as water between the particles is lost through evaporation. The result is a loss of plasticity and a general embrittlement of the clay. To counteract these tendencies, aggregate additives such as sand or quartz tend to be mixed into clays, as are organic materials like straw, hair, wool, or animal dung that not only resist shrinkage and cracking phenomena due to volume loss but also provide mechanical support and resistance.

DETERIORATION

Walls and wall coverings based on clays are susceptible to the mechanical action of water (runoff, rain) and therefore have a reasonable "life expectancy" only in climates characterized by low precipitation, such as deserts. In contrast, such clay-based features are not greatly affected by rising damp through capillary action because water makes them swell, ostensibly closing off the pores within them. It is for this reason that clays were employed in the past as a moisture barrier in structures. Even today bentonite is employed as a water barrier.

Given these basic characteristics, one can readily deduce that the general preservation of clay features is threatened when they are exposed to a less humid environment, such as occurs on removal of the enveloping damp earth during excavation. Even assuming that the clay has survived in its original form, exposure to the open air will begin the process of evaporation and the consequent loss of volume and structural consistency. Maintaining the original level of moisture or implementing controlled slow drying followed by gradual impregnation with ethyl silicate is the only feasible option for conserving artifacts of unfired clay (adobe), although this method has drawbacks (see chap. 9).

Gypsum

PROPERTIES

Together with clay, gypsum is one of the oldest known binders, its use having been attested in Egypt more than five thousand years ago. Gypsum plaster can be used without additives or aggregate fillers but remains susceptible to moisture. For this reason it tends to preserve and be recovered from interior contexts or from regions with a dry climate.

Gypsum ($CaSO_4H_2O$)[2] is obtained by the heating of selenite. When mixed with water gypsum undergoes a chemical reaction that results in the creation of a rigid crystalline structure with good resistance to mechanical stresses.

DETERIORATION

The resulting material at the end of the chemical reaction or hardening of the plaster remains vulnerable to water and can deteriorate in moist environments. Because of this property it is probable that gypsum mortars and plasters recovered from a moist burial context will not retain their original mechanical properties. They will very likely appear slightly pink in color and have a crumbly texture indicative of physical and chemical deterioration. The possible conservation interventions and treatments in such cases are generally highly problematic and virtually unfeasible (for suggestions, see Mora, Mora, and Philippot 1977).

Lime

PROPERTIES

Lime is created by heating naturally formed limestone or marble composed of calcium carbonate ($CaCO_3$) and various impurities (silicates, alumina, iron oxides). Heating releases carbon dioxide (CO_2) from the stone, leaving a basic powder of anhydrous calcium oxide (CaO), better known as quicklime. If this powder is immersed in water ($CaO + H_2O$), a soft paste of "slaked" lime results ($Ca(OH)_2$). Slaked lime reacts with carbon dioxide present in the atmosphere ($Ca(OH)_2 + CO_2$) to again produce calcium carbonate, from which it originally derived (for further information about the cycle of lime, see Appendix 3).

Lime-based mortars always include aggregates such as sand or pumice because lime alone has very little mechanical strength after setting. If aggregates are added to the lime, the crystalline structure that forms during setting bonds to the granules of the aggregate and creates a material with very strong and notable properties.

DETERIORATION

Lime-based mortars are generally susceptible to the effects of water, to atmospheric sulfur dioxide, which transforms the calcium carbonate into a calcium sulfate (i.e., gypsum as a sulfate crust), and to the acidity of soil. Lime mortar interred for a long period in damp soil will typically be weakened, especially if the soil has an acidic pH (see chap. 2), in which case one may expect the mortar to be friable and less resistant to mechanical stresses, with a tendency to powder during drying.

Aggregates

PROPERTIES

Aggregates are defined as both the materials added to binders during the production of mortars (sand, pumice, straw, hair, etc.) and the structural elements held together by the binders themselves (bricks, stones, tesserae, etc.). The list of possible aggregates one may encounter during the course of an archaeological excavation is exceedingly long, and their characteristics cannot be addressed here in detail (see works cited in the bibliography). In general, however, aggregates can be divided into two main groups: natural (e.g., stone) and artificial (e.g., brick).

DETERIORATION

Every aggregate will react differently to the forces acting on it depending on its own physical or chemical characteristics. By extension, each will have its own form of weakness. A porous calcareous stone, for example, will have a different resistance to deterioration than a nonporous siliceous stone. Likewise, fired clay, such as bricks or paving tiles, will have the properties of a porous material but a resistance to deterioration forces dependent on its specific composition, level of firing, and so on.

Inorganic Materials Common to Objects

Metals

Metal objects can be pure (gold, silver, copper, iron) or alloys (bronze, pewter).[3] However, archaeological finds of pure metal are extremely rare (occasionally

Table 3.1 Metals and Alloys (late Neolithic to 3rd century A.D.)

Metal Object Type	"Pure" Metal	Alloy
Silver	Silver	Silver + gold = electrum (a naturally occurring alloy)
Gold	Gold	Gold + silver = electrum (a naturally occurring alloy)
Iron	Iron	Iron + carbon = steel (archaeological iron)
Copper	Copper	Copper + arsenic Copper + tin = bronze Copper + lead = bronze Copper + tin + lead = bronze Copper + zinc = brass Copper + zinc + lead = brass Copper + silver Copper + gold
Lead	Lead	Lead + tin = pewter
Tin	Tin	Tin + lead = pewter Tin + copper = bronze

gold and copper); they are more commonly composed of some form of alloy. Iron, for example, is usually combined with some carbon atoms.

PROPERTIES

In general, metals and metal alloys are lustrous, hard, and nonporous and have a crystalline molecular structure and high mechanical strength and high chemical reactivity, meaning they oxidize and are susceptible to attack by acids and alkalis. In addition, metals melt rather than burn.

DETERIORATION

All metal artifacts with the exception of gold are produced by first extracting a metal from an ore. This takes an enormous amount of energy, which makes the extracted metals chemically unstable and subject to corrosion phenomena that create greater thermodynamic equilibrium by returning to a state close to that of the ore from which they were obtained. Figure 3.1 summarizes the typical life cycle of a metal object.

Instability is dependent on the composition of the metal artifact and its reactivity with external environmental elements (O_2, SO_2, CO_2, H_2O, salts, acids, etc.) contained in the soil or the air. More stable metals (gold and silver) are less reactive and therefore more resistant to atmospheric agents. Less stable metals, that is, those that are more reactive (iron and copper), are inevitably subject to corrosion.

Corrosion processes are caused by electrochemical reactions that occur between the metal and the moisture and oxygen present in the environment, whether ambient or terrestrial. These reactions first affect the outer surfaces of the metal, partially transforming them into progressively more nonmetallic compounds, or corrosion products (oxides, carbonates, and sulfides), which in themselves can alter the appearance of the object. In some instances, as with iron, corrosion can be so severe that recovered objects may bear little to no resemblance to their original form.

Corrosion can be inhibited but not stopped altogether. It is a spontaneous, inevitable, and irreversible process. Theoretically the majority of corrosion occurs in the burial environment, suggesting that the greatest alteration to the chemical, physical, and mechanical properties of a metal object take place after interment. It is equally true, however, that the rate of chemical reaction rapidly decreases in the burial environment and eventually ceases. At this point equilibrium has been established between the metal and its surrounding environment. As soon as this equilibrium is disrupted or altered (an increase or decrease in oxygen levels, moisture, or pollutants) the corrosion process is restarted. Importantly, this is exactly what happens at

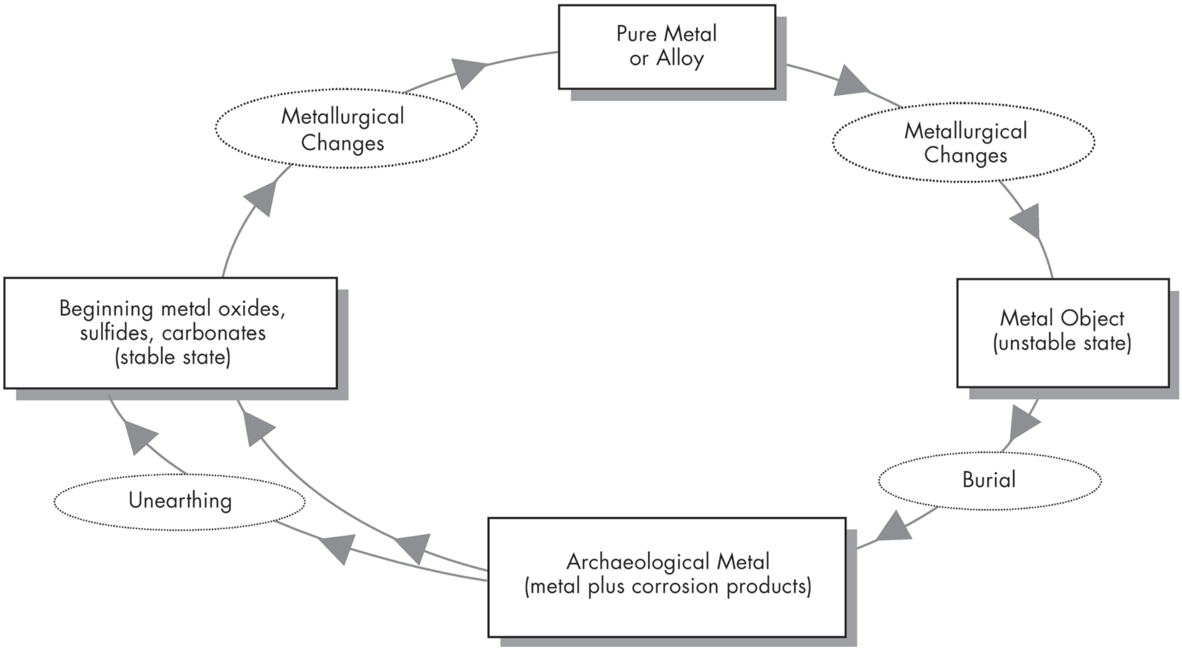


Figure 3.1 Diagram of the typical life cycle of a metal object.

Table 3.2 Basic Stone Categories

Conventional Categorization	Typology (some examples)
Stones used in construction (sedimentary, igneous, metamorphic)	Slate Sandstone Basalt Limestone Plasters Granite Travertine Tuff
Precious stones (minerals and gems)	Emeralds, topaz, sapphire, etc.
Semiprecious stones	Agate Coral (calcareous coral) Lapis lazuli Obsidian (volcanic black glass)

Source: *Garzanti Technical and Scientific Encyclopedia,* 1984; Watkinson and Neal 1998; Plenderleith and Werner 1986.

the moment of excavation, when the object is removed from the ground and exposed to a new environment.

Stone

An infinite number of minerals and rocks (mineral aggregates) can be included under this broad classification. Conventionally stones are divided into two major categories: building stones and precious stones. Table 3.2 presents the basic typologies of rocks and minerals commonly recovered from archaeological contexts.

PROPERTIES

In general stones have a crystalline structure and high resistance to compressive forces and do not burn. Stones that contain large metallic inclusions, such as iron or copper, may show localized oxidation or discoloration. Carbonates, such as most limestone and marble, can be susceptible to biological attack and acid degradation.

One of the properties that, more than anything else, characterizes most stone is porosity. This can be defined as the hollow or air space between particles in a solid material. The amount of porosity inherent in a stone has a direct effect on its ability to absorb liquids or vapor, on how it responds to thermal stresses, and ultimately on its mechanical strength and resistance.

DETERIORATION

Porosity is the primary factor regulating the survivability of stone objects and features, specifically their susceptibility and reaction to environmental factors. In wet or humid burial or climatic conditions, porosity allows water in liquid or vapor form to penetrate into the interior of a stone object or feature, coating all the internal surfaces until eventually achieving complete saturation. During this process water can deposit substances dissolved or suspended within itself (salts, acids, alkalis, gases, biodeteriogens, etc.), which can interact with the stone and initiate chemical reactions, such as acids dissolving carbonates, or give rise to cyclical physical phenomena like the crystallization/deliquescence of salts. In climatic conditions at or under 0°C or 32°F, water itself can freeze inside the larger pores, transforming into a crystalline solid of greater volume than its liquid form. Following reactions between acids and carbonaceous stones, the objects or features may undergo cycles of partial dissolution and leaching that further deplete and weaken their internal microstructure.

The phenomenon of crystallization, whether from water itself or from deposited salts, creates great physical stress within the porous structure of stone, eventually provoking small lesions, cracks, surface exfoliation, and, eventually, complete detachment of portions of the object or feature. The presence of water in liquid or vapor form (humidity) can cause moderate expansion of the total volume, depending on the nature of the stone and its state of preservation. Any of these phenomena alone or in combination could have occurred to a limited degree within the burial environment prior to excavation.

Table 3.3 Classification of Common Ceramic Types (Based on Italian Criteria)

Category	Subcategory (basic)	Ancient/Historic Manufacture (examples)
Terracotta	Without coating	Prehistoric and protohistoric vessels, Roman ceramics such as urns, amphorae, olpi and lamps, bucchero, pots and vases, votive statuary, objects, architectural and ornamental elements, etc.
	Glazed	Late Roman and medieval ceramics
	Enameled	Medieval ceramics, such as majolica
	Engobed	Roman ceramics (amphorae) and medieval ceramics (e.g., sgraffito)
	Engobed and glazed	Medieval ceramics (e.g., sgraffito)
	Glazed and enameled	Medieval ceramics (majolica)
	Clay slipped	Greek ceramics (black and red figure) Roman ceramics (light, italic, or dark sigillata)
Fine earthenware (whiteware, creamware)	With/without coating	Objects and ceramics of the 18th century
Stoneware	Without coating	Objects and ceramics of the 18th century
	Glazed	
	Enameled	
	Clay slipped	Roman ceramics (Gallic sigillata)
Porcelain	With/without coating	Oriental vases and objects
Faience		Mesopotamian and Egyptian objects and ceramics

The most common effects of visible deterioration on archaeological stone materials of high porosity are described in chapter 5.

Ceramics

Ceramics are composed from solid, nonmetallic inorganic materials forged cold and consolidated hot (M. Korach, in Emiliani 1971). This class of material is vast and can be divided into five main typologies that encompass all the ceramic wares produced in ancient times (table 3.3).

PROPERTIES

Ceramics have a crystalline structure, sometimes combined with a glassy phase, that has good compressive strength but little resistance to stress and shock forces, rendering them fragile. In general they are not soluble, but some of their components can be partially dissolved, leached, or plasticized. Most ancient ceramics are porous in nature. Those that contain calcium are susceptible to acid and biological attack. Ceramics will not oxidize under normal environmental conditions and will not burn, but if exposed to temperatures higher than those of their original firing they can undergo chemical and physical transformations such as color alteration, deformation, and/or vitrification.

DETERIORATION

General wisdom has it that ceramics have good physical and chemical resistance. This is certainly true of ceramics that have been fired at medium-high temperatures (from 1100°C to above 1400°C), such as porcelain or stoneware. In reality, however, most archaeologically recovered ceramics are of a “terracotta” classification type, fired in temperatures between 700°C and 1000°C. Some have been exposed to the minimum temperature (600°C) to be considered a fired ceramic. This means that most archaeological ceramics are porous in nature and thus no less subject to the deterioration mechanisms of chemical attack or physical phenomena of crystallization/deliquescence of salts or water than stone (see above).

Even ceramics with a vitreous, nonporous surface, or slip, which are theoretically more resistant than those without, can suffer damage. This may be due to the nature of the surface itself or, more commonly, derives from the different properties between the porous ceramic body and the nonporous ceramic surface. Even in cases where the ceramic body has a higher porosity than the exterior slip, if salts are present the surface will be subjected to pressure from the salt crystallization between the coating and the substrate (subefflorescence). Such forces first create swelling or lifting of the slip and localized fragmentation and eventually lead to partial or complete separation of the surface from the ceramic body. Examples of this behavior are often seen on Roman-era clear *sigillata* vessels as well as excavated majolica.

Finally, breakage in all its manifestations (fissures, cracks, flaking, exfoliating, etc.) should not be overlooked as the principal form of damage and deterioration for ceramics. This is especially true in that breakage typically allows for the previously mentioned forms of chemical and physical deterioration by exposing the porous body of a ceramic to intrusion by moisture.

Glass

Ancient glass was created from the fusion of silicon dioxide (SiO_2), in the form of sand, with an alkali flux (sodium or potassium) and an alkaline-earth stabilizer (such as calcium). Sometimes lead (Pb) was used instead of sodium, conferring a greater transparency to the glass. Colored glasses were obtained by the addition of metallic oxides, such as iron, manganese, or lead.

PROPERTIES

In the strictest sense of the term glass has not a crystalline structure but rather an amorphous one. This ambiguous structure has many advantages—for example, it makes glass nonporous and chemically resistant—but also some disadvantages. Chief among the latter are poor resistance to compressive, tensile, or shock forces, rendering glass fragile and sensitive to temperature changes. Too little or too much alkali as a flux can make glass hygroscopic and susceptible to damage from moisture (Plenderleith and Werner 1986). Soda glass, so called because of the use of sodium as the flux, is particularly susceptible to “weeping” or leaching when too much calcium carbonate was used as a stabilizer. Most glass, with the exception of glass pastes, is characterized by its transparency. But transparency is directly affected by the amount of mineral impurities in the glass, which can endow haziness and color, cause air bubbles, and influence the actual state of preservation.

DETERIORATION

Archaeological glass is subject to corrosion of a sort. The phenomenon is different and more complex than that previously described for metals. Considerably simplified, glass corrosion is due to the selective loss of sodium or potassium from the glass matrix, initially from the external surface. Corroded areas subsequently become more fragile and susceptible to further corrosion that penetrates deeper into the glass (Watkinson and Neal 1998). As a result, affected areas may show signs of differing degrees of deterioration: porosity, pitting, opalescence (partial loss of transparency), pearly or silvery iridescence, surface crystallization (“crizzling”), flaking, and detachment, leading to an overall thinning of the glass mass.

Organic Materials Common to Objects

All organic materials have a cellular structure (lattice, lamellar, spongy, fibrous, or canalled) and are, to varying degrees, flexible. Organics are highly hygroscopic and able to absorb or release large amounts of moisture. This is due to their tendency to keep their relative humidity in equilibrium with the ambient environment. If drier than their environment, organic materials will absorb moisture; when wetter, the contrary is true. The capacity for absorption is related directly to the material’s cellular structure. Organic materials are

Table 3.4 Classification of Organic Materials

Animal	Vegetal
Bone, ivory, antler	Wood, cork
Hair	Paper
Horn	Cotton
Nails, hooves, feathers, cuttlebone	Linen
Leather, hide	Hemp
Wool	Jute
Silk	Grains
	Seeds
Protein as principal constituent	Cellulose as principal constituent

Source: Based on Ginier-Gillet, Hiron, and La Baume 1987; Watkinson and Neal 1998; Berducou 1990.

also affected by light, susceptible to biodegradation, and combustible. The deterioration of organic materials depends on the specific cells that make them up and, importantly, the structure into which these cells are organized. Cellular structure is responsible for the distribution of moisture within the artifact: uniform distribution such as in leather and textiles or directional flow as in wood or bone.

Water has dual significance with relation to organic materials, as both an agent of deterioration and an agent of preservation. As an agent of deterioration, water first produces swelling. The degree of swelling is dependent on the specific organic material's cellular structure: slight swelling is typical of dense cellular structures (bone and ivory); intermediate swelling, of lamellar structures (leather, mummified skin); and significant swelling, of vegetal "canalled" structures (wood). Water then begins to hydrolyze cellulose and protein fibers and eventually, together with oxygen, creates a sympathetic and fertile environment for the growth of biological microorganisms (bacteria and fungi). These phenomena lead to a progressive and irreversible loss of cohesion within the organic material.

As an agent of preservation, water replaces the voids and gaps created by the physical and chemical deterioration process mentioned above, in essence becoming an integral part of the cellular structure. This process is known as waterlogging and occurs when the water creates weak chemical bonds with the residual healthy portion of the cellular structure and in so doing preserves material cohesion. The stability of waterlogged materials can be maintained only if the burial environment is deficient in or deprived of oxygen. By contrast, if oxygen is present biological and chemical attack will predominate.

Bone and Ivory

PROPERTIES

Bone and ivory have similar properties, beginning with their composition. Both are composed of roughly 30% protein (collagen and ossein), fats, and mineral salts of calcium (calcium phosphate associated with calcium carbonate and calcium fluoride). The most common mineral in both is hydroxyapatite, while ivory also has dentine. Bone and ivory have a dual structure, irregular and spongy on the inside and compact and lamellar externally (the cortical part). The internal spongy portion of bone is less dense and more discontinuous than that of ivory, which is harder, more compact, and regular.

DETERIORATION

The composition and structure of archaeological bone and ivory make them generally less susceptible to deterioration than other organic materials. With that said, however, they can be colonized by mold and bacteria, and in damp burial conditions both materials undergo hydrolysis of their ossein component. Aside from the characteristics of the materials themselves, an alkaline burial environment ($pH > 7$) can cause deterioration of the organic portion of both bone and ivory, while acidic conditions ($pH < 7$) may affect the mineral component.

Wood

PROPERTIES

Wood is made up of lignin and cellulose and has a complex, yet oriented fibrous cellular structure. It is easiest to visualize this structure as a bundle of straws. Each straw represents a lignin fiber and has an internal spiral throughout its length. The internal spiral is cellulose and constitutes the structural strength of the straw (fig. 3.2a).

DETERIORATION

Wood suffers the greatest degradation if interred in a moist and well-aerated burial environment. In these conditions it is readily attacked by both mold and fungi. In soils that are either alkaline or acidic (anywhere above or below a pH of 7), the cellulose portion of the structure deteriorates, and typically the greater the acidity or alkalinity of the soil, the greater the severity of deterioration. In extreme-pH soils archaeological wood is rarely preserved.

Wood preserves well in dry environments (one only need think of Egypt) but can be attacked by termites. At the opposite extreme, if the soil is very damp or wet and poorly ventilated, chances of preservation are also very good. In wet conditions, the wood will typically absorb large amounts of water up to saturation, whereby the water then begins to slowly dissolve cellulose (hydrolysis) until it almost completely replaces this component, becoming itself the only physical support of the ligneous structure (fig. 3.2b). This creates a new equilibrium of lignin/water (waterlogged wood). When waterlogged, the wood is swollen and dimensionally distorted but still maintains a recognizable shape. Despite being in a very weakened state, waterlogged wood can be preserved for centuries in this condition (an analogous phenomenon affects leather). When waterlogged wood is exposed to air, as after excavation, the water present within the structure

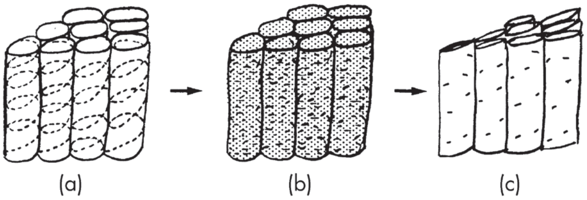


Figure 3.2 Simplification of the structure of wood (based on de Guichen 1995): a) normal wood: lignin + cellulose; b) water-saturated or waterlogged wood: lignin + cellulose + water; c) wood exposed to the environment on recovery: deteriorated lignin + cellulose.

begins to evaporate and the remaining lignin is no longer sufficiently supported and will collapse (fig. 3.2c).

Leather

PROPERTIES

Leather as we know it is obtained by chemically treating animal skins, known as the tanning process. The various substances used in this treatment (tannins, oils, smoke, etc.) serve to conserve the principal component of skin, collagen. As such, leather has a tangled fibrous structure that endows it with good physical durability. Despite being quite resistant and less hygroscopic than wood, leather is very sensitive to the presence of water, which can lead to biological attack and to its complete deterioration.

DETERIORATION

Leather can be recovered in a fair state of preservation where the burial environment is completely dry (desiccated) or very wet (saturated), the oxygen content is very low, and the pH acidic (<7). As with wood, in wet conditions water can play a dual role: initially dissolving and leaching out some of the leather's components, such as tannins, which creates gaps and voids in the cellular structure, and then filling these hollows and making itself an integral stabilizing part of the structure. Under wet conditions, the leather can act as a form of filter, trapping various inorganic materials dissolved in the water (carbonates, silicates, oxides, etc.). Leather has an affinity for insoluble iron salts, which on initial crystallization contribute to the weakening of the fibrous structure and subsequently confer a blackish-brown color and increased brittleness on the leather. Leather can already begin to delaminate within the burial environment because of such reactions.

ENDNOTES

1 This section is based on de Guichen 1995.
2 "Gypsum plaster" refers to natural materials based on calcium sulfate plus a variable amount of water (see Appendix 3).
3 This section is based on Berducou 1990; Leoni 1984; and Watkinson and Neal 1998.

CHAPTER 4

Messa in luce: Exposing or Unearthing Objects and Structures

Messa in luce, or unearthing, is the process of revealing an object or feature during excavation. It is distinct from the archaeological process of excavation in that it often is not limited to the removal of the earthen mass immediately around an object or feature but also involves removing much of the soil on its direct surface. As such, the process of unearthing often includes a de facto form of preliminary surface cleaning and in this context is intended to indicate a combination of these two acts, excavation and cleaning, in order to distinguish them from their more formal definitions in the fields of archaeology and conservation, respectively.

Conservation Issues

Conservation issues arise the moment excavation begins. When soil is removed in close proximity to archaeological features, issues relative to unearthing or exposure and its relation to and impact on various materials' surfaces come immediately into play. These issues constitute the starting point of the practical conservation of archaeological materials and are the focus of this chapter.

Removal of Soil in Close Proximity

Many of the most common problems associated with soil removal close to archaeological materials are due to the exposed portions being heavily damaged, deteriorated, or unstable. This holds true for both immovable features and movable objects. In many cases, for example, misaligned or weakened walls, frescoes, or vases, problems of stability and structural integrity may occur following the removal of the soil in which they were embedded. In many such instances the burial soil acts as a support to contain the archaeological remains and can even behave as an adhesive between detached fragments. This is often the case with small fragile artifacts that are both thin and long, highly corroded metals, or mosaic tesserae that have lost their binding mortar.

Regardless of the material to be excavated, the removal of soil should always be planned and executed in a controlled manner. In some instances the complete liberation of an artifact from the surrounding soil can mean its complete destruction. In such cases, using the appropriate excavation methodology is an advantage. The gradual horizontal removal of soil (a technique used in modern archaeological excavation) can lead to the slow emergence of an artifact or feature and thus allow for a more objective assessment of its condition. This in itself can provide a better understanding of an object's potential vulnerabilities and help in identifying conservation needs and appropriate intervention measures.

As noted in chapter 2, the first excavated portions of an object are also the first to be exposed to new environmental parameters. This can lead to rapid deterioration of these areas, especially in cases where the artifact is still interred in damp or wet soils. The physical stresses of volume contraction of the wet soils during their drying by exposure to air can be translated to an object or feature. These stresses can act on archaeological materials in different ways, ranging from the movement of disparate fragments to provoking fracture or the detachment of surfaces (painted or slip surfaces on ceramics), whole features (wall plasters or frescoes), or corrosion layers (glass and/or metal).

Any procedural suggestions for close soil removal in wet burial conditions must be very basic given that the number of actual variables one may encounter during excavation can be considerable, the least of which may stem from conservation itself. General conservation considerations for soil removal in damp environments are as follows:

- Devise appropriate protective coverings and shelters for excavated objects, features, and areas (see chap. 6).
- Intersperse removal of static supportive adjoining soil with stabilizing treatment interventions (see chap. 7).
- Avoid removing soil where it is adhering detached or detaching fragments in place and instead consolidate the archaeological material together with the surrounding soil (see chap. 9).
- Keep the soil moist with fine-mist water applications.

Surface Cleaning

When soil removal comes to the point that soil is in direct contact with an object's surface, understanding the specific characteristics of the material itself becomes paramount, as do the techniques and tools employed. Cleaning as a function of conservation is described in chapter 11, but in the context of any form of cleaning, even preliminary cleaning as an extension of excavation, it is important to recognize any potential consequences or shortcomings. The most important thing to keep in mind is that cleaning is irreversible. Any level of cleaning, if performed without careful consideration of the archaeological material and its state of preservation, can cause severe damage and the loss of information. Typical results can be various surface abrasions or scratches, as well as the loss of surface features, colors, or even decorative elements. This holds equally true for large features and small artifacts.

Principles of Exposure/Unearthing

There are certain measures in excavation methodology that can have a preservative effect. These measures should, at the very least, attempt to minimize the trauma to an object or feature during the exposure/unearthing phase of excavation. To this end, a few simple procedures can be proposed:

1. Carefully remove soil from the surface:

- Carefully consider whether the soil performs a supportive or containing function for the archaeological feature or object and whether this should be disturbed.
- Remove only the amount of surface soil necessary for the intended purpose of cleaning. If cleaning is meant to allow the material type and function to be identified, then it may be sufficient to simply remove enough of the larger clumps or grains of soil. The object or feature will remain covered by a thin layer of soil that may mask any surface details or colors but will most likely not prevent the material type and function from being recognizable. If cleaning is for documentation purposes, such as photography, then preliminary cleaning may need to be performed to reveal details, colors, decorations, and the state of conservation (for preliminary cleaning technique, see below).
- Before cleaning a large portion of the surface, clean small, discrete, and representative areas to ascertain the nature of the object, surface decoration, and level of preservation.

2. Avoid human damage:

- Consider the need to remove surface dirt (see (1) above).
- Avoid causing mechanical stresses to weakened, fragmentary, or fragile surfaces by the improper use or implementation of a trowel, dental pick, or other excavation tools.
- Do not create the detachment or collapse of already weakened features, such as walls or wall plaster, by removing soil that is keeping the feature or fragments in place by means of containment or adhesion. In such cases it would be prudent to proceed only with discrete excavation of representative areas, or in serious cases or with finds of particular importance, consult with or involve a conservator.
- Do not attempt to remove adherent or stubborn soil deposits, encrustations, or corrosion. This is especially important for small, fragile, or deteriorated objects but is also often important for large features like walls, where excessive exposure can be counterproductive. Such interventions are best undertaken by conservators during unearthing or left until later, especially if conservation will be necessary anyway.
- Resist the temptation to remove soil from small objects such as coins or glass fragments by wiping the surface with the fingers. The risks of abrading the surface and removing potentially important information, details, or corrosion layers is very high and completely avoidable by resisting this impulse.

3. Manage the transition from burial to external environment:

- To the extent possible, minimize the amount of exposure to the elements (see chap. 2) by implementing systems of temporary or permanent shelter and protection designed to inhibit direct exposure to visible, UV, and IR light radiation, rain, or moisture (see chap. 6). Doing so allows some control over the rapid drying of damp soils and changes in temperature and humidity to be achieved.

4. Stabilize the microclimate:

- Minimize fluctuations in temperature and humidity. In addition to implementing general coverings and protection, prepare localized systems of protection (see chap. 6) and conservation packing (see chap. 12) prior to and at the start of any unearthing operations. This is especially important for damp or moist artifacts and for organic items (wood, leather, ivory, textiles), which should be kept moist or dried very slowly in a controlled manner and then kept dry. If objects are recovered dry, they should be maintained in this state and not exposed to high humidity or direct moisture.

5. Stabilize structural integrity:

- Unstable edges and walls of earthen trenches or those areas of excavation to be left exposed to the elements should have some form of containment or support, such as netting, textile facings, or artificial bulwarks like stakes with plywood or dry masonry/brick containment walls. The same approach should be considered for archaeological features like walls and wall plaster that have a propensity to erode or collapse.
- Medium-sized to large features or objects (inscriptions, stelae, columns, etc.) that have sections that are detaching may need to be held in place with strapping, ropes, or tourniquets or by combining such techniques with systems of shoring and containment. (See chap. 7.)
- Medium-sized to small objects and features (inscriptions, capitals, statues, ceramics, etc.) may need to have fragments and/or flaking portions adhered in place with reversible resins. In the case of larger objects and features, adhesives can be combined with gauze or other open-weave textiles to create a reversible surface netting for containment. (See chap. 7.)
- Fairly complete objects of medium size (broken vases, statues, etc.) that are highly fragmented or have detaching sections or surface exfoliation may require containment created with temporary wrappings or open-weave textiles combined with reversible resins. (See chap. 7.)
- In the case of archaeological features or objects that are crumbling, flaking, or detaching from their structural support and are destined to remain in situ indefinitely or for a long period, consolidation should be considered, combined with the creation of adequate shelter and protection from the elements (see chap. 9).

6. Document the presence of small, movable objects:

- *In situ:* When small objects cannot be removed and packed immediately after excavation, prevent them from being inadvertently stepped on or damaged in any other way by placing small vertical flags (such as those used in construction to indicate boundaries) in proximity to them. The same flags, if numbered, can help with the documentation of specific find spots after the objects have been removed. In areas where a great number of small objects are recovered, this system can also create a ground map of finds without having to use the objects themselves as markers.
- *When removed:* It is good practice during excavation to keep an initial basic registry of small finds and objects, noting their basic material and condition, as well as any particulars. Preprinted forms that include basic identification information—provisional or excavation inventory number, state of preservation—using unequivocal and generally accepted terms can be used (see chap. 13).

7. Protect excavated surfaces from mechanical damage:

- Protect horizontal features (mosaics, earthen floors, or archaeological layers) as they are being excavated. Protection serves for both conservation and continued excavation, especially when no temporary or permanent shelter is planned for the excavated area and the area is still subject to traffic from personnel and excavation equipment such as wheelbarrows. Protective measures should be able to withstand any mechanical stresses caused by foot traffic or regular excavation activities and minimize the transmission of any of these forces to the underlying soil or feature to avoid aggravating already weak or fragile areas. They should be lightweight and easily removable to facilitate further excavation if necessary. In this regard various textiles (see chap. 6) or shock-absorbing materials (see chap. 12) can be used, as well as scaffolding planks or boards or any combination of the two, as befits the situation.
- Protect exposed vertical surfaces (archaeological sections, wall plaster, frescoes, etc.) from erosion and man-made damage such as surface abrasion and scratches due to visitation or ongoing excavation.

8. Reduce the amount of time an excavated object is left exposed:

- Depending on soil type, climatic conditions, and an object's condition, and after proper documentation, objects should be removed as soon as possible (see chap. 10). The closer removal of the object is to the moment of its full exposure, the better. At the very least, objects should be removed before the excavation is completed and closed.

Conservation Techniques for Exposure/Unearthing

Although much of the archaeological literature describes the proper use of standard tools and instruments for excavation (Barker 1981, 90–94; Carandini 2000, 182–84), none provides practical guidelines or truly addresses the issues of soil removal in close proximity to surfaces and of de facto preliminary cleaning. Below we suggest techniques proven through their application on excavation and implementation by professional conservators, archaeologists, and nonspecialists alike.

Structural Features

The following are some suggestions for the unearthing and preliminary cleaning of features such as walls and floors that are generally well preserved but can present sensitive surfaces subject to physical deterioration (plasters, mosaics, architectural terracottas, etc.). These techniques are not intended for painted plasters such as *fresco* or *secco* wall paintings, which often require conservation specialists.

REMOVAL OF SOIL IN CLOSE PROXIMITY TO A FEATURE

If one excludes the problems associated with precarious remains such as tall or eroded mortar walls that present the possibility of collapse, the removal of surrounding soil should not be a cause for great concern. The only possible exception is plastered walls where detachment of plaster or fresco sections is well documented. Aside from these examples, soil removal can usually proceed with trowels to within a few millimeters of the surface. This is typically indicated by the high points of any undulating or uneven wall or floor surface that first come to light. From the moment the highest or farthest point of any feature becomes evident, the continued use of a trowel for soil removal can lead to significant damage by scratching, scraping, or abrading these and other more delicate points, creating an artificially flat surface.

The probability of damage is significantly higher when working with damp or moist soils because it can be more difficult to differentiate between the texture of the soil and the surface of the feature. The result will be an apparent cleaning of the surface, which is not the removal of solely soil but also potentially portions of the surface layer and can lead to irreparable damage to entire sections of horizontal or vertical surfaces. This is obviously unacceptable from a conservation standpoint but is equally unsatisfactory from an archaeological perspective.

In moist or inconsistent soils it is often preferable to discontinue the use of trowels and instead proceed with small metal, plastic, or even wood spatulas of different hardnesses. Sculptural and modeling spatulas and tongue depressors are commonly used and are very adaptable. In some cases a low-suction vacuum can be used—but with extreme caution. In these cases, the mouth of the vacuum tube should have an appropriate-sized mesh covering and the tube never allowed in direct contact with the surface of the object or feature.

CLEANING FRAGILE AND DELICATE SURFACES

Any form of complete exposure or unearthing in the field implies a certain level of preservation. Even so, surfaces that are flaky, powdery, or already detached from their architectural backing are not good candidates for complete soil removal. The same holds true for painted or decorated surface features, which, even if well preserved, are better left for careful cleaning in a more controlled environment.

At the very least the full unearthing of any object or feature should not be approached in the same manner or with the same technique as general excavation. The first step is to stop using trowels and, eventually, any form of spatula. A proper approach requires progressive adjustment of the tools used based on the particular situation, need, and surface type.

Dry surfaces can generally be fully exposed using appropriate-sized soft- and semisoft-bristled brushes, either 7 to 8 cm wide and 2 cm thick rectangular or 2 to 3 cm round. The length of the bristles is very important. In general the shorter the bristle, the greater the transfer of force to the surface being cleaned. Short-bristled brushes are suitable for use perpendicular to a surface, moved in a rotary fashion to dislodge any soil particles; long-bristled brushes tend to move dislodged particles around.

Brushes are counterproductive on damp or wet surfaces, especially the longer and the softer the bristle. In general, brushing a wet surface tends to create a mud from the finest soil particles, which is then spread over the surface, where, on drying, the soil will be more tenaciously adhered to the surface than before. Moreover, the mud can act as a form of abrasive against the underlying surface as it is being moved around with the brush. Therefore, while exposing archaeological materials in damp conditions, one should opt for other solutions. Any solution, however, will always be a compromise between the need or desire to expose the surface and the responsibility not to damage the object or feature.

Figure 4.1 Preliminary cleaning of flooring in opus signinum for the purposes of documentation showing before and after.

METHODOLOGY

A satisfactory preliminary cleaning technique for robust uneven or rough floor surfaces such as opus signinum or mosaics includes using brushes with short, natural or synthetic, soft bristles (such as those used in shoe polishing) in combination with water, spray bottles, natural sponges, and absorbent paper toweling (figs. 4.1, 4.2). Application should proceed one square meter at a time, as follows:

1. Lightly apply a clean, wet brush to a dirty surface area, and, while holding the brush in the same position, make a series of small semicircular movements to dislodge large soil particles with the brush.
2. Apply one or two sprays of water to the same area, and again apply the brush in one quick and larger semicircular motion to definitively move the particles loosened in step 1.
3. Immediately afterward apply a clean and slightly moist, not wet, natural sponge with light pressure to the treated area so as to absorb and retain any dislodged soil particles as well as those finer particles dissolved by the water.
4. Finally, place a sheet of absorbent paper towel on the area to absorb any remaining moisture or soil particles. The paper towel can also serve as an

Figure 4.2 Detail of the preliminary cleaning of a section of flooring in opus signinum for the purpose of documentation.

indicator of whether cleaning should proceed or be suspended. A towel showing particles of anything other than the soil is a sign to stop all treatment.

These steps can be repeated several times as needed to achieve a preliminary cleaning appropriate for documentation. Afterward, dampened sheets of Japanese tissue or a breathable fabric can be placed over treated areas to encourage a gradual and slow drying that should reduce the possibility of efflorescence forming.

Although preliminary cleaning such as this is intended to be performed meter by meter, the major preoccupation of many excavation directors is the amount of time needed for such operations to be performed. As an illustration, a square meter of opus signinum can be cleaned in approximately two hours by appropriately trained personnel. It must be stressed that this type and level of cleaning should not be confused with full cleaning, which by its very nature may involve a slight amount of physical damage to the surface.[1] All the same, the extent of this damage is hardly comparable to the resulting damage if the surface were to be unearthed completely with trowels or spatulas. Equally, this technique can prove dangerous to surfaces that are virtually dry, especially if excessive amounts of water are used.

A similar technique can be adopted for the cleaning of terracotta surfaces by simply eliminating the use of brushes and working exclusively with a sponge (fig. 4.3).

Small Objects

The act of exposure may require much greater attention and care for small finds. This is particularly true for smaller or very delicate objects. Such materials can usually withstand fewer mechanical and physicochemical stresses than materials associated with fixed structures or features, whose mass can often better absorb vibration from excavation activities and climatic shock associated with unearthing.

Figure 4.3 Preliminary cleaning with a synthetic sponge of a Capuchin tomb made up of terracotta slabs.

Because of the great number of object types and potential states of preservation possible, it is difficult to suggest general techniques for preliminary cleaning of small objects in situ. All the same, given that it is inevitable that many objects will need some degree of exposure in order to recognize them and understand their archaeological context, some recommendations for good practice are indispensable. The techniques described below may prove applicable in many cases but may be inappropriate in cases of extremely fragile, unstable, or deteriorated organic objects made from leather, wood, or textiles and for inorganic artifacts like heavily corroded metals or glass. More than a specific technique, what is essential is a clear understanding of what should and what should not be cleaned.

REMOVING SOIL CLOSE TO SMALL OBJECTS

The removal of soil around objects requires great attention and caution because of the often small and fragile nature of the objects to be unearthed as well as the stresses placed on them by soil removal. Slightly moist soils are favorable for excavation; however, the full unearthing of artifacts is fraught with risk, whether the soil is dry and hard or wet and muddy. When one is dealing with dry soils, small amounts of soil should be moistened sequentially, not wetted, avoiding any areas of the object that are already exposed. A good technique is to spray a fine mist of water in the air over or around the soil to be removed and then allow it to be absorbed. Repeat this process until no additional moisture is absorbed. At this point the mass of soil should appear moist but not wet and will be slightly expanded and softened and thereby easily removable. Ideally humidification is limited to the soil alone and does not involve the artifact surface, in which case the soil will virtually come off on its own due to the movement involved in the expansion of the soil (fig. 4.4).

A flexible metal spatula can be used to remove thicker layers of soil (no less than 2 cm) from around an object. As work progresses toward the surface, the spatula should be replaced with finer and/or softer tools such as scalpels (interchangeable, with no. 10 or 15 blades) or plastic or wooden spatulas like tongue depressors and bamboo skewers. Dry residual surface soil can also be removed with soft natural- or nylon-bristled brushes. Brushes should not be used in the case of wet or muddy soils.

Figure 4.4 Soil removal with a wooden spatula after initial wetting with nebulized water. Once small portions of soil swell, they become easier to remove.

Figure 4.5 Initial cleaning of a terracotta amphora with a synthetic sponge.

Removing muddy, clay, or silt soils is much more problematic. On the one hand, if these soils are allowed to dry out, some objects, particularly any organic materials, can be severely damaged or even lost. On the other hand, removal of wet, sticky, or pasty masses of soil can cause more vulnerable objects to break or, as in the case of leather or textiles, to tear. A uniform strategy is difficult; much depends on the specific nature of the site and the object and material types recovered. Ideally objects are block lifted (see chap. 10) and microexcavation performed in a controlled laboratory environment. Barring this, work can be performed on-site with extreme caution using rounded semihard tools of plastic (spatulas, spoons, tongue depressors, etc.) or even of soft wood such as balsa.

CLEANING SMALL AND FRAGILE OBJECTS

In principle the considerations described for removing soil from near a feature hold true for small objects. In these cases, however, any type of preliminary surface cleaning can prove even more difficult and, by extension, carry greater risk of damage or loss. With this said, if at all possible thorough cleaning of small or friable artifacts should be done in a laboratory environment by conservators.

If preliminary cleaning in situ is deemed necessary and unavoidable, the nature of the material, its moisture content, and its condition must all be taken into careful consideration. The use of trowels, any kind of spatula, and all types of brushes should be stopped immediately once the majority of soil in proximity to the object has been removed. The last layer of fine soil can then be removed in the following ways:

a) If the soil is dry, small brushes with extrasoft, average-length bristles can be used (typically size 1 to 20, with natural or extrasoft nylon bristles of 15 mm length).
b) If the soil is damp or wet, brushes will create a mud that can act as an abrasive paste if worked over the surface. Instead, small commercially available sponges, cut to shape and slightly moistened, are ideal for preliminary cleaning in such conditions (see chap. 11). The sponges should not be rubbed or slid along the surface; instead small sections of the sponge should first be moistened with water spray and then tamped lightly on the surface (fig. 4.5). Soil particles will be absorbed into the pores of the sponge and held in place. This technique is highly effective in wet conditions but should not be used on dry objects or on archaeological metals or glass.

ENDNOTE

1 It is perhaps appropriate to say that any form of cleaning, even that undertaken during conservation treatments, will involve superficial abrasion and loss of minute amounts of the material being cleaned. This is usually perceptible not to the naked eye but only by careful examination under magnification (10× or higher).

Identification and Assessment of Materials

The first step in on-site recovery and eventual conservation is recognition of the constituent material of an object or a feature. This typically begins with identifying the class of material, such as mortar, stone, clay, ceramic, glass, wood, or metal, and the specific type within a class of material, such as bronze from silver or marble from tuff. For conservation purposes, it is preferable that initial identification include not only simple shape and functional or material characteristics but also condition. This, in turn, can help in the identification of the object and in the assessment of immediate risks and the planning of subsequent actions.

In many cases identification of all these factors is done on a macroscopic level, without the aid of specialized equipment, and on surfaces obscured by soil deposits or encrustation and altered by corrosion or deterioration. For this very reason, basic parameters for recognizing and identifying materials are necessary.

Parameters of Identification

Immovable features are often recognizable and interpretable from their location within a site and their physical presence within the archaeological stratigraphy. Artifacts, on the other hand, are not always immediately identifiable, and one must often rely on factors such as shape, color, weight, and surface texture or details as basic indicators.

Most identification is done despite having to interpret altered or obscured surfaces. Damage, deterioration, or loss can not only mask the appearance and intelligibility of a surface but also change the tactile feel of a material and, in the case of artifacts, alter physical characteristics like weight and texture. This is especially true of corrodible materials like glass and metal or in cases where soil and corrosion products are intimately mixed. Fortunately, the identification of many materials, particularly porous ones such as ceramics, stone, or masonry, is affected by surface soiling or encrustation alone. Accordingly, in some instances light preliminary cleaning (see chap. 11) of loosely adhered soil from a discrete area may aid identification.

The rest of this chapter examines the most common types of recovered materials, focusing on the logical sequence of events, from (1) what may appear during excavation to (2) what can happen in the short (minutes), medium (hours), and long (days) term after unearthing and (3) what can be done during and after excavation to prevent further alteration or deterioration. Because of the many artifact materials possible, we have provided tables for each common material type, with its identifying features. These should be understood as purely indicative and as an aid to characterization.

For an overview of material properties and deterioration mechanisms, see chapter 3.

Immovable Features

Masonry Walls

Although it is virtually impossible to summarize all possible variations, this discussion is intended as an aid in assessing and understanding masonry structures that may be found during the course of excavation.

WHAT MAY APPEAR

A distinction must be made between mortar-bound masonry walls (mortared walls) and and dry masonry walls (unmortared walls) or stones piled without mortar. In the first case the constituent parts of the wall are held together by a mortar, whereas in the second case the parts are held in place by gravity. The level of cleaning necessary for the identification and documentation of a masonry structure may be circumspect enough to not fully reveal the true nature of construction. Fuller examination in selected areas should attempt to identify the major component of the wall, such as bricks, stones, or pebbles, and whether a binder is or is not employed. The material between components may be residual earth or an original binder; careful attention should be paid to distinguishing between the two as they can be confusing.

WHAT MAY HAPPEN

With unmortared walls, the hollow spaces between different structural components may be filled with earth, dirt, or sand that when dried may shrink in volume and become crumbly. In some instances this can compromise the stability of the wall.

With mortared walls, dirt or other substances may alter legibility of the true nature of the wall but do not generally pose immediate structural risks. Their removal allows for an accurate assessment of the state of preservation of the binding mortar, which in itself may still prove to be structurally viable or could be weakened and friable or, in the extreme, mechanically insufficient to maintain long-term structural integrity.

WHAT CAN BE DONE

After the previous observations, one arrives at an irrevocable decision: how to remove any loose and extraneous earth or soil without compromising the stability of the feature.

In the case of unmortared walls, the soil to be removed can be moistened and softened with an adjustable spray bottle. One should proceed prudently and cautiously, constantly checking the stability of the various components. Where walls are structurally unstable, semifluid mortar injections (grouting) may be used (see chap. 9 for suggested grout compositions). Care must be taken to ensure that there is no significant alteration of the wall's appearance as a result of the act of consolidation or the type or color of mortar chosen.

In the case of mortared walls, the approach is the same, employing a fine water mist from a spray bottle to reveal the actual state of the mortar itself. In cases where friable or weakened mortar is found and some of the components may be loose or movable, a lime-based mortar can be used as a consolidant. It is paramount in such instances that the lime mixture used replicate as closely as possible the original mortar. In particular the inert particles used in the mix should be appropriate to the original mortar in both color and grain size. If the original mortar is partially or completely disintegrated and has poor mechanical properties, consolidation by impregnation with ethyl silicate may be a viable option (see chap. 9).

Painted Wall Surfaces

WHAT MAY APPEAR

Many wall remains may have sections or fragments of painted plaster still preserved on their surface. Like walls themselves, these can be divided into two general types: *a fresco* painted plaster and *a secco* painted plaster. The distinction is whether the pigments were applied when the plaster was wet, with the plaster's lime serving as the binder (*a fresco*), or after the plaster was dry, with another form of binder, such as *tempera a secco* (egg yolk, casein, animal glue, oils).

Wall plaster painted *a fresco* has a relatively smooth, fine surface that is resistant to moisture and abrasion, making it able to withstand the action of moistened swabs. Such surfaces can often be partially or wholly covered by calcareous deposits and encrustation.

A secco painted surfaces are quite the opposite. These are opaque and tend to be less robust and acutely sensitive to moisture, which renders their surfaces very fragile. Such surfaces are commonly obscured by calcareous encrustation, which may have caused some loss of the painted surface. Even so, it is possible to recover well-preserved surfaces in archaeological contexts. In these cases it is important to first determine if the surface is truly made with *a secco* techniques by testing resistance to a moistened swab and if so to remember that the unabated drying of such a surface can lead to its complete deterioration.

WHAT CAN HAPPEN

A white veil of crystallized soluble salts may appear on *a fresco* painted surfaces because of drying; *a secco* painted layers may retract, crack, and begin to flake.

WHAT CAN BE DONE

For *a fresco* painted surfaces, Japanese tissue strips, moistened with demineralized or deionized water, should be applied to allow any salt crystallization to occur on the tissue and not on the plaster surface.

For *a secco* painted surfaces, flakes can be re-adhered to the substrate by placing strips of Japanese tissue on the surface and applying a thin 5% solution of acrylic emulsion through the tissue. This prevents a glossy buildup from forming by guarding against overapplication. Prior to drying, the tissue should be removed and discarded (see chap. 9).

Wall Plaster, Painted and Unpainted

WHAT MAY APPEAR

The types of possible plaster conditions one may encounter can be summarized as follows:

- Various degrees of friable and crumbly rendering
- Partially detached from the wall itself
- Cracked and with large lacunae

WHAT MAY HAPPEN

- Progressive crumbling while drying out
- Complete detachment and collapse of the plaster from the wall
- Enlargement of cracks and gaps or edge detachment during drying out

WHAT CAN BE DONE

- Creation of a temporary shelter to allow for slow drying (see chap. 6)
- Cohesive consolidation of the plaster itself (see chap. 9)
- Creation of temporary supports (props) to hold fragments in place (see chap. 7)
- Grout injection of semifluid lime mortar to reestablish continuity between detaching plaster and the wall (see chap. 9)
- Temporary sealing of edges with a lean lime mortar (see chap. 7)

Floors: General

The term *floor* encompasses many types, from beaten earth to lime-based coverings and even large mosaics. Regardless of the type of flooring encountered, it is fundamental to assess the following in each case:

- The archaeological importance of the floor in its context
- The types of stresses, environmental and physical, the floor will be subjected to during the course of excavation
- The logistics and costs associated with conserving the flooring in situ
- The logistics and cost of temporarily lifting and removing the floor for safekeeping and replacing it in its original position at the termination of all excavations

These considerations, as mentioned earlier, form the basis for formulating and developing necessary conservation interventions, whose importance is often undervalued or completely neglected. It is often the case, in fact, that intervention on an excavated floor, or simply its protection, is decided against even when it is known that it will be subjected to months of foot traffic, loaded wheelbarrows, and exposure to the elements. This usually results in great loss or damage to the floor, which in itself complicates any future treatment in terms of level of intervention and cost.

The need to understand and predict the types of features, artifacts, and materials that may come to light cannot be stressed enough. This foresight allows for proper planning, which in itself makes successful interventions in a timely fashion much more feasible. As such, anticipation and planning are a means to (1) effectively reduce the potential deterioration of and damage to a recovered material and (2) reduce the overall costs associated with conservation. Floor levels always represent the link between stratigraphy (vertical) and context (horizontal), giving both the temporal and spatial levels of occupation in a chronological sequence. This basic fact renders floors incredibly important in archaeology, and they should be understood as such by *everyone* involved in archaeological excavation. Even if only for this reason, floorings should be incorporated into conservation planning and treatment.

Initial basic treatment decisions must be based on understanding and evaluating the types of forces that will be acting on a floor. The following possibilities should be considered:

- Whether the flooring will be preserved in situ and whether this is best done by means of a temporary shelter (wooden boards resting on layers of polyethylene padding or sand)
- Whether the flooring will be documented and then partially removed for continued archaeological excavation of lower stratigraphy
- Whether the flooring will be lifted and later placed back in its proper location and orientation

In any of these three cases the consultation of appropriate professionals is important:

- If the flooring is to be preserved in situ, a conservator is essential to advise on the particular approach and implementation.
- If the flooring is to be documented and removed to allow for further excavation, the role of the archaeologist is crucial.
- If the flooring is to be lifted and later repositioned in situ, close collaboration and coordination between conservators and archaeologists is necessary to plan the timing and sequence of intervention, as well as all appropriate documentation.

We can now turn to specific floor types and the logical sequence of events.

Lime-Based Floors (Cocciopesto, Opus Signinum, Opus Sectile)

WHAT MAY APPEAR

All lime-based floors share a common basic composition: lime and various aggregates mixed with colored river stone or ceramic fragments (*opus signinum*) or ceramic fragments only (*cocciopesto*) or stone pieces inserted in a regular geometric pattern (*opus sectile*). The visual differences are notable, but their conservation concerns are largely the same due to their shared lime mortar composition.

The major conservation issues for these three types of flooring and thus lime-based floorings in general are as follows:

- Lack of cohesion within the lime mortar itself
- Insufficient adhesion of the stone or terracotta fragments to the lime mortar
- Cracks, fissures, or missing areas whose edges are unstable and susceptible to continued deterioration
- Specific deterioration of the aggregate constituents

WHAT MAY HAPPEN

- The lack of cohesion within the lime mortar may not be visible when the flooring is still damp following excavation. This lack of cohesion will become more apparent during drying as the resultant stresses cause crumbling and powdering. Such mortars are highly susceptible to mechanical forces.
- Although the lime mortar may still have good adhesion, the lack of adhesion between the lime matrix and the stone or terracotta components can lead to their loss through foot traffic, sweeping, and so on.
- Borders, whether of cracks or missing areas, are generally quite fragile and will continue to erode and deteriorate.
- The deterioration of the terracotta and stone constituents can, in turn, cause new voids, which can lead to accelerated border erosion.

WHAT CAN BE DONE

- Cohesive consolidation of the lime mortar (see chap. 9)
- Adhesive consolidation to re-create physical bonds between stone or terracotta constituents and the lime mortar (see chap. 9)
- Edging and pointing of all crack and void edges with a lime-based mortar (see chap. 7)
- Specific consolidation of the stone constituents (see chap. 9)

Mosaic Floors

WHAT MAY APPEAR

At the moment of excavation, it may be difficult to fully assess the condition of a mosaic floor. The spaces between individual tesserae will most likely be filled with moist soil or sand, which can give a false impression of completeness and stability. Using small brushes, sponges, or swabs, very carefully remove any obscuring and incoherent soil from the grouting to get a better sense of whether:

- The tesserae are well embedded and still adhered to the bedding mortar
- The tesserae themselves are deteriorated
- Hollows or voids are present where the mosaic has detached from its bedding mortar
- Lacunae exist

WHAT MAY HAPPEN

Obscuring or overlying soil that dries at all, especially if it contains clay, will often shrink in volume, creating stresses and strains on the mosaic that can provoke:

- Progressive detachment of the tesserae from the lime mortar
- Progressive deterioration of stone or glass tesserae
- Sinking or collapsing of areas of the mosaic over hollows or voids
- Further erosion of the edges of cracks or areas of loss
- Creation of new cracks or losses due to human mechanical stresses such as trampling

WHAT CAN BE DONE

- Adhesive consolidation of loose tesserae and the mortar bedding (see chap. 9)
- Cohesive consolidation of the bedding mortar and grout (see chap. 9)
- Application of a temporary facing to all fragile tesserae or temporary removal of any loose tesserae (see chap. 7)
- Edging and pointing of all edges of cracks and voids (see chap. 7)
- Temporary covering of the flooring to protect it from mechanical damage

Movable Objects Composed of Inorganic Materials

Iron

A rusty reddish-brown color is a key indicator for iron material. It reveals past corrosion phenomena but does not signify the actual degree of mineralization, which is very important for iron objects. For this purpose accurate observation of the actual shape and overall volume of the object are better indicators. It can be useful to use a small magnet, which will indicate if there is any surviving noncorroded iron. See tables 5.1–5.4.

Table 5.1 Iron

What may be visible	Condition
A more or less saturated orange/brown surface color with incorporated soil	Slightly moist, well-aerated soil with fairly neutral pH
Light orange protuberances or bumps associated with an overall lightness of weight	Well-aerated soil
Irregular and blistery details and edges; rough, irregular surface; highly altered and virtually unrecognizable object form or shape	Advanced or fully mineralized object (more stable)
More or less universally blistery details and edges; rough but still regular surface; recognizable object form or shape	Partially mineralized object = ACTIVE material state! (unstable)
More rarely	
Whitish/light gray surface color	Chalky soil
Black surface color with bluish spots	Anaerobic soil

Table 5.2 Iron

Field test			
Objective	**Type of test**	**Result**	**Meaning**
Confirm the extent of mineralization of the archaeological metal	Small earth magnet (flat, cylinder shaped); do not use horseshoe-shaped magnets because too strong	Attraction	Some preserved metal
		Minimal or no attraction	Full mineralization (complete corrosion), no preserved metal

Table 5.3 Iron

What could happen	Condition
Object may fracture or fall apart during unearthing, removal, or temporary packing	The object is completely mineralized or at an advanced stage of mineralization = Fragile
Rapid and unavoidable reactivation of corrosion mechanisms to the detriment of any remaining metal A) Thin longitudinal fissures in the corrosion layers B) Subsequent delamination of the corrosion layers in relation to the fissures	ACTIVE material state! Partial or limited mineralization, humid environment
Formation and detachment of ovoid-shaped portions of corrosion	
Small, brown, acidic, bubble/droplet-shaped exudates	ACTIVE material state! Situated in very wet soil

Table 5.4 Iron

Condition	What can be done
In general	Avoid leaving in the ground.
	If dry: avoid humidifying or wetting; pack immediately with environmental conditioning agents such as silica gel (see chap. 12).
	If wet: dry out the object slowly and keep it dry; pack immediately with environmental conditioning materials like silica gel. Do not dry if associated with organic matter; instead pack immediately in a microclimate container and take quickly to a conservator (see chap. 12).
	If waterlogged: maintain its wet/saturated state and remove from the soil as soon as is feasible, pack immediately afterward in a microclimate container, and take quickly to a conservator.
	If it presents fractures or appears to have the risk of fracturing or breaking up, is thin and long in shape, is small, or appears in any way fragile: undertake a block lift to remove the object with surrounding soil (see chap. 10), handling as little as possible, and pack immediately with appropriate supports (see chap. 12).
If highly or completely mineralized	If dry: keep in an environment with low relative humidity, 15% or lower.
	Remove from the soil, lifting and packing with great caution: probable fracturing or falling apart.
	Always remove from the soil with a block lift (see chap. 10).
	If dry: never humidify or wet; this could cause swelling and fracturing; remove and perform initial cleaning using so-called dry techniques (see chap. 11); consolidation may be necessary prior to lifting; if full mineralization is more than likely, there is no need to pack within a microclimate.
	If wet: let slowly dry on its own; remove from the soil and undertake initial cleaning without further wetting the object; in other words operate as if it were dry.
If little mineralized; ACTIVE metallic material!	If dry: never humidify or wet; this favors the continued corrosion of the object; remove from the soil and undertake initial dry cleaning as soon as is feasible; eventually pack within a controlled microclimate (see chap. 12); document the condition of the object (see chap. 15 and Appendix 7).
	If wet: allow to dry; remove from the soil/effect initial cleaning without recourse to wetting; in other words, proceed as if it were dry.
	If waterlogged or very wet: remove from the soil as soon as possible; pack within a controlled microclimate (see chap. 12); turn over immediately to a conservator (immersion in water will not prevent iron from further corrosion) or document the condition of the material (see chap. 13 and Appendix 7).

Copper Alloys

Unlike iron, copper alloys can vary considerably in appearance depending on the type of soil in which they are found. In general copper alloys are chemically less reactive than iron but still susceptible to corrosion. See tables 5.5–5.7.

Table 5.5 Copper Alloys

What may be visible	Condition
Green color with adhered or incorporated soil; an irregular pattern of spalling, fine pitting, and superficial microfissuring that reveals an underlying light green powder	Common condition; ACTIVE corrosion!
Dark green (primary color); thin, compact, and smooth surface with an even appearance and good preservation of details	Aerated soil (particularly favorable condition)
More or less light green • Associated with dark green boils or warts • Associated with a rough, uneven surface with a loss of detail	Aerated, damp, acidic soil
Object formed from thin sheeting	
Recognizable body/shape of the object	
More rarely	
Superficial brown color	Wet soil
Superficial solid layer of black	
Metallic surface with black spots	
Superficial golden/yellow color	
Superficial blue color associated with a sugaring surface	Dry soil
Green/light blue superficial color	

Table 5.6 Copper Alloys

What could happen	Condition
Reactivation of active corrosion A) Continued spalling or pitting, followed by the development of voluminous light green powder B) Partial swelling and microfissuring of the outermost compact layer	Underlying layers or pockets of latent active corrosion (light green color)
Small, thin finds (needles, fibulae pins, etc.): if highly corroded can easily break or fall apart during excavation, lifting, or packing	Highly or completely mineralized object = Fragile

Table 5.7 Copper Alloys

Condition	What can be done
In general	Avoid endowing any type of mechanical forces or stresses to thin-walled or needle-like thin objects.
	If small, thin walled, needle-like, or appears at all fractured or fragile: remove from soil with block lifting (see chap. 10), minimize handling, and pack protectively (see chap. 12).
	If dry: store in an environment with relative humidity at or below 35%.
If dry or slightly damp	Let dry, and avoid rehumidifying or rewetting.
If waterlogged or saturated	Remove from the soil as soon as is feasible; pack immediately in a controlled microclimate (see chap. 12).
If damp or saturated and associated with organic materials	Do not allow the object to dry out; remove from the soil as soon as is feasible, and pack in an environmentally controlled container (see chap. 12); take to a conservator.
If with active corrosion	Remove from the soil as soon as is feasible, document the condition of the object (see chap. 13 and Appendix 7), and pack in a stable microenvironment (see chap. 12).
If coins	When highly corroded, avoid cleaning the surface by wiping as this can cause abrasion and subsequent loss of detail or possible breakage if fully mineralized; pack within a container as described in chapter 4.

Silver and Gold

As with copper alloys, the surfaces of silver objects present many different colors, which may not always be reliable indicators for identification. See tables 5.8–5.10.

Lead and Lead Alloys (Pewter)

Lead and pewter, as well as tin and zinc, have similar-looking superficial corrosion products. Even so, color can be an aid to recognition, especially if combined with other observations, such as the presence and pattern of microfissures and cracks. See tables 5.11–5.13.

Table 5.8 Silver and Gold

What may be visible	Condition
Black color associated with a smooth surface	Common: damp or wet soil
Even or spotted green color	Silver alloy with copper (can be confused for copper or bronze)
Whitish-green color	
Violet/purple color	Oxygenated and wet soil
Smooth, even, and flat surfaces	
More rarely	
Tarnished or darkened yellow	Minimal corrosion, dry soil

Table 5.9 Silver and Gold

What could happen	Condition
Black superficial surface oxidation (silver sulfide)	If pure silver
Outermost surface with a gray to purple/violet tone	If soil is wet and oxygenated
Green color, possible reactivation of the corrosion process on the surface	If combined with copper as an alloy

Table 5.10 Silver and Gold

Condition	What can be done
If the color varies from black to a grayish-purple or violet	Avoid fluctuations in temperature or humidity; remove from the soil as soon as possible, and pack; document the condition of the object (see chap. 13 and Appendix 7).
If the color is a variable green	Follow the actions suggested for dealing with copper alloys.
If the outer surface is corroded or embellished	Pack with care to avoid any form of abrasion to the corroded or embellished surfaces.

Table 5.11 Lead and Lead Alloys (Pewter)

What may be visible	Condition
Thin, white to gray layer; May be covered with a thin layer of light brown soil and corrosion products, sometimes together with brownish-violet streaks	For lead and pewter, most commonly alkaline, neutral, or slightly acidic soil
Compact, fragile, thin, dark gray layer associated with: Light gray spots Dark gray or brown-violet warts or pustules Deep pitting (rare)	Lead and pewter
Dense microfissures with a rectilinear pattern in parallel to any creases or folds	
Microfissures with a craquelure pattern	
Dark gray color associated with a powdery white encrustation	Zinc (late medieval)
Deep pitting	
More or less saturated dark gray with an earthy hue	Tin
More rarely	
Red spots	Lead and pewter
Inherent weight	Lead

Stone

The elements that help in identifying stone are similar to those for ceramics, and distinguishing between the two can be difficult. Like ceramics, stone can be found in pieces, but it is generally less prone to fragmentation and breakage because of its greater thickness and mechanical strength. Equally, color is not a reliable signifier because of the wide range of possibilities. Instead, identification is generally easiest when many elements are considered together: color, thickness, weight, surface appearance, and fragment size. See tables 5.14–5.16.

Table 5.12 Lead and Lead Alloys (Pewter)

What can happen	Condition
Deformation or distortion due to mechanical forces imparted during excavation	Lead
Breaking off of small parts in correspondence to microfractures	
Generally chemically stable corrosion	
Hydrolysis of the corrosion products (Turgoose's theory, to be substantiated)	In the case of tin, as an alloy or by itself

Table 5.13 Lead and Lead Alloys (Pewter)

Condition	What can be done
In general	Handle with extreme caution; high probability of mechanical damage (deformation or breakage in relation to microfissuring).
	Do not use cardboard containers for storage or any form of paper products with a slight acidity in relation to the object, as these will initiate corrosion.
	Do not use any form of polyvinyl acetate–based consolidants (e.g., Vinavil, Mowilith), as these can release organic acids.
If highly fissured	Block lift (chap. 10), and implement packing with adequate protection (see chap. 12).

Table 5.14 Stone

What may be visible	Condition
Rarely thin or curved profile objects	
Fragmentation, flaking	In general
Flakes and polygonal fragments with rounded edges; wide, irregular, or worn break edges and fractures	
Well-adhered encrustations	
Notable weight	
Flakes and polygonal fragments with sharp edges; concoidal, wide break edges and fractures	Siliceous stones (such as granite)
Great notable weight	

Table 5.15 Stone

What can happen	Condition
In the case of fluctuations in temperature, relative humidity, and water: contraction/expansion cycles, loss of cohesion of the outer surface (powdering), and microfissuring	Some porous stones, whether damp or wet
Soluble salt movement toward the exterior surfaces creates physical stress within the porous structure of the stone and produces efflorescence	
Disaggregation, "sugaring" of the exterior surface	

Table 5.16 Stone

Condition	What can be done
If damp or wet	Let dry slowly.
If porous	Light, cautious cleaning if the surface is not deteriorated; avoid cleaning with water; never use acids or other chemical reagents.
Fragile objects, highly fragmentary but held together by soil	Limit the amount of soil removed from the surface; avoid any form of cleaning if surfaces are powdering/chalking.
Exfoliating slate slabs	Stabilize the object (see chap. 7), block lift, and pack with adequate protection that incorporates shock-absorbent materials (see chap. 12).
Slabs, terracotta blocks, or revetments	

Ceramics

For ceramic materials, the variables between aesthetic appearance and state of preservation are endless, so our discussion focuses on the most common states of recovery and alteration phenomena. The first color that usually comes to mind with ceramics is a reddish-orange; however, though this color is often encountered, it cannot be considered a reliably consistent indicator because of the vast possible range of colors one may encounter in archaeological ceramics. Other parameters, such as thickness and surface glazes or slips, can be useful (see table 3.3). Weight can be a key element in discriminating between terracotta and stone. See tables 5.17–5.19.

Table 5.17 Ceramics

What may be visible	Condition
Fragments, sherds, or scaling	In general
Adhered soil	Terracotta without coating (slip, glaze, or any other form)
Powdery surface when dry; matte surface when wet	Terracotta with powdered surface
Relatively thin, curved or somewhat curving fragments	Terracotta vessel with or without coating in the form of slips or glazing
Exfoliation and expansion of thickness	
Scales and triangular or polygonal fragments with worn or rounded edges	Terracotta tiles, bricks, etc.
Color: from a light red to black (including all shades of red, orange, yellow, brown, and gray in between)	Terracotta and stoneware without coating
Primarily white color with a glossy surface	Porcelain or glazed fine earthenware (whiteware)
Thin fragments and/or chips with sharp, concoidal break edges	Porcelain
Iridescence, craquelure effect	Terracotta or fine earthenware (whiteware) with slip, glaze, or some form of vestment
Swelling of the glazed surface in relation to eventual flaking	

Glass

In addition to the predictable shards, glass can show very distinctive forms of surface deterioration, iridescence, and corrosion, which in themselves indicate an immediate need for conservation. See tables 5.20–5.22.

Table 5.18 Ceramics

What can happen	Condition
With temperature or relative humidity fluctuations or direct contact with moisture, alternating expansion and contraction may happen, as well as a loss of cohesion of the ceramic surface; may become powdery; and/or microfissures and cracks may form in the ceramic body and its surface, especially if thin and compact.	Moist or wet terracotta
The movement of soluble salts from the interior of the ceramic toward the external surface will create physical stresses within the ceramic fabric in the form of swelling and the creation of salt efflorescence on the surface.	
The movement of soluble salts from the interior of the ceramic toward the external surface will create physical stresses within the ceramic fabric; will create salt efflorescence between the clay body and the applied surface slip or glaze; will create swelling of any coating to the point of its fracture and eventual dislocation; will create salt efflorescence on the surface.	Moist or wet ceramics with coating (glaze, slip, etc.)

Table 5.19 Ceramics

Condition	What can be done
Damp or wet terracotta with/without coating	Allow to dry slowly; avoid rewetting (see chap. 6).
	Preliminary cleaning with extreme caution only if absolutely necessary (see chap. 4); do not submerge in water, and never apply any form of acid or other chemical reagents.
	Avoid cleaning if the surface is powdering or if coating has a craquelure appearance or displays cracks, swelling, or iridescence or is in any state of detachment.
	Avoid using water if treating bucchero or prehistoric ceramics.
Terracotta slabs, tiles, bricks	Pack with appropriate padding to protect against mechanical forces and stresses (see chap. 12).
If the surface slip or glaze or any form of surface treatment/decoration displays swelling, cracking, or exfoliation	Do not remove adhering or stabilizing soil; stabilize the fragments (see chap. 7) and block lift (see chap. 10); pack with appropriate padding to protect against mechanical forces and stresses (see chap. 12).
If fragmentary and held together by surrounding soil	
If fragile or structurally weak	

Table 5.20 Glass

What may be visible	Condition
Fragments or shards	In general
Clouded or loss of transparency and brilliance	Glass in the process of corroding
Sugary appearance	Crizzling (glass in the process of structurally breaking down)
Mother-of-pearl-like iridescence	Exterior layer of glass is extremely fragile and in the process of detaching from the rest of the object
Silver-like iridescence	

Table 5.21 Glass

What can happen	Condition
Detachment of the iridescent layers, whether opaque, mother-of-pearl-like, or silvery	Minimal fluctuations in relative humidity are sufficient
Detachment and loss of enameling (instances of decoration being applied to the glass surface)	
Reactivation of the corrosion process	

Table 5.22 Glass

Condition	What can be done
Always	Do not clean the surface of any soiling.
If damp or wet	Do not allow to dry, remove from the soil as soon as is feasible, and pack in a stable microclimate (see chap. 12).
If dry	Do not rehumidify or wet.
If the surface has opaque, mother-of-pearl-like, or silvery iridescence	Avoid any form of superficial or other cleaning; remove from the burial environment as soon as possible; if necessary block lift the glass object or fragments (see chap. 10); pack in a stable microclimate, especially with regard to the relative humidity (see chap. 12); document the condition of the object or shards (see chap. 13 and Appendix 7); transport to a conservator immediately for treatment.
If decorated by painting or enamel	
If crizzling	

Movable Objects Composed of Organic Materials

The following general characteristics are common to movable objects composed of organic materials. If found damp or wet they are:

- Soft and pliable to the touch
- Less fragile than when dry and can be deformed
- Subject to irreversible structural damage if they shed moisture on unearthing

If the objects are found dry they are:

- Generally very fragile

The initial phenomena of deterioration immediately after excavation are linked to water loss, which can provoke shrinkage and, depending on the specific material, lead to rigidity, deformation, cracking, flaking, crumbling, and general fragility.

Refer to the tables specified under each type of material below for details.

Bone and Ivory

See tables 5.23–5.25.

Wood

See tables 5.26–5.28.

Leather

See tables 5.29–5.32.

Table 5.23 Bone and Ivory

What may be visible	Condition
BONE	
White/pale yellow color	Common
Lightweight (if dry)	
Grayish-white color, powdery appearance; in relation to blackish/blue areas, more fragmentary and with a reduced volume in relation to the rest of the object	Burnt
Irregular, circular-sectioned; many break edges and a surface with longitudinal and parallel cracks and fissures	Skeleton, long bones
Dual morphological structure: a spongy interior and a dense, compact exterior	
Thin-walled (4 to 5 mm) and lightweight large fragments with an open curvature with three morphologies (two dense, compact exterior structures and an internal spongy structure); sawtooth-like join lines on the surface	Skeleton, cranium
IVORY	
Grayish-white color	Common
Superficial lamination (similar to overlapping shingles), sharp break edges	Generic
Dense, compact, laminated, and irregular circular section with a reduced internal cavity devoid of a spongy morphology	
White-grayish color with blackish-blue spots	Burnt
Consistent bluish-black color	

Table 5.24 Bone and Ivory

What can happen	Condition
Contraction, pronounced distortion, and curvature	BONE damp or wet (rapid drying)
Enlargement of cracks and fissures, collapse of highly fragmentary areas, breakage	
Internal cracking, immediate fracture	IVORY damp or wet (rapid drying)

Table 5.25 Bone and Ivory

Condition	What can be done
BONE	
Skeletons (especially human)	If dry: avoid rewetting.
	If damp or wet: allow to dry very slowly. In the case of long bones, rapid drying will result in distortion and a reduction in volume (dimensional alteration), resulting in the cracking of the cortical portion of the bone.
	If wet: avoid the use of cardboard boxes for packing or storage as they can quickly absorb moisture and weaken considerably, potentially collapsing or falling apart, and do not possess appropriate properties for being in contact with bone (see chap. 12).
	If they can be removed in sections of pieces: • If they are intact or only lightly fractured: gradually remove surrounding soil until they are completely exposed and free; methodically remove piece by piece after full and proper documentation. • If they are highly fragmentary and fractured and held together or in place by the surrounding soil: block lift in logical parts (see chap. 10). • Packing: Plastic containers are preferred to any form of cardboard, especially any paper products made of recycled material as they can be very acidic. Avoid wrapping bones in paper, as this is acidic and if the bone is still damp they can adhere to the surface; in addition, any form of graphics or printing on paper can be transferred onto the bone's surface. Utilize geotextile or nonwoven spun-bonded textiles (see chap. 6), and instead of wrapping the bones individually, use the textile to create an accordion-like configuration where the bones can be placed into the recesses, immobilizing them while allowing them to still be visible. In this way, successive layers can be created one on top of the other.
	If they cannot be lifted individually: undertake to block lift the assemblage under the guidance of a specialist or a conservator.
IVORY	
If damp or wet	Do not allow to dry, especially small, thin, and lamellar worked objects; remove from the burial environment as soon as possible, and pack in a stable microclimate (see chap. 12).

Table 5.26 Wood

What may be visible	Condition
Dark brown, apparently whole	Waterlogged
Soft to the touch: a spongy effect after slight pressure	If wet or saturated with water

Table 5.27 Wood

What can happen	Condition
Strong volumetric contraction, especially on the exterior, which can contract up to 80–90%	If saturated with water or waterlogged
Structural collapse	
Powdering and breaking up of the fibrous external surface until complete loss of cohesion, rendering the object difficult to remove and virtually impossible to handle	
Immediate formation of radial and tangential cracks	
Immediate distortion and deformation	

Table 5.28 Wood

Condition	What can be done
In general	Remove the minimum amount possible of surrounding soil; reduce the time of exposure (see chap. 6)
	Once packed, store at a low ambient temperature (3°–4°C)
	If completely dry, do not rehumidify or wet
	Handle with care
If damp or wet	Keep damp or wet; remove from the burial environment as soon as possible, and pack in a stable microclimate (see chap. 12); document the object, and turn it over as soon as possible to a conservator
	Do not wet further
If waterlogged	Request the immediate involvement of a conservator; avoid any drying (see chap. 6)

Table 5.29 Leather

What may be visible	Condition
Dark brown color (can be confused with soil)	Damp
Black or very dark brown color (can be confused with soil)	Completely waterlogged, gelatinous consistency
Whole, even, and stable appearance	

Table 5.30 Leather

Field test			
Objective	**Type of test**	**Result**	**Meaning**
Verify structural condition	Needle (insert a needle perpendicularly)	Easy and complete penetration of the needle with little resistance, gelatinous consistency	Structural loss
		Partial penetration with some resistance	Partial preservation of structure
Verify the surface condition (only if not gelatinous in consistency)	Absorbent paper, small sponge, or soft white fabric (pass gently over a section of the surface of the object)	Black and brown residue deposited onto the surface of the absorbent paper, sponge, or clean soft white cloth	Exterior layer or surface is altered (may not exclude the total alteration of the leather structure)

Table 5.31 Leather

What can happen	Condition
Immediate drying followed by: • Volumetric contraction with a wrinkling and folding of the surface and subsequent distortion, possible delamination and exfoliation • White circular blooms on the surface (efflorescence)	If damp or wet
Immediate drying followed by: • Strong volumetric contraction, folding and wrinkling of the surface, distortion, cracking, exfoliation, and powdering Loss of the object!	If waterlogged

Table 5.32 Leather

Condition	What can be done
Always	Remove the minimum amount possible of surface soiling; minimize the time of exposure of the object to environmental factors.
	Once packed, store in a low-temperature location (3°–4°C).
	If completely dry, do not rehumidify or wet.
	Handle with care.
If damp	Maintain dampness or saturated state; remove from the burial environment as soon as possible and pack in a stable microclimate (see chap. 12); fully document the object, and consign immediately to a conservator.
	No further wetting.
If wet or waterlogged	Do not directly touch the object; avoid any form of initial cleaning.
	Request the immediate involvement of a conservator.

Coverings and Shelters

Overview

In general, coverings or shelters are seen as solely a conservation need. This view denies the obvious advantages of their use for excavation activities. For example, even an inexpensive and temporary shelter of tubing and corrugated roofing can allow work to continue uninterrupted in conditions of rain, snow, or extreme heat and sun. Moreover, coverings have decided economic and scientific benefits by helping to preserve sensitive in situ features, objects, and stratigraphic sections and protect them from direct sunlight, heavy showers, and freezing nighttime temperatures. This, in turn, helps to limit the loss of archaeological information and to allow for its continued study, in addition to reducing the potential costs of future conservation work. Well-planned shelters can also serve to create a physical presence, providing a provisional work space over areas in need of treatment, or to restrict access to excavated areas, protecting against intrusion or theft. Such shelters can also be used to highlight ongoing excavation work or to allow greater visibility by enhancing the site presentation and making features more accessible to the public.

Coverings and shelters can be classified according to a number of criteria, the most common being the point of implementation and the length of intended use. There are improvised or temporary coverings and shelters that can be put into use during the course of excavation, for conservation work, or between seasons, as well as long-term or permanent ones that are constructed at the close of an excavation. In the latter case, one must consider further factors, as permanent coverings or shelters can have a profound influence on the long-term conservation of a site. In addition to their visual presentation and impact on the landscape, they create a new microclimate in close contact with the artifacts.

Criteria for determining the appropriate covering or shelter depend heavily on the interpreted significance of a site or feature and its perceived archaeological and cultural value. This basic decision often determines whether a site or feature is ultimately to be preserved visually (with a shelter) or reburied (with a covering). From a strictly conservation standpoint, the decision whether to use shelters or coverings should depend on the material(s) to be conserved and its state of preservation, the specific environmental parameters of the site, and the available funding. Regardless of type, all will require constant maintenance and monitoring.

Conventional Classification

A conventional classification of the most commonly used coverings and shelters has been developed by the authors using the technical characteristics and functional properties of each as a means of differentiation (table 6.1).

Typology and Implementation

The following discussion focuses on temporary shelters and coverings. Long-term or permanent measures and their myriad considerations and factors are beyond the scope of this book. For further discussion on this topic, concise, current

Table 6.1

Cloth, textiles, netting	Plastic or synthetic fabrics Awning or shading fabrics Agricultural netting or textiles Nonwoven textiles and geotextiles Gore-Tex®, Sympatex®, and other waterproof / breathable membranes Tar paper
Structures and roofs	Traditional shelters created from scaffolding members Rigid or bent-pole (tensile) tents Polycarbonate shelters Metal and glass shelters Wood and tile shelters
Containers	Buildings Subterranean structures
Localized protection	Small modular covers Temporary climatic "wafers" Capping of a top-wall
Reburial	Covered with chemically and physically stable, modern materials incorporated into modern foundations Reburied

scholarship can be found in postprints of the ARKOS group (AA.VV. 2000).

Basic Requirements for Temporary Shelters and Coverings

Based on their typology, temporary shelters and coverings must fulfill certain basic requirements:

- Protect excavated areas from climatic factors such as direct sun and moisture
- Not provoke or exacerbate environmental factors, such as increasing humidity levels or temperatures, that can prove detrimental to objects or features
- Not chemically or physically interact with or alter archaeological features or objects
- Not impede dramatically further excavation, documentation, or study

Coverings: Sheeting, Textiles, Netting

From the vast array of industrially manufactured and commercially available forms of synthetic sheeting, textiles, and netting, only a few have found widespread use and application in both conservation and excavation. The majority of these are polyethylene, nylon, polyester, or polypropylene and have been variously used to cover or shelter whole areas or particular features during excavation and between excavation campaigns. Of these, some, such as geotextiles, have also found routine use in both temporary and permanent reburial.

PLASTIC SHEETING

The most common form of temporary or improvised covering is waterproof plastic sheeting, made by casting molten plastic in mass. It is therefore appropriate to devote ample space to this material, its specific characteristics, potential impact on archaeological artifacts and features, and common misuse.

Polyethylene and nylon are the most typically used forms of plastic sheeting. These are similar in appearance, usually semitransparent white or solid black, but differ in chemical composition, which translates to differing molecular weights and, in practical terms, varied resistance to puncture and tear. Importantly, neither is permeable to water or air. This can have both positive and negative implications.

On the positive side, plastic sheeting can be useful where saturated artifacts must remain wet or must be dried very slowly and, for various reasons, cannot be immediately removed or stored under appropriate environmental conditions. Equally, in emergency situations such as sudden rain or snow, these sheets can make an important contribution by creating a barrier of protection against moisture while also providing resistance to the mechanical action of rainfall or the weight of accumulated snow. Combined with its low cost, availability, simple adaptability to various situations, and simplicity of placement and removal, these advantages make it easy to understand why plastic sheeting is widely used. However, these advantages should not overshadow the potential damage that can be caused by improper use, which then must be remedied by conservation, adding to costs and schedules.

Impermeability can also prove to be a negative characteristic in some situations. After heavy or prolonged precipitation, rainwater can accumulate and pool in the lower areas between features or in the voids and recesses of uneven pavements or excavation floors. The weight of the water can create strain on the plastic sheeting, resulting in tears and possible drainage under the covering. Even worse, much of this force may be transferred to the highest points of features, such as the tops of walls. If the plastic covering is large in scale, removal after storms can become problematic because of accumulated water and, if not done with care and planning, can even run a risk of wetting the very features that the covering was intended to protect.

All these examples indicate that the greatest misuse of plastic sheeting is putting it in direct contact with structures, features, or artifacts. This is more egregious if the plastic sheeting is fully or semitransparent and the covered areas are in direct sunlight. In these cases an inevitable warm and humid microclimate will be created that not only favors bacterial and plant growth but also leads to the chemical depletion and physical weakening of the materials that make up features and objects. A further consideration and risk is that condensation can form under plastic sheeting when temperatures fall, such as during the night. Combined with normal temperature changes between day and night, a cyclical change between humidity (gas) and condensation (liquid) can lead to the saturation and eventual deterioration of archaeological materials.

If exposed to solar radiation and sunlight for long periods, all plastic sheeting will begin to deteriorate. This is usually manifested in a gradual hardening of the plastic, resulting in eventual cracking and tearing. A similar effect can be caused by continued exposure to freeze/thaw cycles. Consequently, any plastic coverings used long term should be subject to regular monitoring and should be replaced when necessary.

For the proper use of plastic coverings:

- Avoid covering objects and features that will continually be in direct sunlight. Coverings are better suited for areas that are partially or wholly shaded.

- Suspend the covering a few centimeters above the surface of the features or artifacts rather than in direct contact with the surface to allow a constant flow of air and thereby minimize or avoid the possibility of biological growth or attack and condensation.
- Black plastic sheeting is generally preferable, especially with organic finds. There is a prejudice against dark coverings because of their greater absorption of heat, but much of this can be mitigated if it is employed in shaded areas or combined with insulating fabrics or textiles such as geotextiles.
- Avoid continual placement and removal of the sheeting because this can expose the archaeological features or objects to continued drastic changes in environment and humidity levels (see chap. 2).
- Use sheeting of small to medium size (2 × 2 or 3 × 3 m) to facilitate removal, particularly after rain or snow.
- Regularly check the condition of the covered features or objects.
- For prolonged use, perform a preventive treatment with a biocide to arrest or inhibit biological growth and attack under the plastic covering.
- Periodically monitor the condition of the sheeting and maintain and replace when necessary.

Ultimately, it must be kept in mind that even though the use of waterproof plastic coverings may seem more economical than shelters, the overall assessment of cost-effectiveness for long-term protection will usually prove favorable to shelters.

AWNING OR SHADING FABRIC/TEXTILES

Awning or shading fabrics are typically woven polyester fibers of a tight, regular mesh. Unlike polyethylene sheeting, polyester fabrics are woven and thus breathable while also being impermeable. This is highly advantageous because it offers many of the benefits of plastic sheeting with little of the risk of creating a microclimate. With this said, however, impermeability is continuous only as long as the fabrics are kept in tension and not allowed to be in direct contact with portions of features or artifacts. Any areas of contact can allow water to pass. Dark colors, such as blue, brown, or gray, can also create shade, reducing the passage of visible and IR light, and are excellent protection against UV light as well. In addition, awning/shading fabrics are generally highly resistant to puncture, tearing, or cutting and can withstand substantial mechanical loads caused by high winds.

CULTIVATION AND GREENHOUSE TEXTILES AND NETTING

This category of textiles refers to those typically used in horticulture, which are often found at plant nurseries, or used as truck tarpaulins. There are two basic types that are practical for use on excavations for both archaeological and conservation purposes: shading fabrics and nets and ground coverings.

Shading nets are by far the most commonly used type and are made up of polyethylene fibers arranged in a more or less regular weave pattern, the compactness of which creates various densities that determine the specific weight (85–170 g/m^2) and the degree of shading (20–90%). These typically are found in three colors: white, green, or black. Such fabrics are breathable, lightweight, and easy to employ, most having reinforced edges with incorporated eyelet holes for anchoring to rigid frames. The denser weaves (60%+) protect against wind, hail, and frost but not completely against rain. When used horizontally as roofing, this fabric serves as a physical barrier against rain but does not prevent dripping.

These textiles have found use for both archaeological and conservation activities in the horizontal as an alternative to other types of temporary shelters and vertically as a perimeter fence because of their properties of blocking the sun and the wind. The most obvious benefit of using these textiles is being able to work under favorable conditions of temperature, light, and air. From the perspective of conservation, netting can significantly reduce the amount of direct sun radiation on exposed archaeological remains, as well as prevent the rapid drying of freshly excavated or damp materials. It can play a functional and important role on a temporary basis (on localized and small modular shelters; see below). If netting is used as a covering over large excavated areas, however, its characteristics are not appropriate for indefinite use or as a means to replace other forms of shelter in the long term. As with plastic sheeting, shading nets are subject to wear and tear and degrade with prolonged exposure to the elements and therefore must be checked periodically and replaced.

Ground coverings are generally a dense network of polypropylene fibers (roughly 105 g/m^2). Their use usually requires no special preparations, as they are designed to rest on the ground and be in direct contact with soil. They are air and water permeable. Ground coverings have high resistance to mechanical wear from foot and vehicle traffic, which suggests their use as “runners” for particularly sensitive portions of a site where continued activity is likely. They are often used as a form of fencing and improvised roofing to provide shade over in situ objects or features.

GEOTEXTILES

Geotextiles are fabrics made from polypropylene or polyester fibers formed by either woven or nonwoven methods. Nonwoven geotextiles are created by so-called needle punching or spun bonding. Needle-punch textiles are very soft, having a feltlike structure, and are available in several thicknesses. Spun-bonded textiles are much thinner, having a paper-like appearance. Both geotextile types are air permeable and have good vertical permeability to moisture.

Nonwoven textiles are manufactured in a wide range of weights and densities (15–150 g/m^2) and are used in a wide variety of fields (medical, construction, etc.). Low- to middle-weight *spun-bonded* fabrics (17–30 g/m^2) can be used as an insulated covering for mobile finds that must remain in situ and are used in their packing as well (see below and chap. 12).

Needle-punched geotextiles are widely used in construction and landscaping and are designed as a form of soil reinforcement for the stabilization of roads, railways, airport runways, riverbanks, drainage systems, and retaining walls, to name a few features. They are becoming ever more present on archaeological excavations, especially in cases of reburial or in urban projects where it is necessary to quickly protect and isolate archaeological features from new construction. In these scenarios geotextiles appear to respond well to the needs of archaeologists and architects as an interface or barrier between archaeological stratigraphy and new earthen fill or between ancient or historical structures and new concrete foundations or slabs.

Nevertheless geotextiles are often wrongly implemented or used because they have, up to now, been assigned nearly miraculous protective properties. It should be noted that they do not perform any function whatsoever in protecting surfaces and materials from moisture, aside from buffering the mechanical action of falling rain and hail. Also, when draped over the high points or undulating surfaces of features, they can pose the risk of pulling or placing strain on edges or high points, especially in cases of reburial where the weight of the earthen backfill during interment will pull on the fabric. Another potential drawback is the fact that when used as a covering geotextiles can act as a receptor for dust, dirt, soil, and water. The finer particles of these substances can gradually migrate through the nonwoven fibers onto the surfaces of the objects or features below, creating a colloidal interface, which is an ideal microclimate for root growth of some plants. Finally, spun-bonded geotextiles can deteriorate rapidly if subjected to direct UV sunlight or continuous handling or mechanical action, especially when wet.

Geonets (or geogrids) are a wide industrial category of nets made for soil erosion control. They have an open bi- or tridimensional structure made from polyethylene resin, often laminated with geotextiles on one or both sides. They can be used to prevent or contain erosion of excavation trench walls, reinforcing their weight-bearing capacity.

Gore-Tex® is not a fabric geotextile per se but rather a hydrophilic membrane of polytetrafluoroethylene (PTFE) with a closed, microporous structure (1.4 billion pores/cm^2, each pore being 700 times greater than the largest gaseous water molecule), which ensures absolute impermeability to liquid from one side and permeability of air and gas and water from the other side. This membrane is somewhat delicate, so it is coupled with other protective fabrics, such as polyester, the choice of which is important because their properties (i.e., impermeability) can have adverse effects on overall performance (D'Albore 2000). Gore-Tex® is also resistant to chemical, biological, and acid attack and can sustain a wide temperature range (–40° to +50°C). In addition, it protects against UV radiation.

Currently there are few documented cases of Gore-Tex® being used on excavations for conservation purposes. This is most likely due to its high cost. Where it has been used, for example, in the southern necropolis of Falerii (Viterbo), records indicate its efficacy and durability as a covering and barrier material (Bellucci, Caretta, and Cristopolis 1999). At Viterbo Gore-Tex® was used to cover a burial monument for roughly four years, with good results.

Shelters

The term *shelter* encompasses all forms of structures, from simple to complex and from temporary to permanent. In the following sections we discuss the theoretical and practical considerations relating to the requirements and function of shelters commonly used during and at the conclusion of excavation campaigns.

The following basic requirements have been proposed for freestanding shelters (Santoro and Santopouli 2000):

- Sufficient height to allow for continued excavation, conservation, and documentation activities; a minimum height of 2 meters should guarantee free movement of professionals below, while a height closer to 4 meters may be necessary for overhead photography and documentation
- Sufficiently lighted to allow for visibility and continued excavation or conservation treatment but not so bright as to fade or degrade pigments or promote plant growth

- Wide enough to completely cover the excavated area and to be structurally stable, even under strong winds, but with as few supports as possible so as to not physically interfere with, interact with, or alter the archaeological features or objects
- Reversible, even if used for a long time, by means of dismantling with a minimum of risk to the structures and artifacts below
- Reusable (if possible)

TRADITIONAL SHELTERS

Traditional shelters are among the most common and practical forms of adaptable shelter ever devised, consisting of a vertical structure of metal scaffolding tubes (A), a horizontal element made of the same scaffolding tubing (B), and a roof (C) of corrugated fiberglass or tin sheets or any form of conventional impermeable covering (fig. 6.1). Roofing with industrial insulated panels (metal or painted plastic outer skin with a polyurethane fire-retardant core) may be particularly useful for sheltering structures or features exposed to large amounts of direct sunlight. Roofs of this type can dissipate the heat buildup of solar radiation by acting as a heat sink.

This type of shelter is especially well suited for ongoing excavations because of its adaptability. A traditional scaffolding-and-corrugated-roof shelter may initially be a small structure and then be expanded up to a size of 80 to 100 square meters as excavation continues. In all of its manifestations, whether small, medium-sized, or large, it is important that this type of shelter be constructed taking into consideration its overall weight and the loads it can support, as well as the slope of the roof and the direction of water runoff and drainage. By calculating and designing for these three factors, disastrous accidents due to the failure of the roof or the entire structure can be avoided (figs. 6.2, 6.3).

With this in mind, we provide some basic guidelines for building traditional tube-and-corrugated-roof shelters. First, an example of traditional shelter construction follows.

In the case of a trench of 2 × 3 m (A), a shelter of 4 × 5 m should be designed to allow for sufficient cover from rainfall and sunlight (B), leaving an earthen perimeter of roughly 1 meter on all sides to act as a walkway or space for temporary storage of materials and equipment (C) (fig. 6.4a). If the edge

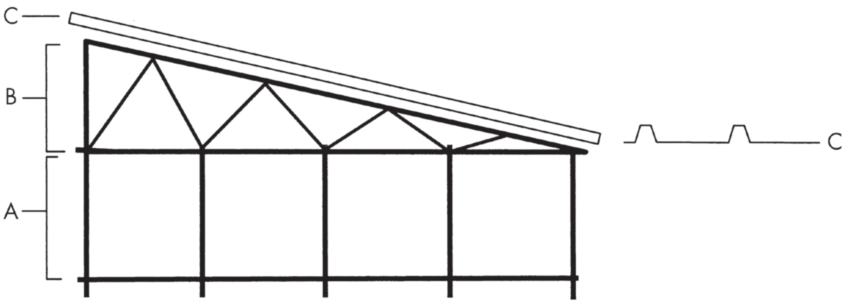


Figure 6.1 Section diagram of the basic configuration of a standard or traditional shelter made from scaffolding legs and a corrugated roof (see also fig. 6.3).

Figure 6.2 A poorly conceived and implemented shelter of corrugated roofing and scaffolding. A medium-intensity snowfall (25 cm in a 24-hour period, the same as that featured in fig. 6.3) caused its total collapse. The same materials and "modular" construction were used for both shelters (slope of the roof, distance between vertical supports). If this proved sufficient to protect the vertical structure featured in figure 6.3, the failure of the same for the greater horizontal area of the first shelter indicates that the roof needed a much steeper slope or that the spacing between vertical support elements needed to be much reduced.

Figure 6.3 A protective shelter properly constructed. The slope of the roof is appropriate for the horizontal area covered, allowing for the progressive discharge of precipitation, even in the event of snow.

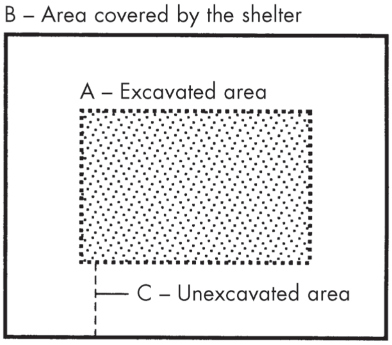


Figure 6.4a Section diagram of the spatial relationship between the excavated area and the area covered by a shelter.

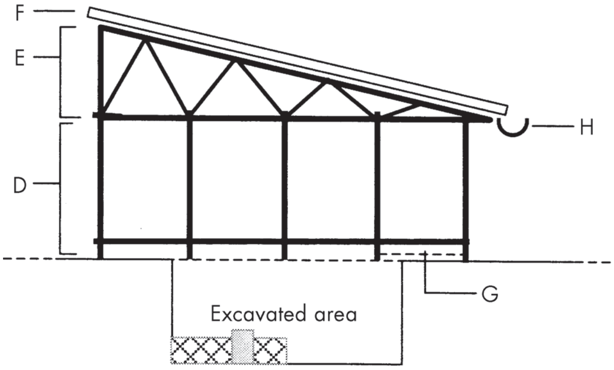


Figure 6.4b Section diagram of a protective shelter.

of the shelter were equal to that of the excavated area, its protective function would be compromised; direct sunlight would hit much of the exposed trench and precipitation could wet its edges and walls, creating risk of their erosion or collapse.

The vertical supports can have a maximum distance of 1.00 to 1.25 m from one another (G). If the shelter is erected in areas where there is snowfall, the horizontal structure (E) should be trussed for stability and to be able to support the weight of accumulated snow. (See fig. 6.4b.)

With regard to the roof, the basic parameters to consider are the slope and the spacing or distance between support beams. Where rain is the only consideration, a 10% incline per linear meter is sufficient. For areas where snow is a factor, a slope of 20% to 25% per meter is necessary. Storm water and snowmelt must also be considered and the eaves properly oriented to accommodate them, or a system of gutters must be incorporated to capture and direct water safely from the sheltered area. Where snow is uncommon, the distance between roof support beams can be up to 100 to 120 cm; where it is common they should be no more than 60 cm apart to deal with possible accumulation.

In terms of safety, any jutting points, corners, or bolts on the scaffolding that one could bump into should be covered or padded. A perimeter fence of netting could be made at the edge of the exposed trench or at the edge of the shelter to prevent falls into the excavated area. In urban excavations, perimeter fences help give visibility and ward against accidental trespass by the public. In such situations, transparent polycarbonate panels or wooden or metallic panels with clear polycarbonate windows may be better suited than simple netting as a perimeter barrier (Carandini 2000).

From an aesthetic standpoint, these types of shelters are quite unattractive and have a considerable impact on the appearance of a site or feature. Even so, they are highly effective in many respects (economic, organizational, logistical, and technical) and are practical and adaptable to most archaeological situations. It is for these reasons that, with or without perimeter fences, this basic form of covering is the most commonly used for ongoing excavations and for protection between excavation seasons. In general, scaffolding framework (fig. 6.5) and simple roof shelters offer the following advantages:

- They protect artifacts from precipitation (rain, hail, snow) and direct sunlight.
- They reduce the action of wind while simultaneously allowing for moderate air circulation, which can be useful to inhibit the growth of macro- and microorganisms.
- They may inhibit or prevent the formation of surface frost on excavated areas and structures in areas with cold winter climates.
- They lower costs by reducing or preventing deterioration of in situ structures or artifacts as well as stratigraphic sections, which in turn minimizes the amount of recleaning of excavated areas and the need for conservation intervention.
- They allow continuous visual monitoring of the state of preservation of recovered materials and features.
- They allow for excavation work or conservation activities to continue unimpeded in all weather conditions.
- They avoid the complicated operations of repeated covering and uncovering of excavated areas.

By contrast, there are a few disadvantages:

- They need many vertical supports around their perimeters (usually one per meter), which can be physically disturbing to ongoing excavation and documentation and visually disturbing to the presentation of the site, structure, or feature.
- They may incur the costs of short- or long-term rental.

Excavated areas can also be successfully covered using alternative sheltering systems. Small to medium-sized trenches (up to 4 × 6 m) can be effectively covered by ready-made modular tents or greenhouse structures, better known as tensile structures, which consist of a constructible/collapsible frame that is kept in tension with sheeting (preferably white cotton or polyester rather than PVC). One drawback is that these need to be anchored well to the ground for stability in strong winds. This can involve cords, stakes, or rods that might impede movement outside of these structures or be obstructive to other activities on-site. A bigger and more advanced adjustable tensile structure could be applied in the case of more extended areas (fig. 6.6).

In the event of large or irregular excavation areas (larger than 30 m^2), traditional scaffolding shelters may be better than small, prefabricated modular coverings. Beyond these dimensions an ad hoc approach to either type of system is advisable.

Specifically constructed shelters can also be designed and created to the exact conditions and planned operations of a site. An effective example

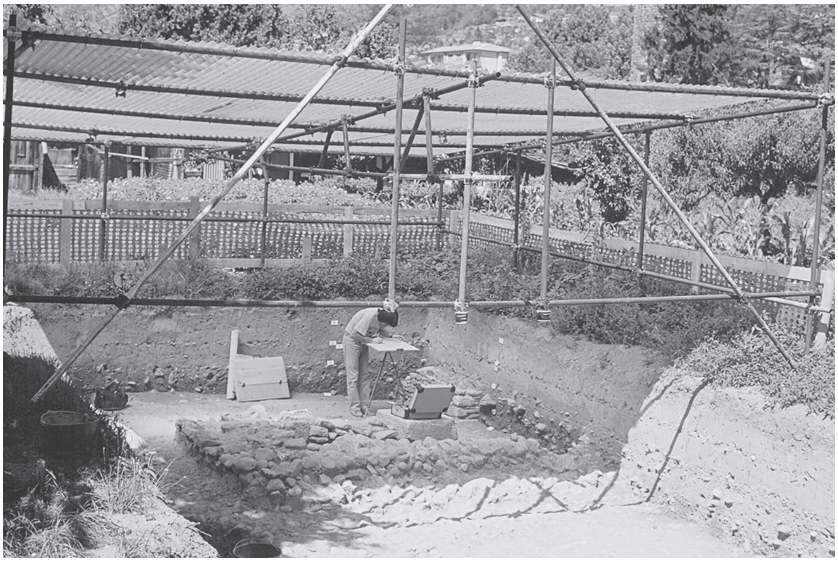


Figure 6.5 Shelter made from scaffolding legs and corrugated roofing panels to protect an excavated area during its ongoing excavation. The diffused and filtered light permitted by the corrugated roof facilitates the preservation of the recovered features but does not impede documentation or further excavation activities.

Figure 6.6 A mobile shelter for the temporary protection of areas under excavation in the urban center of Aosta.

of this is the city of Aosta, Italy, where a series of twelve excavation trenches were to be dug in the historic urban center. Here, two movable wood frame and corrugated fiberglass paneled structures were designed and built to be moved from one excavation area to the next without dismantling and with minimal effort (fig. 6.7). The fiberglass panels allowed optimal lighting conditions for work while protecting excavators and conservators from rainfall. When activities were completed in one area, the shelter could be lifted onto casters and moved to the next location. In addition to creating a good working environment, the shelters allowed the public to view the work being performed while preventing access by unauthorized personnel.

Another alternative is so-called framed tent structures, such as those used for outdoor weddings or temporary military facilities. Tent structures can be fabricated to the specific dimensions of various materials, making them highly adaptable to project needs and environmental conditions. In general they have characteristics superior to all other forms of shelter; they are highly functional and easy to use. It should not be overlooked that such structures may prove to be more cost-effective in the long run than most other traditional, modular, or ad hoc solutions. In addition, they are aesthetically pleasing and offer better integration with the landscape and the overall site (AA.VV. 2000).

Localized and Small-Scale Shelters

Localized shelters are defined as small to medium-sized coverings meant to be used for a short duration to protect significant or vulnerable artifacts or features during the course of excavation or immediately after unearthing to allow for their full documentation or emergency stabilization.

Figure 6.7 An adjustable-height modular tensile structure for the protection of features during their conservation.

SMALL MODULAR SHELTERS

Small modular shelters are those that can be easily placed and removed at any time and at any point on a site without physically interacting with the objects or features they are meant to shelter. These can be commercially available structures, such as collapsible tents or canopies, which can be easily modified and adapted to any particular situation. Likewise, these can be structures designed and fabricated specifically to and for a particular set of parameters.

The following are basic requirements for localized structures:

- Must be lightweight, self-supporting, adjustable, noninvasive, easy to assemble and use, and easy to remove and disassemble
- Must be able to be fixed in place without external cords or other types of anchors that can damage the surrounding archaeological stratigraphy or become an obstacle to further excavation
- Must protect the object(s) in question and the area immediately around it from all forms of precipitation (rain, sleet, snow) and direct sunlight
- Should not create a microclimate that can prevent air flow or create condensation
- Must not interact with or damage the object(s) it is meant to protect
- Must be made of materials that can withstand sun, wind, and rain and will not easily break under sustained or sudden load
- Must be able to function for short (e.g., emergency) as well as long-term use

A prototype conforming to the above requirements was built in 1999 by the Department of Cultural Heritage of Aosta Valley (northwestern Italy) for rescue excavations and emergency interventions. The small shelter consisted of conventional galvanized steel arches from small garden greenhouses with a polyester tent fabric as the covering to create a tunnel-like structure (fig. 6.8). The total dimensions were 1.20 m long by 0.80 m wide by 0.70 m high. The fabric did not cover the two short ends or the very bottom of the long sides so as to prevent it from coming into contact with moist earth or pooled water and from losing its impermeability through capillary action.

The tent fabric is removable. It is secured to the frame by a series of Velcro anchor points, making it easy to remove for washing or to be replaced with other fabrics depending on the conditions. Under intense sunlight exposure, the polyester fabric can be replaced with shading fabrics or used in association with a reflective aluminum-coated fabric textile. The entire shelter is anchored to the ground by small tent stakes rather than external straps or poles. Alternatively, small sandbags can be used to weight against winds and to keep the structure in place. The low and round shape, combined with the open ends, makes it resistant to wind gusts and prevents the creation of a hot and humid microclimate.

The total cost of this small shelter was roughly 35 Euros, including fabric and Velcro. The individual arches provide adaptability in terms of size to meet space requirements or peculiarities of terrain.

In principle, a similar type of localized shelter of inclined panels to create a triangular tunnel was devised in 1989 to protect medium-sized archaeological finds in the petrified forest of Dunarobba in Umbria, Italy (Piperno 1993). Looking to the horticultural industry, one sees many possibilities for all sorts of adaptable modular structures. In particular,

Figure 6.8 A modified portable greenhouse structure used to provide localized temporary protection for a burial in the process of being excavated.

polypropylene structural elements and polycarbonate paneling show great promise for creating affordable structures of all possible shapes and sizes.

"CLIMATE WAFER"

A "climate wafer" is a multilayered covering intended to be in direct contact with the recovered object to maintain the relative humidity and temperature at the time of its excavation. This type of covering becomes essential in the case of very fragile, environmentally sensitive materials like organics, especially those recovered from wet, cool, oxygen-deprived soils that may react adversely to ambient environmental conditions (see chaps. 3 and 5). Their use can be essential in guaranteeing the stability of many object types but should generally not be considered for metal finds, particularly iron.

Several variations of this type of covering can be created in situ depending on the nature of the artifact, its state of preservation, and the logistics and resources available. Based on reported experiences, a general illustration is provided here of a wafer covering designed by the Department of Cultural Heritage of the Aosta Valley to allow for gradual drying of inorganic remains from very wet environments that otherwise would be subjected to rapid drying and resulting decohesion (fig. 6.9). Such an application could be effective on friable ceramics or mortars, such as in a floor of opus signinum.

This wafer-like covering is composed of several superimposed layers, the first a prewetted, heavyweight geotextile (200 g/m^2) placed in direct contact and conformed to the specific shape of the object or feature in question (fig. 6.9, 1). The geotextile acts as a protective layer to and physical separator from the other superimposed materials. The next layer is common aluminum foil (fig. 6.9, 2), which acts as a thermal barrier, followed by a 4 to 6 cm layer of moist soft soil applied over the aluminum foil to act as an external heat dissipater (fig. 6.9, 3). Another layer of aluminum foil is added over this (fig. 6.9, 5) to insulate solar radiation and light and keep the earth moist. In cases where the artifact or feature must remain covered for long periods, the insulation properties of the layered wafer covering can be improved by incorporating polystyrene foam or insulating foam between the moistened earth and outer aluminum layer (fig. 6.9, 4).

All these layers can easily be removed together and reapplied if necessary. When such a system is used, the type of material and its condition must be considered carefully and the thickness of layers adjusted so that the total weight of the covering and the application of the different layers does not cause any type of damage to the object.

In the case of small to medium-sized waterlogged or wet organic finds, a possible variation of the layered "wafer" covering is to replace the initial layer of geotextile with a thin film of polyethylene food wrap. This layer can be covered with moistened earth and the entire assembly covered with aluminum foil. In other words, the wafer covering is a concept; the types, numbers, and sequence of layers are adaptable to the nature of the material to be covered. A word of caution: aluminum foil should not be put in direct contact with an object or feature without an insulating material in between (geotextile, damp earth, etc.) because, although it acts as an insulator from the sun, it can conduct the resultant heat directly to the artifact.

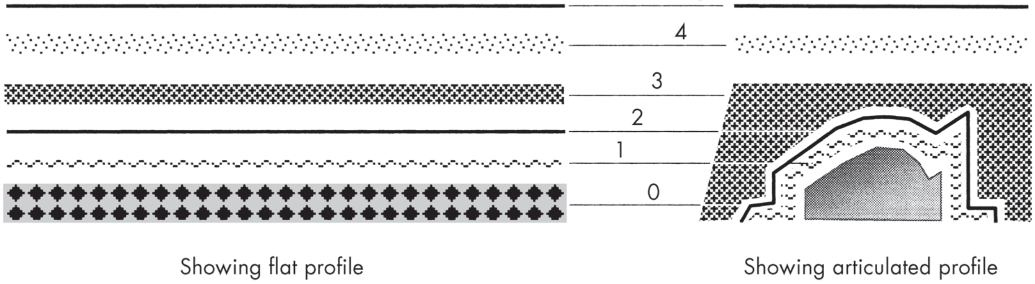


Figure 6.9 Section diagram of a "climate wafer."

Stabilization

The majority of archaeological materials have found some form of equilibrium within the burial environment (see chap. 2). For many materials, this was reached at the expense of physical stability. Accordingly, most of these objects or features will display extreme fragility at the moment of their exposure due to deep and diffuse structural fracturing or localized areas of exfoliation or disaggregation.

The soil surrounding archaeological remains often serves a protective function against environmental and atmospheric agents and, importantly, as a structural support. As unearthing progresses, this stability can be gradually removed or undermined, making it necessary to develop and implement a temporary system that re-creates support. This can take a wide variety of forms.

Most stabilization involves a series of activities or operations aimed at preserving the physical state of an object while allowing excavation to continue. All these operations must meet the following basic requirements:

- Rapid and easy deployment, installation, and removal
- Maximum reversibility to allow the continuation of archaeological and/or conservation work
- Limited interaction with and minimum alteration to the material in question

The most common stabilization operations respond to two basic types of problems: structural and mechanical.

Structural Intervention

When the physical stability of an archaeological feature is in question, either during or after excavation, some form of external support is not only appropriate but most likely necessary. Any form of intervention should respond to the specific factors affecting the stability of the remains. This is done by carefully considering all the possible forces acting on the feature and the potential movements they could provoke. Identifying these two variables should then define the critical points in need of support. This is a specialized skill and should be entrusted to competent individuals to perform or, at the very least, to plan the appropriate actions to be taken.

Shoring or Bracing

Shoring or bracing is commonly used on vertical masonry structures to counter the force of gravity and in so doing prevent sections from bulging or ultimately collapsing. It can also be considered as a support for typical wall coverings such as plaster or frescoes. In all these cases, whether large or small, the following basic parameters guarantee proper implementation:

- Shoring should cover and support a larger area than that in question in order to adequately absorb, distribute, and counter any forces acting on the feature.
- If, as is common, wooden bracing is used, the point of contact between the support and the feature should be pretreated with a broad-spectrum biocide, and a water-permeable interface such as geotextile included (see chap. 6). This will prevent the formation of condensation and/or microorganisms between the point of the wooden brace and the archaeological remains. If the support is to remain in place for a long time, it may also be necessary to pretreat the wood with an insecticide, especially against termites.
- If supports or braces are to sustain delicate or vulnerable surfaces, it is advisable to incorporate a shock-absorbent material of sufficient thickness and density, such as expandable polyethylene foam (see chap. 12), between the shoring and a permeable, chemically resistant, and inert interface material that is in direct contact with the surface of the feature (see chap. 6).
- Supports or bracing should interfere as little as possible with excavation or other common archaeological activities.

Large areas of wall plaster that are undulating or bulging in sections and threaten to detach entirely from their masonry support usually require an intensive treatment of consolidation and reanchoring through injection grouting. In terms of time, this type of intervention can increase exponentially in relation to the amount of surface area to be treated, often making it difficult to undertake within the parameters of a regular excavation season. In cases such as this, shoring provides a temporary means to safeguard and preserve the structural integrity of the plaster while allowing the archaeological and conservation programs to proceed virtually unobstructed or altered.

One of the techniques that can be used to temporarily support large sections of wall plaster is summarized in figure 7.1:

- The surface of the archaeological remains is covered with a thin barrier or isolating layer, such as aluminum foil or polyethylene plastic food wrap.
- A board also covered and isolated by aluminum foil or polyethylene plastic food wrap is placed in front of the section of wall plaster at a distance of about 2 cm from the feature's surface.
- The space or void between the board and the plaster surface is filled with polyurethane resin combined with a foaming agent to cause expansion.
- Any excess polyurethane foam from the edges is trimmed after expansion and curing.

This type of support has no chemical interaction with the archaeological material and effectively supports the entire surface of the plaster by casting any peculiarities, details, or undulations in a lightweight material (expanded polyurethane). Once in place, the support effectively counteracts the force of gravity if braced from behind (fig. 7.1) and immobilizes the plaster, allowing the conservation treatment of reanchoring by mortar injection to be performed without obstacle at any point in the future. After treatment, the support can be removed without any adverse effects to the archaeological substrate. The only potential downside to such a support is the relatively rapid decay (about ten months) of polyurethane foams when exposed continuously to UV rays and oxygen.

With a similar approach and any number of materials that fulfill the basic requirements of barriers and space fillers, simple braces or supports can be implemented throughout a site for many circumstances, from shoring up portions of walls at risk of falling to supporting smaller features or mobile objects.

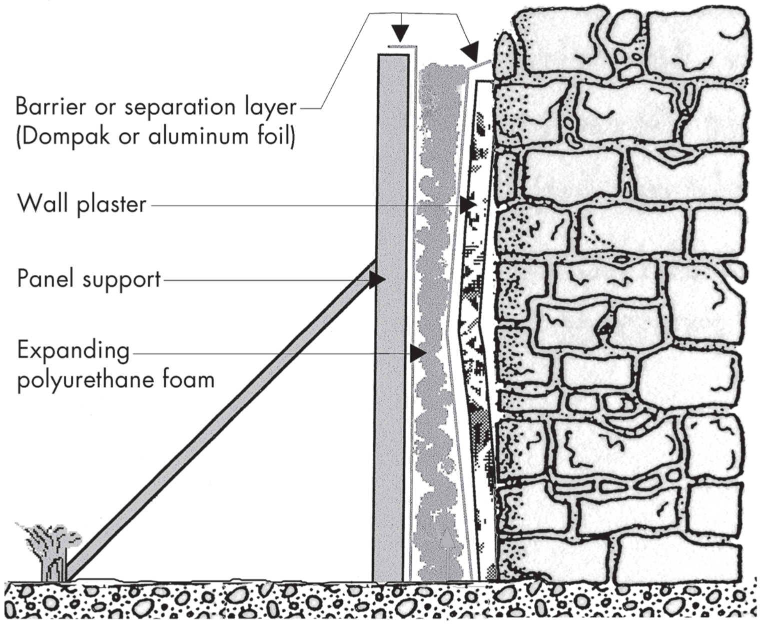


Figure 7.1 Section diagram of a support for wall plaster.

Strapping or Ratcheting

The technique of strapping or ratcheting is based on holding pieces of an object or feature in place by using adjustable strapping around their exterior as a form of binding. Once in place, the strap is put in tension, which in turn exerts pressure along its length. The strap thus serves to contain and immobilize any exfoliating fragments or large sections that have completely separated from the rest of the material body (figs. 7.2, 7.3). Where a single strap is inadequate to stabilize the object, two, three, or even more straps can be employed parallel to or crossing one another to cover more surface area. Equally, if necessary, strapping can be combined with rigid lengths of wood or piping, as well as panels, placed between the strap and the feature to act as a form of splint or structural reinforcement.

Field experience has suggested that this technique is particularly well suited and effective for cylindrical, square, and rectangular materials of all scales. Ratcheting can also be used to stabilize small to medium-sized portions of composite masonry or remaining earthen features, as long as it is possible to completely encircle the feature and an appropriately shaped paneling can be added as reinforcement (see fig. 7.2). In other cases, ratcheting can be used with or without boards to help in block-lifting operations.

The main advantage of strapping systems is that they are an inexpensive, quick, and reversible form of support that does not involve the use of specialized equipment, techniques, or personnel. Their use can stabilize a situation that otherwise would result in gradual

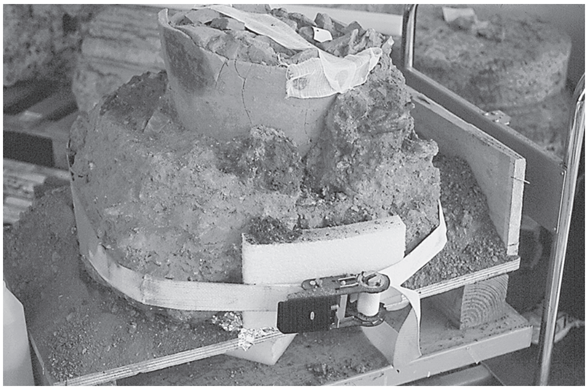


Figure 7.2 Portions of an amphora fixed in place with cotton gauze and consolidant and immobilized for block lifting with adjustable ratchet straps.

loss of fragments or eventual collapse. Unlike some forms of shoring or bandaging (see below), strapping also has the advantage of leaving much of the feature or object exposed, allowing for constant monitoring of the situation, as well as avoiding the possibility of creating a microclimate.

In principle, all strapping or ratcheting systems can temporarily ensure stability. They are not effective in the long term in cases of excessive or extreme forces (here shoring may be a better option), nor are they an extremely localized technique like gluing or facing that can immobilize multiple small fragments. In this sense, strapping techniques are generally very good for stabilization during excavation but may not be the best possible option for all situations.

Strapping can be performed with many different types of materials, depending on the nature of the archaeological remain and its state of preservation. The following are materials that have been commonly used on excavations.

Ratchet straps: Ratchet straps consist of flat, woven nylon straps that have a metal ratcheting mechanism at one end (see fig. 7.2). The opposite end of the strap is fed through the ratchet and pulled tight, and then the ratchet is used to gradually adjust to the desired tension. The advantage of these forms of straps is that they are infinitely adjustable to both the size and the condition of an object or feature and are reusable. In general, these are best suited for temporary and quick stabilization of medium to large features that are not highly fragmentary, friable, or crumbly. Such straps can also be used to secure objects in place during transport. Their resistance to water and sunlight make them suitable for prolonged outdoor use.

Plastic straps and buckles for commercial packaging and transport: These types of straps are generally of polypropylene or polyester and have a thickness of 0.5 mm and a width that varies from 12 to 13 mm. Unlike ratchet straps, these are not premanufactured or adaptable to the dimensions of a feature but rather can be cut to the desired length and then put in place along the principal orientation planes or at various angles to involve or avoid certain edges or fragile protuberances (see fig. 7.3). These are suitable for temporarily containing highly fragmentary remains of small to medium dimensions and are resistant to water, UV light, most chemicals, and extreme temperature changes. They do not tear or fray but lose their mechanical properties as soon as they are cut perpendicular to their length.

Figure 7.3 Adjustable-tension polypropylene (PP) straps used to hold large exfoliating sections of a marble inscription together.

Velcro® strips: Different sizes and colors of Velcro® straps are easily available in fabric stores. Velcro® is not designed to work in great tension. Compared to plastic straps, Velcro® has the great advantage of being fairly flexible, allowing a better fit on irregular and uneven shapes, and can be quickly and easily adjusted or removed at any time. The compressive forces Velcro® can endow are far more modest than those possible with ratchet or plastic strapping, which lends its use to smaller and more delicate materials and remains. Strips in use should be checked regularly as they tend to gradually release their initial tensile force.

Elastic bands: Elastic bands are formed by weaving warps of latex threads with wefts of polyester threads. They are available in many sizes and colors and are easily found at most fabric stores. In general they are sold as flat, white ribbons of various widths that can be cut to specific measurements so as to give greater or lesser compressive pressure depending on how tightly they are wound. This adaptability makes them well suited for use with different volumes and shapes; they find their greatest use in temporarily stabilizing freshly excavated small and delicate remains. Because elastic bands contain latex they are sensitive to UV light and do not have long-term chemical and physical stability. This makes their use appropriate as a temporary means of stabilization and not as a long-term measure.

Bandaging

Bandaging is a technique that has been widely used on excavations for a long time. The technique is similar in principle to strapping but differs in that it covers or encases a far greater amount of the feature or object in question. Bandaging is usually employed when a recovered material is highly fragmentary or friable or has multiple structural failures requiring it to be fully contained. Depending on the condition of the object, its features, and the type of further excavation or cleaning that is to take place, bandaging can be undertaken from top to bottom or vice versa, or at strategic points of vulnerability only. Likely future work and its required access to the object will also help determine the type of bandaging material to be used.

Bandaging has been widely described and recommended for block lifting (see "Supported Block Lifting" in chap. 10). But it is also very practical during the course of excavation, provided that its use is based on understanding and balancing conservation needs with archaeological ones. Indeed, as an alternative to traditional conservation approaches to stabilization (see table 10.1), bandaging can be equally effective, and it is easier, quicker, and more adaptable to various situations. Accordingly, a brief discussion follows of the various systems of temporary bandaging used at the moment of unearthing (see chap. 4), as well as during later operations of removal, lifting, and transport (see chap. 10).

Plastic wrap and polyethylene films for packaging: These types of plastics come in large, transparent white or black rolls, manufactured to wrap boxes, crates, and/or luggage. Those suitable for small to medium-sized archaeological materials are roughly 10 cm in width, slightly elastic with good tensile strength, and impermeable to water. These last characteristics suggest their use for bandaging or wrapping objects or features such as fragile organic or earthen remains recovered in a waterlogged or wet state that are to remain damp or are to dry out slowly (fig. 7.4).

Figure 7.4 A highly fragmentary ceramic urn and its contents, immobilized and block lifted from damp soil with polyethylene bandages.

The physical characteristics of the plastic are well suited to the requirements of bandaging but at the same time can have a decisive effect, both positive and negative, on the microclimate of the recovered material. If transparent plastic is used, it can allow for partial monitoring of the bandaged remains. At the same time, however, if exposed to the sun clear plastic has a tendency to favor biological growth by creating a greenhouse effect. Conversely, black plastics prevent the passage of sunlight, avoiding most of the phenomena associated with this, but tend to create condensation. Based on these observations, we suggest exercising caution; use impermeable bandaging only after considering the nature of the material to be stabilized, its condition and specific state of humidity (wet, moist or dry), and its possible reactions to a new microclimate.

Jute and cotton medical bandages: Jute bandages are usually obtained by cutting strips from larger swaths of jute cloth or from used bags or clothing. Jute is very resistant and strong, able to counteract sizable forces, which makes jute bandages suitable for use on large objects or features such as highly fractured blocks of stone. Cotton bandaging, on the other hand, is typically purchased in predetermined sizes and strengths, depending on the size of the weave. All the same, in comparison to jute, cotton is a weaker fiber, and thus cotton bandages are more appropriate for small to medium-sized artifacts.

Unlike plastic or polyethylene strips, both jute and cotton bandages are permeable and breathable, allowing both moisture and air to pass. This can be an advantage or a disadvantage. Either fiber type can be used dry or can be premoistened with water. If the fabric is used damp, it is preferable to wet it prior to its application as moisture elongates and swells the fibers slightly, resulting in a slackening of tension after the bandages are already in place.

Both cotton and jute bandages can be used to stabilize objects during lifting operations. They can also be used in association with other materials, such as plaster, wax, or resin, if one desires to perform a more traditional form of immobilization (see chap. 10) in which bandages act as reinforcement, covering and protecting the archaeological material's surface.

Elastic bandages: Elastic bandages, commercially sold as ACE™ bandages, are completely synthetic fabrics, usually composed of woven polyethylene fibers. They are of standard dimensions, and unlike jute or cotton fabrics, they cannot be impregnated with plaster, wax, or resin. Due to their elasticity and softness, elastic bandages adapt very well to irregular shapes and surfaces. For the same reason, they are highly adjustable in terms of the amount of tension they can provide, beginning with almost imperceptible force and reaching levels similar to those that can be obtained with polyethylene plastic sheeting.

The main advantage of elastic bandages is their adjustability and even distribution of forces. They are particularly effective for temporary stabilization of fragile, highly fragmentary materials, as well as for use in lifting and block lifting. Bandages of 4 to 6 cm in width are most commonly used, but all elastic bandages are susceptible to degradation when exposed to the elements, in particular UV rays.

Tubular medical socks and stockings: These can have various compositions (50% cotton, 35–45% polyester, 20–40% polyamide, 25–30% latex, etc.) and adapt well to irregular shapes and surfaces. Because of their particular weave and fiber compositions, they are very delicate on fragile materials, exercising a minimum but uniform force. The advantages are many, including their ease of application and removal, which makes them ideal for emergency situations; their tubular shape, which confers the ability to completely contain a fragmentary object; and their open structure, which allows for easy monitoring of the object's condition (more than plastic films; fig. 7.5). In addition, they are particularly well suited for dry or wet materials and do not run the risk of creating a microclimate as plastic bandages do. One of their major disadvantages, however, is that they lose elasticity within fifteen to twenty days if exposed to the elements.

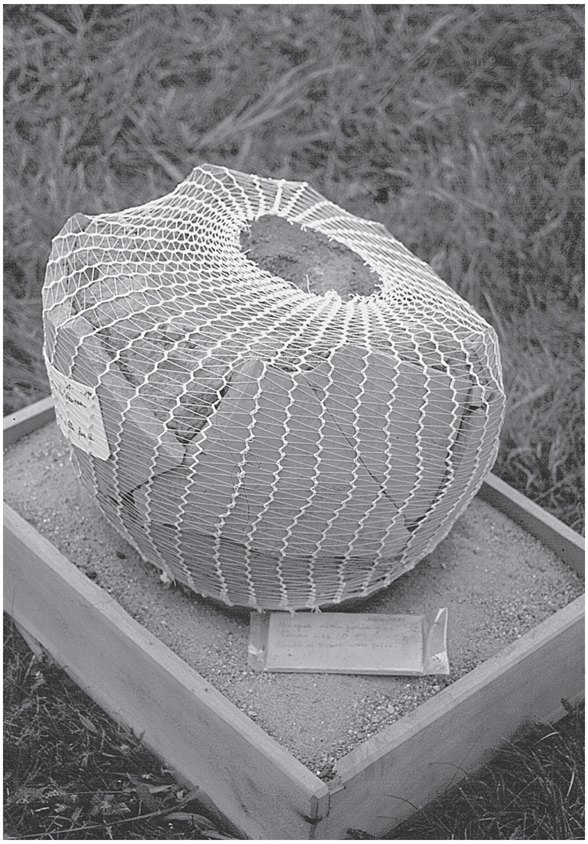


Figure 7.5 Tubular elastic gauze bandage used to restrain a highly fragmentary ceramic urn and its contents.

Of course, all the materials described above can be applied alone or in any combination according to specific needs.

Mechanical Interventions

Some wall or floor coverings (wall plaster, frescoes, mosaics) and decorative elements (details of sculptures or architectural features) may be recovered virtually separated from their structural support. Usually only a layer of damp soil or silt is what is still holding them together, and drying may cause the adhesive properties to be lost, resulting in their final detachment. A temporary mechanical intervention may help to avoid this fate by:

- Maintaining the spatial relationship of the covering or decorative element to its structural support
- Allowing consolidation and reanchoring operations to occur

Mechanical supports generally involve adhering a lightweight material to the surface of the affected feature to serve as a bridge to a larger or more stable section, tacking fragments in place, or creating containment edges or borders. There are many types of such supports. The examples discussed below have been proven successful in the field and illustrate the concept.

Facing

The facing technique uses small sections of permeable natural fabric, usually cotton gauze (gauze strips or pads typically found in stores or pharmacies are well suited) or Japanese tissue, applied to the surface of the object in question with a reversible acrylic resin (e.g., Paraloid® B-72 in acetone solution 20% weight/volume [w/v]) or an acrylic emulsion or dispersion (e.g., Primal® AC 33 at 5% volume/volume [v/v]) (fig. 7.6). The size of the gauze or tissue strips or sheets and the type and concentration of acrylic resin depend on the size, material, and specific condition of the artifact. For example, large stone fragments or crumbling wall plaster may require large strips and a high percentage solution of acrylic resin for stability (fig. 7.7), while loose tesserae on a mosaic or exfoliating flakes of ceramic may require a thinner acrylic solution with small gauze strips to hold them in place.

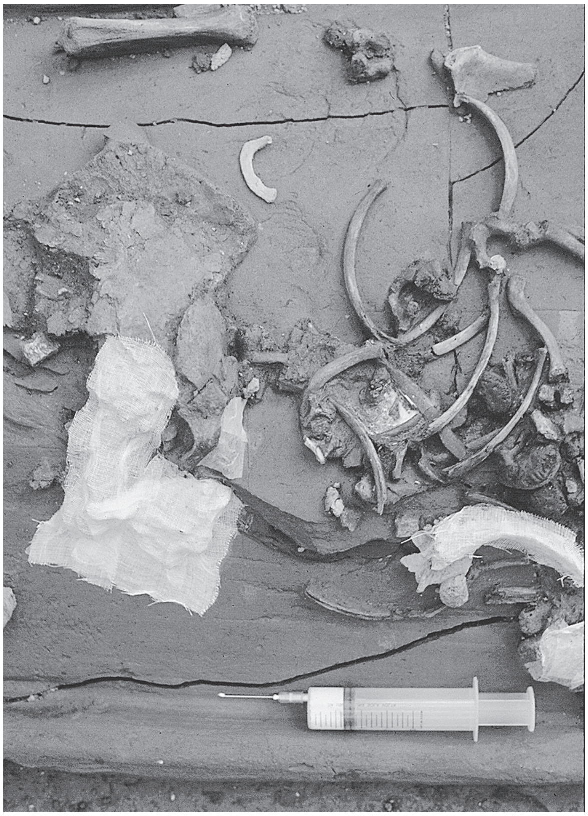


Figure 7.6 Cotton medical gauze and acrylic emulsion used to fix portions of a human skeleton to the terracotta support slab with which it was found.

In some instances, such as with mosaics or portions of wall plaster, the loose or separating portions can be removed and temporarily stored and later rejoined in situ. Of course this should be considered only if there is accurate and extensive graphic and photographic documentation. Consolidation and/or edging with an appropriate material may also be an alternative to stabilization with a facing but will depend on the time and conditions available as this method can be more labor-intensive and entail ethical concerns.

Adhesives

Adhesives can be used only for very specific cases and on a localized scale, such as for chips or small fragments that are easier to reattach to their point of origin than to fix using other mechanical interventions such as facings. In such cases, the objective is not to reassemble something from its constituent fragments but rather to avoid the loss of connection between small fragments or, in extreme examples, the complete loss of a feature. Reattachment must be exclusively a preventive measure and not cross over into the realm of reconstruction. For this reason, preference should be given to weaker and more chemically reversible resins, mainly those that can be softened or dissolved with a common solvent such as acetone or alcohol.

Some resins commonly used in conservation and appropriate for use in the field are single-component resins: cellulose nitrate based (UHU yellow tube, UHU ART blue tube, HMG) and vinylchloro/ketone copolymers (UNIMAST red tube). These are easily available and simple-to-use manufactured resins that commonly come in 25, 50, and 100 mg tubes with applicator tips. When any form of resin is used to temporarily secure fragments, it is preferable to apply small droplets in a few points rather than cover the entire join surface.

Aside from these commercially available resins, the acrylic adhesives common to conservation are a very good alternative. The best known of these is Paraloid® B-72, a methyl methacrylate. These can be dissolved in different solvents to varying concentrations according to the situation. A common solution would be around 30% w/v in acetone (see Appendix 4).

Figure 7.7 Cotton canvas and acrylic solution used to stabilize the edge of a highly fragmentary stone stele. Note the absorbing cushions inserted into the larger cracks to allow for the slight movement of the individual fragments while holding them in place.

It is preferable to not use vinyl-based resins. This is true unless the conditions of recovery are extremely adverse, such as waterlogged or very damp finds. In these cases commercially available wood glues should be avoided, and commercially prepared conservation resins (e.g., Mowilith DMC2 in solution or emulsion) or specially prepared vinyl resins (e.g., polyvinyl acetate or polyvinyl alcohol dissolved in denatured alcohol) should be used instead.

Bicomponent, or two-part, resins such as epoxies (Araldite) or polyesters (Sintolit) should only be employed by conservation professionals.

Finally, cyanoacrylate (Superglue, Loctite, Cyanolit, etc.) should be avoided at all costs.

Grouting

Grouting is typically used on detaching wall plaster or on mosaics or other floors where lime-based mortars were used as the original bedding material. If the situation calls for this type of intervention, such as large undulations on wall plaster or sizable voids or hollows under floors, then certainly the treatment should be undertaken. Mortar injections make use of watery lime-based mortars with hydraulic additives, such as volcanic sand or pumice, to re-create a bond between the detached feature and its structural support. Using lime mortars can establish a sufficient bond between the two within relatively few hours. In cases of extreme emergency or where the structural support and feature are fairly damp, hydraulic lime mortar mixtures can be used that will create sufficient adhesion in roughly twenty minutes.

When working in the vertical, where the weight of the injected mortar can be the cause of detachment, this form of intervention usually involves having to also create some form of external support, whether structural or mechanical. These external supports, whether a facing or a bracing, must remain in place only for the amount of time necessary to reestablish adhesion. Typically such supports are made with braces of wood with a foam insulator and aluminum foil as a barrier layer. However, any suitable material can be employed because the brief time of use creates little risk of biological growth or condensation.

Temporary Infilling and Edging

During ongoing excavations, it may be necessary to use temporary infilling and edging repairs for a number of reasons, such as to prevent the leaking of injected mortar from the borders and cracks of treated wall plasters or to stabilize edges of wall plasters or mosaics or other floor materials (edging). It should be taken into account that protective edging will eventually be removed, and this action should not jeopardize or damage the original archaeological material. Accordingly, a sufficient amount of adhesion must be endowed without being too weak or too strong. This is typically done by using a so-called lean mortar mixture of 1 part lime to 3 parts volcanic sand or pumice. Color should also be considered; ideally the mixture should be given a color that is different enough from the archaeological material to be discernible as new by the public and by archaeologists and conservators at a later time.

In very wet conditions where the setting of lime would be virtually impossible and hydraulic lime mixtures would prove too strong and too hard to be considered temporary, wet clay can be used instead. Here, clay is simply pressed and molded into edges or gaps as a support. Equally, this technique can be used to secure the borders of mosaics or to immobilize tesserae in instances where the inherent moisture in the mosaic would preclude the use of any form of acrylic resins to affix a facing or adhere any small fragments in place (see above). Clay used in this way has excellent elasticity and dimensional stability, provided that it remains moist. If allowed to dry, the clay will lose volume and become brittle, effectively defeating its function as a mechanical support.

Prevention of Biological Attack

Biodeterioration refers to any undesired change to a material's properties due to the activities of micro- and/or macroorganisms (for further discussion, see Caneva, Nugari, and Salvadori 1991). As a general definition this is valid, but for conservation purposes it needs clarification. Micro- and macroorganisms usually play an important role in the alteration of both organic and inorganic materials, leading to undesired changes such as progressive loss of cohesion and eventual compositional transformation. Biodeterioration is not an isolated phenomenon but rather is closely linked to other physical and chemical forms of deterioration. When related to mechanical phenomena, it is referred to as *disintegration.* When associated with chemical processes, it is known as *decomposition.*

The colonization of exposed archaeological structures or their remains by microorganisms usually begins in places where dust and moisture accumulate, typically those that contain materials with high porosity. These areas tend to be colonized first by bacteria, algae, and lichens and then by mosses, which in themselves retain moisture and can lead to secondary colonization by macroorganisms (plants). Plant growth is the more dangerous of the two types of colonization because of root growth. Roots make their way into cracks and interfaces between structural elements and their binders, eventually taking over whole portions of walls (figs. 8.1, 8.2).

Preventing biological attack aims at inhibiting or at least slowing micro- and/or macrocolonization. This can be achieved with indirect methods (i.e., changing the ambient environment to one less favorable to biological growth) or direct methods (i.e., changing the physicochemical nature of the substrate that organisms grow on (altering the nature of the archaeological material).

Direct Methods

Consideration of potential biological growth is usually part of any conservation treatment. The purpose of any form of intervention in this respect is to control or eliminate, as much as possible, the factors that contribute to biological deterioration. The effectiveness of such a treatment will depend on the method and the materials used. Further biological growth is possible even after treatment if favored by environmental factors. In other words, only an alteration in or eradication of the source will prevent biodeterioration. If this is not possible, as may be the case in the field or with immovable features, then maintenance and retreatment must be considered.

Figure 8.1 A severe infestation by climbing plants. Root infiltration is most likely extensive and may affect the stability of the structure.

All the same, before any form of treatment is undertaken, one must first attempt to answer the following questions:

- Is treatment necessary or essential?
- Can the material be treated without damage?
- What are the effects of treatment?
- Will treatment have to be repeated, and if yes, how often?
- Are there any other preventive methods?

Figure 8.2 After the plant has been killed. The removal or rotting of the roots can still cause serious damage to the masonry and may lead to its collapse.

For details, see the diagram shown in figure 8.3.

Direct treatment can take many different forms:

Mechanical: Removal of early biological growth by hand and with tools. This technique does not remove all the possible seeds or spores and thus has limited effectiveness over time.

Physical: Various physical techniques such as exposure to UV light, gamma rays, ultrasonic waves, low-frequency current, and cold show good experimental results. Unfortunately, all such methods prove harmful to the original archaeological material.

Biological: This method is based on using a species antagonistic to or competitive with the undesired biological growth. This can be highly effective but carries the risk of replacing one biological agent with another.

Chemical: Currently this is the most widely used form of direct treatment in that chemistry offers an unlimited number of possibilities and continually developing products. Among chemical treatment options, the appropriate choice is usually based on the following factors:

- Effectiveness on organisms at the source of the cause of deterioration
- Low toxicity to the operator
- Low risk of pollution to groundwater and soil
- No interaction or adverse effects on treated archaeological materials

Chemical biocides are classified as follows:

- Bactericides
- Algaecides
- Fungicides
- Insecticides
- Herbicides

Indirect Methods

The relationship between the environment and biological growth makes it clear that the most effective indirect conservation techniques target the ambient factors that allow and encourage such growth. These factors are:

- High relative humidity
- High temperatures
- Poor ventilation
- Sufficient natural light
- Dust, dirt, and grime on the archaeological material

Of these factors, relative humidity and temperature have the greatest impact. If the relative humidity is too high, the following actions may alleviate the problem:

- Isolate the feature or object from capillary action.
- Create drainage around the areas of excavation.
- Do not allow water to pool or stand.
- Allow for or create ventilation.

High temperatures promote the growth of microorganisms, as well as the reproduction of insects (especially at or above 15–16°C). Another possible effect of high relative humidity and temperatures is condensation and the wetting of the objects or features at night when cooler temperatures prevail. This is especially true for more conductive materials like some kinds of stone or metals.

Treatment Strategies

Treatment approaches are most easily arrived at by systematically answering a series of appropriate questions. The sequence of questions was well summarized by Caneva, Nugari, and Salvadori in 1991 and is the

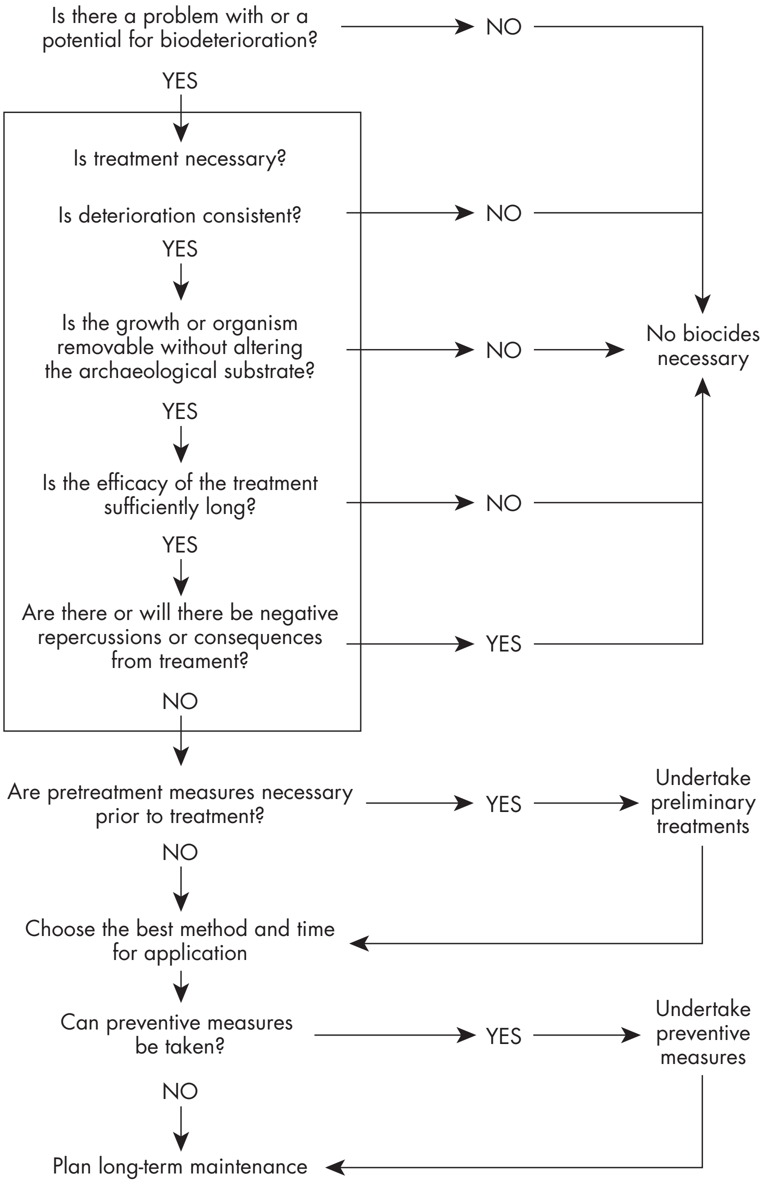


Figure 8.3 Diagram highlighting the issues to consider prior to undertaking measures to treat biodeterioration (from Caneva, Nugari, and Salvadori 1991).

basis for figure 8.3. The following sections attempt to expand on the possibilities for treatment by considering the many pertinent variables affecting decision making, as well as the many possible approaches.

Recognizing Biodeterioration

One of the primary problems one first encounters is recognizing biological attack. It is usually fairly easy to discern plant species or mosses, but algae or bacteria can be easily misinterpreted as a chemical attack, soluble salts, or earthen particulates. This is particularly true for inorganic archaeological materials; for example, bacteria can produce a black encrustation that can be confused with a sulfate crust caused by atmospheric pollution on limestone or marble surfaces.

To help in identifying the presence of biological attack, it is useful to understand that such activities:

- Are usually associated with moisture
- Produce moisture themselves, typically in the form of microscopic droplets
- May vary in color, depending on whether they are active or dormant, such as green to red to brown

Identifying the Type of Biological Attack

The only truly reliable way to identify the specific type of microorganic growth is by in vitro cultures analyzed by a specialized laboratory. These obviously entail a cost and a time delay in allowing the culture to develop and be interpreted but can provide information on the specific strain and genus and accordingly the most appropriate biocide to deal with it.

Practical Considerations

It is beyond the scope of most excavations in terms of time and budget to scientifically identify the specific type of biological attack that may be present. Consequently, to achieve and exercise reasonable control over biological growth, the following practical steps should be seen as a priority and should not depend on the outcome of any form of analysis:

- Remove soil, dust, and particulate accumulation from archaeological remains that can encourage biological growth.
- Prevent or limit the supply of water to the remains, whether in the form of rain, rising damp, or condensation.
- Limit, if possible, the amount of light and new seeds or spores reaching the remains by means of shelters or coverings.
- Check any biocides that may be used for their compatibility with the material of the archaeological remains.
- Plan for periodic maintenance and survey of the remains and the efficacy of treatment to determine if some steps need to be repeated or new ones implemented.

With regard to selecting a chemical biocide, the criteria for selection have been thoroughly discussed in numerous publications found in the bibliography and are discussed below, under “Biocides.”

Treatment Steps

Because the identification of specific species of biological growth is difficult in terms of costs and too time-consuming for most ongoing excavations, it does not make sense to treat with one or many specifically formulated biocides that may not be effective because they do not target the growth in question. Instead a broad-spectrum treatment is usually considered the best option to try to eliminate as many common species as possible. One drawback of this approach is that it may not overcome resistant species that could be eliminated by a specific biocide. Accordingly, this approach can only be considered a short-term solution, but it does present the following advantages:

- After the application of broad-spectrum biocide there will be a period of quiescence during which the microbial population absorbs and assimilates the biocide, stops growing, and then succumbs. It is difficult to give a precise duration for this phase as it is influenced by various factors (relative humidity, type of biological growth, life cycle stage, etc.), but it generally will last between one and three weeks.
- After this period there will be a quantity of decaying organic matter that can become the food source for the development of biological species that were resistant to the biocide used. These species now find themselves in a virtually ideal environment without natural competitors, where the biocide has been predominantly metabolized by the dying organisms and with abundant nutrients for further growth provided by those same dying organisms.
- The development of biological growth will be localized at this point to areas with a favorable microclimate and sufficient nutrients.

At this stage sampling of any new growth is recommended to determine the specific species by in vitro culture. Identification of the species should help in the selection of the appropriate biocide to eliminate all forms of remaining biological growth.

It should be emphasized again that if the conditions of relative humidity, temperature, and light are not altered in some way, new growth will begin at some point because the factors that determine growth have not been changed. If these environmental parameters cannot be altered (see chap. 16 on long-term conservation), then a sustained program of periodic biocide application should be planned.

Biocides

Bactericides, Fungicides, Algaecides

ORGANIC COMPOUNDS

Hydrogen peroxide: Used in its highest concentrations to suppress algae and lichens on the surface of stone. This is a strong oxidizer and can bleach or lighten the surface of the treated material, so much care must be taken in its application. It is effective only when applied directly to the algae or lichen and its action does not last over time.

Sodium hypochlorite (bleach): Used in aqueous solutions (between 2% and 7%) to eliminate algae and lichens on stone surfaces. This may cause whitening or bleaching of the surface of the treated material. Moreover, if not completely removed from the stone surface after use, it can cause yellowing. Sodium hypochlorite is corrosive to skin and can lead to sensitization and allergies.

ORGANOMETALLIC COMPOUNDS

Mercury derivatives: These were widely used in the 1980s, especially pyridyl mercury acetate, but are now generally avoided because of their toxicity.

Tin derivatives: Tri-n-butyl tin (TBTO, Merck; Thaltox, Wykamol) is an effective algaecide and fungicide. It has been used with good results on stone and mural paintings, as well as on wood, where it is highly effective against so-called red fungi. Another tin derivative of similar efficacy is tri-n-butyl tin-naphthenate (Metatin 58-10, Acima Chemical).

PHENOLIC COMPOUNDS

Phenol is one of the oldest disinfectants known and is used as a measure of the effectiveness of other disinfectants. It was widely used in the past but is now suspected of being potentially carcinogenic. It is corrosive to metals.

Penta-chlorophenol (PCP) (Dowicide EC7, Dow Chemicals) and its sodium salt, sodium *penta-chlorophenol (PCPNa)* (Dowicide G, Dow Chemicals), were widely used in the past because of their broad-spectrum effectiveness. They are now generally considered too toxic for use. They can interact negatively with certain material substrates, darkening wood or discoloring and altering basic pigments.

Ortho-phenyl phenol (OPP) (Dowicide 1, Dow Chemicals; Topane S, ICI) and its sodium salt, sodium *ortho-phenyl phenol (OPPNa)* (Dowicide A, Dow Chemicals; Topane WS, ICI; Mystox WFA, Catomance), are highly effective on a broad range of algae, fungi, and bacteria. Their toxicity is tolerable, with OPP being preferred for use because it seems to interact less with most material substrates. These should not be used on textiles or other colored fabrics because they can produce immediate discoloration.

Di-chlorofene (Panacide, BDH). This is a good product with broad-spectrum effectiveness and very low toxicity. It is commonly used as a disinfectant for paper-based food packaging and has little to no negative interaction with material substrates, including organic ones.

Quaternary ammonium and its derivatives (Preventol R50, R80, R90, Bayer; Hynamine 3500, Rohm & Haas; Cequartyl, Rhone Poulenc; Neo Desogen, Ciba Geigy) are widely used in medicine against bacteria, algae, and fungi (i.e., sterilization of needles and operating rooms). Their effectiveness against lichens is debatable. Their effectiveness is very short-lived because they are unable to kill spores. The presence of nitrates can significantly reduce their effectiveness.

MIXTURES

Sodium dimethyl dithiocarbamate + sodium 2-mercaptobenzothiazole (Vancide 51, Vanderbilt) has been used successfully on stone, plaster, and painted surfaces for the treatment of algae, bacteria, and fungi.

Tributilene naphthenate + quarternary ammonium salts (Metatin N 58-10/101, Acima Chemical) has proven effective against biodeterioration in subterranean environments.

Insecticides

Most insecticides are very toxic to all forms of life, humans included. Halogen derivatives have been found to be generally effective, but they can be dangerous to handle and apply. Chlorinated organic compound mixtures are dangerous as well because they accumulate in the food chain.

Pyrethrin and the pyrethroids are the only known products commonly used as an insecticide without known risks to humans.

Herbicides

The control of larger plant growth, such as weeds, vines, and trees, can be achieved only with products that interfere with photosynthesis. Such substances can also be effective against algae. All herbicides are classified as one of two types:

- Selective, active on only very specific forms of plant development
- Nonselective, preventing any form of plant growth

Treatment of architectural remains and features usually includes the application of a nonselective herbicide to prevent any form of large plant growth. The most commonly used herbicides tend to be nitro-organic in nature:

- Ammonium sulfate (Ammate, Du Pont) is locally applied to the roots of trees to halt their development.
- Fluometron (Lito 3, Ciba Geigy) is used against mosses and lichens; Monuron and Diuron are used against the most common weeds and vines that grow on large architectural remains.
- Simazine (Gesatop, Weedex, Ciba Geigy) is widely used to prevent the growth of most common weeds and plants, as well as lichens and mosses on archaeological sites.
- Picloram (Tordon, Dow Chemicals; Uniran, Ciba Geigy) is a powerful nonselective herbicide used for total control of any form of vegetation and therefore should be used with extreme caution to prevent polluting waterways or groundwater and to prevent serious environmental harm.

- Imazapyr (Arsenal, Cyanamid) is a recently developed product, especially for root injection, that has been used successfully to control larger plant growth.
- Glyphosate (Roundup, Monsanto; Spasor, Siapa; Pathox, Phase) has been used with success on lichens and larger plants and has no residual effect once absorbed by the plant(s).

Biochemical Methods

Biochemical treatments make use of chemical compounds of biological origin that cannot intrinsically be considered biocides. Antibiotics, for example, are substances that are produced from microorganisms and developed to eliminate the growth of competing organisms. Streptomycin and penicillin have been used to control the growth of bacteria, fungi, and actinomycetes on wall plaster and stone surfaces.

Enzymes are proteins that act as catalysts for biochemical reactions within cells. Enzymes have been used as a biochemical treatment in various applications, particularly for cleaning stone (Gauri and Chowdury, in AA.VV. 1988). Trypsine, a type of enzyme, was used to remove lichen-formed encrustation from the surface of stone. Given its brevity of effectiveness, greatly influenced by pH and temperature, its application is too complicated to consider it a general and recommendable treatment.

Pheromones are chemical compounds produced by living creatures that have a specific action on other individuals of the same species. Sexual pheromones have been used to control insect infestations in museums. These cannot in the strictest sense be considered biocides because they function by luring male species from infested materials and attracting them into traps, where they are then killed by a specially selected insecticide.

Consolidation

Preliminary Considerations

Consolidation is generally understood as a series of activities intended to endow weakened, weathered, or friable materials with their original mechanical characteristics. But this suggests that the concept of consolidation is both relative and arbitrary. A more appropriate definition is "a series of operations that tend to give a material the mechanical properties sufficient and necessary for its continued preservation." Though this definition is still somewhat subjective, it does not assume that the original characteristics of the material can be restored.

Consolidation on an archaeological excavation should take into the account the following factors:

- The material to be consolidated
- The types of stresses and forces the material must support
- The state of preservation or deterioration of the material

Nature of the Material

As discussed previously, the specific characteristics of the binders and mineral components that make up archaeological objects and building materials greatly influence their preservation. These must be considered in association with the physical context in which an object or architectural feature is present and will be preserved. Considering these factors makes the type of consolidation necessary easier to determine. For example, a porous mortar in a wet or humid context will require more extensive consolidation than a hydraulic mortar in the same context.

Nature of Forces and Stresses the Material Must Support

The specific characteristics of the context a material or feature is to be conserved in also greatly influence treatment decisions. Again using examples common to archaeological sites:

- Decorative plaster on a wall is less affected by gravity than decorative plaster on the underside of a vault.
- Decorative wall plaster is less affected by environmental factors in an enclosed or covered environment than if exposed to the elements.
- A mosaic pavement is affected differently if exposed directly to foot traffic or if protected by designated and raised walking areas.

These examples are representative of just some of the many variables involved and further illustrate that consolidation should always be carried out to achieve only the minimum characteristics necessary to ensure preservation. Excessive consolidation, while potentially reassuring, can radically alter both the physical and the chemical nature of a material in unpredictable and generally negative ways in the long term.

Condition of the Material

As with consolidation itself, the concept of relativity holds true when assessing the state of preservation or deterioration of archaeological materials. This should also be kept in mind when evaluating the need for consolidation and can be aided by applying a reference framework for the different types of possible treatment depending on the type of material and its state of preservation.

COHESIVE CONSOLIDATION

In the case of weak, highly fragile, or friable materials that have lost part or most of their original binder(s), consolidation is intended to replace that which has been partially or wholly lost with a modern substance. In these instances, cohesive consolidation is generally used and usually consists of impregnation until saturation is reached.

ADHESIVE CONSOLIDATION

In the case of coverings or coatings that have lost contact with their original support and to which the connection between the two must be restored, such as plaster separating from the wall, adhesive consolidation is generally undertaken, typically in the form of grouting.

FUNCTIONAL CONSOLIDATION

Structures or decorative wall and floor coverings in all states of preservation that will be exposed to prolonged environmental conditions and/or will be walked on or touched by visitors are often treated with combined cohesive/adhesive consolidation to both reinforce the material (cohesive) and reestablish continuity within the material itself or between the covering and its support (adhesive). Where these two types of consolidation are combined, it is generally referred to as functional consolidation and often takes the form of impregnation and filling of any cracks or voids by means of injections, as well as pointing and capping.

STRUCTURAL CONSOLIDATION

If architectural elements or parts of them are in need of treatment in order to support their own weight or if they are subjected to static forces, structural consolidation is generally needed. Because this type of work is outside the professional competency of a conservator, these operations are feasible only with the involvement of a structural engineer.

Methods of Consolidation

Cohesive Consolidation (Impregnation)

Impregnation is intended to replace or substitute a lost or weakened original material binder with a new one. The new consolidant or binder is applied to the weakened material with syringes, pipettes, poultices, and brushes and is absorbed by means of capillary action. The varying properties of commonly used consolidants have a direct impact on the efficacy of impregnation and require further definition and discussion.

IMPREGNATION WITH ORGANIC MATERIALS

Organic compounds are defined as molecules based on carbon (C), oxygen (O), hydrogen (H), and nitrogen (N) and their derivatives. In conservation, most compounds classified as resins are made up of synthetic organic polymers. The two most common types are acrylic and vinyl resins. In impregnation resins penetrate into the pores of the material through absorption, and a polymeric framework forms around surrounding mineral particles as the solvent or vehicle carrying the synthetic compound evaporates. Such a framework is nonhomogeneous, with the mineral elements encompassed in an organic polymeric lattice structure.

Resins can be employed in two principal forms:

1. *In solution:* The solid component (resin) is dissolved in a liquid solvent. Most solutions consist of equally spaced solid particles surrounded by solvent, which acts as a lubricant, allowing particles to glide easily past one another. Solutions are always transparent and generally have very low viscosity.

Organic resins are not soluble in water but are easily dissolved in a great number of organic solvents, for example, alcohols and acetone. Such solutions are easily absorbed by porous materials, where the resin is deposited when the solvent evaporates. On complete evaporation, the resin will regain its original properties, such as hardness or flexibility.

Impregnation with organic resins can restore cohesion to fragile materials but has the potential drawback of leaving a glossy surface residue, forming an impermeable barrier to water vapor or uneven/uncontrollable absorption if used excessively. These limitations are associated with the relationship between the volatility of the solvent and the porosity of the archaeological material. Moreover, because the types of solvents used to dissolve resins are volatile, this means that they are flammable and thus can present a fire and toxicity risk.

2. *In emulsion:* a system whereby two nonmiscible components (resin and water) are held together by surfactants (soaps) that bind to both water and resin molecules. Emulsions are always milky in appearance.

The advantage of aqueous emulsions over solvent solutions is mainly practicality during application in terms of flammability and toxicity. A resin is technically flammable, but an emulsion is nonflammable because the resin particles are surrounded by water held in place by surface tension due to the presence of surfactants. Because they are in water, their overall toxicity is far less than that of conventional solvents.

Emulsions have the advantage of considerable adhesive strength but the disadvantage of being difficult to reverse or remove once fully dried. In general, emulsions are made up of microspheres of resin and water with a high internal friction coefficient, making them generally more viscous than solutions. For this reason, emulsions are often used in the consolidation of highly friable materials with small to medium-sized fissures or cracks that are too large for resins in solvent solutions to bridge because of their fluidity. Once dry, however, acrylic and vinyl emulsions tend to have low permeability to liquid and vapor moisture.

In addition to the difference between solutions and emulsions, a distinction should be made between the two organic resins most commonly used in conservation, acrylics and vinyls. Acrylic resins have many significant positive characteristics:

- Good resistance to UV rays, that is, little to no yellowing or color change
- Good dimensional stability under a range of temperatures, both low and high
- Good elasticity and resistance to bending and creep, especially the ethyl-methacrylates
- Long-term solubility, allowing for future or alternative treatment options over a long period

Vinyl resins are very good universal and household resins but tend to be almost too strong for common conservation uses and have many negative characteristics:

- Age and discolor quickly, becoming grayish
- Cross-link and slightly insoluble over time
- Viscous in emulsion form, which can limit the amount of penetration

Accordingly, of the common resins used as consolidants, preference should always be given to acrylics.

IMPREGNATION WITH INORGANIC MATERIALS

Inorganic compounds are molecules comprising the mineral elements silicon (Si), calcium (Ca), and barium (Ba) and their derivatives. As consolidants, they are similarly dependent on a liquid solution penetrating into the pores of the material to be consolidated by capillary action. Likewise, the solvent vehicle carrying the inorganic compound evaporates, precipitating the mineral component and beginning the formation of a crystalline network that binds to all surrounding minerals present in the original material. Unlike with organic consolidants, however, the type of bond that is formed between the consolidant and the material to be consolidated is a mineral one with physicochemical properties analogous but typically not identical to the original material binder that has been lost or diminished.

Following are the primary inorganic consolidants used for cohesive consolidation:

Calcium hydroxide ($Ca(OH)_2$) or slaked lime: Several experiments have been undertaken with saturated solutions of calcium hydroxide, also known as “lime water” (Rossi-Manaresi and Tucci 1984). The application of calcium hydroxide should begin a reaction of carbonization (see Appendix 3, reaction no. 3) on the interior of limestones or mortars, reconstituting the lost or deteriorated original calcium carbonate ($CaCO_3$) binder. The results of these experiments are somewhat controversial, although deserving of note. In general, consolidation with calcium hydroxide can be used for slightly degenerated wall plaster or floorings located in covered locations or exposed to limited thermal changes (i.e., avoiding severe cold or heat) and, above all, away from direct moisture and freeze/thaw cycles.

Barium hydroxide ($Ba(OH)_2$): Consolidation with barium was first tested and developed by the Opificio delle Pietre Dure (OPD) and S. Lewin (Ferroni and Dini 1981). The basis of the technique is the chemical reaction between $Ba(OH)_2$ and calcium sulfate ($CaSO_4$) present in lime-based degraded mortars and stones. The reaction produces barium sulfate ($BaSO_4$), an insoluble salt that takes the place of the degraded calcareous binder within the mortar or stone. This method has notable advantages for light-colored materials and for painted wall plasters or true fresco paintings. Despite the sometimes overenthusiastic literature, however, there are some potential drawbacks to the use of barium hydroxide in that it may have a negative reaction with basic pH pigments and could blanch or whiten darker materials and stones. The application of barium hydroxide is very sensitive and requires controlled, precise execution. The advantages of this method are related directly to the amount of mineral binder present in the material to be consolidated and its conversion from something highly soluble, $CaSO_4$, to something insoluble, $BaSO_4$. Therefore, aside from consolidation, there is a chemical conversion and neutralization of any gypsum present in a material.

Ethyl silicate (ethyl silicon esters): Ethyl silicate compounds are made up of a silicon atom bonded to an ethyl molecule diluted in organic solvents, generally methyl ethyl ketone (MEK). There are also commercially available methyl silicates (a silicon atom bonded to a methyl molecule), widely used in Austria but generally not recommended because of their toxicity and tendency to attack the optic nerve. Ethyl silicates with added polysilanes to give hydrophobicity are also commercially available. In whatever form, the extreme fluidity, low viscosity, and slow evaporation rate of ethyl silicates allow for deep penetration into porous materials. The initial evaporation of the ketone and eventually of the ethyl alcohol solvents leads to the precipitation of amorphous silica in the capillaries of the material being treated. The silica then forms covalent (very strong and stable molecular) bonds with surrounding precipitated silica atoms (Si-Si). The depth of penetration and stability and the strength of the formed silica-to-silica bond are the primary reasons ethyl silicates have become widely used.

There are certain disadvantages:

- Application dependent on temperature and relative humidity
- Risk of creating a white or glossy film if excess product is used and not removed from the surface of the treated object before polymerization
- Slow reaction time (typically about one month)
- Theoretically impossible treatment in the absence of silica in the treated material, such as with pure limestones or marbles
- Transformation of the chemical behavior of limestone from basic to acidic
- Possibility that the silica bonds can create excessive tension in thin clay materials or ones already weak and cracked or fissured

Impregnation with ethyl silicates is therefore advisable if:

- The material to be treated contains silicon
- The porosity of the material guarantees absorption
- Temperature and humidity can be partially controlled during treatment and polymerization (between 5° and 25°C and between 40 and 80% RH)

Impregnation with ethyl silicates should be avoided if:

- The material to be treated does not contain silicon
- The material is not sufficiently porous or absorbent
- The temperature is too high (above 25°C) or too low (below 5°C)
- The relative humidity is above 80% or if the treated material may be exposed to rain in the four weeks following treatment

To slow the evaporation rate of the solvents and ethyl alcohol, it is good practice to cover or wrap the treated object with aluminum foil or polyethylene sheets for at least two weeks after application.

Adhesive Consolidation (Injection)

The filling of cracks, gaps, voids, or cavities between structural elements (walls and floors) and their coverings (wall plasters and floorings) to re-create structural continuity is a common conservation treatment on archaeological sites. In all cases, the size and volume of the gap or hollow must be determined in order to choose which type of injection material will be most effective. Large gaps or cavities are generally filled with denser, more thixotropic mixtures with fine inert aggregates; small cavities and cracks call for more fluid mixtures with even finer inert additives. A further generalization to determine the type of injection material is the orientation of the void to be treated, whether vertical or horizontal.

In the first case, such as with partially detached wall plaster, gravity will pull all injected mixtures downward to accumulate in the lower portion of the cavity. If injections are not done carefully or gradually, the weight of accumulation can cause further detachment and/or possible fracture or loss of the wall plaster under treatment. In such cases, external supports, reinforcements, and preliminary sealing of the edges can all be used to give the plaster sufficient strength and cohesion to sustain the weight of the mixture, as well as prevent any unwanted leaks. In the case of injections for horizontal gaps or cavities, such as for pavements, the problem of accumulation is not a factor. Instead, one must consider the potential collapse of the material directly over and/or around the perimeter of the cavity or void. For this reason, many horizontal injections are of “expansive” mixtures, which will be described later.

The need for and implementation of adhesive consolidation or reanchoring must be evaluated carefully, with consideration of the following factors:

- *Quantity:* The quantity of consolidant to be injected. Can the material to be readhered support the stress and weight of the injected material? If the answer is no, staggered injections over time, preliminary cohesive consolidation, or detachment should be considered.
- *Solubility:* Resistance to and solubility in water. Nearly all injection materials used for adhesive consolidation contain some amount of water. Can the material itself or any components applied to the material (e.g., pigments on painted wall plaster) support exposure to water? If the answer is no, preliminary cohesive consolidation with a nonaqueous consolidant or possible detachment should be considered.
- *Timing:* The amount of treatment time needed. Is the time needed to properly undertake injection and reanchoring of an architectural element compatible with the time constraints of the excavation? If the answer is no, cohesive consolidation and detachment should be considered. (The problems inherent in detachment are discussed in chapter 10.)

Following are the primary materials used in injection and their forms of application:

Lime mortar and sand aggregate: One of the easiest materials to inject and use on both vertical and horizontal gaps and cavities is a standard mortar of lime, fine sand aggregate, and water to achieve the appropriate fluidity. This type of injection must be done more than once to compensate for the loss of total volume of the mortar due to the evaporation of the excess water needed for fluidity. The overall strength of this mortar is quite low, so this material and method should be considered a general filler for voids.

In the case of large voids or gaps, aluminum powder can be added to the lime mortar and sand mixture to create an expansive mortar during setting. Aluminum in contact with lime causes the formation of gas, which endows a honeycomb or cell-like structure on the mortar, causing it to expand in volume. Though this is useful, it must be kept in mind that the action of the gas creates voids in the mortar, which serve to further reduce its overall strength. In addition, as with all fine particles, when using aluminum powder caution must be taken to avoid irritation or damage to one's respiratory system.

Lime mortar with volcanic (pozzolanic) sand aggregate: Combining lime with a volcanic sand aggregate is one of the surest techniques for achieving a strong adhesive fill material. Crushed brick, grog, or volcanic sands confer hydraulic properties to lime mortar, which allows its use on wet materials, such as damp walls, or in very moist or high relative humidity environments, such as inside enclosures. The set mortar has very good mechanical properties and resistance to liquid moisture while remaining permeable to water vapor. These properties allow these lime mortars to be used in a wide range of common archaeological situations where walls and floors or their decorative coverings will remain in situ.

Casein and lime: Casein and lime, one of the oldest known traditional adhesives, can be used to fill small cavities. This mixture is produced by combining lactic casein (a protein) and lime in the volumetric ratio of 1:7 (casein to lime). In recent decades this technique has unjustly fallen into disfavor due to the misconception that because casein is organic it is sensitive to attack by mold and microbiological growth. This simply cannot be true given the numerous examples of pictorial murals throughout Europe that have historically been treated with this technique and are currently in a very good state of preservation.

Once set, casein and lime does not have great tensile strength, but it is still a commendable material for vertical and horizontal injections into voids that do not exceed 3 to 4 mm and where good adhesion is important. Casein and lime remains permeable to water vapor after setting.

Acrylic emulsions: Acrylic emulsions (Primal®, Plextol, Acronal, Lascaux Hydrogrund) have been used widely in the past thirty years due to their easy availability and preparation (dilution with water). As previously noted, acrylic resins have many favorable characteristics, including good chemical and color stability, elasticity, and high resistance to tensile and shear forces.

To this list of positives we must add some drawbacks to the use of acrylics in emulsion form:

- Impermeable to water vapor
- Different coefficient of expansion and contraction as compared to those of the mineral components of many archaeological materials, potentially causing some stresses between the two (organic/inorganic) due to environmental issues, especially temperature change
- Formation of a hydrophobic barrier that can complicate or exclude any future conservation treatments with the same emulsion or with a lime-based mortar

For these reasons, adhesive consolidation by injecting acrylic emulsions should be avoided. It should be used only as a treatment of last resort or in an emergency (see below) and should never be considered a permanent solution.

Consolidation and Stabilization of Stratigraphy

One of the most common and problematic treatments a conservator faces on archaeological sites is the conservation of stratigraphy. The nature of stratigraphy is intrinsically complex in that layers are sufficiently different in composition and compaction properties to be distinguishable from one another. This, in turn, is what makes consolidation problematic: each material within each layer has its own problems, needs, and porosity.

To approach the issue systematically, the following questions should be addressed prior to treatment:

- Does the profile of the stratigraphy allow for consolidation?
- How wet or dry are the layers, individually and collectively?
- Do all layers require consolidation or only selected ones?
- What are the properties of the layers to be consolidated?
- Are organic materials present (bone, wood, etc.)?

Each of these questions is developed below as a general guide.

Stratigraphic Profile

It is advisable to request that archaeologists leave the stratigraphic section of a trench wall with a slight slope, leaning progressively away from the interior of the trench, from bottom to top. In this position the forces of gravity acting on the stratigraphic section are displaced directly into the ground or the layer below and the section is thus best supported. If the section is perfectly vertical or, even worse, leaning slightly forward, the stratigraphy will overhang and lack support, leading eventually to detachment and loss. The possibility of collapse or detachment is at its greatest during consolidation, whether on a forward, backward, or plumb stratigraphic section, because of the increased weight of the saturated particles on the wall's surface. A backward slope minimizes this possibility.

Moisture Levels of the Stratigraphy

If the stratigraphic section is wet, consolidation treatments must be postponed for the following reasons:

- The stratigraphy will lose volume while drying, potentially causing cracking that could be exacerbated by the presence of a consolidant.
- Penetration of the consolidant is limited because the materials composing each layer are saturated with water.
- The use of resins in solution is ineffective because the moisture already present in the stratigraphy complicates the evaporation process and/or will prevent polymerization of ethyl silicates.
- Emulsions, which have an aqueous base, are useless; one is essentially adding water to already wet materials.

If the drying out of a stratigraphic section is potentially a long process, preventive measures may be necessary, including the use of a general biocide and herbicide to prevent algae, fungal, and vegetal growth. Accelerated drying with hot air should be avoided as it tends to dry only the surface of each stratigraphic layer, possibly provoking its detachment and collapse.

Stratigraphic Layers Requiring Consolidation

Guided by the principle that the best form of treatment is the minimum intervention necessary, each stratigraphic layer must be carefully evaluated to determine which need consolidation in order to survive. In general, the most fragile layers are those that contain material remains from occupational levels and so-called destruction layers because both tend to be inconsistent in their makeup and are poorly compacted. Layers with carbonized organic materials, such as charred remains of wood or seeds, are the most problematic. Alluvial and sedimentary layers, on the other hand, tend to be very compact and do not need consolidation.

Characteristics of Each Layer

It is important to evaluate and understand, to the extent possible, the properties of and substances making up each stratigraphic layer to design a suitable consolidation treatment plan.

- Earth (dirt): Can be consolidated with acrylic resin in solution or with ethyl silicate.
- Sand: If the layer is made up of fine, relatively compact sand, ethyl silicates can be used. If the layer comprises large, noncompact sand grains, then consolidation with an acrylic emulsion may be the best solution. In the latter case, color saturation and darkening of the sandy layer will be inevitable.
- Clay (poorly compacted): Ethyl silicates generally guarantee good results. All emulsions should be avoided because their water content could swell the clay layers and lead to their eventual loss.
- Debris: Variable in properties and poorly compacted, generally consolidated with injections of hydraulic lime mortar to fill cavities and voids between material goods and the soil and within the soil itself. This type of treatment is time-consuming and risky and often requires the treated area to have external supports to prevent possible landslides or collapse.
- Carbonized organic materials: Can be consolidated with the injection of acrylic emulsions.

Layers Containing Organic Materials

The variations in stratigraphy and organic materials are so vast that it makes generalizations about approaches to consolidation difficult. The conservation literature should be consulted for the consolidation of bone, ivory, wood or antler to remain in situ. It is possible to state, however, that many organic materials are vulnerable to biodeterioration in the form of microorganisms and that a preventive treatment with a general biocide should be considered.

Detachment and Removal

Fixed Structures

The techniques for detachment, *stacco* (removal of the entire section of plaster or mortar with its support) and *strappo* (literally, "pulling"; removal of only the paint layer or decorative surface), for fixed features such as frescoes, painted wall plasters, mosaics, and decorative stone floors were developed and used by various restorers in Italy beginning around 1850. Subsequently, the most important Italian laboratories for conservation research and training, the Istituto Centrale del Restauro (ICR) in Rome and the OPD in Florence, have refined the basic practice for both, ensuring their more successful implementation. Until the floods of Florence in 1966, both stacco and strappo had been timidly applied to so-called minor works of art. During the floods, because of the urgency of the situation, these techniques were widely applied to some of the best-known masterpieces of Italian art. From their extensive use at that time, stacco and strappo became generally accepted as viable approaches, especially in Italy but also in the rest of Europe. Only in the 1980s was their practice curbed by the Italian Ministry of Culture. Today in Italy the use of stacco and strappo on decorative wall plasters, frescoes, or floor mosaics is subject to approval by the ministry and only after thorough study and justification.

Because strappo is now considered too detrimental to the integrity of the decorative surface, it is not the focus of this chapter. Only stacco is discussed, referred to simply as "detachment."

Anyone who has witnessed an operation of detachment can testify to the extreme and potentially traumatic nature of the technique; it can be very difficult to undertake and may put the affected material at great risk. The desire to regulate the technique is therefore understandable. Given the inherent risk and difficulty, detachment should be considered only a technique of last resort, when there is no other possible way to preserve a wall or floor covering or decoration. All other alternatives should first be carefully examined. Detachment should be considered only in the following circumstances:

- When the archaeological and/or architectural context that the decorative surface is part of will be irreparably damaged or lost due to larger environmental factors such as floods or landslides or due to public works such as the construction of roads or dams
- When environmental conditions are not compatible with long-term preservation and are impossible to alter or change, such as in areas of periodic flooding or freeze/thaw cycles, structures inaccessible for most of the year, and so on
- When the decorative coverings must be removed to allow for structural consolidation of the architectural context to which they belong
- When operations to reanchor or reattach the decorative covering to their support could result in their destruction or loss (see chap. 5)
- When operations to reanchor or reattach decorative coverings are not feasible within the period of excavation (see chap. 5)

Another important consideration is what will happen to a decorative feature once removed:

- Will it be returned to its historical or architectural context?
- Will it be moved to a museum or an appropriate storage facility?
- Will there be sufficient funds to allow for the removed surface to be rebacked or transferred onto a new support?

These problems may seem academic, but the failure to address them accounts for why museum and excavation storerooms are filled with materials that, after some time, have become difficult if not impossible to reconnect with their historical, artistic, or archaeological contexts. Consequently, it is important to take the appropriate time to consider these factors so that informed and realistic decisions can be made. If, in the end, detachment is deemed necessary, it must be carefully planned in all its stages, with special consideration given to the type of material(s) to be removed and its intrinsic weight, as well as the number and experience levels of personnel needed and the type of environment in which operations will be performed.

Basic Principles of Detachment

Detachment usually begins with the adhesion of a strong support, or facing, to the surface of the decorative covering. The facing serves as a structural and cohesive support of the decorative surface, allowing mechanical force to be applied to the architectural sublayers or support layers: underlayers, or *arriccio,* for frecoes and wall plaster; bedding mortar for mosaics. The mechanical force can take several forms and is what ultimately will separate or detach these layers from their architectural setting. The amount of force required to cause detachment can vary greatly from one case to the next. The thickness of the detached material can also vary significantly and must be evaluated and planned for in advance to avoid being left with overly heavy, unmanageable fragments that are difficult to handle or move.

The first step in detachment is the application of a suitably weighted (thread count, warp and weft type) fabric, cloth, or gauze with the appropriate adhesive for the occasion. The type of fabric weave and thread count should not be too open or too closed and thick so as to make it impossible to contact all irregularities and features. The idea is to achieve as much contact as possible by choosing a weave and thickness of material that will be sturdy and strong, yet flexible enough to adapt to the morphology of the surface. Equally, the type of adhesive to be used should always be reversible, but its properties should be in direct relation to the material to be detached. It is advisable to remove from the surface as much obscuring debris that could prevent proper adhesion as possible. Degreasing the surface with a solvent is also good practice. In the past vinegar or ox gall was commonly used for this purpose, and both are still viable alternatives to common solvents if necessary.

The cloth or gauze should be composed of natural fiber, preferably cotton. The presence of polyester or other common synthetic fibers in fabrics must be avoided because they may react with the solvents used in the process of detachment. It is recommended to first wash the cloth in boiling water to eliminate any possible traces of starch or starching agents that are typically applied to fabrics. These are often vinyl or cellulose based and can also react unpredictably with solvents that may be used during treatment.

The cloth should be laid out flat and ironed if it has wrinkles or folds that could negatively affect surface contact and adhesion. It should then be cut into strips roughly 20 × 30 cm. A rectangular shape is preferable to a square because the long side can be used as a line of orientation and the starting point for resin application and adhesion, with successive strips overlapping by about 1 cm. Proceeding in this manner, the next row of facing can then be applied along the short side, thus avoiding irregular alignments that could potentially cause undue stress concentrations along any one line of overlap.

Facing should begin from the bottom. Starting from the top inevitably results in streaks and drops of adhesive accumulating at the lower portion of the surface to be detached. These in turn can create excessive localized tension, which can pull a pigmented or a fragile surface or, most likely, become an impediment to proper facing of these areas by creating an elevated feature that the cloth must conform to, preventing it from lying flat. After drying, this facing is typically covered by a more substantial layer of fabric, usually canvas or jute. This layer is often what endows consolidative strength to the facing, and the weave and thread count should be proportional to the size/mass of the surface to be detached. Typically, adhesive is not applied to a border that extends roughly 15 cm past the surface to be detached, creating a strip from which operations can begin.

It is imperative to wait for the adhesive to fully dry before beginning any further steps. Any premature tension on an undried adhesive can cause separation of the facing from the surface, with risk of partial loss of the material one is trying to protect, and the need to remove any remaining facing and begin all over again. This precaution applies to any type of adhesive used. The advantages and disadvantages of animal glues and acrylic resins, the two most commonly used resin types for detachment, are considered below.

Traditional Detachment Using Animal Glue

Animal glues are generally defined as adhesives made from animal skins and ligaments and consisting mainly of collagen. They are typically sold in the form of solid beads or blocks and under various names. The most common formulas consist of animal collagen dissolved in water in a double boiler, with 5% ox gall as a surfactant, 2% vinegar as a thinning or liquefying agent, and up to 10% molasses, which functions as a plasticizer to prevent brittleness once the glue has dried.

Animal glues must be applied while very hot to ensure their fluidity and proper adhesion (usually around their boiling point, 115°C, or 239°F). This is the main drawback of the method, particularly if the work has to be done over a large surface area or overhang, such as an archway or a vault.

Advantages:

- Inexpensive and readily available
- Very strong, yet slightly flexible bond
- No toxic vapors (apart from the smell)

Disadvantages:

- Difficult application that depends on the experience of the practitioner
- Susceptible to biological growth and microorganisms
- Nonsetting or problematic setting in very wet or humid conditions
- Large amounts of boiling water needed for softening and reversibility (this makes the technique incompatible with water-sensitive surfaces)

Detachment Using Acrylic-Based Adhesive

A valid alternative to animal glues are acrylic resins in solution such as Paraloid® B-72, B44, and B48N. These resins are typically applied in high-percentage concentrations (approx. 40% w/v) with organic solvents.

Advantages:

- Do not have to be heated to be applicable; can be applied at room temperature
- Application is not absolutely dependent on ambient temperature for performance
- Not susceptible to biological growth or microorganisms
- Choice of solvent determines the amount of time for proper drying (the more volatile the solvent, the faster the drying time)
- Notably flexible bond

Disadvantages:

- Toxicity and flammability of the organic solvents involved (necessitating the use of vapor-filtering masks if being applied in an enclosed environment)
- Quantity of solvents needed for softening and reversibility (this makes the technique incompatible with surfaces that may be sensitive to organic solvents)

Techniques for the Detachment of Decorative Elements

The difficulties inherent in detachment are complex and extremely varied. This is especially true for nonfresco or wall plaster features, which themselves are typically removed using the previously mentioned facing techniques with acrylic resins or animal glues. Decorative floorings vary to a much greater extent in their nature and composition and by extension the logistics of their detachment. For this reason, they are the focus of this section.

OPUS SIGNINUM FLOORS

The materials used to create opus signinum floors are generally analogous to those used for making mosaics. The major difference between the two floor types is the dimensions of the components making up the decorative surface and the thickness of their respective bedding mortars. Mosaics tend to have small, regular tesserae; opus signinum is often made up of irregular-sized pieces and fragments. Bedding mortars tend to be much thicker for opus signinum to compensate for the varying thicknesses of irregular-shaped fragments of stone, pebbles, or ceramics common for this type of flooring. The result of this is that the weight of detached opus signinum tends to be much higher than that of mosaics relative to comparable surface area.

Another key difference is that opus signinum floors tend to be produced primarily with hydraulic aggregates, such as volcanic sands and crushed ceramics high in silica and alumina. These form a much stronger bond between the bedding mortar and the mortar of the decorative layer than do nonhydraulic mortars, which are more common in mosaics. Hydraulic mortars are extremely hard and rigid, which makes opus signinum floors susceptible to cracks and ruptures from settlement and from flexing during detachment operations.

When this type of flooring is removed, an extremely strong resin must be used, combined with a very sturdy facing material such as thick woven jute, to not only minimize the potential for movement during detachment but also adequately handle the weight of the resulting removed section. It is generally best to begin detachment at the line between the decorative and the bedding mortar layer, immediately under the decorative aggregate, with rigid panels of plywood, boards, or metal sheeting to form a support that can be gradually worked underneath and then used to move the section. The average weight of a detached section of opus signinum can vary from 40 to 100 kilos per square meter. This should be taken into account to select the most appropriate form of temporary support and to determine the dimensions of a manageable section. The size of the section to be removed is crucial, especially when one considers that a large surface area will necessitate its division into feasible parts defined by their weight.

MOSAIC FLOORS

Mosaic floors are far less susceptible than opus signinum to damage from movement because the space between tesserae acts as an elastic join that can allow for some tension or compression. Equally, the more uniform size of tesserae (generally no larger than 1 cm) typically translates to a thinner layer of mortar into which they are set, which is itself typically nonhydraulic and thus less tenaciously bonded to the lower bedding mortar. All these factors combine to make mosaics more manageable to remove; the weight of a detached square meter should be somewhere between 15 and 30 kilos.

Detaching a mosaic surface by dividing it into sections to be lifted is generally not a problem because the necessary cuts can be confined to the mortar between tesserae and can often follow the borders of different geometric elements. If rejoined, rebacked, or relaid, a mosaic that has been lifted in sections can feasibly be reunited with virtually no trace of having been divided into pieces. For this reason, the sectioning of a mosaic, if approached prudently, can be performed safely and with every expectation of success.

In some instances, a so-called rolling technique has been preferred to sectional lifting. The concept is the same: a facing is adhered to the mosaic surface and then cut from below at the point between mortar layers. With this technique, however, rather than being lifted in smaller, manageable sections, the entire floor is faced and one end of the facing attached to a large tube along its length and the mosaic progressively pulled onto this tube as the weaker bond line between the bedding planes is exploited. This approach has been used when a mosaic is in relatively good condition and is to be relaid in situ with a new bedding mortar to provide better support and adhesion. In these situations the integrity of the floor as a whole is preserved. This is an inappropriate technique, however, for mosaics that have any degree of settlement or large cracks. In addition, a major drawback, aside from the need for specialized equipment, is that a rolled mosaic is extremely heavy and unwieldy, making it hard to move and store. These problems are compounded if re-laying is not planned to proceed quickly after detachment.

BEATEN OR POURED LIME MORTAR FLOORS

Beaten or poured lime mortar floors are often encountered on archaeological excavations, as they were often used in areas inhabited by the poor or commoners. Use of lime mortar was a rudimentary way of making a level floor, and it is typically of very poor quality. Despite the lack of decoration or refinement of these floors, it may be important to preserve a portion as a representative sample for archaeological representation or analysis. Because these floors were purely functional and rarely intended to be permanent, their state of preservation is often very bad; they are generally highly friable and discohesive, with little mechanical strength.

If one must remove a section of this type of flooring, consolidation with an ethyl silicate to improve mechanical properties is almost obligatory prior to detachment. In the event that a section should eventually have to be relaid in situ, a suitable support must be provided for and any form of foot traffic avoided.

Transport and Storage of Detached Features

Whether originating from a wall or a floor, the applied facing constitutes a solid yet flexible mechanical and chemical support to the detached decorative surface. Even with this support, certain precautions should be taken during transportation and storage:

- Any type of flexing or bending should be avoided, and a rigid support such as wooden planks should be used during handling or transit.
- Bending or flexing is particularly damaging if it occurs near portions of the surface that have not been faced, such as the borders. If bending or flexing is unavoidable during handling or transport, it is best if limited to or concentrated in the area that is reinforced with facing.
- If stacking of removed elements is necessary at any point during transport or storage, space of at least 10 cm should be provided between the layers with a suitable substance, such as extruded polystyrene foam or even polyurethane foam. Foam rubber should be avoided because of its tendency to compress and deform under weight and trap moisture, which can encourage biological attack.
- Good air circulation is a must for stacked sections but is generally a good practice for storage.
- The resins or adhesives used in conjunction with textile to make a facing tend to harden over time. Accordingly, stacked sections should be placed on flat supports so as not to create any deformations or distortions that will be rigidly held once the resin becomes less flexible.
- Because the resins tend to harden over time, it is important to remove the facing material as soon as possible to minimize potential problems or damage. By extension, any plans for rebacking of the material should be taken into consideration prior to commencing detachment.

Movable Objects, Features, or Materials

Conservation Issues

Removal, lifting, and detachment should be done as soon and as methodically as possible, taking into consideration the circumstances and parameters of the excavation itself, the specific soil and environmental conditions, and the condition of the material(s) to be removed.

According to the principles of preventive conservation, any material to be lifted should be removed as soon as possible, preferably immediately on being unearthed or, as in the case of block lifting, prior to being fully excavated (see "Block Lifting" below). The urgency of lifting is due to a number of reasons, not the least of which are the problems that can result from prolonged exposure to environmental factors (see chap. 2). No less worrisome is accidental damage during the ongoing excavation, as from incidentally bumping, scraping, or even stepping on the material to be removed. Simple loss or theft of smaller materials that can easily go missing or unnoticed must also not be underestimated. Last, from a practical standpoint, lifting operations performed while soil conditions are similar to those at the time of unearthing are typically less problematic, as for example on a moist soil that has not gotten wet from rainfall.

Removal can proceed quite rapidly during or immediately after excavation for multiple fragments or small materials that can be lifted as a collection (see "Lifting" below). The same cannot be said for more fragile, complex, or larger fragments or materials, or those that are important to the stratigraphical context of the excavation. While a delayed or slower intervention is often preferable from an archaeological perspective, it is not ideal from a conservation point of view. When removal of objects or features is not considered or planned for, it will be left to the whim of excavators, who may not be fully aware of the conservation issues or associated consequences. Lifting should always be done as soon as feasible, especially as regards fragile, deteriorated, or chemically and physically unstable objects or materials. More difficult lifting operations should be performed by a conservator or at the very least with a conservator's consultation and guidance.

Object or Material Characteristics

For conventional reasons objects and materials can be divided into three main categories based on their relative size:

1. Small objects or materials: seeds, glass beads, coins, fibulae or brooches, bracelets, ointment containers (Barker 1981)
2. Medium-sized objects or materials: cups, plates, bricks
3. Large remains or materials: portions of floors or walls or ceilings, columns, beams

Small and medium-sized objects can typically be found in the following combinations:

a) Fragments or solitary pieces that are basically intact but scattered on the ground or groups of fragments from the same object or material that are dispersed over an area with little relation to their complete original form
b) Whole or large portions of an object that are fragmented or significantly cracked from being squashed, bent, deformed, or distorted but still constitute a recognizable assemblage that is contained within a small amount of soil (fig. 10.1)
c) More or less complete objects that may be highly fractured or collapsed but remain in an intact and recognizable form due to the adhesive properties of the soil that surrounds them
d) A complex assemblage formed by any combination of types a, b, and c, such as a skeleton with preserved bracelets and various funerary accoutrements

For finds of categories 1a and 2a, it is sufficient to use standard recovery practices (see "Lifting" below). For objects or materials related to categories 1b and 1c and 2b and 2c, more specialized lifting techniques may be required (see "Block Lifting" below). For those finds of a more complex or composite nature that would fall into categories 1d and 2d or simply 3, it is generally advisable to consult or involve specialized conservators.

Lifting

Small fragments or objects can physically detach from their surrounding soil due to the contraction of the soil during drying. Barring this possibility, such materials should be lifted by carefully removing the surrounding soil with fine tools, avoiding touching their surface directly, or by using suitably soft implements on the material itself that will not abrade or scratch its surface (see chap. 4). An acceptable compromise

Figure 10.1 Highly fragmentary glass object incorporated into a mass of soil with which it forms a singular block (see category 1b) that was lifted without an external support.

Table 10.1 Traditional Materials for Stabilizing and Containing Archaeological Materials prior to Lifting

Type		Notes
A	Medical bandages in cotton and gypsum used for making casts and splints	Need water and will not sufficiently harden in overly humid or damp environments; require some dexterity and skill to employ properly.
B	Medical bandages in fiberglass and polyurethane resin for making casts and splints (such as 3M Scotchcast)	Will set in ambient humidity or can be wetted with tepid water; are well suited for damp, wet environments; are not particularly well suited for small objects or ones with elaborate profiles, and are at their most advantageous if they can be used to completely envelop a material or object.
C	Gypsums	Special dental or masonry plasters (scagliola, canary): require water to set, can be used alone to bond things together or in combination with cotton bandages and gauze; will not properly set in high humidity or wet environments; require specific tools, dexterity, and experience to employ properly.
D	Waxes	Paraffin, beeswax, etc.: can be used alone (casting) or in combination with impregnated bandages and a heat source; can be useful in very humid or wet environments in which acrylic solutions, emulsions, or resins will not adequately set; cannot be used in very warm climates.
E	Expanding polyurethane foam	Have the double functionality of containment and protection from forces; are very lightweight; have an easy and quick application process if prepackaged industrial cans are used (the use of a two-component resin with a foaming agent is more difficult to employ but is often more effective, especially for large objects or features); can be used in humid, damp, and wet environments; are susceptible to deterioration from UV light.
F	Cyclododecane	Cyclododecane is a solid cyclic hydrocarbon ($C_{12}H_{24}$) that sublimes at room temperature. It can be used for very temporary operations. It appears as a very light white powder, which can be liquefied when heated in a water bath or dissolved in various solvents, e.g., Shellsol OMS (white spirit), hexanes, or xylenes. The liquefied cyclododecane can be directly applied (quickly while it's dissolved or hot) on different materials (stone, ceramic, brick, plaster, etc.) and/or combined with cotton gauze to temporarily immobilize small to medium-sized objects. It is particularly suitable in damp or wet conditions, where it may be difficult to use other, more common materials. After application the cyclododecane has a short life span because it sublimates in a few hours, days, or weeks (depending on climate and exposure, as well as thickness of application).

may be to remove both the material and a thin layer of enveloping soil.

The full excavation of objects in silt or muddy contexts can cause irreparable damage to the objects' surfaces, especially in the case of heavily corroded glass or artifacts with gilding or fragile painted decorations (see chap. 5). The corrosion layer on glass or painted or gilded surfaces may actually adhere more strongly to a silty soil than to their own substrate. In such instances, the materials must be lifted together with a fine layer of soil, approximately 1 to 2 mm, still adhered to the surface.

Phenomena similar to those just described can be encountered in very dry or carbonaceous soils. Accordingly, lifting techniques must be similar but with the one modification that the soil (only the soil) may need to be lightly moistened to facilitate operations.

In cases where the material(s) may be highly fragmented, crushed, or distorted and generally structurally unstable, traditional removal by methodical and careful excavation may prove impossible or damaging to the material itself. In these situations it is always better to resort to either supported or unsupported block lifting. (See tables 10.1 and 10.2; categories 1a and 2a.)

Block Lifting

Block lifting consists of removing the artifact(s) together with the surrounding soil as a more or less solid and compact unit. Block lifting in concept can help to avoid undue mechanical and environmental stress on fragile or fragmentary objects by limiting their disinterment to the initial soil removal that reveals their presence. This in and of itself reduces the potential for exposure to haphazard or risky excavation or cleaning. In some instances, block lifting can preserve important information for later study of the sedimentary context (Berducou 1990). Importantly, this technique allows one to delay full excavation until the assemblage can be removed to a laboratory or similar facility where the environment can be

Table 10.2 Some Examples of Common Support Materials Used in Lifting Operations

Type		Notes
A	Semirigid sheets of copper, brass, aluminum, zinc, or plastic materials such as fiberglass, polyvinylchloride (PVC), polypropylene (PP)	Can be inserted easily into trenches cut in the soil, either alongside or underneath an object or material, functioning as temporary supports during lifting; can be used for objects and materials of limited scope and weight; otherwise they need additional structural support in the form of planks or panels of polystyrene, wood, or polycarbonate. Plastic panels or sheets are preferable if the support is meant to be more than short term (fiberglass or polypropylene); otherwise PVC or metal sheeting should be avoided for storage for any length of time.
B	Extruded foam polystyrene (PS) panels and sheets (insulation for home and building construction)	These are panels commonly used as insulation in construction of roofs and walls; they are typically light reddish/pink, light blue, or light yellow in color. They are lightweight and semirigid, can be easily cut with box cutters and knives, and thus can be customized to small or medium-sized objects or materials. Such panels are not adversely affected by humidity, moisture, or dirt and grime but can be susceptible to gradual damage from UV light and can be dissolved with some chemical solvents.
C	Wooden planks or sheets	These are particularly well suited to the lifting and support of large objects or features, especially hardwoods or those precut for carpentry. Typical resinous woods (pine, fir, etc.) can deform if used in humid or damp environments. Particleboard or panels made with a resin/wood mixture should not be used. Wood sheeting and panels are more expensive than polystyrene panels and, accordingly, should be used where their greater structural strength is necessary.
D	Polycarbonate (PC) honeycomb panels	The semirigidity of polycarbonate honeycomb panels makes them well suited to the lifting of small to medium-sized objects and thus they are a good compromise between the rigidity of wood and the softness of polystyrene and are chemically more stable in the long term.

controlled. This is essential if meticulous and delicate operations—such as gradual consolidation—must be undertaken prior to soil removal, and can be greatly beneficial in cases of highly fragmentary, fragile, or distorted objects. (See tables 10.1 and 10.2; categories 1b, 1c and 2b, 2c.)

If block lifting involves the removal of a large block or section of earth, some of the surrounding archaeological context may be destroyed. Such a large mass may also be difficult to handle, load, or transport. Accordingly, any form of block lifting should be carefully planned and coordinated, considering all these factors. As will be seen, it is possible to address and overcome most issues and logistical problems with some simple steps and basic techniques.

Block lifting can be done in many different ways, depending on the specific case, by combining various techniques and using different forms of equipment. In general there are two conventional ways of proceeding, unsupported block lifting and supported block lifting (Payton 1992). These techniques have many steps in common, which can be summarized as follows:

a) Excavation (see chap. 4)
b) Stabilization (see chap. 7)
c) Preconsolidation (see chap. 7)
d) Initial cut defining the perimeter of the block; pedestaling
e) Containment of the exterior of the block; wrapping the block with a flexible material such as fabric or stretch plastic film or creating a rigid support
f) Secondary cut under the block, effectively detaching the block from the soil
g) Positioning and immobilization of the block on a rigid support

UNSUPPORTED BLOCK LIFTING

In unsupported block lifting there is no containment of the exterior of the block. An unsupported block lift is feasible only when it is not necessary to employ any form of stabilization or consolidation to the archaeological artifact or feature itself—that is, there is no need for steps b, c, or e—even if there may be cracks, voids, or deformation (see “Object or Material Characteristics” above and fig. 10.1). The conditions necessary to opt for the use of an unsupported block lift are as follows:

- The object must be relatively small in size; in principle, applicable to artifacts that relate to category 1b.
- The soil must be compact: either dry and hard or very damp or wet (typical for clay or loam soils). If the soil is only slightly damp or loose and sandy, or potentially both, then there is little probability of success.

- Lifting was planned for from the beginning of the recovery of the artifact, allowing it to be excavated in a way that could facilitate this method.

With an artifact in category 1b or 2b, care should be taken to reveal only its highest part and, if any, a small portion of its elevation; the great majority of the object should remain buried (see fig. 10.1). This way, the soil will continue to immobilize the object, acting as a form of containment. At this point the first cut can be made using fine trowels or semirigid spatulas, beginning with defining the perimeter of the block by responding to the outline of the object at a safe and reasonable distance from it (step d). This distance is dependent on the material type and its condition, as well as the soil type (see chap. 2). If there is a risk of hitting a portion of the artifact or if the block might not be large enough to contain the portions of the object that are still buried, then this distance should be increased accordingly.

There is no need to make deep cuts on all sides at first, as this could destroy large areas of context around the block. Instead, it is preferable to first excavate the profile on the side of the block that is most convenient both technically and archaeologically. This will allow for the full situation to be better understood before the rest of the cuts are made, including the second cut under the block (step f).

Once the sides of the block have been defined, the last step before lifting is to insert some type of sheeting support, rigid or flexible, under the block at the point of the second cut (fig. 10.2). With small to medium-sized objects this is very similar to inserting a knife under a slice of cake. The support can be inserted slowly after the horizontal cut has been completed. With medium-sized to large objects (category b under "Object and Material Characteristics" above) a more rigid form of sheeting or board is useful (support type B, table 10.2). Such supports are typically metal sheeting, such as baking or cookie sheets, or insulation panels, which can be found in various sizes or cut to match the specific job. These can be pushed gently under the undercut block, or if the soil is very compact the block can be slid onto them.

Once the undersupport has been inserted, it and the block must be placed onto a more rigid support and tied down or held in place with elastic bands, Velcro, nylon, or polyester strips for removal from the site (see chap. 7). In some instances tape can be used in conjunction with fabric or textile placed over the object's surface to protect it from the adhesive (see table 12.6). Whatever is used, if it is not properly secured, all the careful planning and implementation to remove the block may be in vain.

Figure 10.2 Insertion of a flexible fiberglass support under the object during the second phase of soil removal, in this case a carbonized timber support.

SUPPORTED BLOCK LIFTING

In supported block lifting there is containment of the exterior of the block. This method is typically used when the archaeological material or the soil or both lack sufficient cohesion or are so structurally unstable that either detachment or lifting would compromise the integrity of the object. Materials that are highly fragile or fragmented (caused by compression), hard and fractured (stone, ceramics, or glass), or corroded (metals) often require use of a supported block lift. In cases where the object or feature is large, the intrinsic weight may be too great and would be detrimental if unsupported when a lift is attempted.

From another perspective, because this technique allows for more soil to be removed from around an object, supported block lifts may be preferred when there is a desire to define the full extent of the object or feature (see chap. 4). In these instances any form of stabilization and/or support compensates for the lack of surrounding soil. For this to be possible, however, proper planning and coordination are essential so that support can follow immediately after excavation. Soil removal, surface cleaning, stabilization, and/or consolidation and support operations should be performed in one uninterrupted cycle.

The sequence of these procedures is related to the nature of the object to be lifted. In cases of exfoliation or high fragmentation, immobilization or consolidation should be part of excavation to avoid the loss of spatial relationships between fragments (steps b and c). This can even apply to seemingly well preserved objects, such as broken but intact ceramics or cracked stone blocks, that may have a tendency to open when the containing soil is removed. The previously listed steps a–g should cover all possible operations, but consolidation may be necessary to varying degrees and implemented at various stages depending on the material characteristics, as follows:

- Localized surface application

  Immobilizing flakes or exfoliating materials with an open-weave gauze and acrylic resin (see chap. 7)

  Adhering detaching or loose fragments with weak, reversible resins (see chap. 7)

- Superficial application beyond the surface

  Consolidating corrosion on metals or glass or immobilizing detaching surface layers such as with wall plaster or frescoes (see chap. 9)

  Preconsolidation of large or extensive areas that are still covered with a thin layer of burial soil (see chap. 9)

- Deeper penetrating application

  Adhesive or cohesive consolidation with acrylic resins or ethyl silicates, undertaken only in cases of absolute necessity and, preferably, performed by a conservator

In principle, deep penetrating consolidation is undertaken only on object types or features in categories 1b and 2b. Localized surface application or preconsolidation can be applied to virtually all object types and in all situations.

Tall artifacts or vertical features such as wall paintings (categories 1d and 2d) may feasibly be block lifted with the use of external supports or straps to immobilize the object itself or the object and block of soil. In many instances the techniques described in the section on discovery in chapter 7 may be sufficient to guarantee success:

- Straps or ratcheting, which can be adjusted to exert a determined amount of pressure on a detaching, delaminating, or exfoliating object or feature
- Polyethylene bandaging strips for wet or humid objects or features, which can also serve to preserve the microclimate while providing support
- Elastic bandages, which allow for forces to be regulated and more evenly distributed on the object or the feature

These immobilization techniques have distinct advantages over any form of chemical consolidation:

- They do not involve the use of chemicals of any sort, whether solvent or resin.
- They do not invade or alter the chemical-physical nature of the object or feature.
- They are totally reversible.
- They are fast and easily used.
- They are relatively inexpensive.
- They do not require specialized knowledge or skills.

In very complicated cases where specialized applications and techniques are necessary or cases where environmental parameters are a major factor, it is best to involve a conservator or someone who has specialized training. These cases typically involve the creation of structural supports through chemical means, such as:

- Cotton bandages soaked in plaster to create a hard-shell cast support
- Fiberglass matting with polyester or polyurethane resin to create a hard-shell support
- Cotton bandages coated or impregnated with beeswax or paraffin wax to support a hard-shell support

These stabilization techniques are well described in the archaeological and conservation literature and have been used traditionally in the removal or lifting of movable heritage. For this reason the methods of application are not the focus here but rather, the factors that influence if and how they should be used (see table 10.1).

Once stabilization has been achieved, detachment may proceed with the first vertical cuts (step d). For objects in categories 1b and 2b, containment of the object or the object and the block of soil may be necessary. This can be done with a flexible fabric or plastic film wrapped around the pedestal or by creating a hard shell over one or the other in plaster, fiberglass, and resin or waxes, using an isolating barrier to prevent their penetration into the matrix of the object or soil. Steps f and g proceed as described in the section on unsupported block lifting.

In cases of large or heavy blocks, an alternative technique using metal rods instead of semirigid and rigid sheets can be implemented. The number and diameter of the rods are dependent on the size and weight of the block to be lifted (fig. 10.3). The rods can be made to pass from one side of the block to the other, via the shortest side, by slow pressure. Once the rods have been passed through, they can be connected to one another at their ends by another bar placed perpendicular along their ends and secured in place with wire. This creates a de facto pallet, with the bars acting in unison; it is especially effective in pebble-rich and rocky soils in which trowels and blades are relatively ineffective at making the secondary undercut.

EQUIPMENT AND APPLICATION

Table 10.2 lists the more commonly used and more easily found materials used as the structural base in block lifting. These have been organized according to their function. As with all the materials listed in table 10.1, these should never be used directly on the surface of any object or feature. In general, when a material is being used in contact with the object or soil surface, an isolating barrier of polyethylene plastic film (for steps a, c, e) or aluminum foil (for steps a, b, c, d, e) should be used. This precaution should minimize the possibility of adherence, damage, or alteration and ensure greater success of the operation.

Where resins, waxes, or plaster are used, it is recommended that the application of these materials be entrusted to conservation professionals or specially trained individuals. These materials have the advantage of being applicable in a semifluid or viscous state, allowing them to conform to the particulars of the undercut and fill any potential hollows or voids (step f).

Figure 10.3

Preliminary Cleaning of Movable Objects and Features

"Preliminary" or "initial" cleaning refers to the first general cleaning, commonly known as *washing*, that is undertaken on most archaeological artifacts and materials during their recovery, immediately after removal from the soil, or in a conservation laboratory.

Archaeological Practices and Conservation Issues

Preliminary cleaning is a form of intervention that has consequences for the preservation and long-term stability, not to mention appearance, of an archaeological material. As such, for all intents and purposes, cleaning should be undertaken with reference to and guided by the principles of ethics for acceptable conservation practice (Pedelì 2001a). Unfortunately this is not the traditional view or practice of cleaning; even today it is applied all too casually to artifacts during excavation, when, once removed from the soil, they are fully immersed in water.

In order to better understand these statements, it is best to define from the outset what is typically involved in the daily practice of cleaning on most archaeological excavations, where even during initial discovery and exposure, an unconscious form of cleaning that can be divided into two basic phases often takes place (see chap. 4):

1. Removal of the earth and soil around an artifact or feature: up to this point the surface of the object probably has not been touched or had any substances applied to it, not even water. Though it is still somewhat covered with soil, the object can be identified in its approximate material type and shape.
2. Surface cleaning: removal of the thin layer of soil still covering the surface and partially masking potential specific details, such as color or applied decoration. At this point the surface is touched by various tools—trowels, spatulas, brushes, or sponges—more or less constantly and may have had water applied to help soften or dissolve the obscuring soil.

The first phase is implicit in the act of excavation and cannot be changed other than to be undertaken with caution and prudence. The second phase, on the other hand, goes beyond what is typically necessary and can be justified in only a small number of situations where it is not possible to identify the significance of the find due to its veiled or obscured nature or where exhaustive in situ documentation is necessary to the point of highlighting the color and every surface feature of a find.

Once removed, the great majority of archaeological finds such as ceramics, stone, glass, and even bone fragments are typically washed. Usually this is done by submerging masses of fragments still covered with soil in large containers of water and then scrubbing them with household cleaning brushes, toothbrushes, or paintbrushes. Although an entrenched practice on most excavations and seemingly harmless from a conservation perspective, it in fact contains many detrimental risks if not undertaken with some care and attention as to the materials being washed and their basic state of preservation. If these basic factors are not taken into consideration, irreversible damage or loss is entirely possible:

- Alteration or removal of organic residues or traces of original use
- Alteration or removal of pseudodomorphs or impressions from other objects
- Alteration, mechanical deterioration, or removal of portions or features of an artifact, such as decorative coverings, painted surfaces, or inlays
- Exacerbation or initiation of chemical, biological, or physical agents of deterioration

If washing is followed by rapid drying, aided by exposure to direct sunlight or strong drafts or winds, the potential for damage or loss is increased. At the opposite extreme, if washed objects are not fully dried, or are left damp or wet too long, and are then enclosed in impermeable storage bags or plastic containers, the activation phenomena of alteration and eventual degradation are very likely. In particular, biological growth is probable on porous materials such as ceramics, stone, bone, and wood, while corrosion of metals or glass may occur or continue.

At this point it is clear that the relatively short duration inherent in archaeological activity is in fundamental contrast to the principles of conservation and preservation (table 11.1). With this in mind, it is important to understand that there are factors that make initial cleaning a necessary part of excavation activities and to outline accordingly some basic principles and practices that can make this a more responsible undertaking.

Table 11.1

Archaeological Aims	Conservation Aims
Identify the class and type of object, in particular, ceramics	None
Sort and inventory objects	
Document the archaeological context from which an object is recovered	
Further materials analysis and study (occasionally necessary)	

Conservation Principles of Preliminary Cleaning

Any form of cleaning, whether during excavation or later in a controlled laboratory environment, is irreversible. This fact in and of itself should lead one to consider the objectives of cleaning prior to any action. Preliminary basic cleaning (Italian *smascherare,* "to unmask") should be intended to reveal only very basic information about an object. Thus, the guiding principles for initial cleaning can be summarized as follows:

- It should allow for the main physical characteristics of the object to be discernible.
- It should allow for the basic state of preservation to be ascertained.
- It should include research into possible "informative elements" present in the overlying soil.

Preliminary cleaning thus should be conceived as a methodological interpretation and gradual dismantling of the soil (Pedelì and Appolonia 1998). In practical terms this translates into the selective removal of extraneous superficial surface soil from the object, leaving any material or substances that have more intimately interacted with it, such as efflorescence, encrustations, or stains. This selective restraint holds equally true for any traces of use, residues that have adhered to the surface, and any incorporated surrounding soil. Alternatively, all such substances can be carefully removed, as long as their presence is thoroughly documented ahead of time and some is preserved for future reference or analysis.

Thus the goal of initial cleaning should not be to clean an object per se but, more simply, to render its basic characteristics more understandable. With this said, the reality is that preliminary or initial cleaning is often anything but a limited or careful process, undertaken with clearly defined objectives and following specific criteria. In the best-case scenario, cleaning proceeds gradually. Even then, if a material is believed to be fragile or sensitive to water, there is often recourse to so-called dry techniques—brushing or picking the soil from the surface—in an attempt to be less intrusive. While this practice is well intentioned, dry soil particles worked over a surface can be abrasive, and potentially more detrimental than using water to soften surface soil to aid in its removal.

In situations where the recovered materials are interpreted as being robust or in good condition, the common practice is to immerse them in tap water and then place them in the sun to dry. The reality is that typically the only advantage to this technique is the rapidity with which objects and features are recognizable. This form of washing should really only be permitted if prescreening has taken place while the objects still contain some burial soil to determine which may be able to withstand the physical forces associated with immersion and drying. At the very least this may lead to the identification of more fragile or inappropriate materials, objects, or features that have delicate surfaces or are in a poor state of preservation. These should then be treated with greater caution.

Immersion or general wet washing cannot be undertaken for the following objects:

- Glass with any form of opalescence or superficial iridescence
- Glass with any form of flaking or exfoliation
- Glass with any form of applied decoration
- Metals, particularly iron
- Ceramics with detaching slip or glaze or any traces of them
- Ceramics with a spalling, flaking, or exfoliating surface
- Ceramics without a surface slip, glaze, or fireskin and a friable, powdery surface
- Ceramics with highly cracked and fissured slips, glazes, or clay fabric
- Ceramics created at a very low firing temperature
- Lime mortars, wall plaster, and painted plaster
- Lime-based decorative pavement fragments

- Wood, leather, fabrics
- Bone or ivory
- Carbonized organic remains, such as fabric or seeds
- Amber

Tools and Techniques

Before a brief description of the primary techniques for cleaning artifacts after their removal from the soil is given, it is imperative to reiterate the importance of first considering the purpose for cleaning. Rather than view this action as a definitive cleaning, it should be seen as the gradual physical elimination of extraneous earthen materials and ultimately of the finest and most intimate layer of soil in a way that does not alter the chemical or physical nature of the object itself.

Dry Cleaning

Dry cleaning excludes the use of water, organic solvents, or any form of liquid. This technique consists predominantly of the use of small brushes (sizes 1 to 20) with soft, medium-length bristles (most animal hair or bristles and fine nylon, roughly 15 mm and longer). Shorter bristles can be too hard and inflexible and abrade delicate or deteriorated surfaces, such as many archaeological ceramics and glasses and most metals. Brushes should not be rubbed or dragged along the surface but held perpendicular to it and gently worked in a circular motion.

The use of toothbrushes should be limited. Even those with soft bristles should be used only if there is no other alternative and only on break edges and not on the surface of a ceramic itself. The bristles on all toothbrushes tend to be too short and thus too hard, and the nature of the handle makes it easy to either exert too much pressure or prematurely wear down bristles, making them shorter and even harder.

Damp or Wet Cleaning

Despite its name, damp or wet cleaning involves the use as of as little water or organic solvent as possible. In general wet cleaning is performed with a sponge that has been moistened with water. The sponges can be natural or synthetic of varying densities. (Table 11.2 lists the three major types of hydrophilic sponges typically used for the cleaning of delicate surfaces, polyvinyl acetate, natural, and "viscous," and their relative properties.) Their use is as described in chapter 4 in the section on cleaning small objects. The soil or deposit to be removed is typically moistened, not soaked or wetted, before the sponge is applied. Contact should only be sufficient to lightly touch the surface in a semirotational movement. The sponge should be rinsed frequently to prevent buildup of potentially abrasive particulates.

Washing

If cleaning is necessary, the decision to use the technique of "washing" (traditional practice of immersion) over "dry" or "damp" cleaning should first be evaluated;

Table 11.2 Extract of Technical Data Provided by Giorgio Mischiatti (MG Company)

	PVA Sponge	**Natural Sponge**	**Viscous Sponge**
Porous material	Continuous with labyrinth-like design	Continuous	Continuous
Rate of absorption (seconds/cm^2)	2"–15"	2"	4"
Resistance to water	No apparent change after 1,000 hours of measurement	Weakening after 500 hours of measurement	Weakening after 200 hours of measurement
Resistance to acids	Dissolves in strong acids	Dissolves in strong acids	Dissolves in weak and strong acids
Resistance to alkalis	Hardens in contact with strong alkalis	Good	Hardens in contact with strong alkalis
Resistance to solvents	Weakens in contact with chloroform and tri-chloroethylene	Good	Good
Various observations	Good hydrophilicity; good water retention; good variation in pore sizes and shapes; good overall characteristics due to the presence of micropores	Good material with limited availability and unstable quality	Limited variation in pore size, endowing limited elasticity

if it is still deemed appropriate, then only water should be used. As initial cleaning should in principle be limited to the removal of loose soiling and deposits, water is the most effective general solvent, and there is no need to resort to the use of other organic solvents or acidic or basic chemical reagents. If anything other than water is believed to be necessary for washing, such a task should be performed by a conservator.

It is recommended practice to wash one fragment at a time rather than large groups or batches. Washing should be done by wetting the entire fragment and cleaning first any of the break edges to understand the nature of the material being cleaned and its reaction to this form of cleaning. Break edges can be cleaned with brushes, while surface cleaning is preferably done with sponges to prevent the application of excessive force.

The removal of soiling, whether from the break edges or the surface, should begin toward the center of the fragment and gradually work outward to the edges. Working in a semicircular motion, maintain a thin film of water so that the particulates that have been removed can travel downward, in the process softening, swelling, and ultimately helping to detach the remaining surface deposits. By working in this manner, greater security is guaranteed, because the fragment and the effects of cleaning can be directly observed. Importantly, this procedure should minimize the amount of saturation of the object being cleaned and the amount of time it is fully submerged.

Any sediments that are removed should sink toward the bottom of the water container, to ensure that the higher reaches of water are free from particulates and thus usable for continuous wetting of the sponge. For this reason it is also important that immersed materials not be allowed to sit on the bottom of the water container and that sponges not be wetted from the lower reaches. Frequent water substitution should reduce the number of particulates in suspension and help avoid potential abrasion.

Drying should occur gradually, preferably in a shaded area free from gusts of wind, drafts, dust, and airborne particulates.

Preliminary Packing On-Site

Conservation Packing

Purpose

The first or preliminary packing undertaken on-site is a crucial part of the conservation process during the excavation and recovery of archaeological materials. Often it determines the future survivability of the artifact itself and any potential analytical significance or associated information (see chap. 13). Despite its importance, responsible preliminary conservation packing is yet to be systematically applied on most archaeological projects. Commonly, these activities do not take into account the potential for creation of a microclimate within a storage container or even the proper positioning of objects within the containers. Equally, many on-site packing solutions do not conceive of potential future scenarios, such as transport or medium- to long-term storage, and thus prove insufficient or even detrimental.

In some cases the on-site packing is the only packing that takes place, one in which finds are transported and will be stored definitively. For this reason packing must not be conceived simply as "boxing" artifacts but must consider conservation (chemical and physical compatibility), logistical (cost, availability of materials), and scholarly (accessibility, handling) issues.

Preliminary packing should at the very least coordinate archaeological practices with conservation principles. For example, the need to maintain the relation of artifacts should not preclude systematic organization with respect to packing by material type or, potentially, state of preservation. This requires recognizing the nature of the materials recovered and their potential deterioration mechanisms (see chap. 3), assessment of their condition at the time of recovery (chap. 5), knowing the properties of packing materials and basic techniques for packing (see below), and predicting the future environment(s) to which the object might be subjected. All these factors are best met by translating them collectively into a basic packing plan for projected finds, complete with materials, equipment, and approach.

Timing

While excavation is ongoing, first packing can be undertaken for a number of reasons:

- If fragments or materials pertain to a stratigraphic layer
- For temporary storage on-site
- For transport from site to excavation warehouse/depot or conservation laboratory

And at specific times:

- Contemporaneous with removal or lifting (see chap. 10)
- Immediately following removal or lifting, during registration and labeling (see chap. 13)
- According to the logistics of transport
- According to the nature of temporary or intermediate storage

Classification of Packing Products and Materials

Our conventional classification of packing materials divides them according to their basic function: containers, padding/cushioning and fabrics, environmental regulators (buffers) and inhibitors.

Conventional Classification

Table 12.1 gives the three basic packing material classifications and their categories.

Table 12.1 Basic Packing Material Types and Categories

Type	Category
Container	Transport and storage
	Storage
	Subcontainers (baggies, boxes, envelopes, tins, etc.)
Padding and Cushioning	Open- or closed-cell expanded polymeric foams, shock and vibration absorbing
	Fabrics
	Paper and acid-free tissue
Environmental regulators (buffers) and inhibitors	Temperature control
	Relative humidity control
	Biocides/pesticides

General Requirements

Any product used for the packing of archaeological materials should meet the following requirements.

1. Chemical and physical/mechanical stability

- With regard to environmental parameters such as UV light, oxidation, and moisture (aging)
- With regard to use and wear
- With regard to acute or chronic forces such as stacking or mishandling (deformation, breaking)

2. Chemically inert

- No chemical interaction or reaction with the archaeological remains
- Contains no chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs)
- Contains no halogens
- Contains no vulcanizing agents
- Contains no acidic or caustic substances

3. Other properties

- Lightweight
- Noncolored (even white is a form of pigment)
- Adaptable
- Fire retardant
- Economical
- Easily available and reparable

The Canadian Conservation Institute (CCI) recommends the use of certain packing materials and the exclusion of others (Tétreault and Williams 1992). These guidelines underscore that the most important factors in selecting packing materials are their chemical nature and stability. The following discussion examines the three functional categories based on these recommendations.

Properties of Packing Products and Materials

Transport and Storage Containers

Various commercial containers are typically used at archaeological excavations to contain, transport, and store artifacts and fragments. They may house the objects directly or may serve as containers for smaller subcontainers. Accordingly, they should have properties that make them adaptable and somewhat universally applicable in a number of differing circumstances. These ideal properties can be summarized as follows:

Mechanical:

- Rigid enough to not deflect or distort much when under load
- Resistant to acute forces (bump, mechanical shock) from handling and transport while under load
- Resistant to sustained forces from storage, particularly compression; being able to withstand stacking

Chemical and physical:

- No chemical reaction or interaction with the archaeological material
- Will not release or leach chemicals, whether gas or liquid, even under unstable environmental conditions: changes in temperature, relative humidity, or exposure to IR or UV light.
- Resistant to environmental factors; will not deteriorate or react when exposed to visible, UV, or IR light, moisture, or changes in relative humidity or temperature
- Resistant to atmospheric pollutants
- Resistant to water and most common organic solvents and chemical reagents
- Resistant to biodeterioration

Table 12.2 presents the form, shape, and ergonomic properties of containers; and table 12.3 presents the basic typology of suitable and unsuitable containers. The majority of transport/storage containers for industrial packing purposes are made of polypropylene. Those that are made from PVC should be avoided at all costs, as they can deteriorate rapidly under exposure to UV light and off-gas corrosive acids that are detrimental to a great majority of material types. Cardboard or wooden containers should also be avoided, especially when dealing with wet or moist artifacts or materials or storage facilities that tend to be humid or damp. Recycled paper products should not be used as they have been repurposed with glues that can emit corrosive gases.

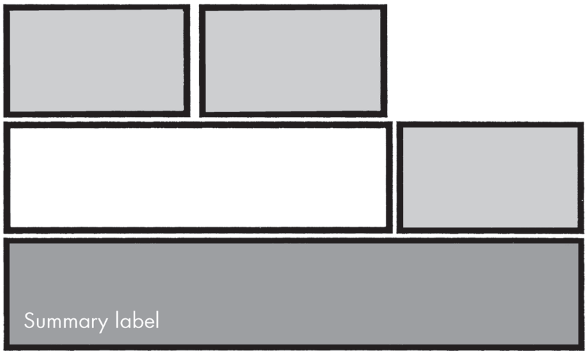


Figure 12.1 Diagram showing how three different types of containers can be combined to accommodate different sizes and types of objects and materials (modularity).

Table 12.2 Form, Shape, and Ergonomic Properties of Containers

Shape	Rectangular
Size and capacity	Appropriate to the size and intrinsic weight of the material or objects recovered; capable of being handled and moved. Typically standard dimensions of commercially available crates are 30 cm W × 40 cm D ×12 cm H (10 L); 30 cm W × 40 cm D × 22 cm H (20 L); and 40 cm W × 60 cm D × 22 cm H (40 L)
Modularity	Standard sizes for easy stacking and conforming to storage shelves (fig. 12.1)
Interior walls and bottom	Straight vertical walls and flat bottom, preferably without many holes and devoid of support ribs
Exterior walls	Good amount of vertical and horizontal support ribs to increase mechanical resistance; stable base with rib configuration that allows for stacking (fig. 12.2a)
Profile and rim	Walls and bottom should not be less than 2 mm thick; the rim should have a flat edge capable of supporting weight
Stacking	The underside of the upper container should fit onto or slightly into the rim of the container below, entering no more than a few millimeters (fig. 12.2b)
Handles	No less than two, on opposite sides
Labeling	Space for all pertinent data associated with the object and archaeological context on a flat and smooth surface on either the short or the long side of the container for ease of visibility
Cover	If possible, covering system should allow for stacking; otherwise not always necessary
Storage	Should occupy as little space as possible when not in use and be able to be stored in uncontrolled environments
Reuse	Should be washable and able to be used in any circumstances where packing is necessary

Table 12.3 Basic Typology of Suitable and Unsuitable Containers

Suitable	**Unsuitable**
Polyethylene or polypropylene boxes Polypropylene or wood pallets	Wooden crates or boxes Cardboard boxes Metal, typically tin, crates or boxes Polyvinylchloride containers Large glass containers Plastic shopping bags, fiber baskets

Subcontainers

The variable sizes of subcontainers allow for differing configurations within a larger storage container and, importantly, for accommodating the type of material recovered. These containers are most useful for small to medium-sized objects or material, such as significant pottery sherds, coins, bracelets, rings, and the like, that must be individually protected. As such, they are often used from the moment of excavation through to long-term storage. They therefore must be able to hold objects that are moist or wet and must remain stable under unregulated environmental conditions. See table 12.5.

As with larger containers, it should be recognized that they may never be replaced. Therefore, they should be suitably stable chemically and physically. A proposed model for subcontainers of the small, quadrangular, semirigid box or "crystal box type," as opposed to the small polyethylene bags that are also commonly used, is as follows.

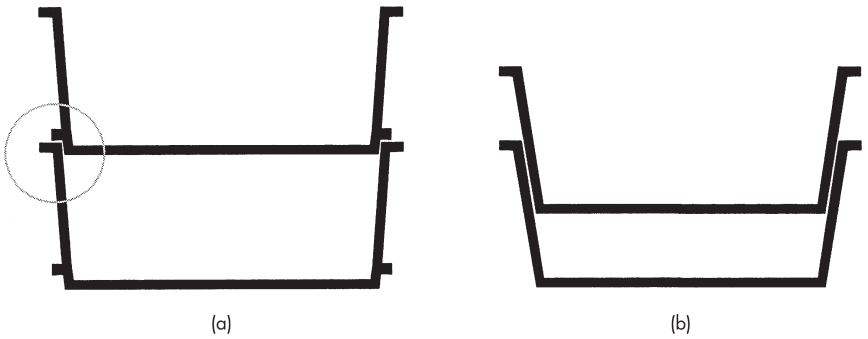


Figure 12.2 Stacking: (a) containers should rest on the interior or exterior of the rim of the one below, allowing the entire interior volume of a container to be usable for storage while preventing the weight from resting directly on the material or object below; (b) containers take up less space in storage when stacked.

Table 12.4 Form, Shape, and Ergonomic Properties

Shape	Rectangular or square
Appearance	Preferably transparent or semitransparent; alternatively, white with a transparent lid
Size and capacity	Able to fit completely within a larger transport/storage container and appropriate to the shape and size of the object or material
Modularity	Preferably of dimensions that allow for easy configurations within larger transport/storage containers without leaving large voids or hollows
Interior walls and bottom	Straight vertical walls and flat bottom, preferably without many holes and devoid of support ribs
Stacking	Stackable with and without lids, the underside of the container fitting onto or slightly, no more than a few millimeters, into the rim of the container below
Cover/lid	Preferably ready-made lids specific to the subcontainer and hermetically sealable to give the option of climatically controllable storage (see below); preferably transparent with a flat, smooth surface with space for noting all pertinent information
Labeling	Space on the sides or lid for easily visible notation of all pertinent data associated with the object and its archaeological information
Storage	Should occupy as little space as possible when not in use and storable in uncontrolled environments
Reuse	Should be washable and usable in any number of circumstances where packing is necessary

Table 12.5 Basic Typology of Suitable and Unsuitable Subcontainers

Suitable	**Unsuitable**
Plastics Polypropylene (PP) Polyethylene (PE) Polyester (polyethylene terephthalate—PET) Polystyrene (PS) Modified polystyrene (ABS, HIPS) Polycarbonate (PC) Polytetrafluoroethylene (PTFE)	*Plastics* Polyvinylchloride (PVC)
Metals Aluminum, zinc, or tinfoil (silver paper)	*Metals* Iron, tin, or painted sheet metal
Glass Mold blown of suitable thickness	*Glass* Free-formed and irregular, thin or crystal
Paper based Nonacidic, archival board	*Paper based* Recycled paper or cardboard
Fabric/textile Bags, sacks, and screens Synthetic (nylon, PE, and PET) Natural (cotton)	*Fabric/textile* Leather

Mechanical:

- Semirigid, having some flexibility or give to be able to absorb acute forces, but should not permanently deform; should adequately support the intrinsic weight of the object and be easy to handle
- Resistant to deterioration, deflection, and distortion when under proportional load
- Resistant to ripping and tearing
- Nonabrasive to the archaeological material

Chemical and physical:

- No chemical reaction or interaction with the archaeological material
- Will not release or leach chemicals, whether gas or liquid, even under unstable environmental conditions: changes in temperature and relative humidity
- Resistant to atmospheric pollutants
- Resistant to biodeterioration
- May be slightly susceptible to exposure to UV light or to common solvents, as long as they are properly contained within a larger container that is resistant to these factors

Many of the most suitable subcontainers are plastic and have been developed for food storage by the food industry. This makes them easily available at a relatively low cost. Examples are:

- Polypropylene (PP), polystyrene (PS), and polyethylene (PE) food containers, with or without lids
- Insulating expanded polystyrene (EPS) containers, such as disposable coolers or certain ice cream containers
- Hermetically sealable PE boxes
- Closable PE freezer and storage bags, with or without holes
- PE tubes (with two open ends) that can be closed using a hot iron or heat sealer
- Slide containers of PP, PS, and PE
- Glass sealable canning jars
- Aluminum (AL) takeout containers

Padding, Cushioning, and Fabrics

Textiles can be used as a separator or a form of interface between the artifact and the packing material, or if bundled or thick enough can be used as a form of padding and cushioning to substitute for expandable materials. All the textiles listed in table 12.6 can be put in direct contact with the artifact's surface during first packing and even longer if periodic and regular checks are made to guarantee their condition. This is especially true for natural textiles, which can be a food source for biological agents, insects, or rodents. Containers that contain natural fabrics should be carefully noted and monitored, especially if the packed objects were moist or wet or if there is no environmentally controlled storage.

Unsuitable packing materials are listed in table 12.7. In general tightly woven fabrics are preferable, as are

Table 12.6 Examples of Suitable Padding/Cushioning/Fabric Packing Materials

Fabric	*Synthetic*	Polyester/polypropylene	Woven or nonwoven geotextiles (regular weaves or irregular and random structure), made in a wide variety of thicknesses and weights for various common applications (building and textile industries, medicine, agriculture, etc.)
		Polytetrafluoroethylene/polyester/polyether	Waterproof hydrophilic membranes such as Gore-Tex® and Sympatex® commonly sandwiched between two layers of polyester or another polymer (very thin sandwich structure)
		Polyethylene	Tyvek®, spun-bonded fabrics
	Natural	Cotton	Rough-spun, gauze, etc., without starch
		Linen	Rough or fine
		Jute	Rough or fine
Expanded materials	*Synthetic*	Polyethylene	Insulation panels for homes
			Bubble wrap packing film
			Closed-cell expanded sheets and strips of Ethafoam®, Plastazote®, and Evazote®
		Polystyrene	Insulation panels for homes
			Packing peanuts
		Polyester	Open-cell soft foam padding

Table 12.7 Examples of Unsuitable Padding/Cushioning/Fabric Packing Materials

Fabrics	*Synthetic*	Polyvinylchloride	Many industrial fabrics
	Natural	Silk	Fabrics for the textile and garment industries
		Wool	
Padding/Cushioning	*Synthetic*	Polyurethanes	Commercially available aerosol
			Canisters or dual component, which can be used for block lifting but should not be used for medium- to long-term storage, especially if exposed to the sun, inside a sealed container, or in storage spaces with possible elevated ambient temperatures
		Neoprenes	Rubber of polychloroprene
		Polyurethanic rubbers	Commercial foam sheets

softer and lint-free fabrics. The weave and roughness are important if the fabrics are in direct contact with materials or objects with a delicate or highly degraded surface. These surfaces can be abraded by a fabric that is rough, and open or loose weaves may snag, especially during transport or handling, and dislodge some of the original material.

Natural fabrics such as cotton or some geotextiles may also have a tendency to cling to surfaces through built-up pile or lint. Most natural fabrics are commercially treated with glues, starches, dyes, softeners, and detergents and should be washed prior to use. This is important for eliminating any and all substances that could be activated in the presence of moisture (ambient or from the object itself) and thus interact with the archaeological material. The hygroscopic nature of most natural fabrics should also be considered, rendering many inappropriate in cases of non-hermetically sealed packing.

A number of commercially available polyethylene foams of varying density are available in all price ranges. These are well suited to initial or preliminary packing needs on-site, as they are easily cut and shaped to the desired function of support or cradling of an object or material. A geotextile or other suitable nonwoven fabric barrier is advisable if low-density polyethylene (LDPE) is used, especially in warmer climates, to avoid any potential adhesion between the object's surface and the packing foam.

Preliminary Packing Techniques

The criteria and techniques described below should be applied according to the material type and value of the archaeological finds, at the discretion of the archaeologist or conservator responsible for these activities on the site.

General Criteria

- Regardless of their condition and the association or grouping during recovery (see chap. 10), most recovered materials should be packed separately based on their material type (stone, ceramic, metal, glass, bone, leather, etc.) and not on their archaeological typology. This is especially true of sensitive materials such as metals or glass, which should always be packed separately and should not be interspersed or mixed with porous materials, especially if those are damp or wet.
- Very small, delicate, or damaged artifacts or those with the greatest susceptibility to physical or mechanical alteration during transport or handling should be further separated and protected in a manner specific to their needs.
- Artifacts or materials that are fairly complete but still very fragile should be packed with padding in a way so as to be as visible as possible; they should not be wrapped or enveloped completely in paper or fabric.
- Any object that had to be removed with a block lift should be packed with padding in such a way as to be immobilized and separated from other materials as well as from the walls of the container.
- If padding is used, it should be used in such a way as to not create too much force or pressure on the artifacts by being too snug between objects or between the object and the container wall.
- Wet or damp materials should always be kept separate from dry materials, especially when wet materials must be kept wet for reasons of preservation.
- Wet or damp materials that can be allowed to dry slowly should not be hermetically sealed but rather placed in subcontainers with suitable holes or openings that are themselves placed within the container in a manner that permits air circulation.

- Wet or damp artifacts or materials should never be packed in containers made of paper (cardboard, envelopes, or bags), wood, or metal (even if varnished).
- Organic artifacts should always be hermetically packed in subcontainers, especially if recovered in a damp or wet state.

Artifact Arrangement

- It is advisable to not overload the containers, particularly transport or storage containers. Avoid filling them to the rim, preventing them from being able to be stacked securely and potentially compromising the well-being of the materials in other containers.
- Artifacts or materials should be organized and distributed logically in their containers, based on stratigraphy, material type, size, condition, and so on (figs. 12.3, 12.4). The criteria for separation must be shared with the archaeologist in charge.
- Coins should be placed in appropriately sized PE bags that are secured to a semirigid plastic label (i.e., alveolar polypropylene) containing all pertinent information and associated data. The semirigid label will serve as a type of anchor and should help in organization and accessibility. Finally, the semirigid label could be placed within a padded transport container (fig. 12.5).
- Larger, heavier, and more robust materials should be placed at the bottom of the container to form the first layer. In principle, they often do not need subcontainers.
- If the recovered materials are damp or wet, their subcontainers should be stacked in such a way as to allow for ventilation.
- All materials, artifacts, and subcontainers should, in theory, be restrained within the container during transport to prevent damage. This is especially true for more complete, small, delicate, or block lifted objects. In these cases, lacking all other alternatives (acid-free tissue or forms of padding), these can be secured in place by surrounding them with excavation soil, provided it is free of gravel or other potentially harmful elements.

Microclimate-Regulating Systems

Packing of Damp and Wet Objects That Can Be Allowed to Dry

This situation typically calls for the use of PE, PP, or PS plastic containers that have sufficient holes to allow for air flow and circulation. (See chap. 5.) Best results

Figure 12.3 An example of packing in sub-, or smaller, containers within a larger container. The objects can be arranged according to their stratigraphic provenance, material type, or state of preservation.

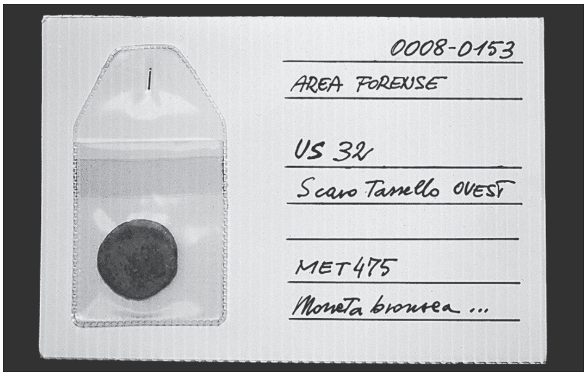


Figure 12.4 An example of an uncleaned metal coin packed in a polyethylene bag that is affixed to a sheet of corrugated polypropylene board.

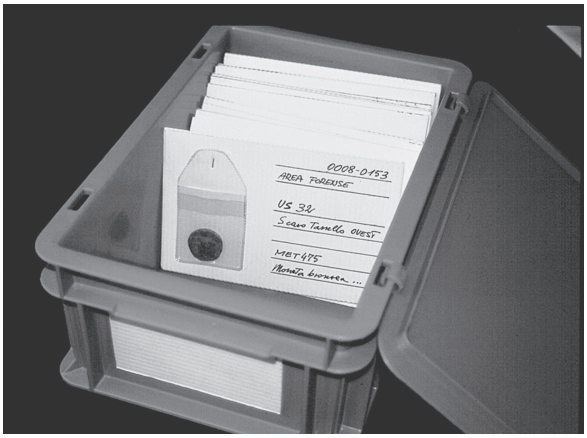


Figure 12.5 Temporary archival storage of uncleaned coins in a larger container. Such a system is highly organized, allowing for easy reference to the coins while also providing optimal storage for small metal finds.

are achieved when the holes are in the upper/higher portion of the container or subcontainer, as evaporation is an upward phenomenon. This holds true even for artifacts or materials that have been wrapped or bandaged for support. By providing a sufficient number of holes, these measures will ensure:

- Progressive and gradual drying of the artifact, material, or excavation soil
- Avoiding buildup of moisture or condensation on the interior of the container
- Avoiding the possibility of biological growth

Packing of Damp or Wet Artifacts That Must Remain Damp or Wet

Theoretically the best way to achieve this form of packing is to use plastic containers that can be hermetically sealed and will maintain the seal. These containers prevent the moisture in the material from evaporating, by not allowing air in to dry out the object. With this said, many general-use plastic containers will not maintain a seal for an indeterminate amount of time and/or may allow vapor to permeate and diffuse through the plastic in both directions. For these reasons, it is often better to use alternative solutions to control the microclimate than to simply rely on the container itself. One of the most effective techniques is to use redundant or multiple subcontainers, one inside the other. This will create a better overall seal and slow or prevent evaporation.

Basic packing systems for maintaining moisture are as follows:

- The damp or wet material is sealed in an appropriately sized polyethylene bag with no added water.
- The artifact and bag are sealed[1] within a second, closable subcontainer (bag or rigid rectilinear container) with a certain quantity of water that is contained in an absorbent material such as chemically stable fabric, cotton, or synthetic sponges.

For organic materials, the following system is preferable:

- Remove all extraneous soil, which may contain salts or microorganisms.
- Use cold storage to prevent biological growth (preferably around 3–4°C). If this is not possible, treat with a suitable biocide (this should be considered a technique of last resort).
- Use double bagging or a container within a container to increase seal, and place the whole assembly in a portable plastic or Styrofoam® cooler (polystyrene semirigid foam). This system can be improved by using freezable ice packs to keep the internal temperature low. The insulation of the cooler also can be increased by lining it with aluminum foil, internally and externally, buffering ambient temperatures and, in turn, slowing the potential rate of evaporation.

The above-described systems cannot be considered permanent or long term and thus should be monitored and replaced if necessary.

Packing of Dry Artifacts and Materials That Cannot Be Exposed to Humidity

In these instances, attempt to reduce the amount of relative humidity within the artifact or material, as well as within the sealed subcontainer. This can feasibly be achieved with silica gel, a microporous hygroscopic granulate of silica (SiO_2). Silica gel absorbs or releases moisture to achieve equilibrium with the environment in which it is placed. If the surrounding environment is humid, the silica gel will absorb moisture. If dry, it will release moisture. This behavior, coupled with silica gel's ability to absorb up to 40% of its own weight in moisture, makes it an ideal environmental buffer (see Appendix 5).

Use of silica gel:

- The dry artifact or material to be buffered should be placed in a sealable, clean, and dry plastic container of PE, PS, or PP, or even glass with a lid and gasket.
- Any padding, fabrics, or other packing materials should not be hydrophilic, as are most natural fiber textiles or paper products.
- Silica gel granules can be preconditioned by heating them for about 20 minutes at 90–100°C and then contained within a relatively open-weave synthetic fabric bag or an open subcontainer, which is then positioned within the container with the artifact. An open-weave bag is preferable to a container because it allows for greater surface area exposure of the silica gel.
- Silica gel should not be placed in direct contact with archaeological material.
- The container holding the artifact and silica gel subcontainer must then be closed and sealed as well as possible; it should not be of a hydrophilic material (cardboard, wood, fabric, leather, etc.).

ENDNOTE

[1] In this case the term *sealed* indicates that the edge of the PE bagging is folded several times on itself and then definitively closed with electrical tape.

Registration and Labeling

This chapter addresses the issues associated with recording basic information that aids in the identification of an object or material during or immediately after its excavation. There are many different types of information that can be recorded, but it is essential to focus on that which allows for the identification of a new and unknown object and its archaeological context, material type, and condition. Registration and labeling should seek to simultaneously convey many different types of information, especially:

- Basic administrative information (site- and excavation-related information)
- Basic organizational information (container, transport, and/or storage information)
- Basic object conservation information

Understanding what type of information is pertinent allows for a basic registration process to be developed in advance that can be applied to all forms of recovered archaeological material in various states of preservation. This will not, however, exempt or be a substitute for other forms of important documentation, such as a daily excavation and finds log or conservation treatment reports, which provide another specific type of information.

It is common to use standardized forms when documentation is purely for archaeological or conservation purposes. These are often hard to adapt or apply to objects and materials, as material archaeological forms may prove too detailed or cumbersome, while those for conservation may be too specific to be applicable. What may prove useful is a generalized form on which basic administrative (sector, layer, and point of recovery), organizational (provisional or inventory number, storage container number), and object (accepted basic terms to describe material type and condition) information is recorded (see Appendix 7).

Types of Information

Below is a brief summary of the types of information needed to effectively and quickly register a single object or group of objects[1] in relation to other artifacts, containers, and subcontainers. This procedure has been developed from practical experience in the first aid, packing, and management of archaeological sites and finds by the Department of Cultural Heritage of the Aosta Valley (Italy). It is consistent with standard international practices and is offered here as a suggestion (see, for example, AA.VV. 1995; Watkinson and Neal 1998).

Site information:

a) State, region, province, community
b) Site name, site code, excavation area
c) Type of intervention, date of excavation, supervisors of excavation, and/or company
d) Context, encompassing soil, geographical information system (GIS) or architectural recording system coordinates (x, y, z, including stratigraphic layer[s])

Container information:

e) Labeling (alphanumeric identifier)
f) Excavation details (context, stratigraphy, etc.)

Artifact/material information:

g) Excavation details (context, stratigraphy, GIS or architectural recording system coordinates [x, y, z])
h) Material type, artifact description, inventory or provisional number (ID), label of associated container
i) Basic condition

Recording Information/Data

Information can be included on various media, depending on the type and amount:

- Data types b, e, f: on containers for transport/storage
- Data types b, f, g: on subcontainers housing the object or material
- Data types b, e, g: on labels, either for the containers/subcontainers or directly on the object itself
- Data types a to i: on preprinted registration forms (see Appendix 7)

From a conservation standpoint data should not be written directly on the surface of any artifacts or material. The authors recommend that finds be recorded on preprinted forms, especially in the following cases:

- When materials/objects are of particular significance or rarity
- Metals and glass
- Organic materials, such as carbonized seeds or waterlogged wood
- When the object is in very poor or fragile condition

Recording Methods and Tools

All transcribed information should be:

- Legible (use capital letters)
- Clear and concise: in general the longer the description or the more words, the greater the possibility of illegibility and misinterpretation
- Chemically and physically stable: resistant to minor abrasion, visible and UV light, and temperature and relative humidity

Alcohol- or solvent-based red or green markers or pens are to be avoided as they will fade when exposed to sunlight. Paint-based or varnish markers should be avoided, whether for labels placed in a container/subcontainer or for labels that might come in prolonged contact with an artifact.

Labels

Basic Requirements

Many of the characteristics appropriate for packing materials are applicable to labels, especially those related to the chemical/physical properties:

- Will not abrade or scratch any archaeological artifacts or materials
- Will not cause chemical reaction or interaction with the archaeological material
- Will not release or leach chemicals in any form, whether gas or liquid, even under unstable environmental conditions with changes in temperature, relative humidity, or exposure to IR or UV light
- Resistant to environmental factors; will not deteriorate or react when exposed to visible, UV, or IR light, moisture, changes in relative humidity, or temperature variations
- Resistant to atmospheric pollutants
- Resistant to most common solvents and chemical reagents
- Resistant to biodeterioration

Recommended Label Materials

- Polypropylene, such as drawing papers and vellums used in drafting or printmaking
- Polyethylene, such as Tyvek, cut into appropriate-sized pieces

ENDNOTE

1 In this case the authors suggest an approach to registration and labeling in which objects and materials can be grouped by their physical characteristics or context of recovery.

On-Site Temporary Storage

General Characteristics

Recovered archaeological materials are typically stored or housed in temporary storage at or near the excavation site. This on-site storage is intended to be used for a short, defined period. On-site storage facilities are typically used as de facto safe houses, providing a place to concentrate excavated materials and limit access to them. From a conservation standpoint, no matter how temporary, such facilities can potentially adversely affect fragile or highly sensitive archaeological materials by provoking or initiating various deterioration phenomena because they are rarely ideally suited to the preservation of excavated finds. At the very most, they provide protection from direct wind, sunlight, and rain, but more often than not, they are also microclimate chambers that create radical shifts in temperature and humidity levels. As "aging chambers," they activate direct chemical and physical changes within the archaeological materials themselves. The most unfit of the more commonly used temporary storage shelters are made of prefabricated corrugated sheet metal or semicircular hothouse tents with transparent polyethylene sheeting. Both of these act like saunas, trapping moisture and hot air, and have no beneficial properties for preservation (Pedelì 2001). These can even be found on well-organized and well-directed excavations.

On any excavation, there should always be an area designated for the temporary placement or storage of artifacts or features that will be transported later to an appropriate long-term storage facility or to a conservation laboratory. Depending on the logistical situation and the condition and needs of the recovered archaeological material, this area may have a true and proper temporary storage facility or shelter. Regardless of the situation or logistical realities, on-site storage should always be short-lived and undertaken with the understanding that it is temporary and that the time and environmental conditions will not be harmful in any way to the stored materials.

Basic Requirements for Temporary Storage

At the very least on-site facilities should guarantee the following:

- Protection from rainfall
- Protection from direct sunlight (preferably dark and fitted with "cold" artificial lighting)
- Good ventilation but not drafty
- Moderate ambient temperature (around 20°C, or 68°F)
- Moderate and stable relative humidity (around 40–50%)

In general, if these basic requirements are not met, within a short time a well-lit and humid storage facility may produce biological growth on porous materials such as ceramics, stone, and bone and corrosion on most metals and deteriorated glasses. Salt efflorescence, cracking, and exfoliation of degraded or particularly sensitive materials such as organic material or highly porous ceramics may also begin to occur in humid, hot facilities. If the time of storage is prolonged, more substantial damage may occur, in particular biological phenomena and vegetation growth, which may also include the deterioration of the storage containers themselves (fig. 14.1). In instances of thermal cycling between hot and cold, even so-called robust materials such as stone and ceramics are subjected to contraction/expansion stress and so they may display fissuring, breakdown, and crumbling (fig. 14.2).

Regardless of the quality of the temporary storage facilities, archaeological metals, no matter the type, should spend a minimum amount of time in them. Organic materials, particularly textiles, leather, and wood, should go directly to a conservation laboratory or a more appropriate storage facility.

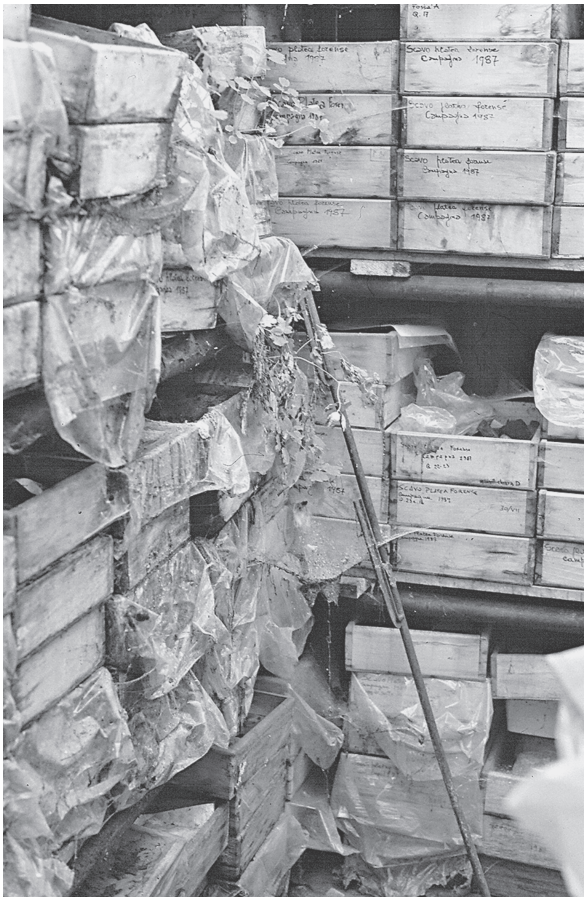


Figure 14.1 "Temporary" on-site storage showing plant infestation from creeper vines and other climbing plant growth. Soil associated with the artifacts and the wood of the containers themselves were used as plant food sources. It should be noted that most of the excavation data transcribed on the front of the wooden storage boxes either is missing or has become illegible.

Examples of Temporary Storage Systems

Temporary storage systems may be grouped into two conventional categories based on their mobility:

- Small movable structures (ready-made or improvised)
- Semifixed, medium-dimension structures

Ready-Made or Improvised Small Movable Structures

- Can be adapted and employed in rescue or urban excavations where other options are simply not feasible
- Cover a small area, typically derived from part of the excavated area

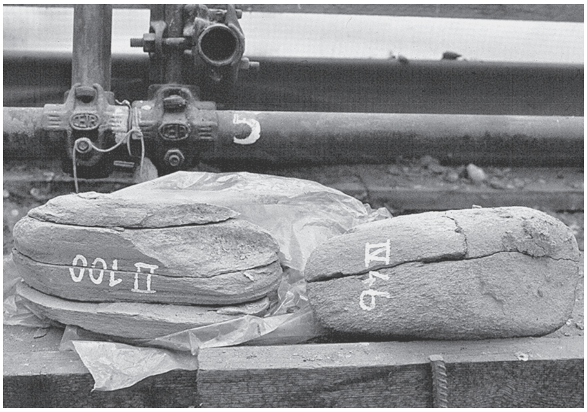


Figure 14.2 Temporary on-site storage of stones that display postexcavation fractures due to cyclical changes in temperature.

- Must shield any temporarily stored finds from view
- Must be easily removable and/or deployable in other areas of excavation
- Must not impede access to the excavated area or movement within it
- Must be able to accommodate several containers for objects or materials, as well as equipment useful for packing operations

Suggestions and requirements:

- Small, lightweight, self-supporting structures of wood, plastic, or metal such as aluminum in the shape of a tunnel or arch (fig. 14.3). The siding can be created from shading fabrics used to protect crops, polyester fabrics used for awnings and outdoor umbrellas, corrugated green fiberglass sheeting, or laminated insulation panels with polyurethane foam.
- All nylon, polyethylene, and polyvinylchloride sheeting should be avoided, as should glass panes, corrugated metal siding, and cardboard.

Medium-Dimension, Semifixed Structures

- Can be used on prolonged excavation campaigns or if there is expected to be a significant amount of recovered material
- Should have some form of shelving system that will allow for easy storage and organization of materials
- Should have proper ventilation as part of the structure
- If it has windows, should have provisions for shading, such as shutters or awnings
- Should have some form of artificial cold lighting that will facilitate organization and storage

Figure 14.3 Effective temporary on-site storage using a small greenhouse frame covered with a woven textile typically used to shade crops and fixed to the ground using ordinary tent stakes. A deposit of this size could protect up to 30 containers (30 × 40 × 12 cm) from the sun. If the frame were to be covered with fabric used for awnings, this could also be impermeable and effective in protecting against rain.

- Must be self-supporting and built with stable materials so as to protect against mechanical stresses and environmental factors such as wind and rain
- Must promote a stable internal microclimate with minimal temperature fluctuations, preferably with insulated walls and roof
- Should have a securable access door that can be locked or padlocked
- Should be used only for storage and not as office space
- Should not be an area of high foot traffic or refuge
- Maintenance and access should be controlled by a delegated administrator or depot manager

Suggestions and requirements:

- Can be made of scaffolding and enclosed with laminated insulation panels with polyurethane foam, commonly found at hardware and building supply stores
- Prefabricated housing containers or trailers, such as those used on construction sites or by aid organizations
- Cotton or polyester tents, such as those used by the military or aid organizations

Alternatives:

- Gazebos with polyester sheeting placed over the open portions
- Recreational multipurpose cotton or polyester tents

Not recommended:

- So-called hangars or small quonset huts in corrugated metal
- Greenhouse structures equipped with polyethylene sheeting

Timing

Artifacts and recovered materials should be temporarily stored in small or medium-sized storage facilities in the following instances:

- Immediately after removal from the soil and/or first packing
- Always if the materials are in an area of the excavation that is unprotected or without adequate shelter from the elements
- Always if the artifact or material is damp, wet, or waterlogged
- Always when the artifact or material is highly deteriorated or fragile
- Always if any form of metal or glass

CHAPTER 15

Documentation

Conservation Log/Report

There is a substantial literature on the types of documentation to be undertaken during excavation. It is not our intention to describe or refine the guidelines for the graphic, digital, or written documentation associated with archaeological activities but rather to propose a systematic approach to conservation record keeping whereby information related to the condition of an object, recovered material, or feature, as well as the type or sequence of conservative measures undertaken, can be documented for easy reference and posterity.

This record keeping should not be seen as comparable to an excavation log or journal, which is more of a daily record of activities. Rather, the proposed information should serve as a type of treatment report, including the nature of the interventions undertaken and any materials or equipment used, in order to create a reference for assessing the initial and ongoing condition of the archaeological material or feature. When read and interpreted later, this form of documentation should not only be a literal record of the condition or stability of an object or feature but also convey any and all conservation issues related to the object and the subsequent interpretation that guided treatment decisions.

Of particular importance in any form of documentation associated with recovery of the object or feature is the following information:

- Description, even summary, of the object, material, or feature
- Any form of graphic or digital documentation undertaken at the time of excavation
- Condition assessment
- Description of the soil's properties
- Description of any existing damage or potential for greater deterioration, that is, fractures, gaps, cracks, and so on
- The presence of any loss or associated fragments
- The presence of any form of decorative coating
- Description of any form of intervention undertaken at the time of discovery or to facilitate its removal from the soil
- Indication of the conditions associated with burial, from a wet or dry context, sandy or gravelly soil, and so on
- In the case of in situ features, indication of whether any form of protection or shelter, whether temporary or permanent, was or will be implemented

Conservation Activities and Treatments

Often in so-called conservation reports one can find the following kind of information: "decorative surface treated with Paraloid" or "consolidated with an injection of lime." Such documentation of activities and materials is of limited use if the object or material has to be further treated in the future. Its shortcomings are obvious:

- There are several different Paraloid® products, B-72 and B48N, which have significantly different chemical and physical properties. Without indication which type of Paraloid® was used, any future treatment in which the resin may need to be softened or dissolved may prove harder or need further experimentation to achieve a result.
- Without indication of the concentration of Paraloid® used or the solvent used to dissolve it, it is difficult to predict what type of penetration may have been achieved, as well as potentially how much resin or consolidant was introduced.
- There are many different types of lime, particularly hydraulic and nonhydraulic, with dramatically different properties. For this reason, it is of paramount importance that this basic type of information be included.
- Since lime alone will have no consolidative effect, it is assumed that the lime has been used in association with an aggregate or a plasticizer of some form. Without this information, predictions as to mechanical strength are difficult to make or explanations as to a mortar's behavior are impossible to ascertain with any level of certainty.

In order to be effective and valuable, conservation documentation should be as precise as possible:

- The type of product or material used (e.g., Paraloid® B-72, lime or hydraulic lime)
- The type of concentration or solution used or proportion used in creating a mixture (i.e., ratio of lime to aggregate) (see Appendix 4)
- The solvent used
- The type or mode of application and number of applications (i.e., for consolidation, impregnation or rejoining, and by brush, spray, sponge, injection, etc.)

Type of Material Used

If the trade name of a product is used (e.g., Paraloid® or Primal®), it is imperative that the industrial or manufacturer's designation be included as well (e.g., Paraloid® B-72, Paraloid® B44, AC-33). This is especially important for some commonly used chemicals in conservation that have a wide range of products (e.g., Rhodorsil and Mowilith, which have many variants).

As stated above, even lime has several variations, the most basic being hydraulic and nonhydraulic. In the case of hydraulic lime, it is important to include the manufacturer in the documentation because there can be huge variations in properties from one manufacturer to the next, as extreme as a difference in compressive strength of 1 to 2.5 (40 kg/cm^2 compared to 110 kg/cm^2). In Europe, recent regulations have required that the manufacturer state the nature of the lime (e.g., NHL = natural hydraulic lime, obtained from the cooking of calcareous and marl stone; HL = hydraulic lime, obtained with the addition of hydraulic compounds to quicklime) and the compression resistance after 4 weeks (e.g., 2.5, 3.5, 5, meaning 25 kg/cm^2, 35 kg/cm^2, 50 kg/cm^2).

Type of Solution or Proportion

The concentration or dilution of a mixture must be accurately documented (see Appendix 4). This information is essential to achieve comparable results or for compatibility. Importantly, this information can be very useful in interpreting the efficacy of a treatment, say, consolidation, its sustainability, and potential alteration over time.

Types of Solvents Used

We cannot go into the chemistry of the different types of solvents and their properties here (see Torraca 1980; Masschelein-Kleiner 1982). It is sufficient to say that it is of the greatest importance to always indicate the type of solvent used in a solution or in direct application, for the following reasons:

- The solvent will influence the viscosity of the solution, which in turn has a direct effect on the penetration of the solution into a material. It is not enough to simply state the percentage of a solution; the solvent must also be included because, for example, a 20% solution of Paraloid® B-72 in an aliphatic solvent will be far more viscous than a 20% solution of Paraloid® B-72 in acetone.
- The solvent used determines the volatility of the solution and therefore the drying time. Extremely volatile solvents can concentrate on the surface of a material once applied and therefore create a surface film with a great concentration of resin at the expense of the area below, which is resin deficient.
- Solvents have a direct influence on the optical characteristics, or appearance, of a resin.

Method of Application

Documentation should indicate the method and number of applications of a material:

- With a brush, spray, or sponge or by saturation, and so on
- Single or repeated applications

This information is typically very useful in evaluating the efficacy of a treatment over time and, if needed, in being able to obtain the same result in similar circumstances.

Long-Term Conservation of Site Features

As mentioned at the outset, there is an inevitable point at which those responsible for an archaeological excavation must consider the long-term preservation of the in situ remains it has exposed. This usually takes the form of short- or long-term reburial or in situ conservation measures to allow for site display and interpretation. Any decisions about postexcavation preservation will have some inherent risk, exponentially greater if not planned for prior to initiating excavation.

Reburial

Reburial of a carefully excavated site should not be seen merely as a makeshift solution. There are specific occasions, such as a lack of financing or political consensus for the construction of suitable shelters, when this is the right decision given the conditions. In these instances, reburial need not be seen as permanent but can be employed as a temporary solution until suitable financing or consensus is reached. Alternatively, this technique can be used as a quick means of mediating immediate threats of inclement weather or rising groundwater.

Temporary Reburial

With any form of reburial it is advisable to utilize a separating material between the archaeological level and the backfill material. This is typically done with a geotextile or with the simple plastic webbing commonly used for safety on scaffolding. These materials are preferred over standard plastic sheeting because their open structure allows for the flow of moisture, avoiding the creation of a microclimate. The placement of this covering is important: it should be installed in such a way as to avoid pulling on or creating tension on any archaeological remains, such as the tops of walls or high features or the edges of cavities or recessed features. Typically this is done by covering remains separately from the earthen floor. The covering should be not so bulky as to allow slippage but loose enough to allow the sheeting to conform to any incongruities.

The backfill material for the excavated area should be free from soluble salts or metal impurities, which can damage archaeological remains or features and contaminate the unexcavated soil. The density and hygroscopicity (potential to hold water) should also be considered. A fill material that is too dense will prove too heavy, putting untold stress on the features below; a material that does not drain well will retain moisture and may create many issues for their preservation.

Because of its low weight, low cost, and availability, expanded clay is one of the most frequently used materials for backfilling. Along with these favorable properties, however, it should be noted that expanded clay does have a high hygroscopicity (it is often used by gardeners to maintain high humidity and moisture around plants) and may have fine, dustlike particulates that can adhere tenaciously to moist materials. For this reason, the use of a separating layer such as a geotextile is crucial, and a campaign of cleaning after its removal should be expected.

As an alternative, polystyrene boards or blocks can be used directly on top of the geotextile or plastic netting layer as a bulk filler and separating agent for a large excavated area. The interstices between blocks and the trench walls or the complex topography of a feature can be filled with polystyrene peanuts or chips to create a more homogeneous and universal covering. These are easily found at hardware stores or shipping/postal facilities and help create a breathable lightweight layer between the area to be protected and the expanded clay backfill. It is advisable to use an additional covering of geotextile or netting on top of this polystyrene layer to facilitate and simplify future removal.

The slightly higher cost and greater amount of work using this more complicated technique is easily justified by the time and labor it saves during the removal process. This technique should greatly accelerate the removal process and is exponentially more efficient the larger the size of the area to be reburied.

Long-Term Reburial

Long-term reburial is usually undertaken when the excavation of a site or a particular area has come to its logical conclusion in terms of information yield (the amount of information possible given budgetary restraints or the time available) or the archaeological potential of the remains to warrant site presentation and interpretation. In these instances, reburial should be undertaken with the understanding that the excavation may be reopened in the future and done in a way that permits future verification or investigation. For this reason, the reburial or backfill material should be clean of all impurities to minimize the potential for contamination and uniform enough to make it easily recognizable and distinguishable from the archaeological soil. The traditional practice of reusing excavated soil for backfilling is, fortunately, on the wane and should be avoided to prevent creating a potentially confusing situation for archaeologists in the future.

Given that long-term reburial is in place for an indeterminate amount of time, preference should be given to lightweight inorganic materials that are stable both physically and chemically. These should also be robust (not susceptible to easy dissolution or pulverization), in order to avoid the creation of depressions within the filled area, and of a fairly uniform size (between 4 and 10 mm) to decrease the possibility of segregation and compaction. If these basic parameters are followed in the selection of a material for reburial, a uniform fill that will not overly compress the archaeological layer and remains while remaining easily discernible and ultimately removable should be feasible.

Conservation Measures for Site Presentation and Interpretation

The theoretical principles and techniques of in situ conservation measures are too vast to be dealt with here. Instead, we examine some of the more universal basic principles inherent in the consideration and implementation of these techniques.

All too often excavated features of any significance are kept open at any cost. While allowing for access, continued study, or visitation, this is a major impediment to the preservation of in situ archaeological remains. For this reason it is paramount to be aware of the many logistical, professional, and economic factors implicit in deciding to conserve and preserve an exposed in situ feature or portion of an archaeological excavation. If these factors are not clearly understood prior to treatment, the potential for a site or feature to have significance to a greater public beyond archaeology and academia may be squandered.

In these cases, it would be preferable and more appropriate to rebury. The examples of poorly planned or implemented site conservation/presentation measures are numerous and readily found throughout the world, often resulting in overgrown sites or, worse yet, areas that are mistreated or refuse strewn. Aside from being an eyesore, in most of these circumstances, the destruction of the archaeological remains is rapid, definitive, and irreversible. Accordingly, what follows is an attempt to describe conservation interventions that preserve in situ archaeological features by accounting for the major factors that determine the degradation of their material composition.

Presentation of an in situ structure or feature should be taken under serious consideration in the following circumstances:

- The structure or feature is of sufficient significance to warrant public presentation
- There is sufficient access to the site for potential visitation
- Sufficient equipment and technology are available to ensure the necessary environmental parameters for long-term conservation

There are three basic forms of in situ conservation measures:

- Exposed and outdoors
- Under protective structures or shelters
- Inside permanent structures or buildings

Exposed or Open-Air Conservation Measures

Exposed or open-air conservation measures are sustainable and feasible only on large structures or features. It would be counterproductive to conserve exposed small features or structures that can easily be damaged or even stolen. In these cases, reburial would be more appropriate, creating a greater probability of survival.

Conservation measures associated with leaving a structure exposed to the elements generally involve the use of sacrificial materials over the original. Conventionally these are mortar based, such as with capping and repointing, and should have less chemical or mechanical resistance than the archaeological material they are protecting and thus deteriorate instead of the original material. Whether just mortar or mixed with masonry, these are often used in a manner that renders them readily distinguishable. (For the basic principles regulating the use of sacrificial material on masonry, see the Athens Charter of 1931 and the Venice Charter of 1968.)

The use of sacrificial materials requires that this form of long-term in situ preservation include establishing a system of periodic monitoring and maintenance. This, unfortunately, is often more true in theory than in practice. In instances of inadequate monitoring and maintenance, the most common results are as follows:

- The sacrificial material completely deteriorates, leaving the original material exposed to environmental factors such as precipitation, freeze/thaw cycles, solar radiation, and potential mistreatment from visitors.
- The sacrificial material proves to be more robust than the archaeological masonry to be protected, causing its possible preferential and accelerated deterioration.

Accordingly, these measures should involve some initial treatment for long-term conservation (see below).

Protective Structures or Shelters

Shelters are typically used for medium-sized structures whose significance or surrounding environmental or climatic conditions necessitate measures more substantial than those for open-air features. The types of structures or shelters are numerous and can make use of many different types of techniques and materials as diverse as fabrics and reinforced masonry. (For a fuller discussion of the various types of structures and materials that have been experimented with and tried over time, see Stubbs 1995.) In all instances, shelters or coverings should ensure these basic requirements:

- Protection of an area considerably larger than the excavated feature to avoid possible wetting from rain
- Reasonable resistance to local environmental elements, such as sun, rain, wind, heat, and cold
- Easy maintenance of the structure itself: if the cost of maintenance is near or equal to that of the excavation, then the use of a shelter is probably prohibitive and long-term reburial preferable

Permanent Enclosure or Sheltering of an Entire Feature or Structure

Permanent enclosure or sheltering of an entire feature or structure can be undertaken in two specific instances:

- When the archaeological feature is already incorporated in or enclosed by a structure that cannot be restricted in its use by the public, such as churches and historic monuments
- When the importance of the archaeological feature and/or environmental parameters necessitate the creation of a permanent protective structure

Both cases require a detailed and well-thought-out plan in order to minimize or avoid the possibility of creating a microenvironment that could be damaging to the feature meant to be protected. The design of a long-term, permanent structure should include the following factors:

- Properly insulated materials, to prevent the creation of condensation or excessive heat exchange with the overlying or surrounding structures (fig. 16.1)
- Sufficient drainage and directional channeling of rainwater around the shelter to prevent leaks or seepage from augmenting existing groundwater levels (fig. 16.2)

Figure 16.1 Vassos, Arcadia, Greece. Protective shelter for a Hellenistic temple situated in difficult climatic conditions (temperature fluctuations of up to 60°C between summer and winter). The remote and inaccessible nature of the site and the frequency of rain were the factors justifying this type of intervention, prioritizing conservation over some aesthetic elements, such as the relationship between the temple and the landscape.

Figure 16.2 Vassos, Arcadia, Greece. Detail of the gravel drainage and its system of containment. Note that the lower part of the protective shelter can be raised to allow for the circulation of air during the hottest periods of the day.

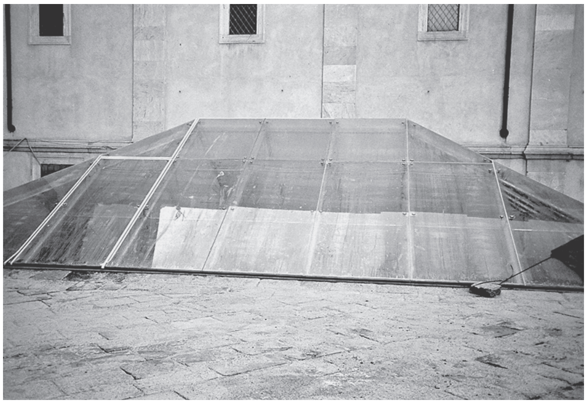
- Adequate climate control systems to stabilize the relative humidity within the shelter, particularly in cases of frequent visitation by the public; in the event of insufficient climate controls, it is imperative to limit the number of visitors in proportion to the capacity of the climate controls to dehumidify the air
- Sufficient controls on the amount of illumination, particularly on the amount of infrared and ultraviolet light (fig. 16.3)
- Control of access
- Appropriate funding for the management of the site: general and emergency maintenance expenses, personnel costs, environmental monitoring, and maintenance of the climatic control systems
- Illumination with low or no ultraviolet or infrared light; lighting sources should not be directed at moist elements of the feature, which can render them more susceptible to microbiological and organic growth

With lack of planning that includes these factors, a permanent shelter can easily become an enclosed saturated environment accelerating and/or exacerbating all the various mechanisms for deterioration discussed previously (figs. 16.4, 16.5).

Figure 16.3 Vassos, Arcadia, Greece. The interior of the protective covering. Here the entire monument is perfectly undisturbed and can be seen and visited.

Protection of Masonry Walls (Capping and Repointing)

It is worthwhile to consider the issues associated with the use of lime-based mortars for capping and



Figures 16.4 and 16.5 The archaeological site of San Salvatore, Turin. Exterior and interior images of a glass protection created to allow for viewing of the archaeological remains below the modern street level. Climate control is very important in the case of glass shelters, because condensation and temperatures can easily build up, defeating the purpose for which the shelter was implemented.

repointing of archaeological masonry. Rather than focus solely on the aesthetics related to the use of such materials, which, in any case, should allow for legibility and critical interpretation of the original masonry, this discussion focuses on constitutive materials and methods of application (fig. 16.6).

An examination of numerous capping and repointing interventions carried out in the twentieth century makes some generalizations possible:

- Most are poorly preserved and cracked and detaching from the underlying masonry.
- Most are generally mortar, with little or no visible aggregate.
- Most contain cement as the principal binder.
- They are often less deteriorated than the surrounding masonry they were meant to protect.

The principal reason for the poor state of preservation of these interventions is the nature of the materials used and the methods of their implementation. Since these interventions are all mortar based, one of the main reasons for their substandard performance is excessive thickness, which, because of the large mass of mortar when applied, forms microfissures and cracks during the shrinkage that accompanies drying. Over time these fissures have grown in size and allowed greater access of moisture and water to the

Figure 16.6 Ostia Antica. Typical mortar capping from the 1950s. Protection is ensured at the expense of the visual impact and legibility of the ruins.

more vulnerable underlying masonry. In addition, the use of inappropriate cements as the binder in the mortar has often introduced soluble salts. These are often responsible for the deterioration and erosion at the point between the masonry to be protected and the protective pointing or capping.

Based on experience and observations of masonry walls exposed to the sun in harsh climates where the daily temperature variation can approach 30°C and seasonally 65°C, some basic guidelines can be proposed:

- Mortar should incorporate aggregates, whether stone or ceramic based, that are as similar as possible to the masonry to be protected.
- Mortar should contain only the minimum amount of hydraulic lime necessary or can include a small amount of white cement (see chap. 9).

In cases where the upper portions of walls are reconstructed as a means of protection and restoration of visual integrity but where the original material components remain visible, appropriate materials of local or salvaged provenance should be used for their physical and aesthetic compatibility. In these instances a distinction should be made between the masonry being protected and the masonry protection. These measures can take several forms, including creating a slight recession, using thicker or thinner mortar joins, or using stones or aggregates of a smaller dimension (figs. 16.7, 16.8) (see Perinetti and Pulga 1989).

If the upper reaches of the wall will have a mortar capping, care should be taken to select an aggregate with adequate size variation (e.g., 0–15 mm diameter) and to not apply a mortar in excess of three times the thickness of the largest aggregate. This is equally true for mortars used for repointing. By following these simple rules one can avoid the major issues affecting mortars from the past century, reducing the possibility of shrinkage-fissuring during curing and ensuring sufficient elasticity of the mortar during dimensional changes due to temperature change (see point C below).

Mortar Recipes for Repointing and Capping

The following recipes have generally been used with success by the authors in various contexts throughout the northwest of Italy and parts of France and Switzerland. These should be seen by no means as absolute for every possible environment but rather as basic starting points.

Mortar recipes should always be developed and applied with the following factors in mind:

Figure 16.7 Castle of Cly (Valle d'Aosta). Detail of a battlement merlon. The upper portion was re-created with rubble stones that were smaller in size than the original stones. At the lower level, gaps between the original stones were repointed.

A. The types of physical and environmental stresses the mortar will be exposed to and have to endure
B. The type of masonry the mortar will be in contact with and its physical (porous/nonporous) and chemical (sandstone, limestone, brick, etc.) properties
C. The maximum thickness with which the mortar can be applied

Determining these three factors will result in mortars that are appropriate for their intended use and responsive to their environment and long-term conditions.

A. Types of Physical and Environmental Stresses

There is a great difference in stresses acting on mortars in protected, sheltered, or indoor contexts versus those used externally or out in the open. Protected, sheltered, or internal mortars will mostly have to address changes in temperature and relative humidity.

Figure 16.8 Castle of Cly (Valle d'Aosta). Overall view of the castle's battlement walls after integration with the technique shown in figure 16.7.

External mortars will have to deal with direct sun and sources of moisture, as well as much greater variations in temperature, particularly freezing temperatures.

Beginning with the principle that a mortar must have at least the basic properties to sustain itself in its particular environment of use, *mortars for sheltered contexts* need no or a minimal amount of hydraulic binder. The basic recipe can be summarized as follows:

- 10 parts per volume of washed and sieved sand
- 4 parts per volume of slaked lime
- Ratio of 2.5:1 aggregate to binder

This basic recipe yields a mortar that is permeable to water vapor and sufficiently dense to protect vulnerable masonry. In more humid or moist sheltered environments, the following variant has proven to set with good moisture resistance:

- 10 parts per volume of washed and sieved sand
- 3 parts per volume of slaked lime
- 1 part per volume of hydraulic lime
- Ratio of 2.5:1 aggregate to binder

Mortars for external or exposed contexts can be best formulated by increasing the amount of hydraulic lime in relation to regular lime and augmenting the amount of aggregate to increase elasticity:

- 12 parts per volume of washed and sieved sand
- 2 parts per volume of slaked lime
- 2 parts per volume of hydraulic lime
- Ratio of 3:1 aggregate to binder

B. Type of Masonry Materials onto Which the Mortar Will Be Applied

Schematically, the materials commonly used for masonry, at least in Europe, can be divided into three basic categories:

- Bricks and/or fired clay: high porosity, low to medium mechanical strength
- Calcareous stones: low to medium porosity, medium to high mechanical strength
- Siliceous stones: low porosity, high to extremely high mechanical strength

Based on these basic characteristics, different mortar recipes are typically used depending on the material type.

In the case of *mortars for external use on masonry composed of brick*, the following recipe is common:

- 8 parts per volume of washed and sieved sand
- 2 parts per volume of brick or ceramic fragments
- 3 parts per volume of slaked lime
- 1 part per volume of hydraulic lime
- Ratio of 2.5:1 aggregate to binder

The recipe includes brick or ceramic fragments as aggregate to increase the hydraulic nature of the mortar while still allowing for permeability of water vapor.

For *mortars for external use on masonry composed of calcareous stones*, the following recipe is typically used:

- 10 parts per volume of washed and sieved sand
- 1 part per volume of slaked lime

- 3 parts per volume of hydraulic lime
- Ratio of 2.5:1 aggregate to binder

In this instance the amount of hydraulic lime is considerably increased to ensure greater bonding to the calcareous matrix of the masonry by replicating the nature of the calcium-carbonate stone by decreasing the porosity of the mortar.

For *mortars for external use on masonry composed of siliceous stones*, the following recipe can be used:

- 12 parts per volume of washed and sieved sand
- 1 part per volume of slaked lime
- 2 parts per volume of hydraulic lime
- 1 part per volume of white cement
- Ratio of 3:1 aggregate to binder

In this recipe white cement replaces a portion of the hydraulic lime in order to increase the amount of siliceous/aluminous material in the binder, replicating the nature of the siliceous stone in the masonry and increasing the amount of adhesion between the mortar and the masonry. At the same time the ratio of aggregate to binder is increased to 3:1 to avoid creating a mortar that is too hard and impervious to water vapor.

C. Maximum Thickness of Mortar

Maximum thickness refers to the thickness with which the mortar can be applied without resulting in fissuring or cracking during drying, which ultimately will then be exacerbated by dimensional changes brought about by cyclical changes in temperature. A study of numerous old mortars that displayed good stability showed a ratio of size of the aggregate to thickness of the mortar application of between 2.5 and 3.0 (Pulga 1995). This same ratio was reproduced experimentally with modern mortars and displayed optimal results in terms of density, firmness, and elasticity.

Based on these findings, care should be taken in selecting an appropriate aggregate in terms of its properties and size. These can be easily verified or refined with the use of sieves or screens set to the appropriate particle size. Accordingly, mortar application should not exceed three times the maximum grain size or dimension of the aggregate in one application (e.g., an aggregate of 10 mm means that mortar of more than 30 mm in thickness should not be applied).

A Few Observations on Hydraulic Limes, White Cement, and Aggregates

Without delving too deeply into the complex chemistry of building materials, it is useful to elaborate on some of the desirable features of the materials that make up the above-recommended mortar mixtures.

Hydraulic lime should be of the type "Pure or Highly Hydraulic" and preferably from a natural source (typically of a slightly gray, brown, or reddish-pink color). Any commercial products labeled as containing "hydraulic binders" should absolutely be avoided, as they often contain substantial amounts of gypsum (calcium sulfate) as a bulking agent to prevent shrinkage, as well as various plasticizers like polyvinyl acetates and alcohols to increase fluidity and adhesion.

White cement, such as Lafarge Superblanc, is recommended for the above recipes to increase the hydraulic nature of the mortar. These types of cement are preferable because they are generally devoid of gypsum or soluble salts. With the use of white cements, however, it is very important to respect the proportions outlined. White cements have high compressive strength (at least 425 kg/cm^2) and a large rate of shrinkage during drying due to their lack of additives. Too much white cement in a recipe can result in a mortar that is too hard and has low permeability to water vapor and that may shrink considerably during drying.

Aggregates should vary in size to compensate for settlement within the mortar matrix while still plastic and, importantly, to increase the elasticity, making the mortar better able to expand and contract with temperature changes. For example, between two types of sand with a grain size variation of 0–8 mm and 4–8 mm, 0–8 mm is preferable because it contains a greater range of particle sizes and will make a more adaptable mortar.

Sand aggregates should be washed prior to their use to remove any clay impurities and then fully dried. The above recipes are based on proportions for dry sand. If damp, sand can contain up to 30% water, which will produce a mortar that has too much binder and water. Sand is typically stored uncovered in stores and on construction sites and thus usually contains a substantial amount of moisture. When used for conservation, sand should ideally be stored under a covering and frequently raked to ensure dryness.

The amount of water added to the mixture must be very conservative and limited to creating a malleable but not runny or overly liquid mortar. When worked with a trowel, the mortar should maintain its form without sagging. Unfortunately, the common use of and overreliance on cement mixers today means that most commercial cements require a greater amount of water to create an acceptably pliable mortar. This fact alone indicates that most mortars for conservation should not be prepared with a cement mixer, as their use is incompatible with creating a good lime mortar. Instead, commercially available static mixer attachments for drills that allow for small quantities of mortar to be created with a proper consistency and with limited amounts of water are recommended.

It is absolutely essential to not use too much water when mixing mortar as excess water will produce:

- Excess dilution of the binder, which can result in an irregular mortar that is in parts too liquid and in parts too dense, leading to difficulty in application and uneven adhesion and drying
- Excessive volume loss due to water evaporation during setting, resulting in shrinkage cracks and fissures
- Inconsistencies in the mechanical properties between the exterior surface of the mortar and its interior

The practice of overwetting mortars originates with masons' overwhelming use of cement in today's construction. Cement as a binder is very strong and will cure even if there are gross errors in proportions during mixing. A more liquid cement can cover a large surface area, even when applied to dry masonry. This is incompatible with lime mortar, where the absorption of moisture by the masonry, especially highly porous materials like brick, will have a deleterious effect on the mortar. For this reason, the appropriate mortar mixture should be chosen according to the three factors outlined above, and the masonry should be well wetted prior to mortar application. If both are done correctly, this should result in a mortar that is well adhered and robust.

UNESCO Guidelines

UNESCO

The Scientific and Cultural Organization for Education of the United Nations

PROGRAMME FOR 1957–58: APPENDIX I

RECOMMENDATION ON INTERNATIONAL PRINCIPLES APPLICABLE TO ARCHAEOLOGICAL EXCAVATIONS 1
(1. See Resolution 4.32(c).)

The General Conference of the United Nations Educational, Scientific and Cultural Organization, meeting at New Delhi, from 5 November to 5 December 1956, at its ninth session,

Being of the opinion that the surest guarantee for the preservation of monuments and works of the past rests in the respect and affection felt for them by the peoples themselves, and persuaded that such feelings may be greatly strengthened by adequate measures inspired by the wish of Member States to develop science and international relations,

Convinced that the feelings aroused by the contemplation and study of works of the past do much to foster mutual understanding between nations, and that it is therefore highly desirable to secure international co-operation with regard to them and to further, in every possible way, the fulfillment of their social mission,

Considering that, while individual States are more directly concerned with the archaeological discoveries made on their territory, the international community as a whole is nevertheless the richer for such discoveries,

Considering that the history of man implies the knowledge of all different civilizations; and that it is therefore necessary, in the general interest, that all archaeological remains be studied and, where possible, preserved and taken into safe keeping,

Convinced that it is highly desirable that the national authorities responsible for the protection of the archaeological heritage should be guided by certain common principles which have been tested by experience and put into practice by national archaeological services,

Being of the opinion that, though the regulation of excavations is first and foremost for the domestic jurisdiction of each State, this principle should be brought into harmony with that of a liberally understood and freely accepted international cooperation,

Having before it proposals concerning international principles applicable to archaeological excavations, which constitute item 9.4.3 on the agenda of the *session*,

Having decided, at its eighth session, that these proposals should be regulated at the international level by way of a recommendation to Member States.

Adopts, this fifth day of December 1956, the following Recommendation:

The General Conference recommends that Member States should apply the following provisions by taking whatever legislative or other steps may be required to give effect, within their respective territories, to the principles and norms formulated *in* the present Recommendation:

The General Conference recommends that Member States should bring the present Recommendation to the knowledge of authorities and organizations concerned with archaeological excavations and museums.

The General Conference recommends that Member States should report to it, on dates and in a manner to be determined by it, on the action which they have taken to give effect to the present Recommendation.

I. Definitions

ARCHAEOLOGICAL EXCAVATIONS

1. For the purpose of the present Recommendation, by archaeological excavations is meant any research aimed at the discovery of objects of archaeological character, whether such research involves digging of the ground or systematic exploration of its surface or is carried out on the bed or in the subsoil of inland or territorial waters of a Member State.

PROPERTY PROTECTED

2. The provisions of the present Recommendation apply to any remains, whose preservation is in the public interest from the point of view of history or

art and architecture, each Member State being free to adopt the most appropriate criterion for assessing the public interest of objects found on its territory. In particular, the provisions of the present Recommendation should apply to any monuments and movable or immovable objects of archaeological interest considered in the widest sense.

3. The criterion adopted for assessing the public interest of archaeological remains might vary according to whether it is a question of the preservation of such property, or of the excavator's or finder's obligation to declare his discoveries.

(a) In the former case, the criterion based on preserving all objects originating before a certain date should be abandoned, and replaced by one whereby protection is extended to all objects belonging to a given period or of a minimum age fixed by law.

(b) In the latter case, each Member State should adopt far wider criteria, compelling the excavator or finder to declare any object, of archaeological character, whether movable or immovable, which he may discover.

II. General Principles

PROTECTION OF THE ARCHAEOLOGICAL HERITAGE

4. Each Member State should ensure the protection of its archaeological heritage, taking fully into account problems arising in connexion with excavations, and in conformity with the provisions of the present Recommendation.

5. Each Member State should in particular:

(a) Make archaeological explorations and excavations subject to prior authorization by the competent authority;

(b) Oblige any person finding archaeological remains to declare them at the earliest possible date to the competent authority;

(c) Impose penalties for the infringement of these regulations;

(d) Make undeclared objects subject to confiscation;

(e) Define the legal status of the archaeological sub-soil and, where State ownership of the said subsoil is recognized, specifically mention the fact in its legislation;

(f) Consider classifying as historical monuments the essential elements of its archaeological heritage.

Resolutions

PROTECTING BODY: ARCHAEOLOGICAL EXCAVATIONS

6. Although differences of tradition and unequal financial resources make it impossible for all Member States to adopt a uniform system of organization in the administrative services responsible for excavations, certain common principles should nevertheless apply to all national archaeological services:

(a) The archaeological service should, so far as possible, be a central State administration—or at any rate an organization provided by law with the necessary means for carrying out any emergency measures that may be required. In addition to the general administration of archaeological work, this service should co-operate with research institutes and universities in the technical training of excavators. This body should also set up a central documentation, including maps, of its movable and immovable monuments and additional documentation for every important museum or ceramic or iconographic collection, etc.

(b) Steps should be taken to ensure in particular the regular provision of funds: (i) to administer the services in a satisfactory manner; (ii) to carry out a programme of work proportionate to the archaeological resources of the country, including scientific publications; (iii) to exercise control over accidental discoveries; (iv) to provide for the upkeep of excavation sites and monuments.

7. Careful supervision should be exercised by each Member State over the restoration of archaeological remains and objects discovered.

8. Prior approval should be obtained from the competent authority for the removal of any monuments which ought to be preserved *in situ.*

9. Each Member State should consider maintaining untouched, partially or totally, a certain number of archaeological sites of different periods in order that their excavation may benefit from improved techniques and more advanced archaeological knowledge. On each of the larger sites now being excavated, in so far as the nature of the land permits, well-defined "witness" areas might be left unexcavated in several places in order to allow for eventual verification of the stratigraphy and archaeological composition of the site.

FORMATION OF CENTRAL AND REGIONAL COLLECTIONS

10. Inasmuch as archaeology is a comparative science, account should be taken, in the setting up and organizing of museums and reserve collections, of the need for facilitating the work of comparison as much as possible. For this purpose, central and regional collections might be formed or, in exceptional cases, local

collections on particularly important archaeological sites—in preference to small scattered collections, accessible to comparatively few people. These establishments should command, on a permanent basis, the administrative facilities and scientific staff necessary to ensure the preservation of the exhibits.

11. On important archaeological sites, a small exhibit of an educational nature—possibly a museum—should be set up to convey to visitors the interest of the archaeological remains.

EDUCATION OF THE PUBLIC

12. The competent authority should initiate educational measures in order to arouse and develop respect and affection for the remains of the past by the teaching of history, the participation of students in certain excavations, the publication in the press of archaeological information supplied by recognized specialists, the organization of guided tours, exhibitions and lectures dealing with methods of excavation and results achieved, the clear display of archaeological sites explored and monuments discovered, and the publication of cheap and simply written monographs and guides. In order to encourage the public to visit these sites, Member States should make all necessary arrangements to facilitate access to them.

III. Regulations Governing Excavations and International Collaboration

AUTHORITY TO EXCAVATE GRANTED TO FOREIGNERS

13. Each Member State on whose territory excavations are to take place should lay down general rules governing the granting of excavation concessions, the conditions to be observed by the excavator, in particular as concerns the supervision exercised by the national authorities, the period of the concession, the reasons which may justify its withdrawal, the suspension of work, or its transfer from the authorized excavator to the national archaeological service.

14. The conditions imposed upon a foreign excavator should be those applicable to nationals. Consequently, the deed of concession should omit special stipulations which are not imperative.

INTERNATIONAL COLLABORATION

15. In the higher interest of archaeology and of international collaboration, Member States should encourage excavations by a liberal policy. They might allow qualified individuals or learned bodies, irrespective of nationality, to apply on an equal footing for the concession to excavate. Member States should encourage excavations carried out by joint missions of scientists from their own country and of archaeologists representing foreign institutions, or by international missions.

16. When a concession is granted to a foreign mission, the representative of the conceding State—if such be appointed—should, as far as possible, also be an archaeologist capable of helping the mission and collaborating with it.

17. Member States which lack the necessary resources for the organization of archaeological excavations in foreign countries should be accorded facilities for sending archaeologists to sites being worked by other Member States, with the consent of the director of excavations.

18. Member States whose techniques or other resources are insufficient for the scientific carrying out of an excavation should be able to call on the participation of foreign experts or on a foreign mission to undertake it.

RECIPROCAL GUARANTEES

19. Authority to carry out excavations should be granted only to institutions represented by qualified archaeologists or to persons offering such unimpeachable scientific, moral and financial guarantees as to ensure that any excavations will be completed in accordance with the terms of the deed of concession and within the period laid down.

20. On the other hand, when authority to carry out excavations is granted to foreign archaeologists, it should guarantee them a period of work long enough, and conditions of security sufficient to facilitate their task and protect them from unjustified cancellation of the concession in the event, for instance, of their being obliged, for reasons recognized as valid, to interrupt their work for a given period of time.

PRESERVATION OF ARCHAEOLOGICAL REMAINS

21. The deed of concession should define the obligations of the excavator during and on completion of his work. The deed should, in particular, provide for guarding, maintenance and restoration of the site together with the conservation, during and on completion of his work, of objects and monuments uncovered. The deed should moreover indicate what help if any the excavator might expect from the conceding State in the discharge of his obligations should these prove too onerous.

ACCESS TO EXCAVATION SITES

22. Qualified experts of any nationality should be allowed to visit a site before a report of the work is published and with the consent of the director of excavations, even during the work. This privilege should in no case jeopardize the excavator's scientific rights in his finds.

ASSIGNMENT OF FINDS

23. (a) Each Member State should clearly define the principles which hold good on its territory in regard to the disposal of finds from excavations.

(b) Finds should be used, in the first place, for building up, in the museums of the country in which excavations are carried out, complete collections fully representative of that country's civilization, history, art and architecture.

(c) With the main object of promoting archaeological studies through the distribution of original material, the conceding authority, after scientific publication, might consider allocating to the approved excavator a number of finds from his excavation, consisting of duplicates or, in a more general sense, of objects or groups of objects which can be released in view of their similarity to other objects from the same excavation. The return to the excavator of objects resulting from excavations should be allocated within a specified period of time to scientific centres open to the public, with the proviso that if these conditions are not put into effect, or cease to be carried out, the released objects will be returned to the conceding authority.

(d) Temporary export of finds, excluding objects which are exceptionally fragile or of national importance, should be authorized on requests emanating from a scientific institution of public or private character if the study of these finds in the conceding State is not possible because of lack of bibliographical or scientific facilities, or is impeded by difficulties of access.

(e) Each Member State should consider ceding to, exchanging with, or depositing in foreign museums objects which are not required in the national collections.

SCIENTIFIC RIGHTS; RIGHTS AND OBLIGATIONS OF THE EXCAVATOR

24. (a) The conceding State should guarantee to the excavator scientific rights in his finds for a reasonable period.

(b) The conceding State should require the excavator to publish the results of his work within the period stipulated in the deed, or, failing such stipulations, within a reasonable period. This period should not exceed two years for the preliminary report. For a period of five years following the discovery, the competent archaeological authorities should undertake not to release the complete collection of finds, nor the relative scientific documentation, for detailed study, without the written authority of the excavator. Subject to the same conditions, these authorities should also prevent photographic or other reproduction of archaeological material still unpublished. In order to allow, should it be so desired, for simultaneous publication of the preliminary report in both countries, the excavator should, on demand, submit a copy of his text to these authorities.

(c) Scientific publications dealing with archaeological research and issued in a language which is not widely used should include a summary and, if possible, a list of contents and captions of illustrations translated into some more widely known language.

DOCUMENTATION ON EXCAVATIONS

25. Subject to the provisions set out in paragraph 24, the national archaeological services should, as far as possible, make their documentation and reserve collections of archaeological material readily available for inspection and study to excavators and qualified experts, especially those who have been granted a concession for a particular site or who wish to obtain one.

REGIONAL MEETINGS AND SCIENTIFIC DISCUSSIONS

26. In order to facilitate the study of problems of common interest, Member States might, from time to time, convene regional meetings attended by representatives of the archaeological services of interested States. Similarly, each Member State might encourage excavators working on its soil to meet for scientific discussions.

IV. Trade in Antiquities

27. In the higher interests of the common archaeological heritage, each Member State should consider the adoption of regulations to govern the trade in antiquities so as to ensure that this trade does not encourage smuggling of archaeological material or affect adversely the protection of sites and the collecting of material for public exhibit.

28. Foreign museums should, in order to fulfill their scientific and educational aims, be able to acquire objects which have been released from any restrictions due to the laws in force in the country of origin.

V. Repression of Clandestine Excavations and of the Illicit Export of Archaeological Finds

PROTECTION OF ARCHAEOLOGICAL SITES AGAINST CLANDESTINE EXCAVATIONS AND DAMAGE

29. Each Member State should take all necessary measures to prevent clandestine excavations and damage to monuments defined in paragraphs 2 and 3 above, and also to prevent the export of objects thus obtained.

INTERNATIONAL CO-OPERATION IN REPRESSIVE MEASURES

30. All necessary measures should be taken in order that museums to which archaeological objects are offered ascertain that there is no reason to believe that these objects have been procured by clandestine excavation, theft or any other method regarded as illicit by the competent authorities of the country of origin. Any suspicious offer and all details appertaining thereto should be brought to the attention of the services concerned. When archaeological objects have been acquired by museums, adequate details allowing them to be identified and indicating the manner of their acquisition should be published as soon as possible.

RETURN OF OBJECTS TO THEIR COUNTRY OF ORIGIN

31. Excavation services and museums should lend one another assistance in order to ensure or facilitate the recovery of objects derived from clandestine excavations or theft, and of all objects exported in infringement of the legislation of the country of origin. It is desirable that each Member State should take the necessary measures to ensure this recovery. These principles should be applied in the event of temporary export as mentioned in paragraph 23 (c), (d) and (e) above, if the objects are not returned within the stipulated period.

VI. Excavations in Occupied Territory

32. In the event of armed conflict, any Member State occupying the territory of another State should refrain from carrying out archaeological excavations in the occupied territory. In the event of chance finds being made, particularly during military works, the occupying Power should take all possible measures to protect these finds, which should be handed over, on the termination of hostilities, to the competent authorities of the territory previously occupied, together with all documentation relating thereto.

VII. Bilateral Agreements

33. Member States should, whenever necessary or desirable, conclude bilateral agreements to deal with matters of common interest arising out of the application of the present Recommendation.

Classification of Materials

Inorganic	*Rocks and minerals*		Stone
			Metal
			Ceramic
			Glass
Organic	*Vegetal*	Timber	Wood
		Fiber	Paper
			Textiles
	Animal		Textiles
			Animal parts

Source: Based on *Science for Conservators,* vol. 1, 1997.

Metals	Gold, electrum
	Silver
	Copper and copper alloys
	Lead, tin, pewter
	Iron, steel
Silicates and derivatives	Stone
	Ceramics
	Glass
Organics	Animal skins/hides and products of animal skin/hide
	Papyrus, parchment/vellum, papers
	Woods
	Textiles/fabrics
	Bone, horn, and ivory

Source: Based on Plenderleith and Werner 1986.

Aggregates and Binders

Binders

Gypsum

Gypsum is a general term used to define a group of natural materials made up of calcium sulfate ($CaSO_4$) and variable amounts of water. The most common forms of plaster are bi-hydrate calcium sulfate: gypsum stone or selenite. Each molecule of calcium sulfate is bonded to two water molecules ($CaSO_4 \times 2H_2O$) and is found in nature as transparent or whitish crystalline agglomerates. Various modifications to the selenite crystals can be obtained through heating, with particular properties achieved at specific temperatures. At 128°C the bi-hydrate calcium sulfate ($CaSO_4 \times 2H_2O$) will lose one and a half molecules of water, becoming hemi-hydrate calcium sulfate ($CaSO_4 \times ½H_2O$), better known as "dental" gypsum, which is very hard and fast setting (one to four minutes); it releases heat during reaction and is well suited to taking impressions and making casts. At 170° to 180°C, the hemi-hydrate calcium sulfate ($CaSO_4 \times ½H_2O$) continues to lose water to become anhydrous calcium sulfate ($CaSO_4$), a slower-setting gypsum (typically around fifteen minutes) that releases less heat and is commonly used in construction. Other forms of plaster can be obtained by heating calcium sulfate up to 1300°C, but these were not known or traditionally used and thus are typically inappropriate to be applied to or in the context of ancient or historical remains.

Lime

Depending on the source material from which it is obtained, lime can be aerated or hydraulic. The characteristics of these two types of lime are further defined below, as are the types of aggregates that can be mixed into them and will affect the properties of the lime mixture.

AERATED LIME: MANUFACTURE, CHEMICAL REACTION, AND SETTING

Lime is obtained by burning calcareous rocks, which are composed of calcium carbonate ($CaCO_3$) and various naturally occurring impurities like silicates, alumina, and iron oxides. Calcareous rocks are a very large family of classification that can differ significantly from stone to stone.

The ancient Romans, who are recognized for their mastery of lime and lime technology, recommended the use of river limestone for the best results. The production of lime by "cooking" is defined by the following reaction:

1. $CaCO_3 + 42\ \text{cal.} = CaO + CO_2$

that is, calcium carbonate ($CaCO_3$) subjected to a given amount of heat gives rise to anhydrous calcium oxide (CaO), better known as quicklime, and carbon dioxide (CO_2).

Calcium oxide in the form of white lumps or powder reacts violently when mixed with water. The water is immediately absorbed, swelling the mass of lime, which in turn cracks and splits, heating rapidly up to 300°C before eventually becoming a soft, pliable plastic mass. This reaction is called "slaking" and is defined as follows:

2. $CaO + H_2O = Ca(OH)_2 + n.\ \text{cal.}$

If exactly 3.22 parts of water are added to 1 part of calcium oxide, a fine, dry, powdery calcium hydroxide ($Ca(OH)_2$) is produced (stoichiometric calculations), which is commercially known and available as hydrated lime. This proportion is widely used by industrial manufacturers to convert quicklime into a usable product, whereas traditional lime mortar production involves the use of large pits or tanks where the calcium oxide is stored in an excess of water to produce a pliable paste known as slaked lime (or putty) ($Ca(OH)_2 + n\ H_2O$).

Calcium hydroxide reacts with carbon dioxide in the air to re-form calcium carbonate according to the reaction:

3. $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$

that is, calcium hydroxide plus carbon dioxide gives rise to the formation of calcium carbonate plus excess water that will evaporate. This reaction is called carbonation.

The reactions just described are better known as the lime cycle. Cooking will produce a lime powder. Slaking will produce a paste that in and of itself is not strong but in association with sand or other aggregates creates a mortar that becomes increasingly hard and durable as it loses water and reacts with atmospheric carbon dioxide. The acquisition of hardness and durability is better known as "setting" and, chemically speaking, is a carbonation. The physical/chemical changes that occur within the mortar mixture during this process begin, at first, with the contraction of the lime mass due to the loss of water from absorption into the surrounding masonry and from evaporation. The loss of water begins to create compactness in the lime mixture, inducing the initiation of absorption and reaction with atmospheric carbon dioxide (carbonation, reaction 3 above), which gives rise to the formation of elongated crystals of calcium carbonate. These crystals create a regular, stable crystalline network with the added aggregates, making a viable strong masonry mortar.

HYDRAULIC LIME

In the third century BC the Romans developed techniques and recipes to obtain so-called hydraulic lime mortars that could set underwater and remain resistant to deterioration in submerged contexts. The creation of these mortars allowed for the construction of aqueducts, sewers, and artificial harbors that are still in operation today. The significance of these accomplishments is that they were created with mortars with slaked lime ($Ca(OH)_2 + n\ H_2O$) as their binder, which does not properly set in wet or high-humidity conditions and is susceptible to the effects of water. The slaked lime was altered through the addition of specific aggregates, so-called hydraulic or pozzolanic, that endowed the mortar with water-resistant properties.

The fact that the Romans did not discover hydraulic lime in itself can be attributed to strict regulation governing the manufacture of lime in the empire. Only calcium carbonate materials free of clay impurities were used to make lime, and after cooking the long duration in slaking pits automatically led to the segregation of any possible hydraulic constituents. The need for mortars that could set underwater and not be adversely affected by prolonged exposure to moisture led Roman architects to experiment with the types of aggregates that could be combined with lime.

Historically, beginning in the sixteenth century stone materials with large amounts of clay impurities began to be used as a source of lime, resulting in a grayish-brown quicklime that had the ability to set in wet environments. These were the first true hydraulic limes. Only in the nineteenth century did chemists demonstrate that firing limestone with clay impurities to 1000°C would yield lime that would react with silica, alumina, and iron oxides to create silico-aluminous bonds that react even in the presence of excess water. Based on these discoveries, the industrial manufacture of hydraulic limes as we know them today began.

Today there is a rough categorization of hydraulic limes:

- *Natural*, if obtained from clayey limestone baked at 1000°C
- *Artificial*, if obtained by mixing hydraulic lime with pozzolanic or hydraulic aggregates

The index of hydraulicity of lime (l) is expressed as the following equation:

$$\begin{array}{ll} \text{Clay-based impurities:} & \underline{SiO_2 + AlO_3 + Fe_2O_3 = l} \\ \text{Calcareous component:} & \qquad CaO \end{array}$$

The higher the hydraulicity (l), the more hydraulic the quicklime. Traditionally limes are classed as follows:

- 0.01 (l) = aerated lime
- 0.1 to 0.16 (l) = minimally hydraulic lime
- 0.16 to 0.3 (l) = medium hydraulic lime
- 0.3 to 0.4 (l) = hydraulic lime
- 0.4 to 0.5 (l) = highly hydraulic lime

The compressive resistance of hydraulic lime–based mortars is directly proportional to the silica content. Setting occurs in two phases: rapid initial setting is due to the hydration of the hydraulic bonds; slow setting is due to the carbonatization of the calcium hydroxide ($Ca(OH)_2$).

Hydraulic (Pozzolanic) Behavior and Aggregates

HISTORICAL BACKGROUND

Both the Greeks and the Romans understood that volcanic aggregates, once pulverized and mixed with lime, gave a good-quality mortar that would set in and be resistant to fresh- and saltwater conditions. The Greeks used volcanic tufa from the island of Santorini, which still enjoys widespread use today in the eastern Mediterranean under the trade name Santorini Earth. The Romans employed the reddish volcanic tufa widespread around the Bay of Naples and, in particular, from Pozzuoli, which is what gives the name "pozzolanic" to any volcanic aggregates that endow similar properties. Where neither of these or other volcanic tufa sources were available, both the Greeks and the Romans employed tiles and bricks to achieve hydraulic mortars. Accordingly, any aggregates derived from pulverized fired clay are known as "artificial pozzolanic."

PROPERTIES

ASTM on cements, Des. C340-58 T, defines hydraulic aggregates as "silica or silica-alumina based materials that, in and of themselves, do not have binder properties. Once pulverized and combined with water, however, they will react with calcium hydroxide ($Ca(OH)_2$) at room temperature to form compounds with binding properties." It should be noted that this definition speaks not to the nature of the aggregates but rather to their ability to combine with calcium hydroxide in the presence of water. Consequently, the ability of aggregates to create hydraulic properties is, in the context of conservation, the capacity to react with calcium hydroxide and harden underwater.

NATURAL HYDRAULIC AGGREGATES

Natural hydraulic aggregates are derived from molten rocks ejected and formed during volcanic eruptions and activities. Liquid magma is typically broken into small droplets when propelled into the air during an eruption and undergoes sudden cooling that effectively crystallizes the unstable physical structure into a solid. This instability renders such volcanically derived sands and soils susceptible to attack by the high causticity of lime and leads to the particular chemical reaction that creates hydraulic properties. Among the most common volcanic aggregates, one can list:

- Pozzolanic soils themselves
- Soil from Santorini (Greece)
- Bavarian Trass
- Compact volcanic tufas (Tarquinian and Romanian tuffs)
- Natural clays, fired and hardened by volcanic activity
- Diatomaceous earth

All these minerals have a very high silica content and can be used as hydraulic aggregates once pulverized or ground.

ARTIFICIAL HYDRAULIC AGGREGATES

This category includes the following:

- Calcined clays (brick, clay, or ceramic dust or pieces)
- Fly ash, produced in large quantities by power plants

Both of these artificial aggregates are predominantly silica and alumina, making them analogous in behavior to natural hydraulic aggregates.

USE OF HYDRAULIC AGGREGATES

Many ancient features and structures contain lime mortar with hydraulic aggregates to seal or protect them from the effects of water (aqueducts, water pipes, bath, cisterns, and the ground course on buildings, to name a few). Such aggregates were used intentionally in these contexts to create a resistant hydraulic lime that is distinct for its durability in the face of the effects of water and wear. Lime mortars with such aggregates are characterized by extreme hardness and low porosity.

Even today hydraulic aggregates can be useful in the treatment and preservation of ancient and historical features and structures. The addition of such aggregates to lime, whether hydrate or hydraulic, will endow useful and interesting characteristics on the mortar, such as:

- The ability to set on damp/wet walls and in wet or humid conditions
- Good resistance to rain and runoff
- Greater hardness than found in mortars of lime and regular sand

Aggregates

As has already been mentioned, aggregates can be defined as materials added to binders, as well as the structural elements within a mortar and held together by the binder. Any classification of aggregates can at best be considered incomplete and open to interpretation. For this reason, only the primary physical characteristics of aggregates are listed here. The physical characteristics influence the strength and durability of the mortar. In general ancient mortars used river sands from the relative vicinity of the work site. The preference for river sands was for specific reasons:

- Near-total absence of soluble salts
- Rough surface texture due to slow erosion by river currents
- Variable mineralogy and size, guaranteeing a selection of grain size and limited porosity related to a sand's location in a river, whether from the riverbank or the river bed, leading to natural segregation

All these properties help to ensure a good-quality mortar. A rough surface guarantees proper bonding between the added aggregate and the lime binder, while the varied mineralogy excludes overly porous sands that would be too absorbent. Variable grain size limits shrinkage. Being river sourced eliminates the possibility of soluble salts, ensuring that the mortar will not be hygroscopic and eventually destroyed by the constant cycling between dissolution and crystallization of salt crystals.

Beach sands are practically antithetical in their properties:

- Strong presence of soluble salts, predominantly sodium chlorides (NaCl)
- Smoother grain surface due to the stronger and abrasive action of ocean currents, waves, and wind
- A more uniform grain size due to continuous wave motion
- A more uniform mineralogical composition due to coastal erosion

A smoother grain surface allows for less bonding to the lime binder, while the more uniform grain size creates the potential for cracking of the mortar due to excessive shrinkage from the loss of water that occurs during setting. Soluble salts, on the other hand, can compromise the hardness of the mortar once the dry phase is reached. Mortars prepared with marine sands are very rare, most likely because their instability leads to limited preservation. Those that have survived display very low cohesion, fragility, and susceptibility to mechanical damage, as well as the tendency to salt efflorescence.

Mortars prepared with crushed porous limestone aggregates, such as travertine, tend to have little hardness and are highly hygroscopic.

Siliceous sands yield hard mortars that can be too rigid in cases of extreme daily or seasonal thermal changes, leading to detachment of the mortar from the applied archaeological or historical substrate.

Consolidants

Preparation

As discussed in chapter 9, “Consolidation,” the consolidants most commonly used in conservation are in the form of *solutions* and *emulsions*.

Solutions

Solutions commonly consist of a solid dissolved in a liquid. Accordingly, the percentage solution is calculated by using the weight of the solid in relation to the volume of the solvent (w/v). Before making a solution, certain characteristics should be verified:

- The solid to be dissolved is actually soluble in the chosen solvent.
- The solid has a specific weight greater than that of the liquid.

The second factor is important for practical reasons. If the solid to be dissolved has a specific weight less than the solvent’s, once dissolved it will float to the surface and form a viscous layer that is difficult to mix into the rest of the solvent below. Using a solvent with a lower specific weight than the solid will ensure that the dissolved solid will settle toward the bottom of the liquid. Solutions can thus be readily made by suspending the solid in the solvent within an open mesh or gauze sack, which should allow for a much more homogeneous solution.

Emulsions

Emulsions involve the dilution of a liquid in another liquid. Consequently, the percentage solution of an emulsion is calculated differently, using the volume of the liquid to be diluted in relation to the volume of the diluting liquid (v/v). As with solutions, there is a certain characteristic that should be verified beforehand:

- The two liquids are miscible at room temperature.

The diluting liquid has to be added to the liquid to be diluted. Once the liquid has been fully added, the mixture is agitated for several minutes to achieve a homogeneous mixture.

Dilutions and Concentrations

The term *concentration* is used when describing the dissolution of a solid in a liquid, whereas *dilution* is relative to the dilution of a liquid in another liquid.

Concentration of a solid in a liquid is understood and indicated as the ratio between the weight of the solid and the volume of the solvent (w/v). As an example, the concentration 12.5% w/v indicates that 12.5 grams of a solid were dissolved in 100 ml of solvent. Dilutions, on the other hand, are often made and measured according to at least three different principles:

a) A dilution of a liquid in a liquid is indicated as the ratio of volume of the diluted liquid to the volume of the diluting liquid (v/v). Using Primal® as an example, a dilution of 30% indicates that 30 ml of Primal® have been mixed with 70 ml of another liquid (e.g., water). This results in 100 ml of solution in which the Primal® is 30 ml of the overall solution. *This is the only method that indicates the actual dilution of the solution.*

b) Erroneously, again using Primal® as the example, if one uses 30 ml of Primal® mixed into 100 ml of a liquid, the proportions are distorted and do not render a dilution of 30%. Instead, the actual dilution is the ratio of 30(v):130(v), and the real dilution of Primal® would be

$$X = \frac{100 \times 30}{130} = 23\%$$

This method has been widely used but is not recommended to obtain an accurate dilution calculation.

c) Dilution of a liquid in a liquid using the relationship between volumes, such as 1:3, is also common. This dilution is mistakenly considered to be equivalent to 30% as it is 3:1. The reality is that the one volume, say, 100 ml of

> Primal®, mixed with 3 volumes, say, 300 ml of water, will yield a 400 ml solution in which the Primal® is present at 100 ml. The actual dilution ratio is therefore 100:400, or 1 to 4, and the real dilution would be
>
> $$X = \frac{100 \times 100}{400} = 25\%$$
>
> *Rather than a percentage dilution, the proper way to indicate this would be to give the ratio 1:3 (v/v) as the dilution.*

Based on this, the three common forms of creating dilutions may appear to be similar but do not produce the same percentage of dilution.

Labeling

To be of any use, a label should contain the following types of information:

- Name of dissolved substance (e.g., consolidant or resin, Paraloid®)
- Concentration or dilution or ratio
- Name of diluting liquid (solvent)
- Date of manufacture

As an example:

> 20% Paraloid® B-72 (w/v)
> in Acetone
> 04/04/2012

Storage

In general, it is good practice to prepare *solutions* only as needed and not to prepare large quantities that may not be needed and thus have to be stored. This is especially important because many polymers will progressively lose some of their physical and chemical characteristics. Many polymers will eventually yellow. Accordingly, any stored solution that already has a yellowish tinge or color should be discarded.

All containers are to some extent permeable to vapors, especially more volatile (organic) solvents. Consequently, it is good practice to draw a line on the exterior of the container with an indelible marker (e.g., lead pencil) indicating the level of the solution and the date. If the level of the solution is later found to be lower than the line, this can be used then as a guide to top off the solution with solvent. As long as the same solvent is used as in the original solution, the desired concentration should be maintained. This is an easy, yet necessary, control, as solutions can potentially double in concentration in six months due to solvent evaporation.

In the case of *emulsions*, separation and sedimentation, with the heavier particulates sinking to the bottom of the dilution, should be understood as common when stored. Consequently, before it is used an emulsion should be agitated for a few minutes to ensure a more homogeneous solution.

Care should be taken to store prepared consolidant solutions away from direct sunlight and any electrical sources or outlets, as well as areas of possible temperature fluctuations, such as near radiators or water pipes. Emulsions should not be exposed to freezing temperatures, as this will cause the separation of water and resin and make them ultimately useless.

Finally, a fire extinguisher should be readily available in any area where solvents and solvent solutions are kept or stored.

Silica Gel

Silica gel is a porous, noncrystalline material composed of 99.7% silicon. It is chemically inert and dimensionally stable, nontoxic, noncorrosive, and nondegradable. Typically silica gel is manufactured with or without a color indicator to signify the basic state of ambient moisture (relative humidity) and its absorption (see chap. 5). The specific characteristics of silica gel allow it to be used for a variety of functions:

- As a desiccant or dehumidifier to remove ambient moisture
- As a humidifier to increase ambient moisture
- As a regulator of ambient moisture through the absorption or release of moisture

The proper use of silica gel as a buffer for archaeological materials presupposes the accurate calculation of specific parameters as regards the relative humidity within various storage environments, whether long or short term. One such parameter is the particle size of the silica gel and its effect on the range of absorption and release of moisture. There are in fact many different types of preconditioned silica gels, differentiated by their particle size, optimized for specific values of humidity: low (Type I, 0–40% RH), medium (Type II, 30–60% RH), and high (Type III, 65–90% RH). With this said, it is somewhat impractical within the scope of this text to give absolute recommendations as to the type of silica gel to be used in certain environments on archaeological excavation, as these factors often vary greatly and can be difficult to control. For this, please refer to more detailed literature dedicated to these specific issues (Thomson 1986; Berducou 1990; La Fontaine 1984).

In the context of preventive measures for archaeological materials, silica gel can be used advantageously within temporary or provisional containers to mitigate drastic changes in relative humidity. Commonly silica gel is used as a desiccant to create an environment that is as dry as possible within containers that contain archaeological metals. As discussed in chapter 2, even low values of relative humidity, 35–40%, can reactivate or provoke corrosion of ferrous materials in a very short time. As a consequence, the timely collection and containment of such materials within a buffered environment is recognized as beneficial and good practice.

Types of Silica Gel

As previously mentioned, silica gel is commonly available either with or without an added color indicator. Type I silica gel with a color indicator when dry (0–20% RH) appears uniformly blue. From 20% to 30% RH, the silica gel will begin to become a mixture of blue and slight pink. Beyond 35% RH, the silica gel should appear uniformly pink. Because of their lack of specificity, color indicators should be used only as an approximation and not as an absolute indicator of the exact relative humidity. It is important to not rely exclusively on the indicator color for humidity readings but rather to couple them with humidity strips or, better yet, with a hygrometer to better assess the situation.

Silica gel is available in many particle sizes. For reasons of expense, as well as health and safety, the finest granules are typically not used.

Preparation

Silica gel can be reused repeatedly by reconditioning it to its driest state. This is most typically done by evenly distributing a thin layer of the silica gel on a metal cooking sheet, such as a cookie tray, and placing it in a heated oven between 120° and 150°C (250°–300°F) for several hours. The process of dehumidifying the silica gel is commonly known or referred to as “activation” or “conditioning.” All conditioned silica gel should be packaged in a timely manner in hermetic containers, such as polyethylene containers for food storage or sealable glass mason jars for canning, to preserve the dehumidified state until it is used in association with an object.

Quantities Required

The given conventional measurement for the use of silica gel is 20 kilograms of silica gel for every cubic meter (1,000 liters) of air. This equates to 20 grams per liter of air. This calculation is based on measurements commonly employed in museums and should be understood as such. In such contexts, display cases or storage containers are typically already within a controlled environment, whereby there is an HVAC (heating, ventilation, and air-conditioning) system that regulates temperature and humidity. Conventional measurements should thus be seen as a rough guideline but not fully applicable to archaeological contexts. Instead, in general, it is advisable to double or significantly increase the amount of silica gel per volume of air to mitigate less controlled ambient conditions of storage, such as using 40 grams per liter of air.

There are at least two reasons that increased silica gel is beneficial for the storage of metallic archaeological materials:

- Artifacts or materials may contain discrete amounts of moisture in the obscuring soiling or layers of corrosion.
- The moisture present within an artifact or material may exceed the capacity for absorption of the smaller amounts of silica gel, potentially negating its use altogether.

For simplicity and ease of operations, it is beneficial to have a range of airtight containers readily available on-site (e.g., 250 ml, 500 ml, 1,000 ml, and 3,000 ml containers) and ready-made quantities of conditioned silica gel in perforated plastic bags or small cloth sachets (bags of 10 g, 50 g, and 100 g).

Duration of Efficacy for Activated Silica Gel

Even the most hermetically sealed container will eventually allow air to enter and its subsequent moisture. Any container with silica gel employed on-site during excavation should be used as a transitional and preservative measure between the potentially damaging uncontrolled in situ environment and the more controlled conditions of the conservation laboratory or medium- to long-term storage. When deployed on-site, especially for metal artifacts or other sensitive materials, these containers should be moved to more stable environs within 24 to 36 hours at the most.

Statistical Study of European Continental Climate

Location: Bourges (France)

Period of study: 1969–1999

- Maximum theoretical temperature range: 59.6°C (from –20.4°C to +39.2°C)
- Days with constant temperature below 0°C: (average) 89.4 per year (1 in 4 days)
- Days with temperature +/– 0°C: (average) 47 days per year
- Number of hours below 0°C: (average) 541 hours per year
- Number of days of rainfall: (average) 137 days (1 in 2.6 days)
- Hours of rainfall: 1998 = 607 hours, 449 mm; 1999 = 816 hours, 880 mm
- Windy days: (average) 41.8 days per year
- Average wind speed: 13.32 km/h (3.7 m/s)

(Data provided by MeteoFrance, collected by CO.RE S.n.c.)

Recovered Materials Form (finds, condition, etc.)

Site Code: ___________ Excavation Coordinates: ______________________ Excavation Director: _______________________

No.	Material	Object Type/Basic Description	Condition	Container
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Date of input: ______________________________

Prepared by: ______________________________

Signature: ______________________________

Equipment and Materials List for a First Aid Operational Unit (FAOU)

Unearthing Objects and Structures

(see chap. 4)

- Semiflexible metal spatula, like those used for painters' palettes; wooden or plastic spatula, such as tongue depressors;
- "Decorator"- and "artist"-type paintbrushes in both round (gradations from 0 to 3 cm widths) and rectangular (varying widths from 2 to 8 cm and 2 cm thickness) sections of soft and semisoft natural and synthetic bristles of variable length;
- Hand brushes of the type typically used for brushing clothing or polishing shoes, in natural and synthetic bristles of variable hardness and length;
- Fine electric vacuum with filters;
- Natural and synthetic sponges of variable density;
- Spray bottles to nebulize and mist water;
- Absorbent paper towels;
- Japanese tissue.

Stabilization during and after Excavation *(see chap. 7)*

Temporary Shoring, Reinforcement, or Support

- Wooden shoring and pickets;
- Various blocks and lengths of wood for creating reinforcements, as well as wooden boards and plywood sheets for supports;
- Wooden wedges of differing dimensions and angles, from thin shims to thick wedges;
- Different types of wood saws (wood, Japanese, and hack), hammers (claw and ball and ping), various types of nails (from brads to roofing nails);
- Polystyrene foam sheets or other forms of padding of a thickness of 2 to 3 mm;
- Geotextile;
- Polyethylene foam sheets, typically used as insulation for houses, or other lightweight sheeting in 5, 10, and 20 mm thicknesses;
- Polyurethane foam sold as an aerosol spray or as two components to be mixed;
- Aluminum foil (sold for food preparation and storage);
- Plastic stretch film (sold for food preparation and storage, i.e., cling film or Saran Wrap);
- Biocides;
- Metal props, adjustable stakes and/or poles such as those used for tents.

Straps and Bandages

- Nylon luggage straps or bungee cords;
- Polypropylene webbing and strapping commonly used for packing and moving;
- Velcro strips;
- Rubber bands or flat elastic bands (latex) for clothing;
- Polyethylene sheeting for industrial packing;
- Jute and cotton medical bandages;
- Elastic medical bandaging, such as ACE™ bandages;
- Elastic medical tubular net;
- Lengths of wood for splints.

Temporary Facing

- Cotton gauze;
- Japanese tissue/paper;
- Paraloid® B-72, in a 20% w/v solution with a volatile solvent (e.g., Acetone);
- Primal® 33 in a 5% dispersion, v/v;
- Various common solvents, such as water, acetone, and ethyl alcohol;
- Mowilith DMC2 (polyvinyl emulsion);
- Polyvinyl alcohol (PVAL) in grain/powder to dissolve in hot water or polyvinyl acetate (PVAC) in grain/powder to dissolve in ethyl alcohol;
- Natural-fiber brushes of varying length and softness;
- Polyethylene containers for keeping solutions and for rinsing and cleaning brushes.

"Emergency" Adhesive Preconsolidation on Immovable Features *(see chaps. 7 and 9 and Appendix 3)*

- Slaked lime putty and hydraulic lime;
- Pulverized brick (terracotta) or any other pozzolans in a pulverized form;
- Fine sand (variable grain size from 0 to 2 mm);

- Concentrated acrylic emulsion (such as Primal® AC33);
- Metal spatula and masonry trowels (various types and dimensions);
- Medical and veterinarian syringes up to 50 cc and beyond with appropriate needles for injection;
- Rubber lens blowers to inject water-based viscous mixture;
- Clean water.

Be aware that all resins and solvents should be contained within closable polyethylene or aluminum containers.

Protection during Excavation

(see chap. 6)

- Waterproof polyethylene sheeting (preferably black);
- Polyester sheeting or tarpaulin, typically used for sun awnings;
- Plastic net for mulching;
- Geotextiles (different weights, both woven and nonwoven);
- Hydrophilic membranes (e.g., Gore-Tex®, Sympatex®);
- Polyethylene film (cling film) and aluminum foil, typically used for food preparation and storage;
- Spray bottles for nebulizing and misting water.

Lifting of Movable Artifacts

(see chap. 10)

- Plaster and cotton gauze bandages or premade cotton gauze bandages impregnated with plaster or both;
- Fiberglass gauze bandages presoaked with polyurethane resins;
- Plasters (basic plaster, alabaster plaster, or dental plaster) and waxes (e.g., paraffin);
- Expanding or foaming polyurethane resins in two components or as a prepackaged aerosol;
- Knives, box cutters, and various rigid and semirigid metal spatulas;
- Metal wire;
- Copper, brass, aluminum, or plastic (fiberglass, PVC, or PE) sheeting for supports;
- Lightweight foam sheets or polystyrene paneling, such as sold as insulation for houses;
- Polycarbonate, wood, or plywood panels and sheeting.

Preliminary Cleaning of Mobile Artifacts and Features *(see chap. 11)*

- Small brushes (sizes 1 to 20) with soft, medium to long bristles in natural and nylon fibers;
- Toothbrushes with very smooth bristles and other dental tools;
- Scraps of smooth commercial sheet polyurethane foam, typically used for padding;
- Natural and synthetic sponges or those specifically for conservation, such as Blitz-Fix;
- Absorbent paper towels.

Preliminary Packing On-Site

(see chap. 12)

- Appropriate containers for transport;
- Appropriate subcontainers;
- Appropriate padding, cushioning, and fabrics;
- Airtight containers, having mechanical and/or silicone seal gasket;
- Thermal containers, such as coolers or Styrofoam (extruded polystyrene) containers for food;
- Polyethylene film (cling film) and aluminum foil, used for food preparation and storage;
- Silica gel (see Appendix 5).

Recording and Labeling

(see chap. 13)

- PP and PE (Tyvek) labels;
- Black indelible and permanent markers, lead pencil;
- Forms for recording basic elemental and identifying information for both immobile features and mobile artifacts (see Appendix 7).

Technical Documentation

(see chap. 15)

- Digital camera;
- Spare memory cards and batteries;
- Sketchbook, transparent acetate sheets, colored pencils, and colored markers;
- Forms for recording material conditions, states of preservation, and any form of intervention.

Personal Protective Equipment

- Suits, overalls, or protective garments in Tyvek, PE, or cotton;
- Safety shoes and footwear;
- Safety gloves of hide for medium- to heavy-duty handling, as well as nitrile gloves for working with most common solvents;
- Dust masks and protective filtered full- or half-face masks for smoke and chemical aerosols and vapors;
- Polycarbonate face shield or protective glasses;
- Safety helmet of polyethylene or other suitable material;
- First aid kit complete with list of contents and manual for use (periodically check for expiration of pharmaceuticals and medicines);
- Telephone numbers of pertinent professionals and professional entities, including medical and fire department;
- Telephone numbers and addresses of relevant services and suppliers, including art supplies, hardware and lumber, packing and storage;
- Common sense (not for sale).

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Corrado Pedelì

* * *

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With this in mind, I believe thanks are due first to Ottorino Nonfarmale, who, roughly thirty-five years ago, furnished me with the fundamentals of what would become my life's work. I remember above all else this caution: "If you go on in this profession, you will have a crisis of identity because we are nothing more than the meeting point of very different disciplines: chemistry, physics, art history, and the skills and knowledge of masons and artists. Do not be discouraged, for in this meeting point the elements and factors are catalyzed to preserve a work of art or to damage it beyond repair. Obviously I expect you to know how to preserve it."

For the rest of my acknowledgments, I wish to follow the order of subjects covered in the book.

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Stefano Pulga

Bibliography

AA.VV. 1988. *I siti archeologici: Un problema di musealizzione all'aperto.* Rome: Multigrafica Editore.

AA.VV. 1989. *Il cantiere della conoscenza: Il cantiere di restauro; Atti del Convegno di Studi, Bressanone, 27–30 giugno 1989.* Padova: Libreria Progetto Editore.

AA.VV. 1997. *Science for Conservators.* Vol. 1: *An Introduction to Materials.* Conservation Science Teaching Series. London: Conservation Unit.

AA.VV. 2000. *I Grandi Restauri, Materiali e Strutture; Coperture per aree e strutture archeologiche, repertorio di casi esemplificativi,* ARKOS.

Andrews, G. 1991. *Management of Archaeological Projects 2.* English Heritage. London: Historic Buildings and Monuments Commission for England.

Anselmi, E., et al. 1979. "Fattori di deterioramento." In *DIMOS, Corso sulla manutenzione di dipinti murali, mosaici, stucchi* (part 2, module 1). Rome: Istituto Centrale del Restauro.

ARC-NUCLEART. 1999. *Conservazione dei legni umidi.* Schede informative a cura dell'Atelier Régional de Conservation, Grenoble.

Bacon, L. 1987. "The Care and Protection of Copper Alloy, Silver, and Gold Objects on Site." In *Conservación arqueológica in situ: Memoria de las reuniones, 6–13 de abril de 1986, México = In Situ Archaeological Conservation, Proceedings of Meetings, April 6–13, 1986, Mexico,* ed. H. M. W. Hodges. Mexico City: Instituto Nacional de Antropología e Historia; Los Angeles: Getty Conservation Institute.

Barker, P. 1981. *Tecniche dello scavo archeologico.* Biblioteca di Archeologia, vol. 1. Milan: Longanesi & Co.

Bellucci, G., L. Caretta, and S. Cristopolis. 1999. "Nuovi materiali per lo scavo, il restauro e la conservazione dei beni archeologici." *Archeologia—Tecnologia 11.*

Berducou, M. Cl. 1990. "La conservation en archéologie." In *La conservation en archéologie, méthodes et pratique de la conservation-restauration des vestiges archéologiques,* ed. M. Cl. Berducou, 15–35. Paris: Masson.

Bergeron, A., and F. Remillard. 1991. *L'archéologue et la conservation—vade mecum québécois.* Quebec: Publications du Québec.

Bergeron, M. A. 1994. "Archéologie et conservation: Convergence ou divergence?" In *Vestiges archéologiques, la conservation in situ: Actes du deuxième colloque international de l'ICAHM, Comité international de gestion du patrimoine archéologique de l'ICOMOS, Montreal (Quebec) Canada, 11–15 octobre 1994 = Archaeological Remains, in Situ Preservation: Proceedings of the Second ICAHM International Conference, Montréal, Québec, Canada, October 11–15, 1994*, org. ICOMOS International Committee on Archaeological Heritage Management, 315–22. Ottawa: ICAHM Publications.

Bettini, C., and A. Cinquanta. 1990. *Vegetazione e monumenti: Esigenze e metodologie nel controllo delle infestazione ruderali.* Viterbo: Union Printing.

Biscontin, G., M. dal Colle, S. Volpin, eds. 1993. *Archeologia recupero e conservazione: La conservazione e il restauro oggi no. 3,* a cura di Masetti Bitelli L., Istituto per i beni artistici, culturali e naturali della Regione Emilia Romagna. Florence: Nardini Editore.

Bromelle, N. S., and P. Smith, eds. 1986. *Case Studies in the Conservation of Stone and Wall Paintings: Preprints of the Contributions, Bologna Congress, 21–26 September 1986.* London: IIC.

Brotherwell, D. R. 1981. "Notes for Guidance in Excavating and Reporting on Human Remains." In *Digging Up Bones: The Excavation, Treatment, and Study of Human Skeletal Remains.* 3rd ed. London and Oxford: British Museum (Natural History) and Oxford University Press.

Caneva, G., and A. Altieri. 1988. "Biochemical Mechanisms of Stone Weathering Induced by Plant Growth." In *I siti archeologici: Un problema di musealizzione all'aperto.* Rome: Multigrafica Editore.

Caneva, G., and G. De Marco. 1986. "II controllo della vegetazione in aree archeologiche e monumentali." In *Manutenzione e conservazione del construito fra tradizione e innovazione: Atti del convegno di studi Bressone, 24–27 guigno 1986,* ed. G. Biscontin. Scienza e Beni culturali. Padova: Libreria Progetto Editore.

Caneva, G., M. P. Nugari, and O. Salvadori. 1991. *Biology in the Conservation of Works of Art.* Rome: ICCROM.

Carandini, A. 2000. *Storia della terra: Manuale di scavo archeologico.* Turin: Einaudi.

Catizone, P. 1990. *Il contenimento delle piante infestanti nelle aree di interesse archeologico, in Archeologia e Botanica.* Rome: L'"ERMA" di Bretschneider.

Cepero Acan, A. E. 1996. "The Corrosion of Metals: A Conservation Approach." Notes for Scientific Principles of Conservation (SPC96 course), ICCROM. Unpublished.

Chavigner, F. 1990. "Intervention sur le terrain." In *La conservation en archéologie: Methodes et pratique de la conservation-restauration des vestiges archéologiques,* ed. M. Cl. Berducou, 36–77. Paris: Masson.

Chavigner, F., and J.-P. Giraud. 1989. "Archéologie: Des restaurateurs sur le terrain?" In *Traitement des supports: Travaux interdisciplinaires, Paris, 2, 3 et 4 novembre 1989.* Paris: ARAAFU.

Child, R. 1999. "Tutela del patrimonio artistico museale." In *Climatologia applicata alla conservazione dei Beni Archeologici e Storico-Artistici, Atti del Convegno Incontri di Restauro n° 2, Trento, 22–24 ottobre 1998,* 37–56. Trento: Provincia Autonoma di Trento, Servizio Beni Culturali.

Ciabach, J., ed. 1988. *Sixth International Congress on Deterioration and Conservation of Stone, Torun, 12–14 September 1988 = VIe Congrès international sur l'altération et la conservation de la pierre: Toruń, 12–14.09.1988.* Torun: Nicholas Copernicus University Press.

Cleland, H. F. 1932. "The Crime of Archaeology: A Study on Weathering." *Scientific Monthly* 35.

Commissione NorMal. 1991. *Raccomandazioni NorMal: 1/88; Alterazioni macroscopiche dei materiali lapidei: Lessico. Rome:* CRR-ICR.

D'Albore, A. 2000. *Materiali.* www.arbiter.it.

De Gattis, G. 2001. "I costi del progetto e del cantiere." In *Lo scavo archeologico, la conservazione dei manufatti architettonici allo stato di rudere in condizione di emergenza.* Museo Internazionale delle Ceramiche in Faenza, Universita degli studi di Firenze, Dipartimento di storia dell'architettura e restauro delle strutture architettoniche, Dipartimento delle costruzioni, Soprintendenza per i Beni Archeologici dell'Emilia Romagna, Servizio Beni Archeologici della Regione Autonoma Valle d'Aosta, CiErre Edizioni.

De Guichen, G. 1992. "La conservazione inizia sullo scavo: Archeologia e restauro in Francia e Inghilterra." *Archeo* 1: 56–61.

———. 1995. "Object Interred, Object Disinterred." In *Conservation on Archaeological Excavations*, 2nd ed., ed. N. Stanley-Price. Rome: ICCROM.

Delattre, N., A. Ginier-Gillet, and X. Hiron. 1989. "Apports et utilization des supports dans le traitement des matières organiques provenant des milieux archéologiques gorgés d'eau." In *Traitement des supports: Travaux interdisciplinaires, Paris, 2, 3 et 4 novembre 1989.* Paris: ARAAFU.

Dowman, E. A. 1970. *Conservation in Field Archaeology.* London: Methuen.

Emiliani, T. 1971. *La tecnologia dell ceramica.* Faenza: Fratelli Lega.

Ferroni, E., and D. Dini. 1981. "Chemical Structural Conservation of Sulfatized Marbles." In *The Conservation of Stone II: Preprints of the Contributions to the International Symposium, Bologna, 27–30 October 1981,* ed. R. Rossi-Manaresi. Bologna: Centro per la conservazione delle sculture all'aperto.

Gauri, K. L., and A. N. Chowdury. 1988. "Experimental Studies on Conservation of Gypsum to Calcite by Microbes." In *Sixth International Congress on Deterioration and Conservation of Stone, Torun, 12–14 September 1988 = VIe Congrès international sur l'alteration et la conservation de la pierre: Toruń, 12–14.09.1988.* Torun: Nicholas Copernicus University Press.

Gininer-Gillet, A., X. Hiron, and S. La Baume. 1987. "Les matériaux organiques." In *Conservation-restauration du Mobilier archéologique, Saint-Denis, 13 juin 1987.* Paris: Direction Général des Affaires Culturelles de Paris Ile-de-France, Direction des Antiquités Préhistoriques et Historiques, Ville de Saint-Denis, Unité de Archéologie, Université de Paris 1, Maîtrise de Sciences et Techniques en Conservation-Restauration.

Guillemard, D., and C. Laroque. 1994. "La manipulation . . . " In *Manuel de conservation préventive: Gestion et contrôle des collections.* Paris: Université de Paris 1, Ministère de l'Enseignement Supérieur et de la Recherche, Direction de l'Information Scientifique & Technique et des Bibliothèques, Office de Coopération et d'Information Muséographiques.

ICCROM. 1982. *Mortars, Cements, and Grouts Used in the Conservation of Historic Buildings.* Rome: ICCROM.

———. 1986. *Preventive Measures during Excavations and Site Protection: Conference Ghent, 6–8 November 1985 = Mesures préventives en cours de fouilles et protection du site: Gand, 6–8 novembre 1985.* Rome: ICCROM.

———, Section française. 1984. *Adhésifs et consolidants, Xème Congrès International, Paris, 2–7 septembre 1984, Institut international de conservation d'œuvres historiques et artistiques.* Paris: Section française de l'IIC.

Johansson, L.-U. 1987. "Bone and Related Materials." In *Conservación arqueológica in situ: Memoria de las reuniones 6–13 de abril de 1986, México = In Situ Archaeological Conservation, Proceedings of Meetings April 6–13, 1986, Mexico,* ed. H. W. M. Hodges. Mexico City: Instituto Nacional de Antropología e Historia; Los Angeles: Getty Conservation Institute.

Jones, J. 1980. "The Use of Polyurethane Foam in Lifting Large Fragile Objects on Site." *The Conservator* 4: 31–34.

La Fontaine, R. H. 1984. *Silica Gel.* Technical Bulletin 10. Canadian Conservation Institute (CCI).

Lazzarini, L., and M. Laurenzi Tabasso. 1986. *Il Restauro della Pietra.* Padova: Cedam.

Leigh, D., et al. 1978. *First Aid for Finds: A Practical Guide for Archaeologists.* 2nd ed. Southampton: RESCUE—The British Archaeological Trust, with the Department of Archaeology, University of Southampton.

Leoni, M. 1984. *Elementi di metallurgia applicata al restauro delle opere d'arte: Corrosione e conservazione dei manufatti metallici.* Opificio delle pietre dure e laboratorio di Restauro/ Florence, Ministero per i Beni Culturali e Ambientali. Florence: Opus Libri.

Masschelein-Kleiner, L. 1982. *Les solvents.* Rome: ICCROM.

Minissi, F. 1978. *Conservazione dei beni storico artistici e ambientali: Restauro in musealizzazione.* Rome.

———. 1987. “Perché come proteggere i siti archeologici.” *Restauro* 16 (90).

Mora, P., L. Mora, and P. Philippot. 1977. *La conservation des peintures murals.* Bologna: Editrice Compositori. English ed. *Conservation of Wall Paintings.* London: Butterworths, 1984.

Muccinelli, M. 1987. *Prontuario dei Fitofarmaci.* Bologna: Edagricole.

Muhlethaler, B. 1973. *Conservation of Waterlogged Wood and Wet Leather.* Works and Publications, ICCROM and ICOM. Paris: Editions Eyrolles.

Newey, H., S. Dove, and A. Calvera. 1987. “Synthetic Alternatives to Plaster of Paris on Excavations.” In *Recent Advances in the Conservation and Analysis of Artefacts, Jubilee Conservation Conference, London, 6–10 July 1987.* London: University of London, Institute of Archaeology, Summer Schools Press.

Newton, C. L., and J. A. Logan. 1992. “On-Site Conservation with the Canadian Conservation Institute.” In *Retrieval of Objects from Archaeological Sites,* ed. R. Payton. Clwyd: Archetype.

Pacciani, E. 1985. “Note tecniche per il recupero ed il restauro dei resti ossei umani.” *Metodologia Scientifica II* (3–4): 205–25.

Parrini, P. 1988. “II degrado biologico: Tipi di prodotti, loro impiego e loro efficacia nella prevenzione e nella eliminazione dell vegetazione infestante dalle murature.” In *Atti del Convegno Nazionale sulla salvaguardia dei monumenti storici dalla Vegetazione infestante.* Cremona: Turris.

Payton, R. 1992. “On-Site Conservation Techniques: Lifting Techniques.” In R*etrieval of Objects from Archaeological Sites,* ed. R. Payton. Clywd: Archetype.

Peacock, E. E. 1987. “Archaeological Skin Materials.” In *Conservación arqueológica in situ: Memoria de las reuniones, 6–13 de abril de 1986, México = In Situ Archaeological Conservation, Proceedings of Meetings, April 6–13, 1986, Mexico,* ed. H. W. M. Hodges. Mexico City: Instituto Nacional de Antropología e Historia; Los Angeles: Getty Conservation Institute.

Pedelì, C. 2001a. “Primo intervento sullo scavo: I reperti mobili.” In *Lo scavo archeologico, la conservazione dei manufatti architettonici allo stato di rudere in condizioni di emergenza.* Museo lnternazionale delle Ceramiche in Faenza, Università degli studi di Firenze, Dipartimento di storia dell’architettura e restauro delle strutture architettoniche, Dipartimento delle costruzioni, Soprintendenza per i Beni Archeologici dell’Emilia Romagna, Servizio Beni Archeologici della Regione Autonoma Valle d’Aosta, CiErre Edizioni, ottobre.

———. 2001b. *Sistema informativo ArkeoKeeper: Guida dell’utente.* In collaborazione con il Servizio Beni Archeologici della Regione Autonoma Valle d’Aosta (in corso di pubblicazione a cura di S.I.CO.RE.).

———. 2002. *Raccomandazioni per la protezione il recupero e la consegna dei reperti archeologici.* Regione Autonoma Valle d’Aosta, Dip. Soprintendenza per i Beni e le Attività Culturali, Direzione Beni Archeologici e Paesaggistici, Servizio Beni Archeologici.

Pedelì, C., and L. Appolonia. 1998. *Tecniche di pulitura dei materiali ceramici antichi.* Faenza: Museo Internazionale delle Ceramiche.

Pedelì, C., and R. Pesciarelli. 1995. “*Arkeokeeper:* Uno strumento informatico per il monitoraggio sistematico degli interventi di restauro sui reperti archeologici mobile.” In *Atti della III giornata di studio sui restauro della ceramica.* Faenza: Museo Internazionale delle Ceramiche.

———. 1997. “*ArkeoKeeper:* Computer Recorder and Controller of Conservation and Restoration Works on Archaeological Mobile Finds.” In *8è journée d’étude “Informatique e Conservation-Restauration du Patrimoine Culturel.*” Chalon-sur-Saône: SFIIC.

Pedelì, C., and S. Pulga. 2000. *Primo intervento sullo scavo: Principi e metodi.* Faenza: Museo Internazionale delle Ceramiche.

Perinetti, R., and S. Pulga. 1989. In *Il cantiere della conoscenza: Il cantiere di restauro; Atti del Convegno di Studi, Bressanone, 27–30 giugno 1989,* ed. G. Biscontin, M. dal Colle, and S. Volpin. Padova: Libreria Progetto Editore.

Piperno, M. 1993. “Preistoria.” *Archeo* 8, no. 6 (100): 35–36.

Plenderleith, H. J., and A. E. A. Werner. 1986. *II restauro e la conservazione degli oggetti d’arte e d’antiquariato.* Turin: Mursia.

Price, J. G. 1975. “Some Field Experiments in the Removal of Fragile Archaeological Remains, in *Conservation Archaeology and the Applied Art.*” In *Conservation in Archaeology and the Applied Arts: Preprints of the Contributions to the Stockholm Congress, 2–6 June 1975,* ed. IIC, 153–64. London: IIC.

Price, N. S., ed. 1995. *Conservation on Archaeological Excavations, with Particular Reference to the Mediterranean Area.* Rome: ICCROM.

Pulga, S. 1988. “Meccanismi di deterioramento.” In *Corso di formazione per addetti alla manutenzione archeological: Principi di base,* 28–45. Dispensa inedita per il corso omonimo organizzato dalla Soprintendenza per i Beni Culturali ed Ambientali della Valle d’Aosta.

———. 1995. “Quelques réflexions sur la réalization technique des peintures murals romaines de Saint-Antoine à Genève.” *Revue Suisse d’Art et d’Archéologie* (RSAA/ZAK) 52.

———. 1999. “*Climatologia nella conservazione di scavi archeologici coperti.*” In *Climatologia applicata alla conservazione dei Beni Archeologici e Storico-Artistici, Atti del Convegno, serie Incontri di Restauro No. 2, a cura dell’Ufficio Beni Archeologici, Trento, 22–24 ottobre 1998,* 89–125. Provincia Autonoma di Trento, Servizio Beni Culturali.

Raphael, T., and N. Davis. 1999. *Exhibit Conservation Guidelines.* U.S. National Park Service, Division of Conservation. CD-ROM.

Roberts, F. C. 1989. “Lifting Freshly Excavated Fragile Objects.” In *Conservation of Metals: Problems in the*

Treatment of Metal-Organic and Metal-Inorganic Composite Objects, International Restorer Seminar, Veszprém, Hungary, 1–10 July 1989, ed. M. Járó. Veszprém, Hungary: Istvan Éri.

Rossi-Manaresi, R., ed. 1981. *The Conservation of Stone II: Preprints of the Contributions to the International Symposium, Bologna, 27–30 October 1981.* Bologna: Centro per la conservazione delle sculture all'aperto.

Rossi-Manaresi, R., and A. Tucci. 1984. "Traitement d'un grès calcique avec un mélange d'acrylique et de siliconate dans l'eau de chaux." In *Adhésifs et Consolidants, Xième Congrès International, Paris, 2–7 septembre 1984.* Paris: SFIIC.

Roy, A., and P. Smith, eds. 1966. *Archaeological Conservation and Its Consequences: Preprints of the Contributions to the Copenhagen Congress, 28–30 August 1996.* London: IIC.

Santoro, S., and N. Santopouli. "La protezione delle aree archeologiche: Ricerca e prassi operativa." In AA.VV. 2000.

Sease, C. 1992. *A Conservation Manual for the Field Archaeologist.* Archaeological Research Tools, vol. 4. Los Angeles: Institute of Archaeology, University of California.

Seaward, M. R. D. 1985. "Lichens and Ancient Monuments: Conservation Issues." In *Proceedings of the International Workshops on Biodeterioration of Ancient Stonework, Auragangabad, India.*

Schmidt, H. 1988. "Schutzbauen." *Denkmalpflege an archäologischen Stätten,* 1. Stuttgart.

Singley, K. R. 1981. "Caring for Artefacts after Excavation: Some Advice for Archaeologists." *Historical Archaeology* 15.

Smith, S. 1998. "British Bronze Age Pottery: An Overview of Deterioration and Current Techniques of Conservation at the British Museum." *The Conservator* 22.

Sorlini, C. 1984. *L'azione degli agenti microbiologici sulle opere d'arte.* ENAIP, Botticino (Brescia). Edizioni del Laboratorio.

Spriggs, J. 1980. "The Recovery and Storage of Materials from Waterlogged Deposits at York." *The Conservator* 4: 12–24.

Stolow, N. 1979. *Conservation Standards for Works of Art in Transit and Exhibition.* Museums and Monuments 17. Paris: UNESCO.

Stubbs, J. 1995. "Protection and Presentation of Excavated Structures." In *Conservation on Archaeological Excavations, with Particular Reference to the Mediterranean Area,* 2nd ed., ed. N. Stanley-Price. Rome: ICCROM.

Tétreault, J., and R. S. Williams. 1992. *Materials for Exhibit, Storage and Packing,* version 4.1, ed. I. N. M. Wainwright. Canadian Conservation Institute, Department of Communications.

Thomson, G. 1986. *The Museum Environment.* 2nd ed. London: Butterworths.

Thorne, R. N., P. M. Fay, and J. J. Hester. 1987. *Archaeological Site Presentation Techniques: A Preliminary Review.* Technical Report EL-87-3. Washington, DC: Department of the Army, U.S. Army Corps of Engineers.

Tiano, P., and G. Caneva. 1987. "Procedures for the Elimination of Vegetal Biodeteriogens from Stone Monuments." In *ICOM Committee for Conservation, 8th Triennial Meeting, Sydney, Preprints,* vol. 1. Los Angeles: Getty Conservation Institute and ICOM.

Torraca, G. 1980. *Solubilité et solvants utilisés dans la restauration.* Rome: ICCROM.

———. 1982. *Porous Building Materials: Materials Science for Architectural Conservation.* 2nd ed. Rome: ICCROM.

United Kingdom Institute for Conservation (UKIC), Archaeological Section. 1982. *Guidelines on Ethics.* London: UKIC.

———. 1984. *Conservation Guidelines.* No. 3. London: UKIC.

Vidale, M. 1993. "Restauro della ceramica: Informazione non registrata + informazione non pubblicata = informazione perduta." In *Atti della 11 giornata di studio sul restauro della ceramica—i materiali e la tecnica, Faenza, 25 settembre, Istituto Statale d'Arte per la Ceramica,* ed. G. Ballardini. Faenza: Museo lnternazionale delle Ceramiche.

Villa, A. 1977. "The Removal of Weeds from Outdoor Mosaic Surfaces." In *Mosaics No. 1: Deterioration and Conservation, Proceedings of the First International Symposium on the Conservation of Mosaics, Held in Rome, November 2–5, 1977,* ed. F. Selvig. Rome: ICCROM.

Watkinson, D., and V. Neal. 1998. *First Aid for Finds.* 3rd ed. Hertford: RESCUE—The British Archaeological Trust; London: UKIC Archaeology Section, with the Museum of London.

Index

Note: Page numbers followed by *f* and *t* indicate figures and tables, respectively.

About the Authors

Corrado Pedelì is a senior conservator-restorer employed since 1985 at the Department of Cultural Heritage of Aosta Valley (northwestern Italy), where he is primarily responsible for conservation projects and scientific direction of conservation sites, monuments, and objects. He specializes in first aid and emergency conservation techniques on archaeological sites. Since 2004 he has been a consultant for ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property), teaching several courses in the Middle East, Asia, southeastern Europe, and Italy. He has served as adviser for many international entities and projects, including Bayern Landesmat für Denkmalpflege on the Research and Optimization Techniques for the Shanxi Terracotta Warriors and Horses of the Tang Dynasty project in Xi'an, China (1999); UNESCO, on behalf of ICCROM, at the International Expert Consultation Meeting on the Ba Dinh and Thang Long Imperial Citadel archaeological sites, Vietnam (2004); and the Directorate General of Cultural Heritage and Landscapes for Lombardia on the condition survey of the Small Cloister of the Certosa, Pavia, Italy (2004–6). Pedelì is also the author of several educational guidelines and articles on the development of materials and techniques for the conservation of archaeological features. In particular, he implemented a condition survey training module based on system approach theory combined with a methodology he refers to as visual organized analysis to support interdisciplinary teams. He has European experience in the field of information technology applied to the management of archaeological collections and sites. He was a consultant and planner in the field of context analysis for the *ArkeoTrac* information system, designed for the automated management of archaeological and conservation activities.

Stefano Pulga is a conservator in private practice. He started as a conservator trainee at the Laboratory of Ottorino Nonfarmale in Bologna, Italy, then at the CREPHART laboratory of Theo Antoine Hemanès in Geneva, Switzerland. Pulga has been involved in numerous conservation campaigns for archaeological heritage and monuments throughout Europe. Under the direction of the Department of Cultural Heritage of Aosta Valley, he has undertaken or coordinated the conservation work on various castles in the region (Fenis, Cly, Ussel, Morgex, Quart, Issogne, Graines) and Roman monuments in Aosta (the Pretorian gate and the city fortification walls). He has served as consultant for climatology and preventive conservation on archaeological sites in France (Poitiers, Auxerre, Limoges, Bordeaux, Bourges), Switzerland (Geneva, Fribourg, Augst-Augusta Raurica), Spain (Mercat del Born in Barcelona and excavations of the cathedral of Barcelona), and Belgium (Archeoforum in Liège). From 2002 to 2005 he was a member of the advisory board of the European project APPEAR (Accessibility Projects: Sustainable Preservation and Enhancement of Urban Subsoil Archaeological Remains), European Commission/Department of Patrimony for the Region of Wallonia, Liège, Belgium. Pulga has given ICCROM-organized and -funded courses in Shigisoara, Romania (1995), Sirmium, Serbia (2006), and Butrint, Albania (2007). Since 2002 he has taught courses covering the basic principles of conservation, lime mortars technology, and climatology in the Faculty of Architecture, Department of Restoration and Conservation, University of Florence, and in Trento, Faenza, and Auxerre in France, Geneva and Fribourg in Switzerland, and Barcelona in Spain. In 2005 he was an adviser and teacher in Project PRODOMEA (Project on High Compatibility Technologies and Systems for Conservation and Documentation of Masonry Works at Archaeological Sites in the Mediterranean Region), Jordan, and from 2010 to 2013 he served in the same capacities in Project AVER (Ancien vestiges en ruine) in Valle d'Aosta/France.

The Getty Conservation Institute

The relationship between archaeology and conservation has long been a complex and challenging one. Yet it is often initial conservation in the field that determines the long-term survival and intelligibility of both movable artifacts and fixed architectural features. For this reason archaeologists and conservators must work successfully together to ensure that recovered material culture—and the many meanings it carries—is properly preserved for future generations.

This volume is intended to facilitate the harmonious collaboration between the parties of this essential relationship, by serving as a hands-on guide to conservation practices on archaeological excavations. Individual chapters concentrate on such topics as excavation and conservation, environmental and soil issues, deterioration, identification and condition assessment, detachment and removal, initial cleaning, coverings and shelters, packing, and documentation.

This book will be of interest to archaeologists, archaeological conservators, site managers, conservation scientists, museum curators, and others involved in the study or guardianship of recovered materials.

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