



INTERNATIONAL CENTRE FOR THE STUDY OF THE PRESERVATION AND THE RESTORATION OF CULTURAL PROPERTY
CENTRE INTERNATIONAL D'ETUDES POUR LA CONSERVATION ET LA RESTAURATION DES BIENS CULTURELS

ICCROM

PREVENTIVE MEASURES DURING EXCAVATION AND SITE PROTECTION

MESURES PREVENTIVES EN COURS DE FOUILLES ET PROTECTION DU SITE



VII D 48

**PREVENTIVE MEASURES DURING EXCAVATION
AND SITE PROTECTION**

**MESURES PREVENTIVES EN COURS DE FOUILLES
ET PROTECTION DU SITE**

Conference

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CONTENTS / SOMMAIRE

Page

FOREWARD / AVANT-PROPOS

v

1. *Preventive Measures During Excavation: Problems and Approaches*
Mesures préventives en cours de fouilles: problèmes et solutions proposées

| | | |
|---------------|---|----|
| A. MELUCCO | Archéologie de fouille et conservation: limites et domaine d'intervention, respectivement de l'archéologue et du restaurateur | 1 |
| N. MILLS REID | On-site conservation of organic materials in Western Australia | 13 |
| M. CARVER | Sutton Hoo: management and intervention on acid sandy sites | 27 |
| P. BARKER | Temporary shelter and site protection | 45 |
| J. SCHOFIELD | Practical problems in the excavation of Roman and medieval London | 51 |

2. *Preventive Measures During Excavation: Techniques*
Mesures préventives en cours de fouilles: techniques

| | | |
|-------------------|---|-----|
| A. BERGERON | Conservation et archéologie au Québec | 63 |
| C.E.S. HETT | Soil section transfers, moulding and casting | 69 |
| A. ABDURAZAKOV | Conservation experience of clay construction in Uzbekistan | 81 |
| R. NARDI | Conservation on the excavation: the Crypt of Balbus in Rome | 91 |
| A. COSTANZI COBAU | Excavated wall plasters: conservation problems | 103 |

3. *Protection of Sites Underwater*
Protection des sites subaquatiques

| | | |
|-------------------|---|-----|
| I. MacLEOD et al. | The excavation, analysis and conservation of shipwreck sites | 113 |
| M. McCARTHY | Protection of Australia's underwater sites | 133 |
| K. JESPERSEN | Extended storage of water-logged wood, when excavated and in situ | 147 |
| C. MEUCCI | Le bateau arabo-normand de Marsala: la protection in situ | 155 |

4. *Protection of Sites on Display*
Protection des sites exposés

| | | |
|---------------------|---|-----|
| J. VOUBE, J. BRUNET | De la protection des sites archéologiques (S.L.), gisements, fouilles et monuments préhistoriques | 161 |
| G. FRASHERI | Archaeological conservation in the castle of Kruja | 181 |
| V. SHTYLLA | L'appréciation des vestiges architectoniques des monuments de l'antiquité et du moyen âge en Albanie | 190 |
| A. ZIELINSKI | Conservation unit of the Dakhleh Oasis Project - an approach to on-site conservation and preser- vation in the Dakhleh Oasis, Egypt | 203 |
| A. BIASIOTTI | Theft protection of archaeological excavations: a test case study | 213 |

5. *Protection of Sites on Display: Roofs and Shelters*
Protection des sites exposés: abris et toits de protection

| | | |
|-------------------|---|-----|
| A. STEVENS | Structures nouvelles de protection des sites archéologiques du Tiers Monde | 225 |
| S. WAANE | Roofs and shelters: the Tanzanian experience | 245 |
| N. AGNEW, M. WADE | A case study of a palaeontological site - The need for planning and protection | 257 |
| T.K.N. DE SILVA | Roof over a monument - Sri Lankan experience | 271 |
| W.O. BOEKWIJT | Salt and crack problems in the Roman bath at Heerlen and their therapy | 281 |
| H. DE WITTE | Protection of archaeological sites: the Bruges situation and the example of the Church of Our Lady | 299 |
| G. SCICCHILONE | The site of the Cathedral at Atri: a case study of in situ conservation of archaeological remains | 309 |
| RECOMMENDATION: | about conservation on archaeological sites made by a working group of archaeologists and conservators at the Ghent conference | 315 |
| RECOMMANDATIONS | relatives à la conservation des sites archéolo- giques faites par un groupe de travail composé d'archéologues et conservateurs à la conférence de Gand | 317 |

FOREWORD

The meeting on "Preventive measures during excavation and site protection" took place in Ghent, Belgium, on 6-8 November 1985. It was jointly organized by ICCROM and the Faculty of Greek Archaeology of the University of Ghent.

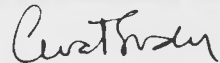
The theme of the meeting was selected as a result of recommendations made at an earlier conference on archaeological conservation organized by ICCROM in Cyprus in 1983. The papers from this conference were edited and published under the title "Conservation on Archaeological Excavations, with particular reference to the Mediterranean area" (ICCROM, Rome, 1984). Among the suggestions made at the meeting was one that more attention be paid to methods of protecting excavated archaeological sites.

Interest in archaeological conservation has focused on the treatment of excavated objects, on the one hand, and on the problems of restoring sites on the other. Less attention has been given to methods of site conservation and maintenance. The need for these arises during the excavation (and even before it) and continues following its completion. Various techniques have been developed and tested in different countries but there has been little exchange of experience derived from them.

This, then, was the aim of the Ghent conference. A call for papers was made, with a few papers being invited from specialists in the subject. The Cyprus meeting had had a Mediterranean orientation; although a conference in Ghent would have a more north European emphasis, it was hoped that contributions from a wider area would be received. In fact, as the papers in this volume testify, there was evidence of wide interest in the topic from different regions of the world.

Moreover, the title of the meeting was deliberately broad in the hope that archaeologists, architects and conservators would be interested to attend. The discussion at the conference between different professions involved in the protection of archaeological sites was one of the most fruitful aspects of the meeting, and gave rise to the series of recommendations prepared by a working group that are printed at the end of this volume.

For agreeing to host this meeting and for making excellent facilities available in Ghent, thanks are due to Professor H. Mussche, head of the Faculty of Greek Archaeology of the University of Ghent. Local organization was in the hands of Lieve Vandenbulcke, a former course participant at ICCROM, with the assistance of other members of the Faculty of Greek Archaeology and the University staff. For ICCROM Nicholas Stanley Price and Susan Inman co-ordinated arrangements for the meeting.



Cevat Erder
Director of ICCROM

AVANT-PROPOS

La conférence sur "Les mesures préventives durant les fouilles et la protection des sites archéologiques" a eu lieu à Gand, en Belgique, du 6 au 8 novembre 1985. Elle était organisée conjointement par l'ICCROM et la Faculté d'archéologie grecque de l'Université de Gand.

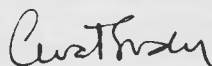
Le thème de la conférence a été choisi en fonction des recommandations faites lors d'une conférence précédente sur la conservation archéologique, organisée par l'ICCROM à Chypre en 1983. Les relations présentées à cette conférence ont été éditées et publiées sous le titre: "Conservation des fouilles archéologiques se référant particulièrement à la zone méditerranéenne" (ICCROM, Rome, 1984). Parmi les propositions faites pendant la réunion, l'attention a été portée sur celles concernant les méthodes de protection des sites archéologiques.

L'intérêt pour la conservation archéologique s'est concentré d'une part sur le traitement des objets récupérés et de l'autre sur les problèmes concernant la restauration des sites. Bien que peu d'attention ait été portée sur les méthodes de conservation et d'entretien des sites, celles-ci se rendent nécessaires pendant les fouilles (et même avant), ainsi qu'après l'achèvement de ces fouilles. Diverses techniques ont été développées et testées dans différents pays mais peu d'échanges d'expériences en ont dérivé.

Ceci fut donc le but de la conférence de Gand. Une invitation à présenter des relations sur le sujet, dont celles de quelques spécialistes en la matière, fut lancée. La conférence de Chypre avait une orientation méditerranéenne et, bien que la conférence de Gand aurait dû être orienté plus vers l'Europe du Nord, on espéra que les contributions proviendraient d'horizons plus vastes. En effet, comme en témoignent les relations contenues dans ce volume, un intérêt très diversifié sur ce sujet s'est manifesté de la part de différentes régions du monde.

D'autre part, un titre assez général fut délibérément choisi dans l'espoir de susciter l'intérêt des archéologues, des architectes et des conservateurs à participer. Pendant la conférence, les discussions sur les sites archéologiques entre les membres des différentes professions fut un des aspects les plus positifs et déboucha sur la préparation, par un groupe de travail, d'une série de recommandations qui sont publiées à la fin de ce volume.

Nous désirons remercier le Professeur H. Mussche, recteur de la Faculté d'archéologie grecque de l'Université de Gand pour avoir accepté d'héberger cette conférence et mis tout le nécessaire à disposition des participants. Lieve Vandenbulcke, une ancienne participante au cours de l'ICCROM, assistée d'autres membres de la Faculté d'archéologie grecque ainsi que du personnel universitaire, s'est chargée de l'organisation locale. Pour l'ICCROM, Nicholas Stanley Price et Susan Inman ont coordonné les préparatifs pour la conférence.



Cevat Erder
Directeur de l'ICCROM

PREVENTIVE MEASURES DURING EXCAVATION:
PROBLEMS AND APPROACHES

MESURES PREVENTIVES EN COURS DE FOUILLES:
PROBLEMES ET SOLUTIONS PROPOSEES

**ARCHEOLOGIE DE FOUILLE ET CONSERVATION:
LIMITES ET DOMAINE D'INTERVENTION, RESPECTIVEMENT
DE L'ARCHEOLOGUE ET DU RESTAURATEUR**

Alessandra Melucco Vaccaro*

RESUME

La communication donne un aperçu général, avec quelques considérations spécifiques sur la situation italienne, des difficultés à tracer la limite entre le domaine d'intervention de l'archéologue et celui du restaurateur, en ce qui concerne la conservation en cours de fouille.

Dans cette optique on discute une expérience didactique, adressée aux restaurateurs aussi bien qu'aux archéologues, et quelques mesures spécifiques de protection du site en contexte étrusque et romain.

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En Italie la *Field Archaeology* a subi récemment de rapides transformations soit dans le renouvellement des techniques que dans la méthodologie des fouilles et c'est justement chez ceux qui suivent la méthode stratigraphique que l'on remarque, en Italie et ailleurs, la plus grande attention aux problèmes de conservation: nous avons en fait ici l'habitude d'observer le sol et, à partir des données matérielles concernant les objets et les structures, de travailler en équipes pluridisciplinaires disposées à la collaboration avec des experts scientifiques à large compétence. On comprend donc que dans les activités sur le chantier les aspects de la conservation commencent à être considérés comme partie intégrante de la fouille et comme étant sous la responsabilité, au moins sur le plan de l'organisation, du directeur⁽¹⁾.

En dépit de quelques signes de nouveautés, il ne faut pas cependant se leurrer. Dans la réalité, au moins selon mon expérience, la séparation entre celui qui fouille et celui qui restaure est encore très forte et si ce *gap* n'est pas rempli, il sera bien difficile d'avoir une amélioration sensible de la situation. Il m'est personnellement arrivé une seule fois de traiter dans un congrès d'archéologues les thèmes de l'intervention d'urgence et de la protection *in situ*: ce n'est pas un hasard, et cela correspond à ce que nous avons à peine dit, qu'il s'agisse d'un séminaire important au titre révélateur "*Come l'archeologo opera sul campo*", organisé en 1981 par l'Université de Sienne⁽²⁾. Mais en général la circulation de l'information entre archéologues et conservateurs est très insuffisante et les occasions de débats et d'échanges d'expériences communes manquent.

Comment les archéologues considèrent-ils le problème?

En principe les opérations de conservation faites au cours ou à la fin de la fouille sont définies "*pronto intervento*" parce qu'elles sont généralement des opérations exceptionnelles que l'archéologue réclame seulement lorsqu'il comprend d'être dans une situation de graves difficultés. Même sans tomber dans le style romanesque des aventures écrites par Ceram, ou familier au public après "*Raiders of the Lost Arc*", des phénomènes macroscopiques de dégradation rapide et même définitive des matériaux et des structures, comme nous le savons bien, peuvent vraiment arriver et, comme l'avertissait Plenderleith, il reste alors bien peu à faire.

Mais est-ce la seule façon de concevoir l'intégration entre la recherche sur le terrain et la conservation?

Certainement pas. Il faut tenir compte que ces considérations restrictives ont, en Italie, leurs racines dans la formation des archéologues qui, au cours de leurs études universitaires, ne reçoivent aucune formation en matière de restauration et de prévention. Cependant en dépit de la spécificité du cas de l'Italie, il existe un retard beaucoup plus général, dû également aux spécialistes de la conservation, à prendre en considération le problème.

Il suffit de parcourir la bibliographie spécialisée et les sommaires des congrès internationaux les plus prestigieux pour noter que la question a été ignorée pendant longtemps. Un texte désormais classique comme *Science in Archaeology* qui contenait les contributions de spécialistes sur une très large gamme de sujets, ne disait pas un mot des problèmes de la *Field Archaeology*⁽³⁾. Dans de nombreux articles consacrés à l'examen des trouvailles archéologiques très fragiles telles que cheveux, ongles, verres, bronzes, textiles, les auteurs laissent clairement entendre qu'ils n'ont pas la moindre idée de comment de tels restes soient arrivés sur les tables de leur laboratoire.

Depuis quelques années seulement les congrès consacrés à la mise au point des principaux thèmes de conservation commencent à dédier une section du programme

de travail à la *Field Archaeology*⁽⁴⁾ et de nombreux spécialistes font des recommandations explicites soulignant que tout ce qui se fait ou ne se fait pas à partir du moment où l'objet ou la structure commencent à apparaître dans la couche archéologique est décisif pour leur survie, bien plus que les interventions successives dans le laboratoire et les traitements systématiques⁽⁵⁾.

L'objet des premières mesures à prendre est souligné en particulier avec un ton ouvertement dramatique et des recommandations chaleureuses dans trois cas exemplaires: dans le cas des bois gorgés d'eau, des objets de fouilles sub-aquatiques et des structures en argile crue. Il s'agit cependant d'exemples extrêmes pour lesquels, avec une insistance justifiée, les conservateurs veulent rappeler aux archéologues que la possibilité de conserver doit être acceptée comme un critère fondamental pour décider si l'on doit commencer ou non une fouille: "*It is only all right to raise material if you know how to conserve it*"⁽⁶⁾.

Je voudrais cependant signaler que le cas de l'argile crue a été jusqu'ici abordé comme un problème typique des pays du Tiers-Monde: l'Italie se considère en général comme le domaine des matériaux de construction durables; considérons la différence de situation par rapport au Centre et au Nord de l'Europe et à l'Angleterre, et la difficulté qui en découle d'appliquer chez nous les techniques de fouille des *open areas* théorisées et pratiquées par Ph. Barker et son école⁽⁷⁾. Cependant, même dans notre pays, une rigueur accrue dans les techniques de fouille commence à révéler une large présence de structures en argile crue, parfois d'époque ou dans des lieux insoupçonnés: je me réfère non seulement aux quartiers archaïques de l'acropole du centre étrusque de Roselle⁽⁸⁾ mais aussi à la villa romaine de Sette finestre où les parois de la zone seigneuriale étaient faites également en argile crue décorée de fresques dignes des habitations de Rome de la même époque⁽⁹⁾. Les mesures de protection temporaire devront donc tenir compte aussi de cette nouvelle découverte en adaptant les indications disponibles jusque-là aux conditions climatiques de l'Italie.

Si nous examinons maintenant les publications sur l'archéologie, nous ne sommes pas surpris, étant donné ce que nous venons de dire, qu'un grand classique de l'archéologie stratigraphique "*Archaeology from the Earth*" de Wheeler⁽¹⁰⁾ soit un des premiers à contenir des informations sur l'organisation et les tâches du laboratoire de chantier. Wheeler, toutefois, s'attachait encore à l'idée, qui aujourd'hui est abandonnée, de la présence permanente d'un expert (chimiste ou restaurateur) sur le chantier. On a cependant l'impression, en lisant le texte, que le père de l'archéologie stratigraphique, à cause de sa propre formation culturelle et professionnelle, est conscient que le problème de la conservation se pose justement au moment de la fouille et non après, mais le savoir et les mesures à prendre concrètement sont, selon lui, l'affaire des autres.

La question est affrontée avec une optique nouvelle seulement dans les textes récents de technique de fouille: je me réfère, par exemple au manuel de Ph. Barker⁽¹¹⁾ qui montre d'être pleinement conscient des aspects de la conservation liés à la fouille, qui sont considérés comme des problèmes propres de l'archéologue.

Plus de détails et des indications plus précises sont données seulement, à ma connaissance, par deux textes (tous deux d'auteurs anglais) destinés expressément aux archéologues et qui montrent de la part des auteurs, experts de conservation, une connaissance directe des problèmes et des exigences concrètes de la fouille.

Dans le premier, de B. Dowman⁽¹²⁾, l'auteur déclare clairement qu'elle s'adresse non pas au restaurateur mais à l'archéologue, mais elle se réfère à un professionnel avec une formation très différente de celle de l'archéologue italien, c'est-à-dire un interlocuteur habitué à se débrouiller entre chlorures et sulfates,

Ph, résines vinyliques et cire microcristalline. Le texte ne peut donc être conseillé aux Italiens comme manuel pratique parce que dans notre pays un tel archéologue ne représente pas la norme. Mais il existe une limitation encore plus importante dans la formulation du texte: dans l'ensemble assez large des informations fournies, la limite n'est pas clairement définie entre les opérations qu'un archéologue, formé en conséquence, peut exécuter et celles qui doivent être confiées au restaurateur et à l'expert scientifique non seulement à cause du raffinement des techniques particulières et de l'habileté manuelle qu'elles requièrent, mais surtout pour la compétence du diagnostic et les décisions à prendre sur le type d'intervention et les matériaux appropriés à cet effet.

Un travail exemplaire, dans sa modestie apparente, est au contraire celui de Leigh⁽¹³⁾: il doit justement son utilité à la clarté de la structure méthodologique et à l'équilibre entre la compétence dans le domaine de la conservation et la connaissance des situations habituellement rencontrées dans les fouilles. "S'il était possible d'enlever les objets archéologiques, de les mettre en lieu sûr et de les confier aux mains du restaurateur plusieurs années après, dans l'état où ils ont été découverts, ce livre n'aurait pas de raison d'être". Une autre qualité du texte de Leigh se trouve dans la description précise des opérations que l'archéologue doit exécuter et celles qu'il signale avec une mise en garde en lettres majuscules "DON'T DO IT YOURSELF": la restauration n'est pas un bricolage et il omet donc, par conséquent, de fournir les informations relatives au processus de conservation proprement dit. Ses indications sont donc très bien pesées, proportionnées aux connaissances et à l'aptitude manuelle de l'archéologue confirmé et considèrent avec une minutie particulière les techniques de stabilisation des objets, d'emballage adéquat, en fonction aussi de l'inspection et de la manipulation pour l'étude dans le dépôt. Ce modèle est le plus convaincant et le plus expérimenté (et du reste Barker s'y réfère), mais il doit être complété précisément en ce qui concerne la protection temporaire des structures *in situ* sur lesquelles il ne dit mot. Il y a, en effet, une partition ultérieure entre le *first aid* par rapport aux matériaux mobiles, qui commence à se frayer le chemin dans la pratique de fouille, et les mesures de protection du site, qui sont presque ignorées par les archéologues: on n'est pas en mesure de percevoir que l'aménagement final du site comme "musée en plein air" est possible uniquement si au terme de chaque campagne ont été entreprises des opérations partiales et temporaires, mais indispensables⁽¹⁴⁾. Il faut en outre mettre en évidence une autre qualité de l'oeuvre: tout part d'une mise au point: la présence continue d'un expert de conservation sur la fouille est une utopie et il est donc temps d'y renoncer en se réservant d'appeler un spécialiste dans les cas où ses connaissances professionnelles particulières soient réellement nécessaires.

Cette constatation, qui est aujourd'hui acceptée par tout le monde⁽¹⁵⁾, nous amène au centre du problème que je voudrais traiter ici.

L'EXPERIMENTATION SUR LE CHANTIER

La situation que j'ai jusqu'ici définie peut se schématiser ainsi:

- Impossibilité de disposer, en cours de fouille, de la présence continue d'un restaurateur et/ou d'un expert scientifique.
- Nécessité de surmonter la division existant, dans la recherche et la pratique, entre archéologues et spécialistes de la conservation.

Prenant acte de cette situation, j'ai décidé de faire une expérimentation sur le chantier avec les buts suivants:

- Définir le domaine de responsabilité et les opérations concrètes qu'un archéologue doit pouvoir exécuter directement, en précisant très clairement les limites du "DON'T DO IT YOURSELF".
- Compléter la formation du restaurateur d'objets archéologiques avec des interventions d'urgence et de protection *in situ*.
- Déterminer les règles de comportement en cas de conflit entre la méthodologie stratigraphique et les exigences de conservation.
- Développer l'habitude du travail en commun.

J'ai, depuis quelques années, avec les élèves de la section archéologique des cours triennaux pour restaurateurs de l'ICR et avec les participants au cours de perfectionnement sur la conservation des matériaux pierreux, organisé des chantiers didactiques, choisissant des campagnes de fouilles qui aient en elles-mêmes un caractère didactique et qui soient bien organisées du point de vue scientifique et avec des structures d'appui ⁽¹⁶⁾. L'activité du chantier, de la durée de deux à quatre semaines, complétée par de courts séminaires sur place, est orientée clairement dans deux directions et s'adresse soit aux restaurateurs qu'aux archéologues.

Quelques-unes des questions traitées sont de portée générale:

- Une série d'informations, adressées aux archéologues, sur les méthodes de stabilisation et d'emmagasinage adéquat des pièces qui peuvent être enlevées de la terre sans difficultés.
- Quelques expériences pratiques, exécutées en commun par des archéologues et des restaurateurs, pour cerner et résoudre les interférences continues entre l'activité de fouille et la récupération correcte des matériaux.

Il s'agit essentiellement:

- De vérifier ensemble la succession correcte des opérations de sorte que l'enquête stratigraphique et les opérations connexes de documentation graphique et photographique puissent se faire dans des temps et de façon tels qu'ils ne comportent pas une permanence trop longue, ou dans des conditions d'environnement défavorables, de pièces fragiles ou sensibles aux changements thermohygrométriques, partiellement découvertes dans la couche archéologique.
- De réaliser par des restaurateurs l'enlèvement de sections de terrain ou autres interventions de récupération sans bouleversement et de façon non-destructive pour l'enquête stratigraphique.

Je voudrais signaler que déjà dans cette phase nous affrontons aussi les problèmes de protection temporaire: souvent en fin de journée, s'il n'a pas été possible d'enlever du terrain tous les matériaux repérés dans la couche, il est nécessaire de les protéger soit pour les besoins de la conservation soit contre les fouilleurs clandestins.

Le cas le plus fréquent consiste d'empêcher le dépôt de la rosée nocturne sur les objets soumis, par exemple, à un traitement de consolidation, en fonction de l'enlèvement de la terre. Dans ces cas-là il a semblé convenable d'utiliser, à la place des feuilles de plastique devenues omniprésentes sur les fouilles, des tissus naturels en contact avec l'objet qui est ensuite recouvert d'un matériau isolant, polyuréthane

expansé ou argile expansée, et successivement dissimulé sous une couverture de terre de fouille.

Une deuxième partie de l'expérimentation concerne en revanche la formation aux opérations de récupération et de protection *in situ* en cherchant de définir la limite entre la compétence et l'intervention de l'archéologue et celles du restaurateur.

Le critère adopté pour ce faire a été de confier aux archéologues des récupérations qui demandent un perfectionnement des techniques manuelles, le recours à des bandages avec du gypse à prise rapide, en limitant autant que possible aussi bien les nettoyages mécaniques *in situ* des objets, que l'emploi de consolidants et de *facing* avec des colles synthétiques.

On réserve en revanche aux restaurateurs toute opération qui comporte des traitements avant l'enlèvement des pièces, en particulier sur les métaux et les matériaux organiques fragiles, ainsi que l'enlèvement de larges sections de terrain avec la mise en place de systèmes complexes de soutien et de soulèvement. En ce qui concerne également la protection *in situ*, on attire surtout l'attention des archéologues sur le fait que le chantier de fouilles ne peut être laissé dans les conditions dans lesquelles il se trouve à la fin des enquêtes stratigraphiques⁽¹⁷⁾. Nombreux sont ceux qui se contentent de recouvrir l'aire avec la terre enlevée auparavant et encore seulement lorsque les clauses précises du permis de fouille les y obligent; l'habitude de placer des feuilles de plastique est également répandue, bien que l'on en connaisse très bien les contre-indications.

Il s'agit aussi dans ce contexte d'étudier et de réaliser une stratégie diversifiée de façon à ce que les pavements, les revêtements, les matériaux de construction soient protégés de manière adéquate, aussi bien des conditions thermohygro-métriques défavorables, que de la croissance de la végétation nuisible. On a constaté qu'une solution simple et facile à adapter est celle de se servir d'une couche d'argile expansée pour la protection des pavements en mosaïque⁽¹⁸⁾ et en terre battue et en général pour les niveaux de fouille qui demandent des conditions de protection particulières. Le même matériau peut être utilisé également pour les (Fig. 1-2) éléments structuraux à demi-enterrés tels que murs, fragments de colonne, parois avec des restes de revêtements⁽¹⁹⁾; dans ce dernier cas on confie au restaurateur le fixage préventif des éléments qui se détachent ou qui sont désagrégés en injectant un coulis de mortier de composition variée expérimenté par l'ICCROM; on peut procéder ainsi pour le fixage des lacunes des mosaïques, pour rétablir l'adhésion au support de revêtements de stuc ou de fresque, de colonnes, parois etc.; on construit finalement des coffres en bois tapissés de grilles en plastique et on les remplit d'argile expansée.

EVALUATION DES RESULTATS

L'expérimentation a eu des résultats très positifs soit pour éclaircir certaines questions méthodologiques et d'orientation générale, soit sur le plan de la formation pratique.

A part le fait de mieux définir les domaines respectifs d'intervention entre archéologues et restaurateurs, le chantier didactique a atteint l'objectif non négligeable de limiter le plus possible l'utilisation aveugle des *facing* avec des colles synthétiques qui, faits dans les conditions défavorables du chantier, présentent des contre-indications bien connues à cause de dégâts qui peuvent se produire au moment de leur enlèvement dans le laboratoire.

Toutefois l'absence d'habitude au travail en commun et la différence de formation de base entre l'archéologue et le restaurateur sont difficiles à surmonter dans une période de temps si courte; il faut alors multiplier et diffuser ces occasions d'intervention intégrée.

Bien que ne prétendant pas résoudre de cette façon une série de situations qui doivent être affrontées au niveau de la formation, il me semble juste de souligner l'utilité de l'expérimentation.

Celle-ci a comme conséquence non négligeable d'inciter les experts de la conservation à un contrôle plus assidu des conditions réelles d'application sur le chantier de techniques d'intervention expérimentées seulement en laboratoire.

NOTES

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11. Barker 1977 cit.; voir aussi: D. Browne, *Principles and Practice in Modern Archaeology*, London 1975; M. Joukowsky, *A Complete Manual of Field Archaeology. Tools and Techniques of Field Work for Archaeologists*, New Jersey 1980.
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- 13) D. Leigh, *First Aid for Finds 2*, Southampton 1978.
- 14) On envisage le problème du "musée en plein air" séparément: v. p.e. *5ème Cours international pour restaurateurs*, organisé par le Centre hongrois de Restauration, sous le patronage Unesco, Veszprém 29 juin - 9 juillet 1985.
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16. Settefinestre (Orbetello), villa romana, 1980-81 (Comitato italo-inglese e Università di Sienna; Osteria dell'Osa (Roma), necropoli protostorica, 1982 (Soprintendenza Archeologica di Roma e Università La Sapienza di Roma); Pratica di Mare (Roma) area dell'antica Lavinium, 1984-1985 (Università La

Sapienza di Roma); Civita Musarna (Viterbo) calidarium, 1985 (Ecole Française de Rome).

17. A démontrer combien soit encore long le chemin à parcourir vers une prise de conscience des problèmes ici discutés, même de la part des fouilleurs les plus avertis, je cite, avec malice, l'abandon du site au terme des investigations stratigraphiques du couvent de S. Vincenzo al Volturno (Molise); sur la fouille v. R. Hodges, J. Mitchel, "Excavations and Survey at S. Vincenzo al Volturno. 4th Interim Report", *Archeologia Medievale*, 11, 1984, pp. 321 ss.
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Figures 1-2:
ORBETELLO (Grosseto, Italie),
Villa romaine de Settefinestre;
fixage préventif du stuc d'une
colonne et protection *in situ*
avec argile expansée Leca.





Figures 3-4:
 CIVITA MUSARNA (Viterbo, Italie),
 Calidarium; fixage préventif des
 fresques et protection *in situ* des
 parois en tuf avec argile expansée Leca.



Figures 5-6:
CIVITA MUSARNA (Viterbo, Italie),
Calidarium; fixage préventif des
fresques et protection *in situ* des
parois en tuf avec argile expansée Leca.



Nancy Mills Reid*

SUMMARY

The wide range of on-site conditions encountered in Western Australia - from marine sites to hot, dry inland areas - results in a variety of conservation problems.

On marine sites the organic materials will have been subjected to leaching and hydrolysis for up to 350 years. They are not only fragile in the wet state but on drying show an alarming tendency to disintegrate. The effects of such drying are, at least in the case of wooden artefacts, irreversible.

With some land sites, on the other hand, conditions with temperatures up to 54°C and relative humidities as low as 15% RH may be experienced. Here the artefacts have been dehydrated for up to 40,000 years or possibly subjected to alternating dry and wet conditions, and may also have suffered from excessive exposure to UV light.

For both marine and land sites, conservation problems will be encountered whether artefacts are left on-site or transported to conservation facilities, often over long distances and on rough roads. Artefacts may also in some cases be returned to the site for storage under relatively primitive conditions.

This paper will consider a variety of Western Australian archaeological sites and the associated conservation problems in both general outline and as specific examples.

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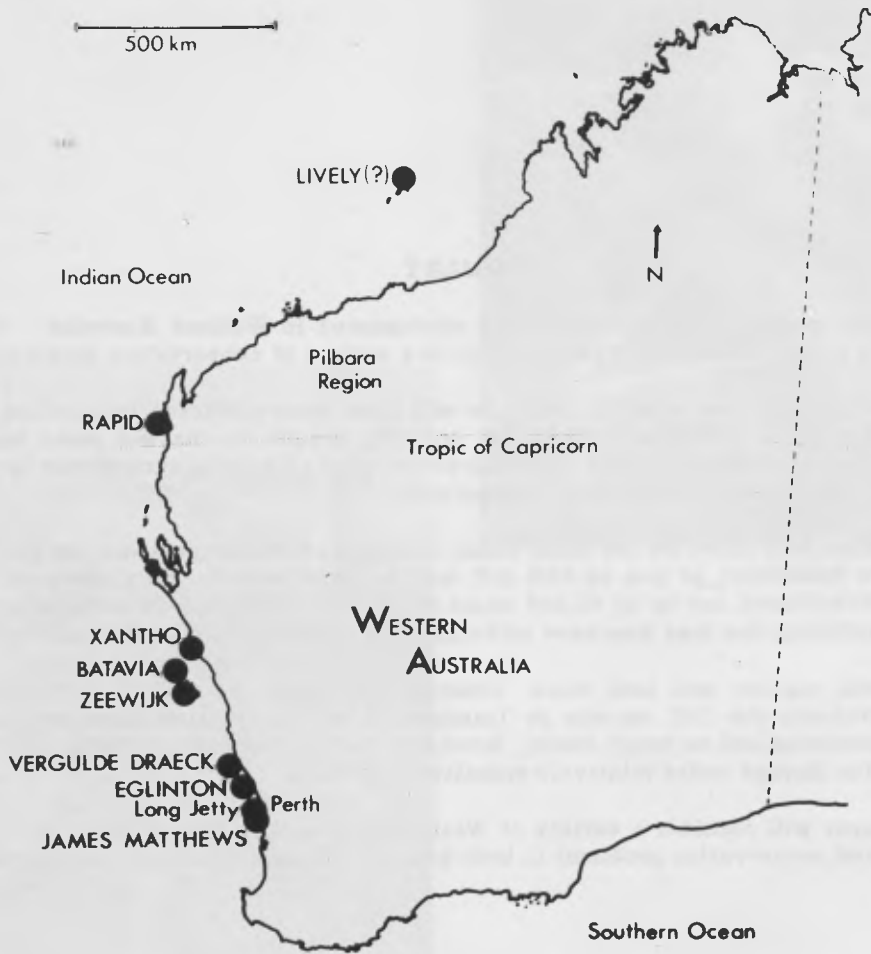


Figure 1. A number of shipwrecks have been excavated along the Western Australian coastline, while inland there are thousands of Aboriginal sites.

INTRODUCTION

On-site conservation in Western Australia is dominated by the physical constraints of climate and distance, and by the resultant population distribution.

W.A. has a land area of approximately two million square kilometres which is comparable to that of Western Europe (fig.1). The total population of W.A. is approximately $1\frac{1}{4}$ million, of which $\frac{3}{4}$ of a million are concentrated in one city complex. Most of W.A. is very sparsely populated, and the small towns which do exist are typically 300 to 600 km apart.

The remains of up to 1000 vessels, ranging from the early 17th century to the present day, lie along the Western Australian coastline. With a small number of these there also exist associated landsites. Inland there are many thousands of Aboriginal sites, the oldest of which date back at least 40,000 years. These include habitation and burial sites and collections of tribal artefacts. For the most part these archaeological sites do not occur near town sites. Those of early colonial occupation (all less than 160 years old) may also be remote from present settlement areas.

In practical terms this means that excavation and on-site conservation expeditions must be self-contained, with no reliance on local supplies of equipment and facilities. ^{1,2} Access to base camps frequently involves travel along many kilometres of rough bush tracks and this poses special packaging problems in the prevention of mechanical damage to equipment and artefacts.

Climatically W.A. is best considered as hot semi-desert. Some rivers are dry for most of the year and there is often no surface water available. In pastoral areas subterranean water of dubious quality may be available from bores. On many sites all fresh water must be carted in, and it is a major problem just to meet drinking and cooking needs. Provision of fresh water for artefact treatment can be impossible.

Air temperatures in W.A. are generally much higher than those encountered in Europe and are usually combined with lower humidity conditions. For example, at the *Rapid* base camp in 1982 the daily maximum temperatures were between 35 and 40°C with minimum relative humidities of 20 to 35%. These conditions lead to very rapid drying of artefacts and exposure for one or two hours during recording can cause irreversible damage to organic materials. The high ambient temperatures produce lukewarm storage solutions with rapid growth of bacteria and slime as a consequence.

With inland sites the problems of heat, isolation and lack of water are much greater than with marine sites. In many parts of W.A. summer temperatures regularly exceed 45°C with relative humidities falling below 10%. Intense sunlight and low humidity conditions result in ultraviolet light levels of up to 3 Wcm²/nm (Pilbara region, July)³. The intense sunlight also has a strong local heating effect with exposed rock surface temperatures above 85°C being regularly recorded in some areas.

MARITIME SITES

The degradation of organic materials in a wreck site environment is influenced by factors such as temperature, pH, salinity, water movement (including current strength and type), availability of oxygen, length of immersion, general chemistry and biology of site and presence of metals ^{4,5,6,7}.

Water temperatures off the W.A. coast range from 16°C in August to 20°C in February in the south and from 24° to 28°C in the north ⁸. As the degradation of organic materials is basically a chemical process, the higher temperatures (relative to European conditions) will result in an increased rate of degradation. Therefore the extent of degradation at 25°C for 200 years may be comparable to that occurring at a temperature of 5°C over 500-1000 years (as in Europe). Microbiological and other biological activity are also enhanced at higher temperatures.

Whether aerobic or anaerobic conditions prevail on-site will of course depend on the extent of any shelter provided by site topography and on the prevailing current. Some W.A. wreck sites are buried during the summer months and uncovered by winter storms, providing a cycle of changing oxygen availability.

The actual conditions found on Western Australian wreck sites vary considerably. Organic materials in a good state of preservation have been recovered from the *James Matthews* (Cockburn Sound, 1841) and from the site of the Long Jetty (off the coast at Fremantle, in use between 1872 and 1921). The seabed at both of these sites consists of rock covered by layers of sand which may shift during heavy storms. For most of the time sand covers the sites, affording protection to organic and other artefacts, but during heavy storms the sites will be subjected to turbulent conditions and the now unprotected materials will suffer. The *James Matthews* site is less prone to the shifting of sand because seagrass growing on the site provides additional stabilization, although it is a shallower site than the Long Jetty (2-3 metres rather than 5-6 metres) and may therefore experience more wave action.

At the other end of the preservation scale is a wreck presumed to be the *Lively* (Rowley Shoals, 1810). The site ranges in depth from two to seven metres and is subject to turbulence from heavy swell and tidal conditions, so oxygen availability is always high. Not only do these conditions mean that oxygen is readily available for utilization in biological degradation but coral debris and sand are continually moved about the site, resulting in actual physical damage to organic and other materials. As a result, the only organic materials so far known to have survived from this site have been several small pieces of oak totalling no more than a couple of kilograms in wet weight.

Other wreck sites exhibit intermediate conditions.

The *Batavia*, a Dutch East Indiaman wrecked in 1629 near Abrolhos Islands, lies in up to 7 metres of water on a gradual slope leading to a fringing coral reef. It is subjected to constant swell conditions and some turbulence when the swell is breaking. The bulk of the ship apparently broke up shortly after impact ⁹ as survivors observed the keel floating away only days afterwards. The fact that a section of the hull was preserved is attributed mainly to the physical protection afforded these timbers by a covering of large stone blocks which were part of the cargo. Subsequent coral growth cemented these into the seabed reef material. Other organic materials such as leather appear to have been preserved in concretion or by burial in pockets of sand surrounded by loose coral.

The *Vergulde Draeck* (Gilt Dragon) was another Dutch East Indiaman, wrecked in 8 metres of water off Ledge Point in 1656. This site is similar to that of the *Batavia* with swell breaking on a nearby reef although topographical features such as reef ledges and overhangs provide some protection. Again the ship appears to have broken up almost immediately and the survival of any organic materials at all is due to a covering of ballast bricks over some of the site ⁹. The *Vergulde Draeck* was apparently turned upside-down as it sank, leading to the ballast bricks providing physical protection for a considerable portion of the cargo which included pottery and leather items.

Another site of some interest is that of the *Rapid*, an American China trader wrecked in 1811 near Point Cloates. As this site lies in 5 to 7 metres of water on the inside of a fringing reef, it is subject to only occasional swells but can experience rough conditions during the cyclone season. However, even here the survival of organic materials appears due to the protection of a rock ballast mound.

Differences in salinity and temperature between the Indian Ocean and European waters together with other factors mentioned above may also mean that different marine fouling organisms will be present⁵. The upper layers of the Indian Ocean have a salinity of 32-37 ppt (parts per thousand) while at the corresponding depths in the Baltic Sea, for example, the salinity can be as low as 6-20 ppt¹⁰. Other European waters such as the Mediterranean have salinities comparable to those found in the Indian Ocean, but temperatures range from 0 to 15°C in northern Europe and from 10 to 25°C in the south¹¹.

The most commonly recovered organic material is wood, ranging from ships timbers to small personal items. The variation observed in the condition of these wooden artefacts is illustrated by the range in percentage water loss after freeze-drying - usually from 100 to 600% (with respect to weight remaining after drying). Corks have also been found on many wreck sites. Many leather items have been recovered from wrecks such as the *Vergulde Draeck*, the *Batavia*, the *Rapid* and the *James Matthews*. Quantities of rope and matting have been found on wreck sites where conditions are physically protective and prevailing anaerobic like the *James Matthews*.

Hessian has been recovered from the *Rapid* and *Xantho* sites. The *Xantho*, an iron-hulled steamship carrying a cargo of lead ore in hessian bags, was wrecked in 1872 in Port Gregory. Here the water is about six metres deep and apart from a frequent strong current the site is protected from most turbulence by a barrier reef. However, as with the wrecks discussed above, only those organic materials which have remained buried for most of this time have survived.

Cannon wadding material made from unrefined plant fibres and cotton powder bags in excellent condition have been recovered from inside iron cannons on the wrecks of the *Batavia* and *Vergulde Draeck*. Small fragments of cotton and other cellulose fibre textiles (some possibly jute) have been found on the *Vergulde Draeck*, *Batavia* and *Rapid* wreck sites. The *Batavia* and *Vergulde Draeck* have also yielded lace and knitted woollen fragments respectively.

Even silk fragments have survived and been recovered from the *Eglinton*, wrecked in 1852 near Yanchep. The *Eglinton* site is similar to that of the *Vergulde Draeck* with a continually breaking swell. Most artefacts recovered here have been preserved in pockets of sand within the limestone reef structure.

Most of these relatively delicate textiles have been preserved due to the presence of heavy materials on the sites as mentioned above. These heavy materials not only provide physical protection but also resist seabed disturbances, thus leading to the formation of anaerobic conditions under which the rate of degradation of organic materials will be minimal. The impregnation of the textiles by copper and iron corrosion products may also have contributed to their preservation.

The case of composite metal/organic artefacts will be considered in more detail later in this report.

RECOVERY AND CONSERVATION ON-SITE

On-site conservation measures for organic materials aim to prevent any further damage which might be caused by changes in relative humidity, biodegradation or crystallization of salts. Artefacts must be given adequate and appropriate support and their movement restricted to avoid any possibility of physical damage. All items recovered must also be carefully recorded and labelled.

Since the remote nature of many sites of interest means that only limited conservation resources can be made available and since very few conservation treatments can actually be started under field conditions, on-site conservation work is generally limited to the production and maintenance of stable storage and transport environments for artefacts. If it is not possible to provide such an environment for an artefact, because of its nature or size, it should be left until the next excavation season when special provision can be made for its care. Financial considerations may also preclude the recovery of some artefacts.

The recovery methods used for fragile organic artefacts may also be limited by available material resources although practical common sense and careful handling can compensate for this to a considerable extent. Many shipwreck artefacts can be recovered and taken to the surface after careful packing with sand to provide support and to limit movement.

Fresh water is often in short supply so that shipwreck materials which need to be kept wet must be stored in salt water. The process of desalination can of course only be started if fresh water is readily available. High ambient temperatures mean that biocide must be used to prevent spoilage but only a limited number of biocides can be used effectively under conditions of high temperature and high salinity. For example, under these conditions thymol is too volatile to be of much practical use.

For these reasons and for health and safety considerations, a commercially available biocide known as Panacide was chosen¹². Panacide is a 5% sodium hydroxide solution of 2,2'-dihydroxy-5,5'-dichlorodiphenyl methane which is effective against bacteria and fungi in either salt or fresh water when used at about 50 ppm active ingredient, and has relatively low toxicity for humans.

The practical requirements for on-site storage for most organic shipwreck artefacts can be met by using light, durable plastic containers and inert packing materials. Where artefacts are too large for the available storage facilities, as in the case of the Batavia timbers, these may be stored wet in black polythene-lined holes dug in the sand^{1,12}. This is not entirely satisfactory as high evaporation rates and shallow water lead to increased salinity and water temperatures. In future, provision of a shade cover over such pits will be attempted.

COMPOSITE OBJECTS

Shipwreck artefacts that consist of several organic materials can be stored on-site using the same general methods. However, objects made from a combination of metals and organic materials present problems because the on-site conservation treatments used for each type of material are incompatible.

Wood/iron and wood/copper artefacts such as ships fittings are often found where the constituent materials cannot easily be separated for conservation. Iron is normally stabilized in a caustic solution with a pH of 12 to 14 and copper is usually allowed to dry out but both of these treatments would result in considerable damage to fragile waterlogged wood.

The wood in wood/iron composites is susceptible to biological attack but must still be kept wet. A compromise is made by storing these materials in $\text{Na}_2\text{CO}_3/\text{NaHCO}_3$ solution at a pH of 10-11 with a suitable biocide. Wood in wood/copper composites is usually found to be preserved by the presence of copper corrosion products which are biologically toxic. These composites are stored on-site in either fresh or salt water and the resultant copper corrosion rate is low enough to be tolerated.

In some cases organic material/metal composites are hidden under layers of concretion and do not receive the correct on-site conservation treatment. Typically the smaller organic component is not recognized and the artefacts are treated as purely metal. However, even in these cases the organic materials have survived reasonably well. For example, some iron cannon balls which had hemp wicks and wooden plugs were amongst a large group of plain cannon balls that were partially deconcreted and then stored in caustic solution on site. Subsequent laboratory cleaning showed that, surprisingly, the organic material was still in good condition. The reasonable condition of the organic materials following this treatment may have been due to iron impregnation and also to the partial neutralization by iron chloride hydrolysis products of the alkaline solution as it diffused into the interstitial spaces.

TRANSPORT

The long distances that often exist between archaeological sites and conservation facilities in W.A. limit the conservation resources that can be made available on-site. The main reasons for this are transport costs and the practical restrictions of time, space and weight on available vehicles.

These factors also place restrictions on the methods that can be used to transport fragile artefacts from sites to treatment facilities. Packing materials that are taken to the site in the first place should preferably be both compact and light, but also durable since they often have to withstand travel by boat and/or over rough roads. Considerable use can be made of light-weight polythene sheeting and stackable plastic storage tubs for artefact containers. Packing materials are not generally taken to the sites, use being made instead of naturally occurring materials wherever possible, particularly seaweed and sand. Seaweed has good water retention, is relatively light and easily moulded and by virtue of its resilience can protect against mechanical impact. It has the disadvantage of being prone to microbiological and chemical spoilage.

Sand can be an effective packing and support medium provided it is kept wet but it too has limitations, particularly as regards weight. An environment with 100% relative humidity can be maintained by placing wet sand in a carefully sealed and watertight humidity and by treating it with chemicals such as Agrosoke and Erosel. Agrosoke is a polymeric soil stabilizer available commercially in the form of free-flowing granules. Its ability to absorb up to thirty times its own weight of water is used to supplement the water retention capacity of soils and sand. Erosel is a modification of Agrosoke with the additional property of forming a hard surface crust and thus minimising water evaporation.

On the 1983 expedition to the wreck of the *Rapid*, an intact but very fragile wooden mess-beef barrel was discovered. It was carefully excavated, packed underwater with sand and then surrounded by other packing materials for the journey back to Fremantle. During transport over rough roads, however, the sand dried out and the barrel, which had been placed on its side, collapsed due to lack of internal support. Although the barrel pieces have since been treated and are currently

undergoing restoration, much of this work could have been avoided had more care been put into the choice and maintenance of the packing materials used. An alternative would have been disassembly underwater with careful recording to aid in later restoration.

Other methods of transporting fragile artefacts ¹³ have met with more success. A wooden pulley sheave from the *Zeewijk* was discovered in its entirety under 0.5 metres of sand on Gun Island, but considerably fragmented due to its age and the penetration of plant roots.

It was decided to cast a support for the sheave in situ using a fast-setting RTV silicone rubber. The sides of the sheave were exposed by careful excavation and the top section covered with food wrap and cast within a corrugated cardboard framework. A board was then placed underneath and the entire assemblage inverted to allow casting of the bottom section.

This procedure not only protected the fragile sheave during transport but was also allowed to remain as a support during the subsequent conservation treatment in the laboratory.

Casting or moulding techniques can be adapted for use underwater ¹⁴. However, methods in current use are more suited to the in-situ modelling of small features of archaeological interest than to the provision of support for fragile artefacts.

LAND SITES

Wood is the most commonly used organic material in Aboriginal artefacts. Bark and feathers are also occasionally incorporated. Apart from those associated with sacred sites, most items were used daily.

No active conservation measures were apparently taken in the manufacture of any of these artefacts - in most cases they were not expected to last and were simply replaced when necessary. However, the traditional practice of coating wooden objects with animal fat may have been an attempted preservation measure. There is also some evidence of limited repair work being carried out with sinew binding and resin consolidation.

The condition of Aboriginal artefacts recovered varies considerably. This is perhaps not surprising in view of the variation of temperature and relative humidity which may be experienced in W.A. In general it has been found that artefacts which have only been subjected to hot dry conditions are better preserved than those exposed to alternating wet and dry cycles. Where artefacts were kept in rock shelters these would not have experienced the same extremes of temperature and relative humidity that would be found in exposed situations. High light intensity (particularly of ultraviolet wavelength) limits microbiological growth but also contributes to the chemical degradation of organic materials left in the open. Red ochres appear less susceptible to mould growth under conditions of high humidity than do white ochres. This may be due to the inhibiting effect of iron pigments.

However, most Aboriginal artefacts are found to be in a reasonable state of preservation and may simply require surface consolidation. Additional restoration work is only needed where the material is quite badly degraded. In both these cases the work is carried out in the laboratory and as such falls outside the scope of this paper.

At present active collection of Aboriginal artefacts is only carried out to a limited extent and there no longer exists a situation where wholesale collection is condoned. While collections are still made for the purposes of research, education and recording of information, co-operation between Aboriginal groups and museums or other research institutions ensures that Aboriginal customs and beliefs are given due respect. In some cases, for example, it may be necessary to limit access to certain sacred items.

There is also a general trend towards the maintenance of material on-site and the return of previously collected items. Export and interstate movement of Aboriginal artefacts are now restricted by law.

As discussed for shipwreck materials, the main aim of on-site conservation for landsite finds is the provision of a stable environment. During both storage and transport artefacts must be protected from moisture. Excessive movement, including vibration and physical abrasion, must also be avoided especially where friable ochre surfaces are involved. It is unfortunate that many of the presently existing collections are stored under less than ideal conditions.

The factors considered above regarding degradation and subsequent conservation measures also apply to post-settlement artefacts. The sheer size of some artefacts such as pieces of machinery presents additional problems. These items must almost variably be treated on-site.

STORAGE ON-SITE

It is often not possible or even archaeologically desirable to completely excavate an underwater site and so most shipwreck excavations leave material behind. Such material should, where possible, be given some protection against subsequent degradation and damage.

The most common means of protecting residual organic material, typically hull timbers, is to cover the site with rocks, ballast bricks or similar heavy materials. These then act as a sand trap, causing sand to build up in the interstices and eventually providing both physical protection and an anaerobic environment.

Ships timbers exposed during the 1982 *Rapid* expedition were covered in this manner at the conclusion of the season's excavation. It was estimated that after two months of subsequent sand entrapment the pre-excavation anaerobic state of the timbers would be re-established.

However, the subsequent year's excavation showed that this burial technique had allowed significant marine borer attack on the timbers. Apparently the rate of sand buildup had been slower than anticipated, and the marine borer attack had occurred while the timbers were still partially exposed. It was suggested that the use of chemical antifouling agents might retard biological attack during the relatively short period while the protective sand deposits were being built up in and around the rock cover. The antifouling agent chosen was tributyl tin oxide (TBTO). Rolls of hessian were soaked in a solution of 2% TBTO in kerosene and then wrapped around the exposed timbers on the seabed. Rocks and stones were placed on top of the hessian to secure this covering and also to act as a sand trap.

The site was re-examined twelve months later and it was found that this method had been reasonably effective in preventing biological attack, even in those areas where sand buildup had not occurred. However, it should be noted that the divers,

although protected by wetsuits, suffered skin irritation after handling the hessian underwater. Despite the effectiveness of this method, therefore, it has not been used since, and cannot be generally recommended.

With regard to on-site storage of land-site materials, a situation exists where in many cases Aboriginal artefacts are returned to their original locations or to the appropriate tribal group. Some of this material had been previously collected, or stolen for sale. A major aim of storage for these artefacts is the prevention of further theft or damage, but the collections must also be made readily accessible to the Aboriginal groups. Storage sheds are often built and located by the particular community. Due to limitations of distance and cost, only basic conservation measures can be taken.

Concrete floors are required, and shelving must be provided to prevent termite attacks. The sheds also provide shelter against extremes of temperatures and relative humidity.

CONCLUSION

The environmental conditions often encountered on Western Australian shipwreck sites are quite different to those found in European waters. Organic materials recovered from these sites are usually found to be either comparable to or less well preserved than corresponding European shipwreck artefacts.

From the evidence presented earlier it would be reasonable to suggest that waterlogged organic materials will only be recovered in a good state of preservation from wreck sites where physical protection has been provided by covering materials such as sand and stones or by marine plant growth. Unless lightweight organic materials are buried or trapped shortly after the wreck has taken place, these will either be carried away by the natural water movement on the site or destroyed by marine organisms. Conditions of extreme water turbulence and relatively high temperatures will adversely affect organic materials, even such large items as ships timbers.

The survival of some organic materials impregnated with iron and/or copper corrosion products may be due simply to coincidence, that is when such materials remain buried and in contact, impregnation will naturally occur. On the other hand, such impregnation may well lessen the effects of biologically and physically damaging factors in the shipwreck environment.

The procedures used for on-site conservation of waterlogged organic materials must provide stable storage environments and protection from biological, chemical and physical damage. Common-sense and careful handling are also required.

Temporary ocean storage of waterlogged organic materials is not generally advisable, as movement to another site (even if this provides a physically stable environment) may result in increased rates of biological, chemical and physical degradation¹.

The question of site treatment after excavation should also be considered. Until a site becomes naturally reburied or returns to its pre-excavation state, protection is required against increased rates of degradation and in some cases against looting. Cathodic protection on shipwreck sites is an example of what can be done for the protection of metal artefacts¹⁵. Organic materials are somewhat more difficult to protect, but perhaps use could be made of slow release chemicals with biocidal properties.

Organic materials recovered from Western Australian land sites with exceptionally high temperature and low relative humidity conditions do not present as many problems regarding conservation on-site. However, storage of these materials on-site requires a compromise to be made between conservation ideals and practical considerations.

The question of whether material related to an active indigenous population should in fact be removed for the purpose of study by another essentially foreign culture must be given serious consideration. Aboriginal groups throughout Australia are active in seeking to place limits on such collections and in returning artefacts to the areas from which they originally came.

ACKNOWLEDGEMENTS

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SUTTON HOO: MANAGEMENT AND INTERVENTION ON ACID SANDY SITES

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Sutton Hoo is thought to be the burial place of King Raedwald of East Anglia, who died about A.D. 625. As such the site is highly significant for the beginnings of the English nation and its history, and attracts a wide and very general public. Finds on the site include precious objects, such as the gold buckle and jewelled baldric recovered from burial mound No.1. These objects provoke interest of another kind, namely that of treasure seekers. However, the real archaeological assets, those most useful for the interpretation of settlement, industries, burial rite and the human behaviour that they imply, are infinitely more subtle, and in many cases scarcely visible. These fragile assets, the ruts, hollows, holes and stains contained in the sand, are vulnerable to unwitting erosion and destruction by man and nature. Here Sutton Hoo shares problems with many other sandy sites, especially in wet climates. Our principal task at Sutton Hoo has been to identify those assets, investigate their vulnerability, and make them more visible.

The site lies in a layer of acid sand about 3 m thick, on a ridge above the river Deben (fig. 1,2). It is marked by a group of 19 tumuli, four of which have been examined, and two of which contained ship burials, including that said to belong to King Raedwald (fig.3). The tumuli, together with a few medieval earthworks, constitute the visible monument, and scheduling has been guided by this (fig. 4). After three years of site evaluation, we can say that the site is much bigger and more varied (fig. 5). It is, first, a prehistoric settlement complex, about 15 ha in extent and enduring from the neolithic period to the Iron Age. Although only ditches, post-holes and hearths are now visible, the prehistoric monuments had included earthworks, with barrows amongst them. It was presumably these earthworks that drew the Anglo-Saxons to the spot. The Anglo-Saxons built a cemetery, marked by the burial mounds, with a settlement about 300 m due north; the early medieval site altogether occupies about 10 ha. The cemetery (of about 4 ha) is characterized by a wide variety of graves. The famous ship burial, excavated in 1939, consisted of a wooden burial chamber in the centre of an oak clinker-built vessel 26 m long beneath a mound (fig. 6). The burial chamber was intact, one of the very few to have escaped robbing. It did so through a lucky accident. The removal of the west end of the mound in the Middle Ages left the extant mound off-centre, misleading the otherwise successful and ubiquitous pillagers of the 16th century. From the burial chamber were recovered 263 objects of gold, silver, bronze, iron, wood, pottery, cloth, fur and feathers; but the structural timbers had all but disappeared and there was no trace of a human body (fig. 7). The ship was only an impression in the sand, marked out by rows of iron rivets, themselves reduced to non-magnetic concretions.

The problem of the missing body has led us to initiate a special investigation into the decay trajectories of human bodies. Although buried bodies are subject to very high corrosion at Sutton Hoo, we now know from work elsewhere on the site that we can detect them, if they are there. At least one other ship burial is known and two cremations in barrows, as well as urned and un-urned cremations under flat ground. But the majority of the evidence for the Anglo-Saxon period comes in the form of simple graves containing bodies. By careful excavation it is possible to recover evidence for the body-shape, the date and the burial rite. Grave-goods have been generally absent, but coffins and grave-goods made of timber have now also been defined, even though they consist only of discoloured sand. One burial contained an animal bone, and another a wooden plough.

The equipment needed to recover this type of evidence is, first, a light aluminium tower, which protects the grave against wind, and from which the excavator can be suspended. The definition stage is aided by electric aspirators, and conserved after recording by consolidation with a water-based PVA compound, to prevent collapse of vertical slices of coloured sand. Recording is by photogrammetry and colour photography as well as conventional description and drawing. Other methods of recording have included moulding, using silicone rubber for the negative

and fibreglass for the positive. The "ploughman's" burial was actually lifted in its entirety by the British Museum, using an epoxy-resin consolidant and a polyurethane packing inside a wooden former. The entire assemblage weighed more than 6 tons and is the largest yet attempted in Britain. The recovery was not entirely successful and the sand-relief has suffered some damage. It should still allow intricate examination of detail, such as wooden dowling which may prove to have been captured in the sand, in spite of the fact that the wooden decay products are only about 1 mm thick. This type of examination will be of the greatest importance for the structural detail of timber ships, such as the tholes used to support the oars, an example of which was observed in 1939.

The features determining the survival of this fugitive but vital evidence are the subject of a special enquiry set up by the Sutton Hoo project and funded by the Leverhulme Trust. It will be concerned with the chemistry of decay on sand and on other kinds of terrain. The object is to identify the decay products and discover methods of enhancing them to make them more visible even when only present in small amounts. At Sutton Hoo for example, we have found that U/V light can cause bone residues to fluoresce, and thus distinguish them from the optically inactive remains of a coffin. A broader objective is to discover those factors that are accelerating or inhibiting the decay trajectory. At Sutton Hoo we believe that among these factors will be the drainage, the presence of minute amounts of clay which allow even soluble decay products to be captured and held, the pH, and the surface vegetation which alters the micro-environment as well as causing disturbance through root action. Thus our site at Sutton Hoo splits into 6 zones within each of which the current survival is slightly different (fig. 8,9). Under the turf of Zone A the pH is 3.5 and although this is theoretically the protected part of the site, disturbance has been considerable owing to the uncontrolled growth of bracken. In Zones B, C, E the disturbance from tree roots is actually less deep. Zones D and F are under the plough, and ploughing has here removed most of the evidence for earthworks, and all ancient features shallower than 25-35 cm, the depth depending on the crop (barley or sugar beet). On the other hand, it is the fact that it was ploughed which allowed us to find the edge of the archaeological site by field walking. But a further factor which will come under investigation by the Leverhulme project, is the effect on archaeological survival of chemical farming, which is practised on these infertile soils in a somewhat severe form. The pH in the field is now 6, in contrast to 3.5 recorded under the turf. Treasure hunters have been actually the first to point out that the application of chemicals to the fields is destroying bronze objects, such as Roman coins, which they are accustomed to unearth in a legible condition.

It will be seen that Sutton Hoo is not simply a group of mounds, some of which may still contain ship burials; it is, like so many other sites, an archaeological archive whose content is of considerable variety, vulnerability and visibility. It is a "soft monument", affected not only by treasure hunters, but by more well-meaning visitors. One mound at Sutton Hoo was robbed as late as 1982, but our surface feature survey (which relies on differences in vegetation species) showed that over 200 other holes have been dug into the Scheduled area over the past 40 years (fig. 10). Other parts of the evaluation showed that the site had been used as a tank training area, an infantry training area and a rifle, 2" mortar and grenade range. Our metal-detector survey showed the wide distribution of bullets from rifle practice (fig. 11). This disturbance, which took place during the war, has at least had the effect of screening the ancient features from modern metal-detector enthusiasts. Last, the popularity of the site encourages large numbers of academic visitors and the general public, who are not without effect on its surface.

The site is now well guarded, and simple measures are in operation for the control of visitors (fig. 12). The project design attempts to integrate the demands of

the management, protection, presentation and further exploration of the site into a single plan. What is less often considered at present is the state of survival of the more subtle, less visible, archaeological features underground, the factors which have caused, or are causing their decay, and the means which could or should be taken to protect and retrieve them. These are matters which affect the whole of archaeological strategy, and the decision of what conservation, what remote mapping, what excavation could or should be done (fig. 13). If we could accurately predict the yield of a rural site on a particular terrain, non-destructively if possible, in terms of its structures, sequence, finds and biological evidence, we would have a way of evaluating whole ancient landscapes in terms of the history and anthropology it can produce. This is the task which I and my colleagues in the project have set ourselves.

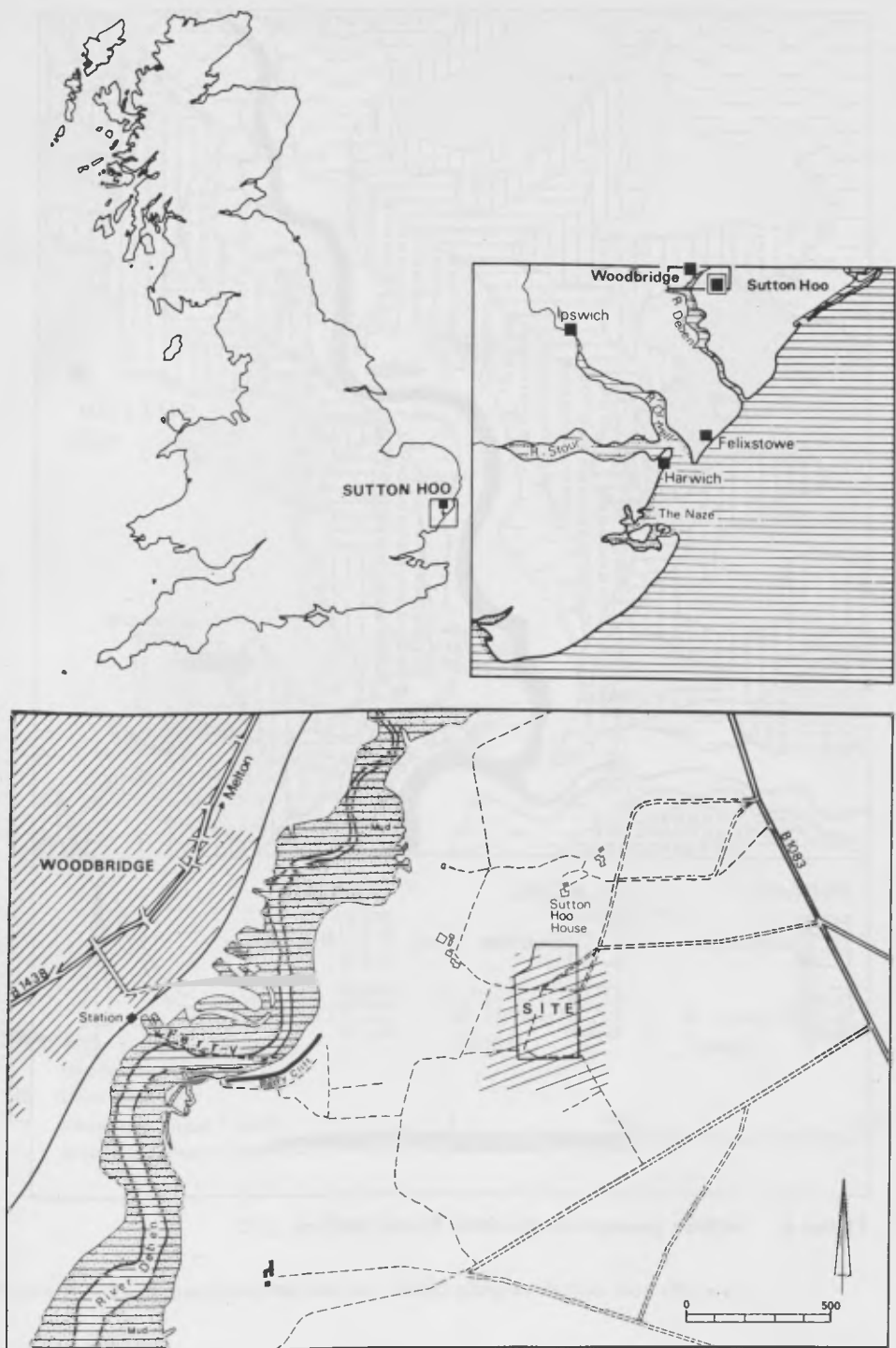


Figure 1. Location of the Sutton Hoo site (Birkeland).

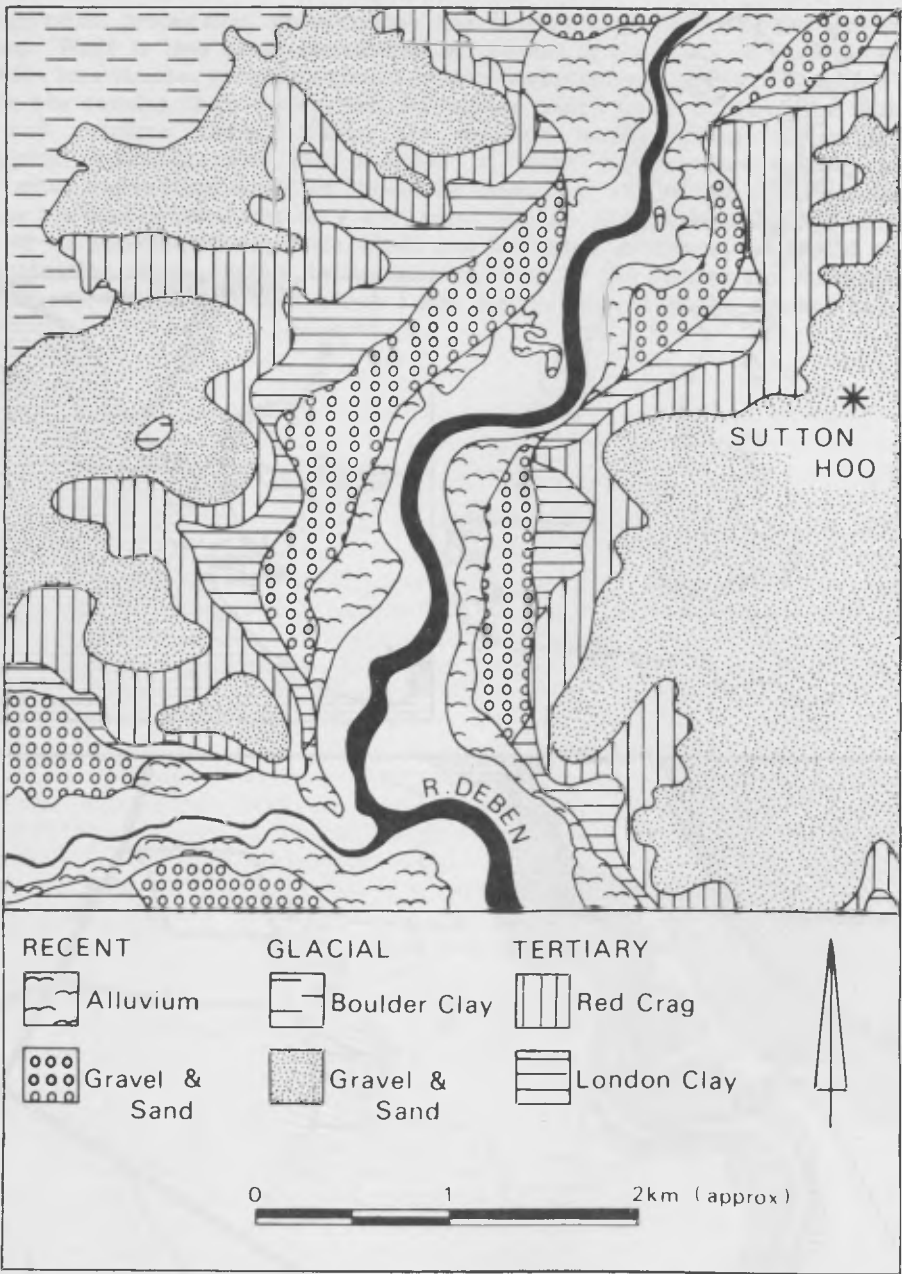


Figure 2. Surface geology (Royle after Bruce-Mitford, 1975).

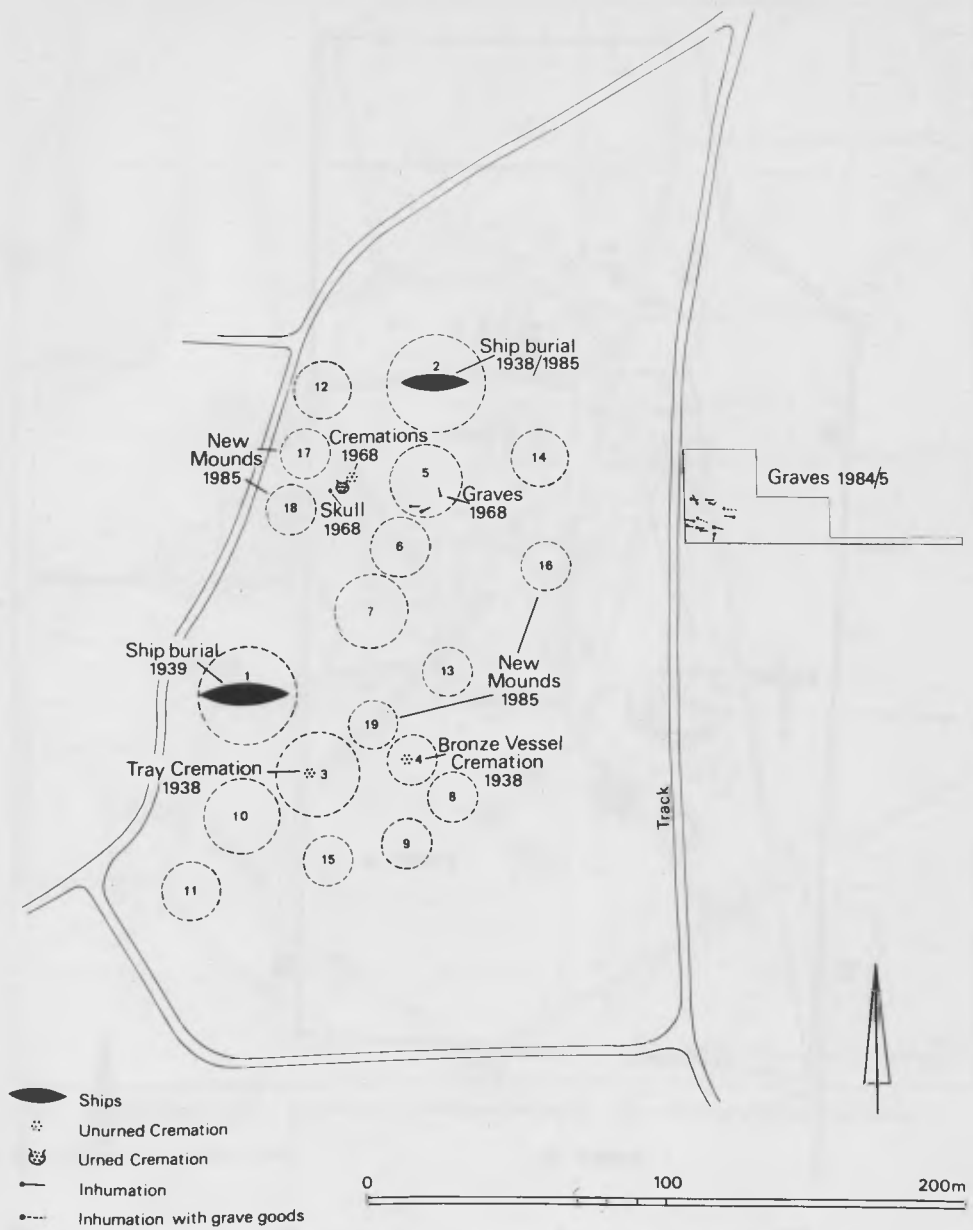


Figure 3. Early medieval burials and burial rites at Sutton Hoo (Hooper).

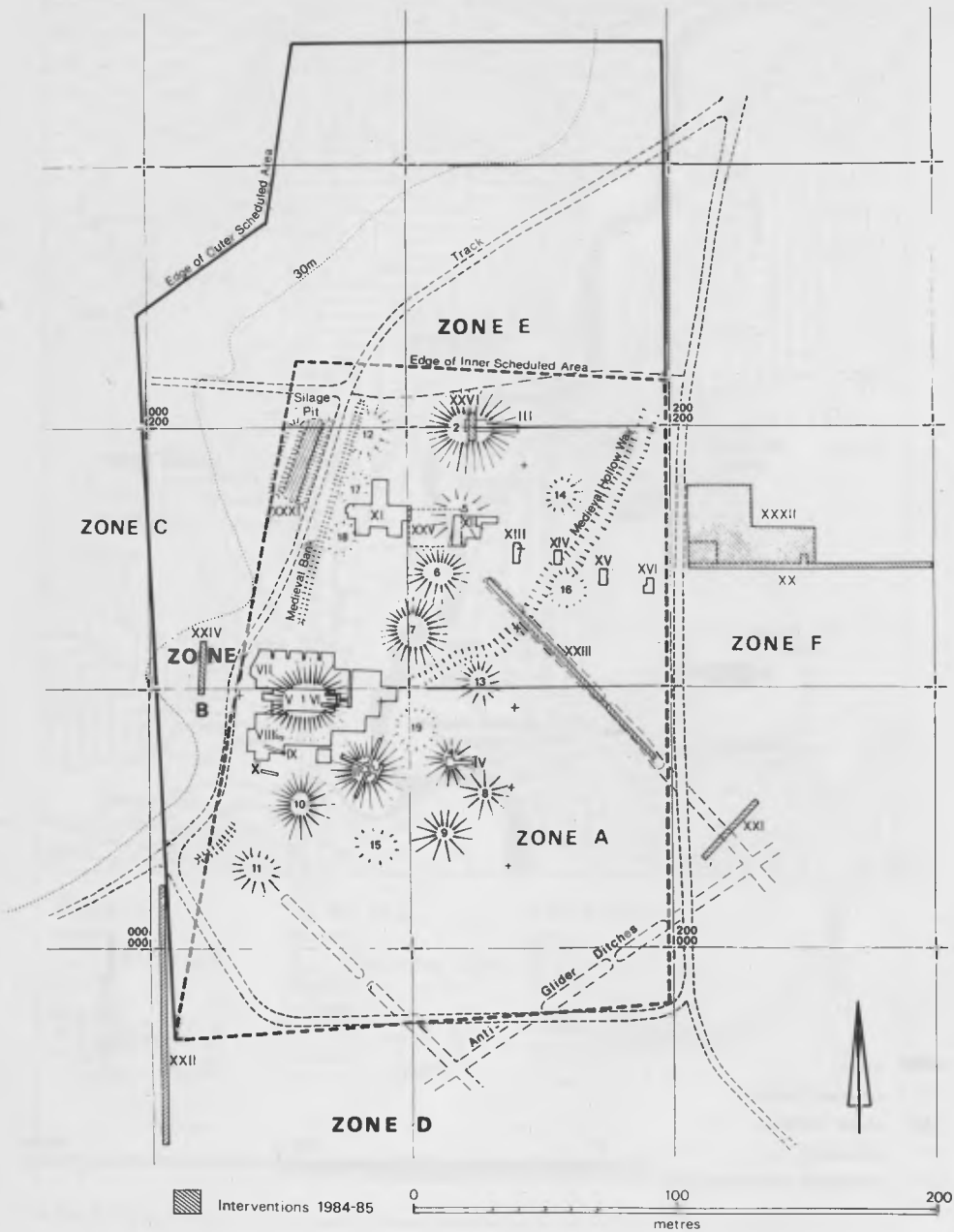
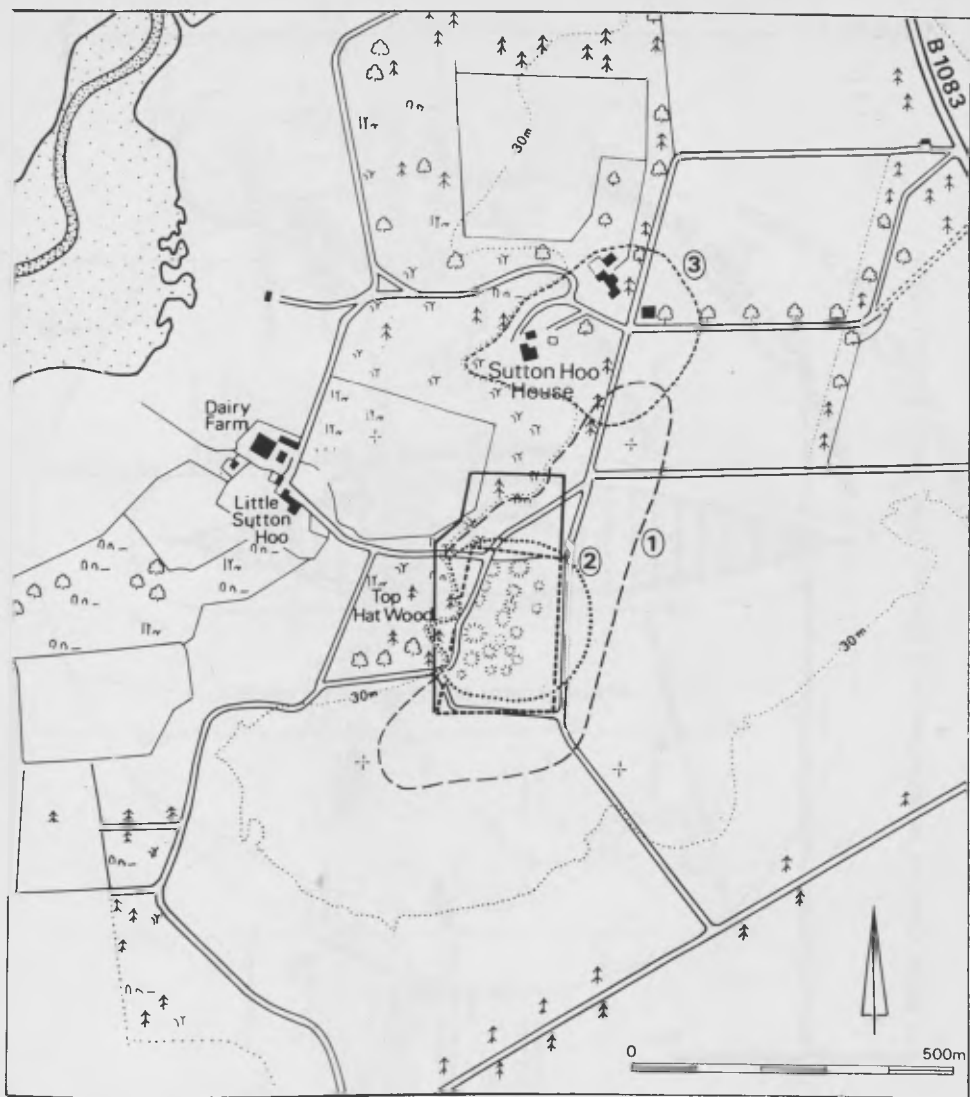


Figure 4. Archaeological interventions at Sutton Hoo 1938-85 (Birkeland/Hooper).



- ① — The prehistoric site ② The Early Medieval cemetery ③ ---- The Early Medieval settlement
 ② & ③ The Early Medieval site

Figure 5. Extent of the prehistoric and early medieval settlements at Sutton Hoo (Hooper).

MOUND 1

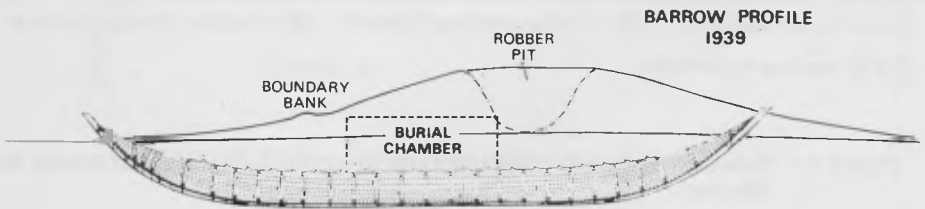
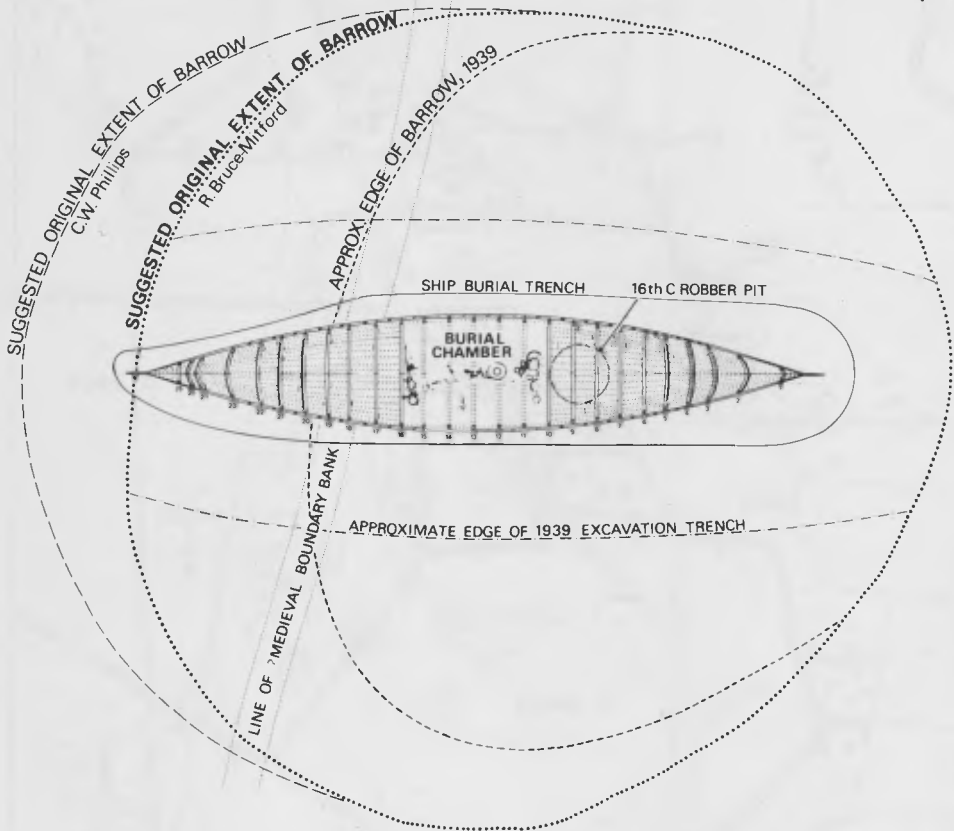


Figure 6. The ship burial in mound 1 (Hooper, after Bruce-Mitford).

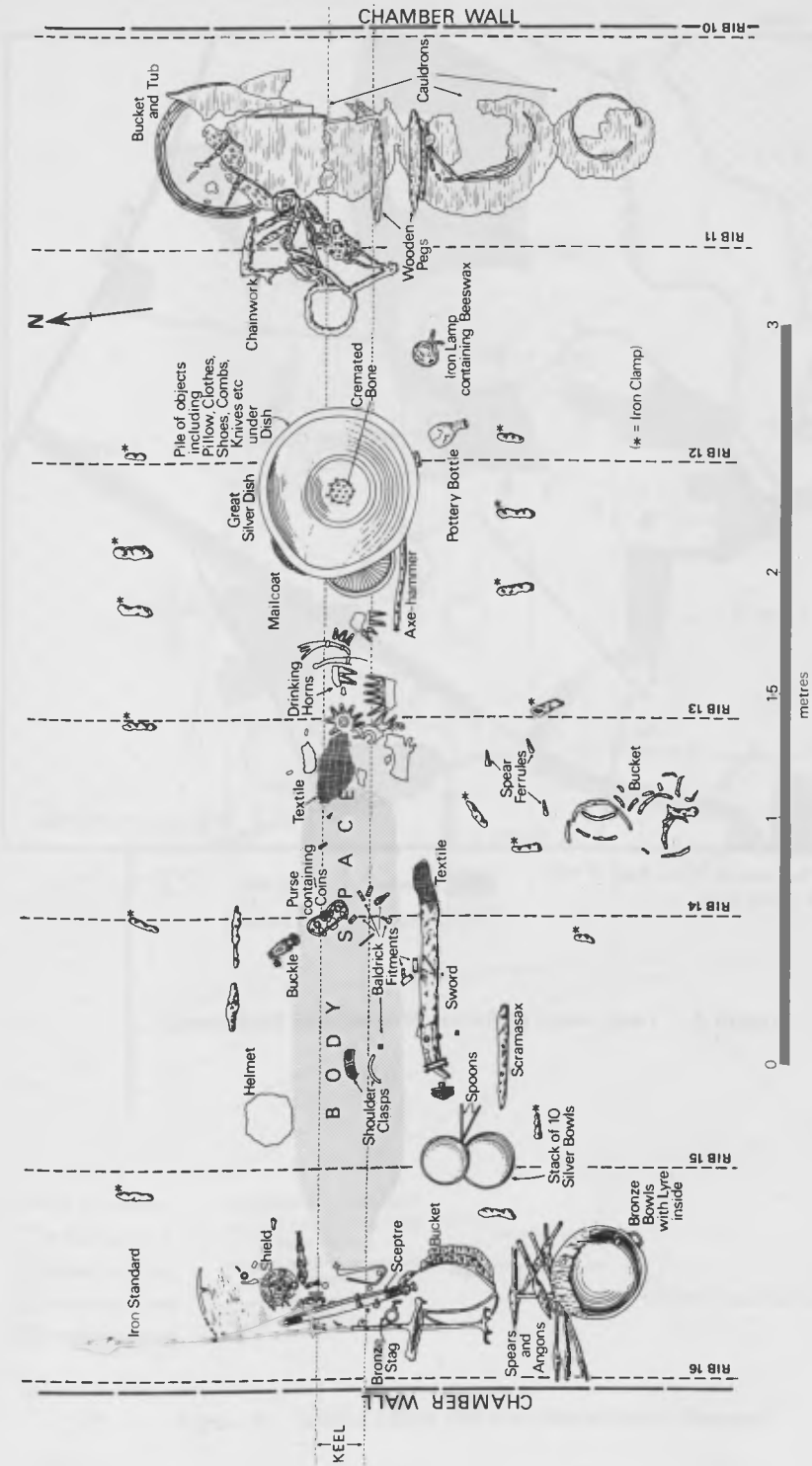


Figure 7. Plan of the burial chamber in burial mound 1 (Hooper after Bruce-Mitford 1975).

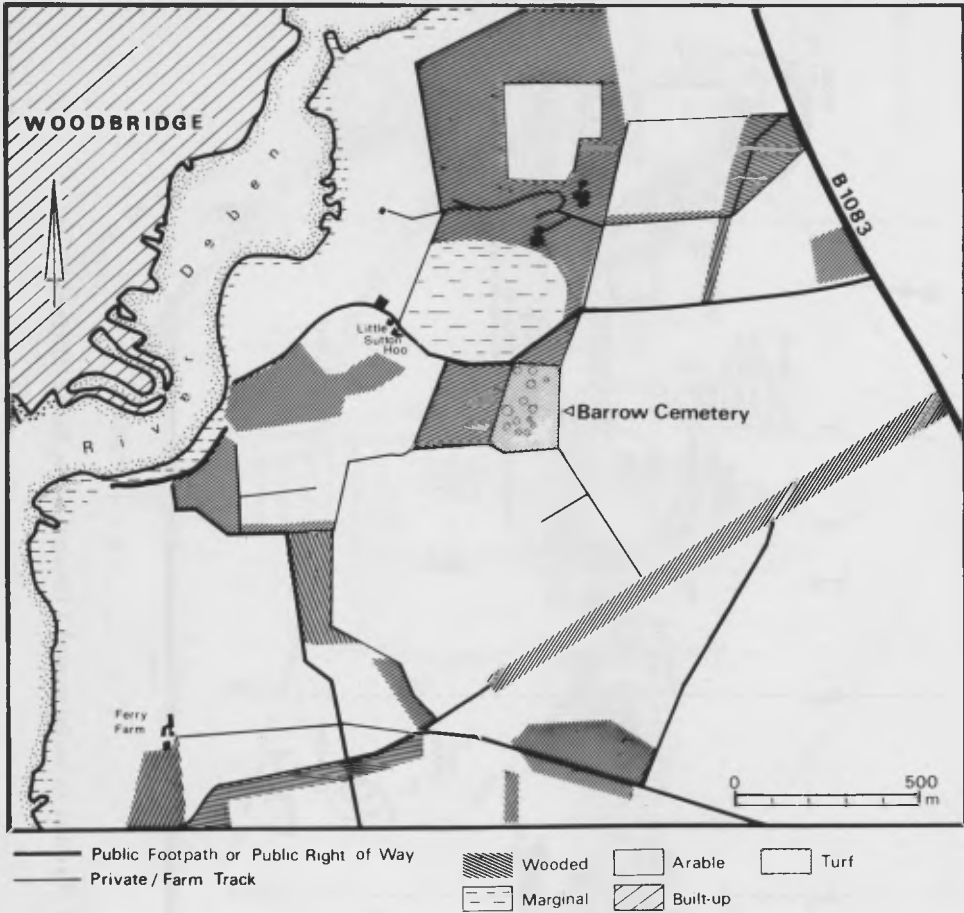


Figure 8. Land usage at Sutton Hoo in 1985 (Birkeland).

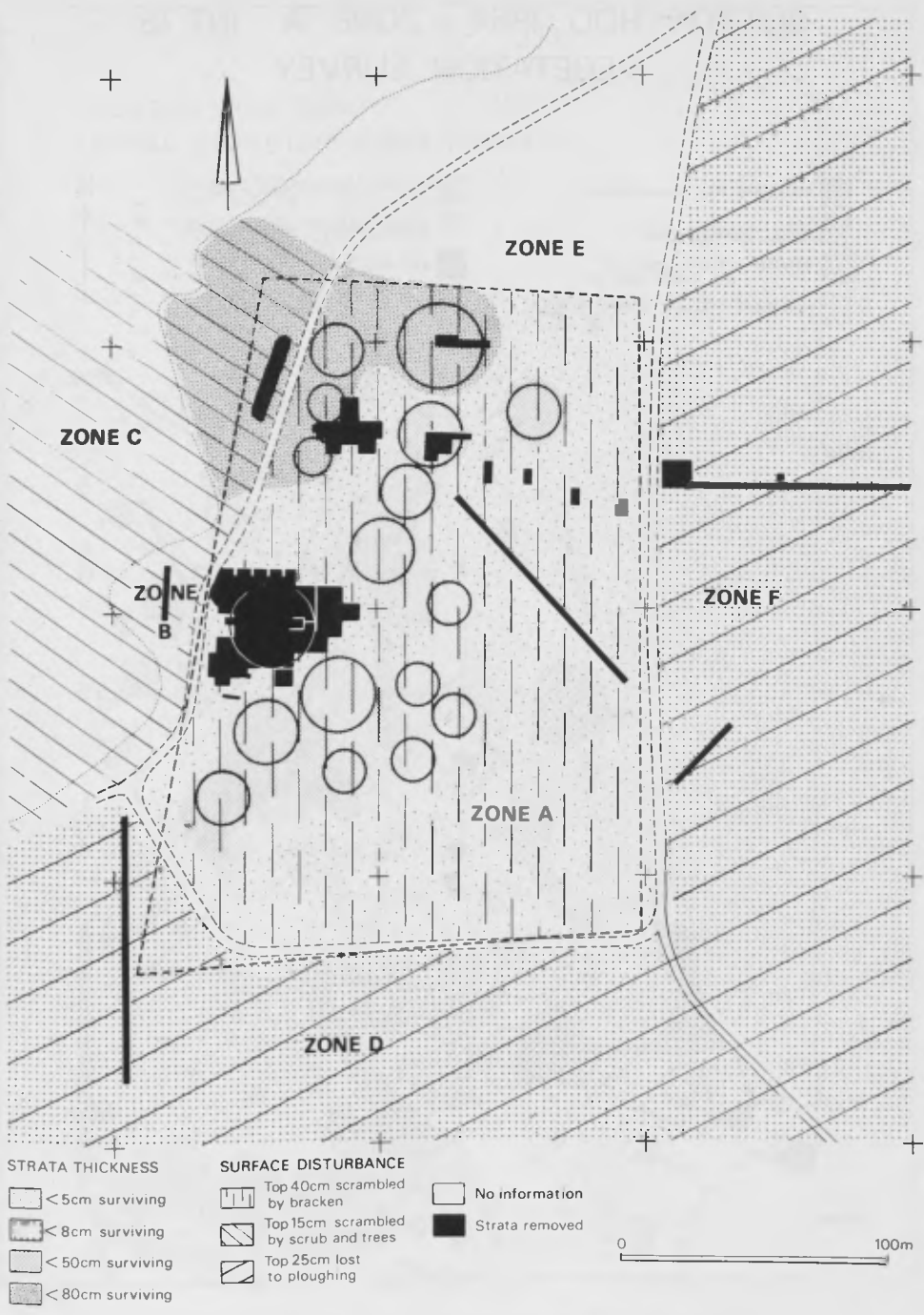


Figure 9. Strata depth and root disturbance (Hooper).

SUTTON HOO 1984 ZONE A INT.18 VEGETATION SURVEY



Figure 10. Surface feature survey of zone A (Copp).

SUTTON HOO 1984

INT. 27

METAL DETECTOR SURVEY ZONE A

- INDIVIDUAL DETECTOR READING
- LARGE MASS OF DETECTOR READINGS
- MD MANURE DUMPS METAL DEBRIS
- A PRESUMED AMMUNITION SCATTER
- FC FENCE LINE CHICKEN WIRE
- FB FENCE LINE BARBED WIRE
- E BARBED WIRE FENCE POSTS
- G GUN EMPLACEMENT
- BM BM HUT DEBRIS
- S SCRAP HEAP

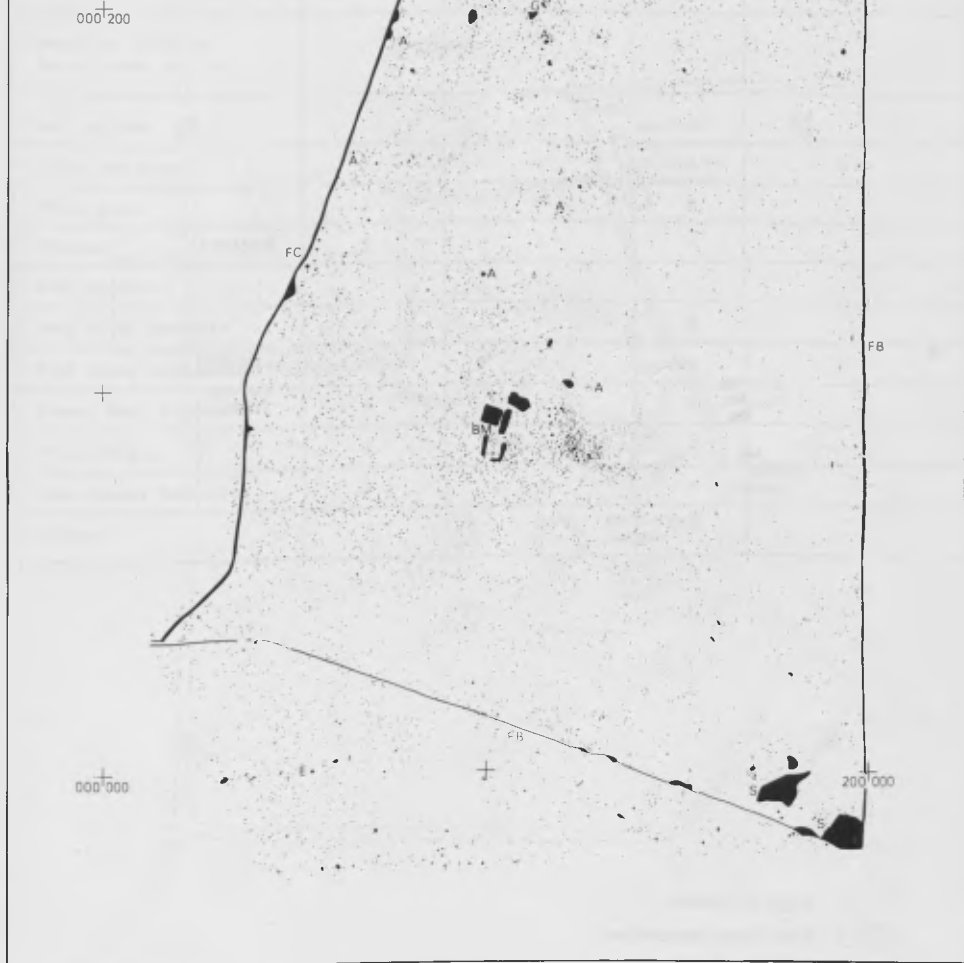
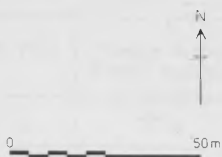


Figure 11. Metal detector survey in zone A (Royle).

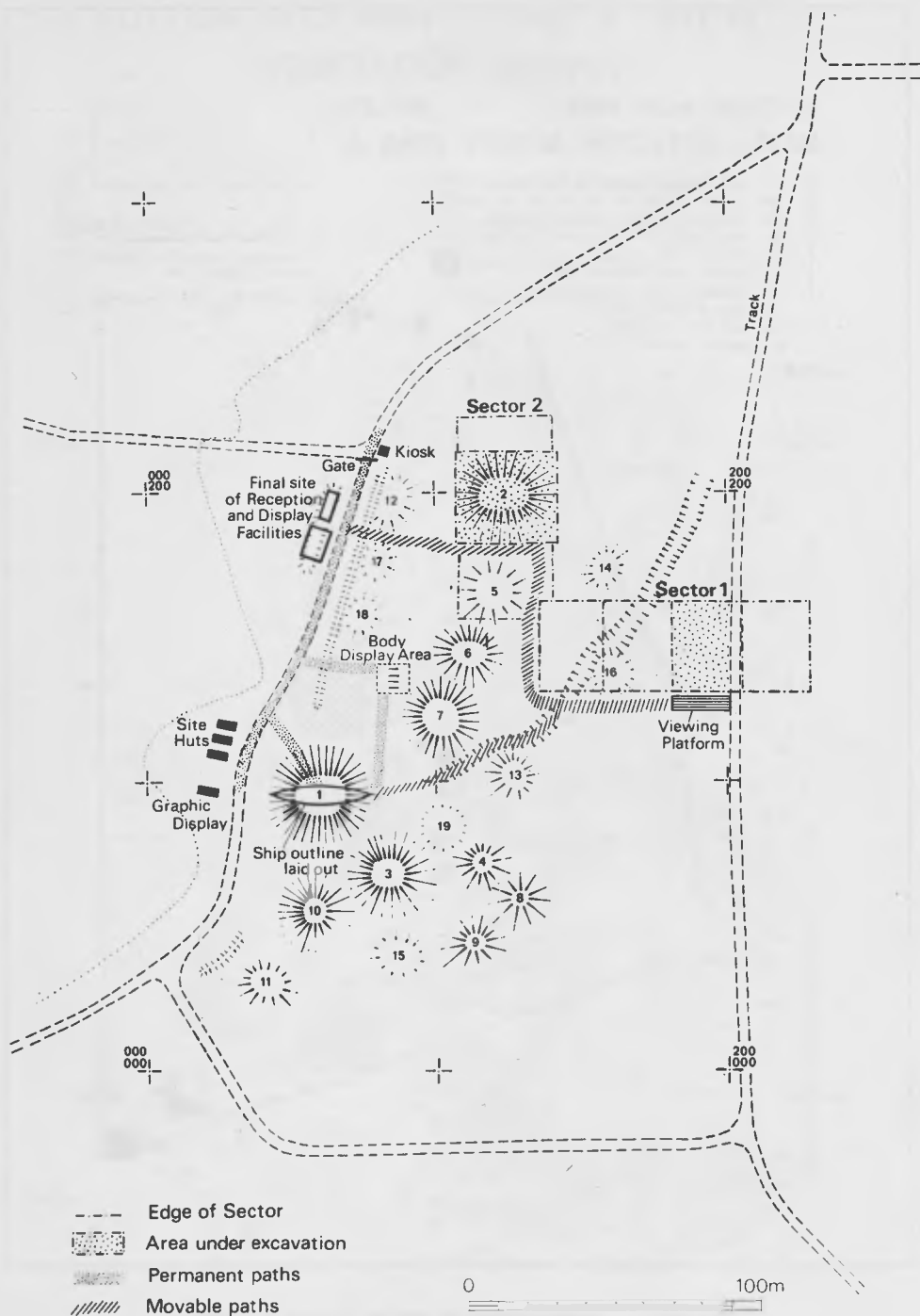


Figure 12. Proposed presentation at the Sutton Hoo site during excavation (Carver/Hooper).

Figure 13. Predicted survival of archaeological information.

| | Fields Zone D, F | Beneath Barrows | On Flat | Remote Sensing (incl. fieldwalking) |
|---|---------------------|-----------------|---------|--|
| Earthworks | X | X | X | X |
| Negative features deeper than 1 m | X | X | X | X |
| Negative features deeper than 0.5 m | X | X | X | |
| Negative features deeper than 0.20 m | | X | | |
| Soil pollen | | X | X | |
| Flint and stone | X | X | X | X |
| Burnt grain | X | X | X | |
| Charcoal | X | X | X | |
| Wood (grain) | | X | | |
| Wood decay products | X | X | X | |
| Bone decay products | X | X | X | |
| Human Body products | X | X | X | |
| Noble metals | X | X | X | |
| Iron (decay products) | X | X | X | |
| Pottery | X | X | X | |

Philip Barker*

SUMMARY

This paper describes simple and comparatively cheap methods of providing shelter on excavations, so that work can continue in bad weather. It suggests that it is cost-effective to provide such shelter so that excavation is not subject to the vagaries of an unpredictable climate. It also describes ways of backfilling excavations between seasons in order to protect them so that the excavation can proceed with the minimal losses of evidence.

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CREATING A MICRO-ENVIRONMENT FOR EXCAVATION

Excavation is one of the principal ways in which primary archaeological evidence is recovered, and techniques which ensure that this evidence is as reliable as possible are constantly being developed and refined. One of them is the attempt to control the vagaries of the weather, which can not only stop work entirely for days on end, but can also distort the results of excavation because of drastic changes in the conditions in which observations are made.

Torrential rain can render a site unworkable or destroy delicate features in sand - equally, baking heat can quickly reduce a clay site to a cracked desert, equally impossible to trowel. Such reliance on chance is hardly cost-effective, leading not only to loss of time and money, but also of temper. Between these extremes, on the other hand, anyone who has ever dug will be familiar with the way in which a shower of rain on a dry site reveals hitherto unsuspected features, which disappear an hour later, perhaps never to be seen again. More subtly, a site can "mature" over the course of a number of days of rain and sun, or even, if left exposed, over the winter, after frost and snow, revealing, because of the slightly eroding effects of the weather, textures and colours not seen before.

The problem, then, is to minimize the destructive and obstructive effects of the weather, while retaining the advantages of variation in humidity, dryness, and light in revealing otherwise undetectable nuances in the soil.

There are other considerations, however. The somewhat "macho" attitude (though the term was not then current) of the 1960's when it seemed to be virtuous to dig on, regardless of the weather, has already resulted in cases of chronic rheumatism and arthritis, perhaps the typical industrial disease of the excavator. Apart from consideration for the health and welfare of those working on site, which should be paramount, it is questionable whether to dig on regardless is, in the end, the most effective way of using the increasingly scarce resources of time and money now available to archaeology. It is arguable that a proportion of the excavation funds might profitably be used to provide an environment in which people can work not only more comfortably but more effectively.

Control over humidity of the soil and over the direction and intensity of the light is, of course, most easily achieved inside a building, for example, in excavations within churches, cathedrals, cellars or warehouses or the like. Out of doors, control of the environment requires shelters suited to the scale and type of excavation. The requirements of all shelters are that they should be waterproof, strong enough to withstand winds up to gale force, and yet, on large sites, be portable. This is asking a lot, yet experience has shown that it can be achieved comparatively cheaply. At one end of the scale is the type of large plastic cover used for temporary exhibitions. These are kept inflated by means of a small difference in the interior air pressure. Since this is maintained by a pump (either electric or petrol-driven), it has the advantage that cold or warm air can be circulated; necessary because shelters of all kinds become very hot in sunshine, but also ensuring pleasant working conditions in the winter. Such shelters can be very large, covering up to 1,000 m². Much cheaper, but correspondingly less effective, are the large horticultural tunnels which can be joined in bays up to 10 m wide and 5 m long. Each tunnel can be joined to the next, forming a continuous shelter of any required length (Plates 1,2). Heavy-duty translucent polythene sheeting is attached to the supports by means of spring clips. With such shelters it has been found necessary to draw the polythene sheet very tightly and to support it by means of strings strung diagonally between the corners of the framework in order to prevent rain collecting in large puddles in the roof. In practice it has also been found necessary to anchor the shelter against strong winds



Figure 1. Simple shelter in use at excavation of Baths Basilica, Wroxeter, England. Length of shelter can be extended as required by adding bays.



Figure 2. Work in progress under shelter with front edge of polyethylene sheet rolled up during fine weather.

by placing sandbags along each side, resting on the horizontal framework. This is preferable to damaging the archaeology by anchoring the shelter with pegs or stakes. If the polythene sheet is spread out on each side of the tunnel it acts as a "skirt", deflecting the rain which runs down the side and which would otherwise erode channels in the excavation. The metal framework has sufficient flexibility to adapt itself to undulations in the site, unless these are very great.

Other shelters may be erected using scaffolding, or forms of angle iron, together with rigid translucent corrugated plastic sheeting. Whatever the construction of the shelter, it provides the opportunity for keeping the soil damp with sprays, or allowing it to dry to precisely the optimum texture and maximum colour contrast, at the same time keeping down the dust which, especially on dry sites, can be very irritating to the skin, eyes and nose.

The problem with spraying is that it is very easy to wet the top centimetre or two while the underlying soil stays dry. Though this enhances the surface colours and textures, it can cause confusion, as this upper moist layer is easily trowelled away, exposing the drier soil beneath, which can appear, erroneously, to be a new layer, though it is simply the same layer in its dry condition. The best sprays, therefore, are those which provide a steady "Scotch mist" (as it is called in England), a rain of fine droplets which eventually penetrates deep into the stratification without, at any time, flooding it.

Even masonry changes colour quite dramatically when damp, revealing, perhaps, differences in the origins of the stone or mortar, and this dampening is best carried out under controlled conditions rather than left to the rain.

The other considerable advantage of working under cover is the control that one has over lighting conditions, not only for the actual excavation, but for photography, when the lighting can be arranged to emphasize precisely those aspects of features or surfaces which are most significant - glancing light to demonstrate worn surfaces, or bring out graffiti, or subsidiary lights to illuminate shadows, for example. Without very powerful lighting this is difficult to achieve out-of-doors, and waiting for the sun to arrive at the optimum point in the sky is very time-consuming.

With the increasing uses of chemical sprays and other methods of soil colour enhancement, together with the use of infra-red and ultra-violet light for photography, an environment that is not subject to the vagaries of the weather is clearly an advantage.

Against all this, it must be said that most excavators would much prefer to work out in the open rather than under tunnels and shelters which are noisy in wind and rain and can become, for some, claustrophobic. The smaller sorts of shelter can, of course, be moved off the site in good weather, or partly opened to enable the site to be seen as a whole, and so avoid the danger of digging the part under the shelter out of context with the rest. The use of shelters is, therefore, a matter of balancing their advantages and disadvantages in the particular circumstances of each excavation.

If shelters are not available, a useful method of maintaining a good working surface when water is in short supply is to cover the whole site, except those parts being worked on immediately, with black polythene sheet. This not only retains what moisture there is on the surface, or conserves what has been sprayed on, but, if the temperature falls appreciably at night, dew forms under the sheeting and helps to keep the surface of the excavation moist.

SITE PROTECTION

If an excavation has to be left open for long periods it is important to protect it from damage by weathering. The surface should, of course, first be recorded as thoroughly as possible. Any vertical face that is left open will be liable to erosion or collapse, taking with it unrecorded evidence. One useful by product of area excavation is that, with few baulks, there is less risk of this kind of loss. Nevertheless every excavation has edges, and excavated pits, post-holes, gullies and the like will need protection. One way that has proved successful is to fill, or better, over-fill, the pits, post-holes etc. with clean sand, and in the case of especially important or vulnerable features, cover them with polythene sheet, preferably black to exclude the light and inhibit plant growth. The features can then be emptied accurately and swiftly on the resumption of the excavation of that part of the site. If they cut through a number of surrounding layers, these layers can be removed progressively, while lowering the backfilling of the features in parallel. If sand is not readily available, sifted earth (derived from the sifted spoil of the site) may be used. If there is any reason to suspect that it might be difficult subsequently to distinguish the backfill, the features can be lined with polythene sheet before they are filled. This is in some ways less satisfactory as the free movement of water is impeded and, in the more extensive features, worms are liable to die under the sheet in considerable numbers, leaving an unpleasant layer to be cleaned off. This can be remedied, to some extent, by piercing the polythene sheet to permit drainage.

The edges of shallow excavations can be protected by packing sand or sifted earth along them and horizontal features, such as floors or hearths, can be protected in the same way. Additional protection from frost may also be required, and here straw bales packed on top of the polythene sheet will give adequate insulation. If a ready source is available, expanded polystyrene chips give excellent insulation, are easily removed, and can be re-used. It will be necessary, of course, to sheet the insulating material to stop its being saturated or blown away. It has also been found possible to protect very large areas by covering them with polythene sheets and then 7-10 cm of sand or sifted earth. This has proved to give adequate protection (in English winters) against rain and frost. It is advisable to pierce the polythene sheet in as many places as necessary in order to drain puddles and to prevent, as far as possible, the soil's becoming sour. Sites that have to be left for more than a month or two without cover (though with postholes and pits protected) will need to be sprayed with weed killer to prevent weed growth, particularly of deep-rooted weeds, as their removal is not only tedious but, more important, will damage the stratification. If it is felt that the use of weed killers might alter the chemical balance of the soil in any subsequent soil analysis, the benefits of preserving the site from damage by plant roots must be weighed against the evidence obtainable from the soil analysis. It is often possible to take the soil samples first, and spray afterwards, thus losing nothing.

Most of the methods described here are cheap and simple, yet enable sites or parts of sites to be preserved for long periods without deterioration.

PRACTICAL PROBLEMS IN THE EXCAVATION
OF ROMAN AND MEDIEVAL LONDON

John Schofield*

SUMMARY

Since 1974 the Department of Urban Archaeology of the Museum of London has carried out many large and small excavations in the Roman medieval City of London in advance of redevelopment. The successful campaign to persuade the developing companies to pay for the recording of archaeological strata on their sites has meant that many large sites have been excavated with, in most cases, a decent (though never adequate) level of funds for staff and equipment. We have therefore been able to experiment with certain aspects of protection of strata and structures both before and after excavation. This paper will cover the topics of using sheet piling to define the excavation area both inside and outside buildings, roofing of excavations, conservation of timber structures and the preservation of masonry structures in new buildings.

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Since 1974 the Department of Urban Archaeology of the Museum of London has carried out many large and small excavations in the Roman medieval City of London in advance of redevelopment. This paper will give some examples of our techniques and methods, dealing mainly with methods of excavation, but also conservation of masonry in new buildings. I will end with a short description of our related work on keeping our observations and analysis as accurate as possible - with the computer.

First I must sketch in the background to our archaeological work as possibly the largest archaeological unit at work in Europe. The city of London is now a very odd place. By day, half a million people work there, but at night its permanent population is about 7,500. The economic changes since the War have had several effects on the types of new building erected. Office development by national corporations or insurance companies produces large buildings, often for the headquarters of the company; and the city has attracted many banks. Since 1971 over 90 foreign banks have established themselves in the city; and they all have deep vaults with strong, thick foundations.

We have in the last 11 years shown that much survives beneath the ubiquitous 19th century basements in those areas now being redeveloped. We have also demonstrated that much worthwhile archaeology survives even beneath certain post-War buildings, as on the waterfront at Swan Lane, Thames Street, where the riverfront deposits are extremely deep. Four metres of Roman and medieval deposits were recorded here, beneath a building erected in 1964. It is perhaps an indication of the ferocity of redevelopment in the city that this multi-storey carpark lasted only 14 years before being rebuilt once more.

TYPES OF EXCAVATION

There are two general types of excavation employed in London. First, area excavations were used in historic towns in the 1960s and sometimes today, though their number and frequency are being cut down by the increasingly high cost of both redevelopment and archaeology. These large sites, if carefully placed in the Roman and later town, serve as "type sites" or detailed cross-sections of all the city's archaeology. The second type is the smaller excavation, trial trench or "watching brief" carried out during building works, often after a major excavation on the same site. Such observations, often under salvage conditions, pursue the features which have been found in the trench to the edge of the development site. Smaller observations can also be useful for the general charting of deposits.

PILING

Because the archaeology of London can be as much as 6.6 m deep from the bottom of cellars (or 10 m from street level), we often require shoring for the sides of trenches. Ten years ago, and occasionally today, we work with timber shoring. This is quite viable as long as the excavators accept two constraints. First, because the shoring is usually inserted in frames about 1 m deep, the sections of the strata at the sides of the trench have to be drawn in 1 m strips before being obscured by the frames. The excavator has only to keep a check on the precise levels to continue the drawing, and make sure all the strata have been drawn before the frame is inserted; otherwise there will be a hole in the section - a very human mistake. Secondly, and more importantly, timber shoring in our experience became horrendously expensive when trenches wider than about 3 m were considered - in effect, this limited the width of the intended trenches to 3 m.

In 1980 I saw how the excavations of Schietzel at Haithabu near Schleswig were using sheet piling to excavate in the water of a lake. We then experimented with sheet piling inside a building, a former school, in a small London site in 1981 (Maloney 1982). The sheets here, cutting into a soft stream deposit, were 9 m long. The height of the school hall ceiling enabled the machine to drive in the sheets of this length. The size of the excavation was 15 m x 3 m, and 7 m deep; in this case the width was dictated by the size of the room in which it was placed.

In one sense my experiments with piling in 1981 were a preparation for the large excavation that we knew would eventually happen at Billingsgate; it took place in 1982. Here the pre-piled area measured 25 m x 22 m (fig.2; Schofield 1982, 1983). The advantages were that we needed very little further support to excavate this area to a depth of about 6 m. This piling cost L.90,000; about 12% of the cost of the whole excavation, and quite justified in my view. There was no other way of exposing a length of the Roman quay.

TEMPORARY ROOFS AND SHELTERS

We have experimented both with mobile shelters of special design and with specially-built roofs over the excavated area; again, the largest of these was specially designed by an engineer for the Billingsgate excavation (fig.3). In this case it was combined with a viewing gallery for the public, which was entered from the outside street but which sat on the edge of the piling for the excavation. A similar feature was employed on the Viking excavation at Coppergate in York. If there is to be large-scale media coverage and interest in the site by the public, the archaeologist must plan both the technical aspects of the excavation and the public access facilities at the same time, and make sure they work together. This is not so easy as it sounds if your site is very large, and the focus of excavation may shift dramatically away from the viewing windows or gallery during the course of the investigation; this has happened to me.

WORKING INSIDE BUILDINGS

We have, on several occasions, worked inside a standing building and dug our trenches in the basement of a building that was about to be demolished. This situation is far from ideal; we cannot remove many partition walls because they support the building above, and the trenches are therefore usually narrow. There are problems with lighting, with removal of spoil and with braces which support the weaker parts of the building. But sometimes we are forced to do this kind of excavation because of the development programme. We work with mobile tungsten-halogen lights and bring in other special lights for the photography.

We have, on one occasion, worked inside the new building on the site. The builders put their piles around the border of the building, avoiding most of the archaeology in the middle, built the ground floor and then placed us inside to excavate while they continued construction. This was not at all ideal, and we had no control over the environment. This is not to be recommended unless the archaeologists can stipulate far more conditions according to their liking.

PRESERVATION OF TIMBER AND MASONRY STRUCTURES

Because all the sites we work on will have future buildings constructed on them, we have to remove the majority of structures we find. The Museum can only conserve parts of timber structures, such as the Roman and medieval quays, or notable fragments of buildings such as mosaic pavements or small kilns. These are all removed to the Museum for safekeeping and possibly, in certain cases, eventual display.

We have excavated Roman and medieval waterfront structures on a large number of sites along the former bank of the river Thames in the last 12 years. These quays have been preserved in anaerobic conditions to a remarkable degree; each one was buried in the land extension of the revetment which replaced it, and only occasionally were the timbers of the quay taken out for re-use when this happened.

When we started excavating the waterfront zone in 1973, we did not have the benefit of detailed advice of an archaeological conservator on site, and thus as ordinary archaeologists we made some mistakes. We quickly found that timbers shrank on exposure to sunlight and air, and this had several consequences. First, the recording of the structures should take place as soon as possible after exposure. Secondly, they should be kept wet. This sounds obvious now with hindsight, but it is very difficult, on a large site, to maintain a system which keeps all the timbers continuously wet; the constant water interferes with excavation and recording. But simply wrapping the timbers in polythene sheeting or plastic foam is not sufficient; they must be sprayed.

Timber structures are sampled thoroughly for dendrochronology; this is often a destructive process, for the best cross-section through a timber is often where it is most interesting or displayable. We have experimented recently with non-destructive means of dendrochronological analysis, such as bores or CT X-ray scanning (used in body-scanning in hospitals) and look forward to the results. But we must admit that until recently the needs of dendrochronology have tended to rule the fate of the ancient timbers.

In the last three years my colleagues in the Museum's Conservation Department have begun saving short lengths (about 3 m) of the various Roman and medieval revetments that have been excavated on waterfront sites. They hope to display them in a special museum being established for the history of London docks. This is a large task and at the moment they are trying to raise funds for the conservation of the many Roman and medieval timbers by a combination of polyethylene glycol immersion and freeze-drying.

The Museum's Conservation Department developed a special strategy for the Roman and medieval revetments excavated at Billingsgate in 1982 (Johnson 1985). During the excavation a constant spraying system was used, the timbers were covered in polyethylene sheets and the revetments supported by modern extendable props. The revetments were recorded by our normal methods, in which each timber has its own number and description; the conservators made a point of asking for large prints of photographs of the revetment to be made immediately, so that they could also number the timbers on the photograph and use the photo as a guide during the lifting, storage and treatment of the component parts. Such large photos have proved to be invaluable for other types of analysis of the same structures, especially the dendrochronological sampling. In addition the conservators ask me to emphasize the importance of attaching durable labels to the timbers: we use unwoven polyethylene labels heat-sealed in plastic bags, nailed very securely to each timber.

The cost of developments, and the cost of rents in the City of London, has meant that conservation in situ has rarely been even contemplated. It has never been contemplated for timber structures. The historic fragments of stone buildings now conserved in the open air in the city, apart from the few complete medieval buildings, have until recently only consisted of pieces of the city wall which lie in gardens. Occasionally, however, in recent years, a notable piece of masonry has been preserved in the future building. This was first negotiated for lengths of the Roman and medieval city wall, which naturally formed the boundary of present-day properties, and thus was easily incorporated into the new building; for example, part of the Roman city wall was incorporated into a new building in the east of the city in 1979. The 3rd century wall formed one side of the future basement, and in front of it were displayed the remains of an unknown interval tower which we found during our excavations on the site. Although the architects in this case were extremely co-operative, I must report that such occasions when we ask for preservation are very rare.

There has, however, recently been an encouraging trend for the planning authorities of the city to insist on retention of historic masonry structures even in the middle of buildings. In 1985 a monastic chapel being was moved intact 20 m sideways, in preparation for being moved back into its position in the future building (fig.4).

THE ARCHIVE AND COMPUTERS

Although this conference is concerned with problems of access to the strata and maintenance of micro-climates on excavations, I would like to end by making the point that just as important, if not more so, are the twin notions that (a) all the archaeological information should be gathered accurately and consistently, and (b) all the information should be preserved in an archive for use by other scholars; not only the finds but also the records should be the subject of conservation and carefully-monitored storage. This is often, at least in my own country, sadly forgotten.

From nearly 200 excavations in the Roman and medieval City of London, we have recovered several million artefacts, and made thousands of drawings and photographs. We see it as the main duty of the Museum of London to preserve these records and objects in an archive, to look after these records and to carry out research on them. In the first ten years of our life as an archaeological unit, we dug up a mountain of artefacts and information. Now, although we are adding to this mountain every day at the same speed, we have decided that we must organize the mountain; and for that we have begun to use computers. They are used for three main purposes: first, for recording, indexes and analysis of the finds; second, for word-processing of reports; and third - though we are still at the experimental stage here - for data recovery on site. We are creating an archive which is run by a computer, because there is simply no other way with so much information. And we look forward to the time when our archive can speak to the archives of other countries - to the time when my computer can exchange information with yours via telephone lines or satellites. We already have bulletin boards on computers, by which I can send data to Australia and Australia can send data to me. We must expand our computerization of every aspect of archaeology, beginning with the quality of information in our archives. And soon we shall find computers on every excavation site, controlling for us the micro-climates.

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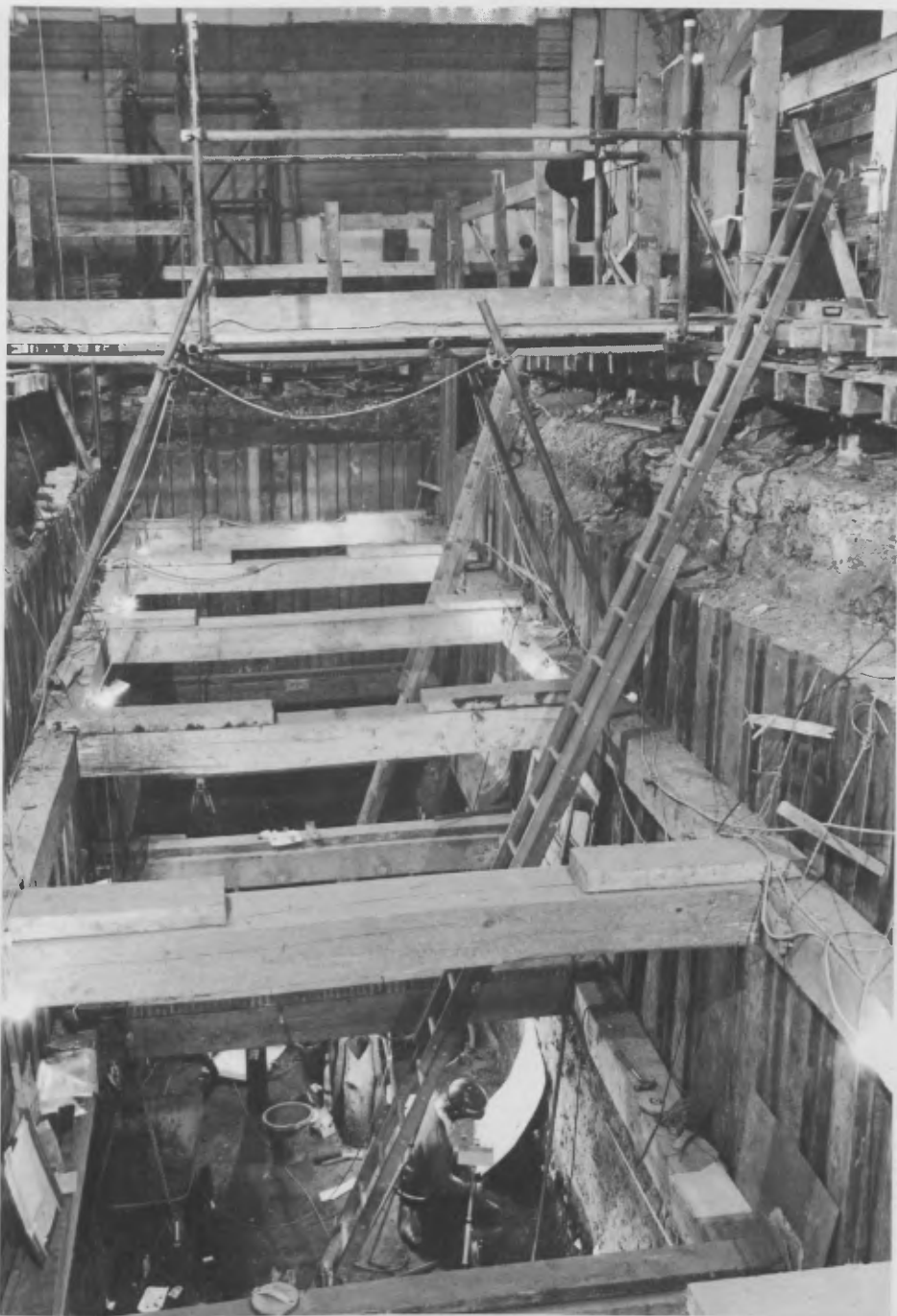


Figure 1. Excavations inside a building at Copthall Avenue, City of London, 1981. In this case a rectangular box of interlocking metal sheets was inserted into the soft ground beneath a school hall before excavation (Museum of London).



Figure 2. The excavation site at Billingsgate, City of London, in 1982, after the clearance of modern basements and insertion of sheet piling to define an area 20x25 m. The excavation thereafter lasted one year and excavated this area down to a depth of 6 m (Museum of London).



Figure 3. Billingsgate, City of London, 1982: as winter approaches, a temporary roof is built over the excavated area. It has open sides and ends to allow cranes to remove the spoil from the excavation (Museum of London).



Figure 4. Mitre Street, City of London, 1984: a chapel from the church of Holy Trinity Priory, Aldgate, is lifted by special crane so that building works can commence on site; it was later lifted back into the same position, but slightly lower down. The chapel was underpinned with concrete and lifted in one piece (Museum of London).

PREVENTIVE MEASURES DURING EXCAVATION: TECHNIQUES

MESURES PREVENTIVES EN COURS DE FOUILLES: TECHNIQUES

André Bergeron

RESUME

Cet exposé présente un aperçu de quelques exemples d'interventions sur les sites archéologiques du Québec et tente de dresser un portrait de la situation actuelle. Le travail de conservation sur les sites de la période historique et préhistorique est principalement caractérisé par le prélèvement de coupes stratigraphiques et de contexte, ainsi que par des moulages *in situ*. Un problème particulier est occasionné par la protection de structures lithiques qui peuvent se déstructurer autant par causes naturelles que par négligence humaine. Dans tous les cas, les ressources limitées en personnel et en matériel nous obligent à effectuer une sélection basée sur la rareté des données à préserver et/ou sur l'unicité du contexte.

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Il est difficile de parler de conservation archéologique au Québec sans parler brièvement du contexte de la recherche archéologique. Disons tout d'abord que la conservation effectuée en contexte archéologique suppose l'interaction de deux groupes de professionnels aux responsabilités et aux mandats bien définis; les archéologues d'une part et les restaurateurs ou spécialistes de la conservation d'autre part. Comparativement aux archéologues, les restaurateurs à oeuvrer dans le domaine sont très peu nombreux et les interventions de conservation sur le terrain demeurent sporadiques et ponctuelles, ce qui peut partiellement s'expliquer par la superficie du territoire Québécois, plus de 50 fois celle de la Belgique. Depuis la création du Centre de conservation du Québec en 1979, un effort a cependant été accompli afin d'augmenter les contacts entre les deux disciplines au moyen de présentation de communications à des professionnels comme à des étudiants en archéologie, ainsi que par la participation aux activités de terrain de certaines équipes de fouilles.

On distingue deux périodes principales en archéologie au Québec. L'archéologie de la période préhistorique étudie l'occupation du territoire par les populations Amérindiennes et Inuits depuis la récente déglaciation ayant débuté il y a environ 15,000 ans, tandis que l'archéologie de la période historique débute son champ d'intervention à l'arrivée des Européens vers le milieu du XVI^e et XVII^e siècle.

De façon générale, les sites de la période préhistorique sont caractérisés par de petites structures dont certains éléments étaient construits en pierre et assemblés sans mortier. La déstructuration constitue dans ces cas un problème majeur, particulièrement pour les vestiges qui sont dégagés au fur et à mesure de la fouille. Leur consolidation à l'aide de matériaux de renforcement est difficile à envisager à cause de l'effet négatif sur l'intégrité des structures et de leur esthétique. Les sites de la période historique sont surtout représentés par des vestiges liés à l'aménagement pour des fonctions à caractère domestique, militaire ou industriel.

Ce sont souvent des ouvrages en maçonnerie avec liant dont il ne subsiste généralement que des fondations. Les sites sub-aquatiques eux sont représentés par des vestiges de navires et d'embarcations dont certains datent du XVI^e siècle.

On peut voir que les types de sites et les vestiges à y préserver diffèrent donc sensiblement pour ces deux périodes et nécessitent des stratégies d'intervention appropriées.

C'est par le biais du travail de terrain effectué sur des sites représentatifs de ces deux périodes que j'aimerais vous présenter des exemples d'interventions effectuées par le Centre de conservation du Québec. Le premier travail de terrain a été effectué à l'été de 1984 à Blanc-Sablon, situé à la frontière du Québec et du Labrador, dans le détroit de Belle-Isle. Notre présence avait été requise par l'équipe d'archéologues afin de tenter de résoudre un problème de fouille causé par un horizon induré. Le sol, fortement minéralisé, rendait extrêmement difficile la fouille de ce niveau d'occupation daté à plus de 7 200 A.A. On voulait étudier la possibilité d'effectuer des levées en bloc de certains éléments, ainsi que le prélèvement de coupes stratigraphiques représentatives.

Aucune solution n'a été trouvée quant à la fouille de l'horizon induré. Ce dernier cependant a permis la préservation d'ossements non carbonisés, ce qui est exceptionnel pour un site de cette période. En raison du temps limité et des contraintes de la fouille, trois ossements dont un associé avec un éclat de débitage furent consolidés in situ. Une émulsion de P.V.A. diluée 1:1 avec de l'eau fut versée au compte-gouttes sur les zones à consolider à deux reprises. Une fois sec, le P.V.A. fut recouvert de papier humide puis de plâtre afin de procurer aux ossements une

matrice de protection. Le pourtour fut ensuite découpé à l'aide de divers pics et une plaque métallique permit de libérer le dessous.

Plusieurs coupes stratigraphiques furent également recueillies au cours des dix journées de travail. Au total, environ 6m² furent prélevés au moyen d'applications de couches de latex à base d'ammoniaque, suivi d'un renforcement effectué avec un matériel fibreux et d'autres couches de latex.

Parmi les problèmes rencontrés, la nature même du travail extérieur, en particulier la basse température et la forte humidité compliquaient et retardaient bien souvent les opérations. La présence d'un apport d'eau en raison de la proximité de la nappe phréatique dans les couches inférieures ralentissait également la prise du latex, ce qu'il fallait compenser par davantage de séchage avec la lampe infra-rouge et le séchoir à air chaud. Dans le cas où il est impossible d'avoir accès à une source de courant électrique ou à un générateur, une alternative intéressante consiste à utiliser un feu de briquettes de charbon de bois que l'on débute dans un contenant métallique. Une fois les flammes parties, la chaleur dégagée le long de la stratigraphie est très efficace pour sécher le latex à condition de placer le contenant ni trop près, ni trop loin de la paroi. Un autre problème rencontré concernait la présence d'un humus de surface très organique qui possédait une grande capacité de rétention de l'eau. Le problème fut contourné en excavant prudemment l'arrière du mur sur l'épaisseur de la couche de façon à couper l'apport d'eau de l'arrière. Il faut cependant prendre garde de ne pas enlever trop de sol, sinon la stratigraphie peut s'effondrer à la suite d'une pluie abondante.

Les stratigraphies prélevées furent déposées dans des boîtes de contreplaqué construites sur mesure et expédiées par bateau au laboratoire, où elles furent ultérieurement consolidées de l'avant avec une solution à 10% de Butyrate de polyvinyle B-98 dans un mélange 90:10 Ethanol/xylène. Elles seront ensuite montées sur des cadres de bois et renforcées à l'arrière avec du polyuréthane expansé afin de participer à une exposition itinérante sur l'archéologie de la Basse Côte-Nord. Des discussions informelles avec les archéologues permirent également d'exposer certains éléments et principes de conservation et d'échanger des opinions sur les solutions à apporter ou à envisager pour des problèmes spécifiques, ce qui est souvent difficile d'effectuer dans un contexte de laboratoire.

Un autre exemple d'intervention concerne le sauvetage et la préservation d'embarcations de la période historique construites entre 1700 et 1740 AD. Le travail de terrain débuta en octobre 1984 sur le chantier de construction du Musée de la civilisation à Québec. Il fallait donc préserver les vestiges d'une embarcation à fond plat qui avait été ensevelie lors des travaux d'édification de la maison du marchand Estebe en 1752, sur les rives du St-Laurent.

Cette embarcation avait été découverte en 1974 et réenterrée puisque les moyens techniques pour la préserver n'existaient pas à l'époque. Le bois étant gorgé d'eau en raison du jeu des marées, une collaboration constante entre l'aspect archéologie et l'aspect conservation était nécessaire. C'est ainsi qu'un restaurateur participa depuis le tout début au travail de réexcavation afin d'assurer l'humidification constante du bois au moyen de boyaux d'arrosage le jour et de ratine de velours humidifiée recouverte d'un plastique de polyéthylène pour la nuit.

En plus du travail de conservation, le restaurateur contribuait au dégagement et à la fouille de l'embarcation. Deux moulages furent également réalisés, dont un avec du latex au polysulphure. Une fois les données recueillies et la fouille complétée, les pièces de bois furent prélevées, nettoyées et déposées dans un bassin de transit en attendant leur transport au laboratoire.

Ce type de collaboration s'est renouvelé quelques mois plus tard lors de la découverte sur le même chantier de 5 autres embarcations à fond plat, ainsi que de trois petits bateaux à voile. C'est lors de la découverte de ces derniers qu'il fut décidé d'effectuer une levée en bloc afin de ne pas retarder les travaux de construction du Musée, tout en permettant l'enregistrement ultérieur des données par l'équipe d'archéologues.

Deux des embarcations, dont une d'environ 10 mètres et d'un poids de plus de 5000 kilogrammes, gelées au moment de la découverte, furent renforcées au moyen d'une structure en bois destinée à empêcher la compression latérale et longitudinale, ainsi que la torsion. Elles furent transportées sur un emplacement temporaire où elles étaient maintenues humides au moyen d'un système de boyaux d'arrosage pour le jardinage. Un local fut trouvé et une enceinte à micro-climat fut construite sur mesure afin de permettre le traitement du bois au moyen de polyéthylène glycol et 400 et 540, avec abaissement progressif de l'humidité relative.

Cette enceinte a permis de poursuivre la fouille en laboratoire et une plate-forme mobile de travail facilite l'enregistrement des données, les échantillonnages, ainsi que les traitements de conservation.

Ces deux cas illustrent bien l'interaction qui peut exister entre conservation et archéologie. Les exemples concrets de collaboration entre ces deux disciplines fournissent un éclairage nouveau au défi complexe que constitue la préservation du patrimoine archéologique mondial.



Figure 1. Le prélèvement d'une stratigraphie au latex au site du temple à Blanc-Sablon sur la Basse Côte-Nord, une site daté à 7200 A.A.



Figure 2. La levée en bloc d'une des embarcations provenant du chantier de construction du Musée de la civilisation à Québec. On peut voir la structure de renforcement destinée à empêcher la compression longitudinale et latérale de ce bateau de plus de 5000 kg.

SOIL SECTION TRANSFERS, MOULDING AND CASTING

Charles E.S. Hett*

SUMMARY

Examples of the use of both soil-section transfers and moulding and casting are given as means for recording and preserving site features. Consideration is given to the materials used and the reasons for the selection of the particular methods and materials.

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INTRODUCTION

The excavation of archaeological sites removes a major portion of the evidence upon which interpretation is based. Visitors to sites will see only the lowest level to which the site has been excavated, artifacts, drawings and photographs, and possibly some reconstruction. In many contexts, site features and soil profiles removed during excavation can contribute very effectively to a visitor's understanding of a site, its development and its excavation. Profiles can be preserved by removing a thin layer of soil. The preserved profile is a soil-section transfer. Site features can be reproduced by means of moulding and casting. This latter process, though it does not preserve original material, can preserve the form and details of site features which may be destroyed during excavation or be subject to an accelerated deterioration once uncovered. Both methods can record detailed site information more accurately than the normally employed methods of drawings and photographs.

SOIL SECTION TRANSFERS

A soil-section transfer is made by peeling a thin layer of soil off a profile. The layer of soil is usually 1-2 mm thick and retains very precisely the overall appearance, dimensions and fine detail of a soil profile. Although soil-section transfers are usually used for recording fine- and medium-grained materials, they can also include objects or rocks up to a diameter of 10 cm. A mirror image of the original surface is produced and for most purposes this effect presents no problems.

Interest in preserving and displaying soil profiles began in the late 1800's and the first work was carried out by soil scientists who collected, transported and displayed soil monoliths⁽²⁾. In the 1930's the "Lackfilm" method of peeling off thin layers of soil was published by Voigt⁽¹⁾. This method used a nitrocellulose lacquer and a cloth backing and continues in use today^(2,3). Although soil-section transfers are made by workers in the fields of soil science^(1,2,3,4), archaeology⁽⁷⁾ and conservation^(5,6), the work and development of methods have progressed with too little communication between disciplines.

A CASE HISTORY: LES FORGES DE ST. MAURICE, TROIS RIVIERES, QUEBEC (figs.1-2)

Trois-Rivières, Québec is the site of a forge and iron foundry which has a long history of use. Excavations by Parks Canada in 1974 revealed a soil profile which showed very clearly a sand casting pit in which could be seen the impression of a cauldron mould infilled with a darker matrix. The profile also included some infilling of bricks and pebbles. Above the cauldron impression there was a hard, dense, compact layer of slag. The making of the soil-section transfer was requested at short notice and two days were allowed for the work. The area to be transferred measured 2x3 m.

Neoprene latex with a cheesecloth backing was chosen for this work. This first adhesive coat was of neoprene latex diluted with an equal quantity of water applied by spraying. The successful application and drying of the first coat of adhesive is the most critical stage in making a soil-section transfer. The first coat must penetrate the entire surface as evenly as possible. Too heavy an application of the first coat can cause slumping and loss of poorly consolidated material such as sand or gravel. The drying of the first coat is critical, particularly when using a rubber latex because each layer forms an impermeable film which will impede any further drying of the first coat later on in the process. In making this transfer, drying of the first coat was

accelerated by the use of two gasoline-fuelled forced-air heaters directed at the base of the profile for several hours.

Once the first coat was dry, subsequent coats dried readily and the work of applying these coats proceeded rapidly. A second coat of latex was sprayed on at full strength after which the surface became sufficiently consolidated for the brush application of subsequent layers of latex and cheesecloth which formed the backing. Two layers of cheesecloth were applied to give sufficient support to the weight of soil, bricks and rubble affixed to the surface.

One problem which arose with this profile was that the slag layer, which overlay the cauldron impression, was very firmly embedded in the soil and could not be pulled away with it. This problem was overcome by hammering over the slag layer with a mallet. The slag broke into smaller fragments and could then be successfully pulled off with the rest of the transfer. The transfer, measuring 2 m x 3 m, was heavy and it required four people at the top surface to support the weight of the transfer whilst two people eased the transfer away from the base. Care was required when easing the larger inclusions out of the soil profile to ensure that they remained well attached to the latex backing. The process of making this transfer is published in enough detail to allow it to be reproduced⁽⁶⁾.

The final mount given to soil-section transfers made of natural and neoprene latex is an important factor in ensuring their permanence. The mount was made by placing the soil-section transfer face down in a box of sand. The transfer was surrounded by a frame and once secure, with the face protected, a two-component polyurethane foam was poured directly onto the back. This mount conforms to all the irregularities of the transfer and provides good support. The transfer is on display and appears to be in good condition after nine years. Other soil-section transfers made in the same year at the Norse site at l'Anse-aux-Meadows are also on display and have survived well.

All of the soil-section transfers mentioned were requested and made during the course of excavations as interesting profiles appeared, but well before plans for site exhibitions were defined. They make a useful contribution to communication with the public.

MOULDING AND CASTING: AN OVEN FROM RED BAY, LABRADOR (figs.3-5)

Threatened site features can be reproduced by moulding and casting. This does not retain or preserve original material but it is the most accurate way of recording features and the casts can be valuable for museum display and site interpretation. An example of moulding and casting of a site feature is the cast made of an oven at the Spanish Basque whaling station at Red Bay, Labrador.

There was an active whaling industry in the area of Red Bay in the mid-16th century. Excavations on the site began in 1978 when a survey was carried out. The Canadian Conservation Institute (CCI) became involved immediately with the excavations carried out by Dr J. Tuck of Memorial University, Newfoundland, on the land station where much of the industry was carried out. A series of ovens which had been used for rendering down whale blubber into oil were uncovered in 1980. Behind the ovens was a wall which had supported a platform for working on the ovens. The rocks that formed the walls of the ovens were extremely friable and the survival of the ovens once exposed was in doubt. The wall on the rear side of the ovens was sound but the remains of the wooden working platform had collapsed and deformed, and the wood was severely degraded. These remains consisted of a length of

approximately 3 m of degraded planking which, even if lifted and conserved, would not have much value out of the context of the site. CCI was therefore asked to mould and cast a section of the platform and the wall behind the oven. The work was undertaken in 1981.

A polysulfide rubber moulding compound was chosen⁽⁹⁾ for the moulding of the waterlogged wood and the wall. This material can be used directly on a wet surface with no separating agent and can be relied upon to cure at low temperatures. It will record fine detail very faithfully. In this case the thixotropic grade was chosen because the mould was to include a vertical surface. Good mixing of the catalyst is very important and this was achieved using an electric drill with a stirring rod. Quantities of approximately 1 gallon were mixed at a time and the moulding rubber was applied using spatulas and trowels. Jute cloth was included in the upper layer to give the rubber greater resistance to tearing. Since the rubber mould is relatively thin and flexible, it requires a rigid outer (mother) mould to retain the contours for casting. The mother mould was made in sections using plaster of paris. The platform and the wall were almost at right angles and in this section a further support of foamed two-component polyurethane resin was made.

Once moulding work had begun on site, it became evident that it would be very desirable to mould not only the platform and wall, but also the oven itself. Fifteen gallons of the polysulfide rubber had been brought to the site and this was sufficient for the platform and the wall, but not for the whole oven as well. Some improvisation became necessary. In this situation, areas beyond the platform and wall which had fine detail and undercuts were moulded with the remaining polysulfide rubber and the areas left were moulded directly with plaster of paris following the methods described by Van Geersdaele when working on the Sutton Hoo Ship impression and the Graveney boat^(10,11,12). For the areas moulded directly with plaster, a clay slip was used as the separating agent. These areas consisted principally of the earthen floor of the oven and the more substantial rocks. Since plaster moulds are rigid, great care had to be taken when selecting the location of separating lines between the individual sections to avoid any undercuts which could become locked in. The separating agent between plaster sections was again a clay slip. The final plaster mould consisted of 54 sections.

The work of moulding and casting this site feature measuring 12 m² occupied two to four people for eight days. The mould was returned to Ottawa and a cast was made using epoxy resin and fibreglass. Due to problems with separating the resin from both the plaster of paris mould and the polysulfide rubber, only one cast could be made from the mould. Assembly of the mould and casting required 3-4 months of work, after which the cast was shipped to the Newfoundland Museum where it is now on display.

DISCUSSION

In both the example of the soil-section transfer and the reproduction of the oven, the archaeologists have had to make their decisions well ahead of firm plans for museum exhibition or site interpretation. This situation is typical. As excavation continues on a site it is rare for the archaeologist to have definite plans for display or for the long-term future of a site. Very often these areas of concern lie with different organizations. With these uncertainties it requires good judgement to decide when to commission the work described.

Soil-section transfers can be made rapidly and relatively inexpensively without impeding the progress of archaeological excavations. Over the past 50 years a

variety of methods and materials have been used effectively, including synthetic resins in solution, moisture-curing polyurethanes and natural and neoprene latexes. Most of the author's experience in making soil-section transfers has been in areas which are predominantly cool and wet. In these situations natural and neoprene latex emulsions are able to penetrate damp substrates, have good adhesion and will cure. In these same situations most synthetic resins in solution or emulsion will not dry satisfactorily. The latex rubbers have a significant number of advantages over other materials as follows:

- (i) Latexes can be applied by spray. Spray application of the first coat of adhesive can cause much less disturbance to friable and poorly consolidated surfaces than brushing or pouring solution over the surface.
- (ii) When travelling to a site only the latex, cloth backing and equipment need be carried. Carrying flammable solvents on aircraft or across international boundaries can cause problems.
- (iii) When working in deep pits or poorly ventilated areas of sites, significant health and safety hazards can arise with the use of synthetic resins in solution, epoxy resins or moisture-curing polyurethanes.
- (iv) Clays and peat can be lifted with the rubber latexes, whereas these materials cannot be readily lifted with resin/solvent systems. It is probable that on these substrates epoxy resins and moisture-curing polyurethanes could be effective^(8,13,6).

OTHER CONSIDERATIONS

Shelf Life: Natural rubber latex has a shelf life in storage of 6-12 months, although this may be extended by storage at low temperature. Neoprene latex has a longer shelf life than natural rubber latex. Similar problems of shelf life arise with epoxy resins, moisture-curing polyurethane resins and synthetic polymers in emulsion.

Ageing Properties: Unfortunately, no studies have been done on the ageing of soil-section transfers. If soil-section transfers are considered as archival documents, they should be made with as long a life-expectancy as possible.

Soil-section transfers made with natural rubber latex have shown a marked discolouration and deformation after less than ten years' storage. Others made with Quentglaze (a moisture-curing polyurethane) have shown much better ageing properties in the same environment. On a theoretical basis neoprene rubber latex should have very much better ageing properties than natural rubber latex. This appears to be borne out in practice; the transfers made at l'Anse-aux-Meadows and Trois-Rivières using neoprene rubber latex, which were all backed with foam polyurethane resin, have remained in good condition. The ageing properties of epoxy resins vary widely between manufacturer and formulation⁽¹³⁾. Further comparison between the different materials is not possible without testing.

MOULDING AND CASTING

The processes of moulding and casting are very much more complex than that of making soil-section transfers. The skills required are acquired by lengthy training and experience. Direct moulding with plaster of paris of complex forms is very specialized work.

The introduction of flexible moulding compounds has reduced significantly the complexity of much of the work of moulding, and a number of flexible moulding materials have been used for archaeological site features. Silicone rubbers, polysulfide rubbers and natural rubber latex have been used satisfactorily. Silicone rubbers and natural latex have been used for moulding petroglyphs, runestones, statuary and dinosaur tracks. Of these two materials, silicone rubbers are most commonly used. Silicone rubbers will penetrate deeply into porous materials with which they will remain firmly and irreversibly embedded. Rubber latex moulding compounds have a lesser tendency to penetrate porous materials than silicone rubbers, but exhibit high shrinkage. Casts should be made from rubber latex moulds very soon after moulding.

In the example of the mould and cast made at Red Bay, polysulfide rubber was chosen because of its known ability to set at low temperatures on wet substrates. Polysulfide rubber is the flexible moulding compound most commonly used for casting waterlogged wood. This material can leave a black stain on some substrates and is unpleasant to use in large quantities. All of the flexible moulding compounds need to have an outer rigid (mother) mould. The mother moulds are usually made of plaster of paris or of fibreglass-reinforced resin. The flexible moulding compounds mentioned will exhibit shrinkage on ageing and deteriorate in storage, and for this reason casting should be carried out soon after the moulds have been made.

Casts today are usually made of epoxy resin and fibreglass which gives a strong and light-weight reproduction. The lifespan of a cast will depend to a considerable extent on the environment in which it is exposed; high light levels for example can shorten this lifespan. Plaster of paris can be used for both moulding and casting, but its use for both purposes has diminished with the introduction of synthetic resins and fibreglass. Plaster casts are, however, more permanent and the collections of moulds and casts of antiquities in museums now have a great documentary value where original objects have suffered deterioration and loss. Plaster moulds have the disadvantage of being very heavy and bulky, making heavy demands upon storage space.

SUMMARY

From the examples and discussion above it can be seen that a variety of different methods and materials is available to record and preserve aspects of archaeological site features. The work described can only be carried out at certain appropriate stages of excavation.

Soil-section transfers can be made readily and an interested archaeologist could acquire the necessary materials and experience to make them himself without undue difficulty. Moulding and casting are a great deal more expensive and time-consuming operations both on site and in the laboratory. Moulding operations carry a risk of damage to site features and both moulding and casting require a very considerable amount of expertise and experience. Both of the techniques described have their place in field archaeology and it is hoped that bringing them to the attention of the archaeologist may cause them to be considered at the appropriate stages of excavation.

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Figure 1. Transferred soil profile showing sand matrix, impression of a cauldron and overlying slag layer.





Figure 2. Peeling of the transfer from the soil profile.



Figure 3. Applying polysulfide rubber to the wall.



Figure 4. Direct moulding of the oven floor with plaster of Paris (note: red clay separating agent).



Figure 5. The assembled mould of the oven ready for casting.

CONSERVATION EXPERIENCE OF CLAY CONSTRUCTION IN UZBEKISTAN

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The territory of Uzbekistan abounds in large sites of ancient towns and settlements representing remnants of the world's earliest civilizations. Archaeological excavations started as early as the end of the 19th century but acquired a genuinely scientific and systematic character only in the years of Soviet Power and supply us with the most abundant historical material testifying a high level of culture, art and craftsmanship in this territory. Qualitative changes have taken place in methods of study of the republic's architectural monuments as well. While before stratigraphic excavations were predominant, in the last few decades mostly planigraphic studies are in progress. This results in revealing large architectural ensembles, religious and defensive structures, palaces, residential and trade quarters in various historical and cultural regions of the republic.

Most of these objects of study are valuable monuments of ancient architecture and town-building art and thus the problem of their preservation and presentation in museum collections is one of the most important issues today.

Conservation of archaeological monuments in Uzbekistan is an extremely complicated task connected with many difficulties, since they are built of materials of low precipitation resistance such as clay mixed with straw, clay blocks and mud bricks manufactured of loess and loess loams.

Structures of analogous type are being discovered by archaeologists in other Central Asian republics and in the Caucasus. Similar monuments are also widely spread in other countries: in Afganistan, Iran and Eastern Turkestan (Sin-Tzyan). For this reason, the problem of mud brick monument preservation and the working out of methods of their conservation are of not merely regional but global importance.

Conservation of adobe archaeological structures has been an object of specialists' attention for over 20 years and was an issue for discussion at many regional and international conferences and symposia held both in the USSR and abroad. Such international conferences took place in October 1961 in Barcelona, in September 1963 in Leningrad (2), in Venice (3), and finally, special meetings gathered under the initiative of ICCROM (International Centre for the Study of the Preservation and the Restoration of Cultural Property) were held in 1972 and in 1976 in Yazd in Iran (4,5), in 1980 in Ankara (Turkey) (6) and in 1983 in Cyprus (7).

Such specialized conferences took place in our country as well. In October 1966 in Sevastopol there was a meeting dedicated to conservation of architectural and archaeological monuments of southern regions of the USSR (3). Problems of the preservation of cavern complexes were discussed in 1982 in Yerevan and Tbilisi (8). Measures for archaeological conservation are permanently under the control of the republican and national bodies for protection and restoration; they are discussed at almost every conference or meeting on archaeological studies and restoration of ancient monuments. Great attention is being paid to this problem by the Soviet Committee of the International Council on Monuments and Sites (ICOMOS). Upon studying materials of the above-mentioned conferences and symposia and other special literature, one comes to a conclusion that there are no generally acknowledged common methods and recommendations on mud brick conservation.

The world practice uses a number of methods based mostly upon conservation by means of saturating the constructions with chemical substances (water-repellent and film surfaces), with polyurethane and epoxy resins, polymeric solutions, liquid glass and other substances. When the above-listed means are used they produce superficial effects which do not ensure deep penetration of the consolidating agents into the

construction and, hence, the monuments' protracted conservation. The consolidating agent mostly recognized abroad is a partially hydrolized ethyl silicate solution. The consolidating substance on this basis is prepared as follows: one part of 37% HCl, 34 parts of 96% denaturated alcohol and 65 parts of ethyl silicate (9).

Wall surface treatment using scarce substances becomes very expensive. Moreover, experiments prove to be effective only as far as the saturation of vertical walls is concerned, while horizontal ones are soon destroyed under the influence of rainfall. This is why the most efficient approach for the conservation of ancient mud brick structures is to use solutions not of ready polymers but of their monomers, realizing the polymerization reaction inside the material under consolidation.

There are several well-known methods of using monomers for architectural conservation: the phenol-alcohol method for consolidating wood buildings by Professor V.E. Vikhrov (10), the butylmethacrylate method for the protection of sculpture by E.F. Fedorovich (11) and the isocyanate method for the conservation of sculpture and adobe structures worked out at the Institute of Archaeology of the Academy of Sciences of Uzbekistan which we began to develop as early as 1967 (12-16).

The isocyanates' capacity to polymerize under normal conditions is based first of all upon peculiarities of their chemical structure and upon non-limited possibilities of changing this structure. Important factors that determine their main characteristics are the flexibility of isocyanate chains and the variety of functional groups which create wide possibilities for development of intermolecular links. Thanks to these characteristics, isocyanates enter easily into reaction with water, alcohols, carboxylic acids and also with some mineral salts of the soil. This interaction results in polymers and oligomers of varying structure and properties (with urethan, urea, biuret, allophanate, carbodiimide, isocyanurate groups) and in the synthesis of polymers with cross-linked structures.

Isocyanate monomers used for mud brick conservation have some advantages as compared with the other monomers: polymerization reaction may be realized in many ways: in sunshine, by infra-red heating, or by simple heating of surfaces, which is very important in field conditions. The polymerization products are extremely weather-resistant and thus the durability of consolidated structures is fairly high (frost-resistance over 10-15 cycles, salt-resistance over 160 days). Thanks to the deep penetration of monomers, the structures' compressive strength may be very high, similar to that of burnt materials (over 75 kg per cm²). Because of the high durability, the structure obtains considerable solidity with regard to climatic factors, the exchange of water between the external and internal strata takes place normally, which secures evaporation, that is, the wall "breathes". This results in preventing exfoliation of the external consolidated layer while the structure's colour and texture remain unchanged, an important consideration for historic sites.

For the estimation of conservation methods we have worked out certain parameters satisfying the demands of restoration practice. In short, these demands are as follows:

1. Consolidating agents must not distort the structures' original colour and texture.
2. They must penetrate easily into the thickness of material, providing durability of conservation.
3. Consolidating agents must be resistant to external climatic factors.

According to these demands, experiments have taken place and problems of efficiency of certain conservation methods have been discussed. The samples' colour and texture changes have been ascertained visually with the help of an atlas of colours or by spectro-photometer 01-10.

The conservation effect was controlled by means of measuring the compressive strength of the selected samples that were consolidated in different ways. Taken as basic climatic factors were temperatures of -15°C , $+25^{\circ}\text{C}$, $+40^{\circ}\text{C}$, $+60^{\circ}\text{C}$, relative humidity being 60% and the temperature $+60^{\circ}\text{C}$, relative humidity being 100% and the temperature $+60^{\circ}\text{C}$. In the case of thermal destruction, test samples were studied under temperatures of $+25^{\circ}\text{C}$ up to 250°C .

Temperature and relative humidity were obtained in TER thermostat and in the G-4 humidity chamber. The influence of sun rays was estimated by studying the samples under the PRK-2 lamp. Frost resistance was measured on the basis of existing methods by means of alternate freezing at -15°C in a refrigerator and thawing out in water at room temperature. Besides the above-mentioned factors, the samples' resistance to mineral salts and micro-organisms was ascertained (17).

To reveal the mechanism of the polymerization process in every given case, the accumulation of isocyanate groups in the loess structure saturated with isocyanate solutions has been studied by means of taking the infra-red spectra of loess cubes after polymerization.

These experimental studies have shown that the consolidating agents' optimum ratio is as follows: 30% of diisocyanate + 70% of technical xylol + 1% of catalyst (triethylamine). This concentration provides for the highest durability indices and respectively low surface processing costs (3 roubles 12 kopecks per m^2).

As has already been pointed out, the polymerization reaction of the given mixture within a loess construction may be in process under the influence of both ultra-violet rays (under the PRK-2 lamp or in field conditions) and temperature (in a drying oven or in the atmosphere). But the reaction speed is not equivalent. Under ultra-violet radiation it is lower than under heating. While in the case of radiation high durability indices are obtained in 12 hours, under heating it takes only 4 hours, that is under the influence of temperature the polymerization reaction is three times as fast, the catalyst being necessary. In general, the temperature increase from 25°C to 250°C results in an increase in compressive strength (up to $108,7 \text{ kg per cm}^2$), but temperatures higher than 200°C are undesirable because the sample's surface starts darkening due to thermal ageing of the polymers. Keeping the consolidated samples in a humid atmosphere (under 60°C with relative humidity of 60% or 100%) for up to one month, their compressive strength increases first from 50 up to 102 kg per cm^2 and then in 4 months begins to fall as low as 50 kg per cm^2 .

The consolidated samples' capacity to absorb water depends on the polymerization conditions. In the case of heating, it reaches an average of 2,8%, and under ultra-violet radiation of 1,8%.

Testing the consolidated samples by placing them in a salt solution (concentration of salts equal to that of the Central Asian saline lands) has shown that they sustain the influence of mineral salts for 40, 120 or 160 days perfectly well. A longer exposure to these conditions results in the formation of mineral salt layers on their surface without the destruction of the samples proper.

Perhaps the formation of cross-linked urea derivatives by means of interaction of isocyanate groups with moisture causes a discharge of carbon dioxide which forms micropores both within the loess texture and on the material's surface. This promotes easier salt migration within the structure, without its destruction.

The consolidated samples appeared to be resistant also to soil micro-organisms. Specially selected soil fungi have shown no influence on them throughout 15 days.

Thus the complex of physical and chemical tests carried out has revealed a certain resistance of consolidated samples to the severe climatic conditions of Central Asia.

Now, let us dwell upon the question of the cost of our methods as compared with other restoration and building operations. As stated above, in the Institute of Archaeology of the Academy of Sciences of Uzbekistan, three variants of the given conservation methods have been worked out, all of them based on using diisocyanate monomers. In all three cases the expenditure for consolidating solutions per m² of wall surface is the same: 1.5 kg of diisocyanate + 3.5 kg of technical xylool + 0,1 kg of triethylamine. Their costs are shown in Table 1.

TABLE 1

| N°. | Type of treatment | Type of material | Costs per m ² of treated wall surface (roubles) | Durability of treatment (years) |
|-----|---------------------------------|--|--|---------------------------------|
| 1. | facing | cement mortar | 1.09 | 2-3 |
| 2. | painting | lime, cement and other painting compositions | 0.22 1.67 | 3-4 |
| 3. | film covering | polymeric materials | 1.51 | 2-6 |
| 4. | hydrophobization | silico-organic liquids GKJ-94 GKJ-11, etc. | 1.26 | 5-6 |
| 5. | compound processing | hydrophobization + film covering | 1.96 | 10 |
| 6. | saturation | diisocyanate I | 24.42 | 17 |
| 7. | saturation | diisocyanate II | 16.92 | 11 |
| 8. | saturation | diisocyanate III | 4.32 | 8 |
| 9. | repair of constructions' facing | tiles covered with glazes of various colours | 40-150 and more | |

As shown in the table, wall surface conservation costs per m^2 approximate those of ordinary construction operations and thus may be recommended to construction practice.

Since 1974, simultaneously with the laboratory tests, the conservation methods successfully stood the field tests.

The first experiments have taken place in Fayas-Tepe in old Termez, where the dome of the ancient stupa had to be conserved. Taking into account the successful field consolidation practice, we expanded conservation works in 1974 in the site of Sapalli-Tepe, a settlement of the Late Bronze Age situated at a distance of 60 km to the north-west from Termez. The conservation works were concentrated mostly in a residential quarter quite near the entrance of the settlement (fig.1). Along with silico-organic varnishes, isocyanates were used for wall treatment. The consolidation was fairly successful and durable. Recently, in June 1985, the consolidated fragments were examined once again. The construction was found in satisfactory state and did not have any significant damage. The total area of the diisocyanate conserved fragments then constituted 120 m^2 .

The large fortification wall of the 5-6th centuries B.C. was discovered in Afrasiab, an old site of Samarkand. Its conservation with the help of the tested methods was begun in 1977. In 1978 the treated surface reached 630 m^2 . The state of the structure after the conservation was quite satisfactory (fig.2). Last year an earthquake caused the collapse of the wall's central part. It was restored and conserved once again in 1984.

Since 1979 the Akh-Tepe site in Tashkent has been another experimental object. The site had been formed gradually from the 5th up to the 8th century A.D. It comprised ceremonial, religious and household buildings. The total consolidated surface area was over 600 m^2 . Besides isocyanate conservation methods, we have tested means of insulating the wall's least waterproof fragments (base and ridge) with the special plaster prepared from liquid glass. The latter experiments went on at the other sites as well (fig.3).

In the last few years, small experimental conservation works have also been done in other Central Asian republics: in Turkmenia in the old Nissa site, in Kazakhstan in the Otrar site.

Thus, the total area of old constructions where the methods have been introduced is now 1,350 m^2 .

As a result, with the successful introduction of conservation methods, scientific experimental grounds for the improvement of new techniques are being created in different historical and cultural regions of the republic. These grounds are to become a base for future museums in the open air. They will provide not only the preservation of the most precious ancient sites but also a demonstration of the results of the archaeological studies and a partial recovery of the investment involved in such studies.

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Figure 1. Residential quarter of the Sapalli-Tepe settlement (2nd millennium B.C.) after conservation.



Figure 2. The fortification wall of the Afrasiab settlement (5-6th centuries B.C.) after restoration and chemical conservation.



Figure 3. Household rooms (5-8th centuries A.D.) of the Akh-Tepe settlement after partial restoration and chemical conservation.

CONSERVATION ON THE EXCAVATION : THE CRYPT OF BALBUS IN ROME

R. Nardi*

SUMMARY

The paper reports a series of in-situ conservation interventions carried out during the excavation campaigns in the Crypta Balbi in Rome. The area, situated in the centre of the city, is more than 2500 sq.m in area and is particularly interesting for its historical stratification of more than two millennia duration. The interventions described here are:

- consolidation of a wall of mudbrick laid in clay;
- consolidation of a wall of fired brick laid in clay;
- consolidation of a floor mosaic;
- recovery of ceramic material and a "Capuchin" tomb;
- conservation/restoration of coins.

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This report arises from a series of conservation interventions carried out in situ during the excavation campaigns for the Crypta Balbi in Rome. These operations were carried out by the Centre for Archaeological Conservation (CCA), a group organized with the aim of providing a practical response to the conservation problems involved in an archaeological excavation.*

To explain something of the background: the Crypta Balbi excavation involves an urban area in the centre of Rome encompassing some 9,500 m², of which 3,500 m² are outdoors. This corresponds to the city block formed by Via Caetani, Via delle Botteghe Oscure, Via dei Polacchi, and Via dei Delfini.

The work began in November 1981 (in application of Law 92/81), and is directed by M.L. Conforto of the Archaeological Superintendency of Rome and by Prof. D. Manacorda of the University of Siena. To date, a variable number of archaeologists -- researchers, graduates, students - from various Italian universities have participated in the excavation, up to a maximum of 70 per campaign. There have been six campaigns interspersed with laboratory research activities. The results of the work are published contemporaneously with the excavation: three volumes are already available, and three others are in preparation.⁽¹⁾

Some information is given below to orient the reader regarding the characteristics of the excavation and the conservation interventions.

The area is situated in the centre of the city, in a zone that over the past two millennia has experienced a continuous superimposition of human activity. Thus today it presents an exceptionally interesting historical stratification.

Since the Augustan era, when L. Cornelius Balbus (13 B.C.) built a theater with an attached crypto-portico -- the Crypta Balbi -- there has been continuous building, restoration, adaptation and demolition, all in the same area.

In the Middle Ages, a fortress known as the Castellum Aureum rose over the ruins of the ancient monument. The churches of St. Mary and St. Lawrence were built inside. In the sixteenth century the area was occupied by the large complex of the conservatory of St. Catherine of the Rose; this was demolished 40 years ago.

Since then the zone has been left completely abandoned: thus the archaeological investigation functions both as an instrument of historical analysis and also as a process of urban renewal.

A few figures related to the first three years of research: the area was divided into 11 test trenches totalling a study area of 2,690 m², with 4,450 m³ of dirt removed. There were 84,930 man hours employed for the excavation.

Some figures on the "productivity" of the trenches are available for the area known as the "Garden" (trenches I and III), which correspond to levels of post-mediaeval date (naturally in an urban environment).⁽²⁾ The strata (ca. 1,000 m³ of archaeological deposit) have yielded 18,118 fragments of majolica of

* The Centre for Archaeological Conservation is a private firm located in Rome and directed by the author; it was established in 1981 by personnel with training in archaeology (University of Rome, "La Sapienza") and experience in restoration (Istituto Centrale del Restauro); its area of interest is conservation on excavations and ancient monuments.

Renaissance and post-Renaissance date, equivalent to about 315 kg, and 3,947 fragments of plain wares, equivalent to about 270 kg. Moreover, there was a noteworthy amount of metal, stone, glass, and diverse other materials. Against this background, it is easy to imagine the variety of materials and structures that one can encounter, and how many types of choices can be made regarding their conservation -- in situ or not.

As regards conservation, 4,900 man hours were supplied, necessary for the following operations: piecing together 627 ceramic objects (plain, glazed, slipped, majolica); restoration of 218 metal objects (bronze, iron, silver); restoration and conservation of 220 coins; restoration of 36 objects of glass paste and glass; consolidation of 33 m² of mudbrick wall structure and 32 m² composite structure (brick laid in clay); consolidation and cleaning of 27 m² of wall plasters and mural paintings; consolidation of 8 m² of mosaic floor and cocciopesto floor; recovery and microstratigraphic excavation of objects in metal, ceramic, bone, and ivory and of a "Capuchin tomb". About 25% of the work time indicated must be attributed to interventions to help the archaeologists during excavation and for the study of materials.

The conservation data come from the computerized forms that accompany each find and record every phase of the intervention. These data are purely indicative, as they cannot be directly correlated to the information about the excavation given earlier. The latter, in fact, include areas that have been excavated but are not yet under study; only at that point do the finds arrive at "restoration" so as to be prepared for drawing, photography and examination.

Nevertheless, one useful though purely indicative fact emerges: conservation and restoration have required (in terms of time and therefore money) 5% of the total energies employed in the excavation; this proportion is more than acceptable in any budget.

The interventions described here are as follows:

Structures in situ:

- 1) Wall of mudbrick laid in clay
- 2) Wall of fired brick laid in clay
- 3) Floor mosaic

Movable objects:

- 4) Recovery of ceramic material and a "Capuchin" tomb
- 5) Conservation/restoration of coins

Other interventions carried out in the same excavation area and concerned with wall plasters, in situ and fallen, mural paintings and masonry structures are reported at this meeting by A. Costanzi Cobau (see the following paper).

1) WALL OF MUDBRICK LAID IN CLAY

This is a semi-circular structure, 4.20 m in diameter and 0.80 m thick, which rises 3.70 m above the present excavation level. Without getting involved in speculation as to the dating and significance of such a structure (the last layers have still to be excavated), I might mention one hypothesis among many that it was a

large kiln for materials, prepared and never used, and therefore never fired. In any event, such a wall is a rarity in the Roman climatic environment. This example has been chosen as the first because it experienced to its own cost the transition between the absence and presence of conservators on the excavation. In fact, it had been partly exposed to environmental agents (the structure was a quarter excavated in plan and 1 m in elevation); rain, wind and algae had dissolved most of the external facing, leaving a shapeless, unrecognizable nucleus.

We decided to intervene by setting up some preventive measures that would permit the regular excavation process to continue without threatening the integrity of the remaining structure: a rigid roof of metal tubing and corrugated plastic to keep off rainwater, flanked by bamboo screening in order to limit insolation, overheating and drying of the clay. This last problem called for additional measures: due to organizational requirements, it was necessary to work most of the summer in order to permit the archaeologists to deepen the trench prior to a consolidation intervention. To avoid having the wall dry out irreparably during this period, with the consequent risk of contraction, crack formation or total collapse, and to allow subsequent in-depth consolidation while the structure was still wet, we devised a "drop-by-drop" wetting system with a water tank that refilled itself automatically. This kept the structure damp even when the yard was closed for holidays. Tests on samples made it possible to set the water dosage so that the quantity emitted was entirely absorbed deep into the structure without any puddling or overflow. A biocide treatment (Ciba Geigy Lito 3 algicide) completed the preventive measures.

Then followed the intervention proper. For this we decided, insofar as possible, to use the sole material of which the wall is made - clay - with a minimal addition of hydraulic lime (10% Lafarge hydraulic lime, low in salt content)⁽³⁾; this was to avoid denaturing the character of the wall itself with the addition of extraneous products. We were perfectly aware that this decision could mean less "solidity" of the wall once it was restored, but we preferred to deal with this problem by planning for future roofing and protection (and thus take a risk) rather than immediately sacrificing the appearance and the "precarious" but "genuine" character of this kind of structure, perhaps by flooding it with synthetic materials.

A brief inquiry among some former brick makers, who had gone out of business more than 25 years ago, enabled us to locate a clay pit in the city that contained material similar to the clay in the wall (consistency, colour, purity); thus we had the necessary access to raw material for the intervention.

The intervention was divided into two parts: one involved internal consolidation of the structure, with repair of cracks and reinsertion of detached blocks; the other involved integration of zones of external facing to meet static requirements.

For the first type of intervention we carried out, as mentioned above, infiltrations of a clay solution combined with 10% hydraulic lime. (This percentage was considered suitable after sampling for fluidity, colour and resistance. The resistance could not be excessive in relation to the original material or it would have meant inserting a rigid element into a fragile structure and upsetting the static equilibrium.) The mixture was then injected into the cracks and detached areas, which were first treated with water and alcohol; where necessary the larger detached zones were re-positioned against the body of the structure by means of expanding braces, which were removed once the mixture dried. As an indication, the consolidation of about 19 m³ of wall required 60 kg of grout, equal to 3 kg/m³.

For the second type of intervention (repair for static purposes where the external mudbrick facing had fallen away) we adopted the compromise of inserting

"half-baked" bricks. For this, another sampling was done, this time with a potter's kiln. Progressive tests of firing were made in increments of 100°C (from 100° to 900°C) on clay samples with different amounts of sand added to the mix, in order to study their behaviour on cooling, colour changes, and resistance.

The samples thus obtained were subsequently tested for resistance to artificial rain. The desired result was to obtain bricks that were as similar as possible to the original mudbrick (in size, shape and colour) but resistant to water, and to use graphic documentation in order to avoid the risk of falsification.

This was in order to make statically solid integrations (as they had to serve as supporting ribs on the sides of the structure) which would also eventually act as an impermeable outer protective barrier.

Unfortunately, the results were not exactly what we had hoped, due to the relatively high firing temperature required to make the clay impermeable (above 400°C), which produced a colour distinctly different from that of the mudbrick. At least the areas of integration will now be easy to distinguish from the original structure.

Nevertheless, the wall as a whole has regained its own stability, it is currently protected from water, sun and biological attack, it stands up without external supports, and the area is ready for excavation of the part still below ground.

2) WALL OF FIRED BRICK LAID IN CLAY

Not far from the preceding structure, a calcara (lime kiln) was brought to light. This was abandoned at a moment of full activity (in medieval times) and has thus survived intact. It is composed of a circular wall, 3 m in diameter, 0.25 m thick, 2.80 high, divided into two parts: the upper was for loading the marble, which was found heaped at the side, the lower for the wood fuel, found as charcoal in situ; between the two are remains of an air space found covered with a molten glassy material. The wall is composed of re-used Roman bricks laid in clay, then partially and irregularly fired when the kiln was used.

The consolidation intervention was greatly facilitated by the type of structure itself, by the colour and consistency of the bricks and fired clay setting bed: in fact it was possible to use, as a consolidant by infiltration, the mixture of hydraulic lime and brick dust developed by the ICCROM Research Team under G. Torraca (see paper by A. Costanzi Cobau).

The consolidation naturally involved the entire structure, including the vitrified parts, in order to ensure the presentation of the complete functional entity on completion of the excavation.

In this case as in the preceding one, a preliminary treatment of wetting followed by a biocide was necessary to permit regular progress of the excavation and avoid the risk of damage to the structure during the four weeks required to excavate it. For this we used the same methods as for the mudbrick wall, given that roofing for the area had already been prepared in order to conserve the wall plaster.

3) FLOOR MOSAIC

In 1961, also in the lime kiln area, some "test pits" had been sunk for purposes of "archaeological investigation" and reached the level of a black-and-white Roman

floor mosaic. The excavation was heedlessly continued, cutting right through the mosaic. It was thus necessary for us to consolidate the remaining tessellatum until such time as the entire trench reaches that depth and exposes the floor level completely. The intervention was of two kinds: one to reattach the tesserae to the setting bed, the other to contain the edges where the mosaic had been cut and where the tessellatum was progressively disintegrating.

The first operation was carried out by infiltrating an hydraulic mixture of white lime (Lafarge), marble dust and very fine sand (1:2:1); the second was done with a border of "Roman stucco" (slaked lime, marble dust, sand, 1:2:1). The latter technique proved to be effective if two conditions were met: the lime had to be thoroughly slaked (two years at least; Vitruvius says three) and the stucco had to be carefully worked, with repeated scraping after application.

As mentioned above, it was felt useful also to present some examples of interventions on movable materials that for study purposes or, as in the following case, for later replacement in situ, required treatment in the field.

4) RECOVERY OF CERAMIC MATERIAL AND A "CAPUCHIN" TOMB

One find was a large amphora, containing other ceramic material, which had been crushed in a collapse; the other was a "Capuchin" grave containing a child's body; both were in the subterranean trench in the "Cellars". A "Capuchin" tomb, as we know, is a simple burial with the body, which is usually wrapped in a shroud, surrounded and covered with large flat tiles that are stacked edge to edge at an angle.

The reason for treating these two finds differently from the normal stratigraphic excavation was the prospect of replacing them in a museum or in situ, for eventual presentation of these areas to the public. Indeed, among the ultimate aims of the excavation, apart from publication of the information gathered, is to transform the site into a sort of museum of itself, with some of the finds displayed in exhibition rooms set up inside the ample premises available on the spot and some on the site where they were discovered, together with the structures -- naturally without taking liberties with the chronological or aesthetic aspects of the site -- to form a sort of "anthology of reality" of the expressions of life that have characterized the area over the past 20 centuries.

For these finds we used the technique of microstratigraphic excavation: isolating a stratum with part of the object exposed, drawing a plan at full scale of all the evidence contained using acetate overlays and indelible pens, consolidating the fragments with acrylic resin (Paraloid B72 in trichloroethane) after prior drying of the zone, transporting the "microstratum" piece by piece according to the order recorded on the acetate overlay that had been spread on a box with a rigid support, and so forth, one microstratum at a time, carrying everything into the laboratory.

At this point the entire tomb was cleaned (with water and alcohol, mechanically with scalpels, and with localized applications of AB57 in emulsion with micronized silica for the areas having carbon deposits mixed with dirt)⁽⁴⁾. It was protected (with Paraloid B72 in trichloroethane, at 1.5%) and prepared for remounting in situ or in a museum.

From the ceramic material collected, on the other hand, the principal amphora was isolated and put aside for treatment; the rest of the material was consigned for study as if it were a single stratum. The treatment of the amphora was similar in all phases to that of the tomb, but it was then pieced together using epoxy resin (Uhu Plus) spread on surfaces treated with acrylic resin (15% PB72 in trichloroethane) as a reversible primer. The piece is ready to be replaced in situ or exhibited.

5) CONSERVATION/RESTORATION OF COINS

The method described below was developed for conserving excavated coins in a situation with an unsuitable climate. The coins were first restored (with scalpels under a microscope. Rarely, for purposes of legibility, we used alternate baths of an alkaline solution of Rochelle salts and an acid solution of 10% sulphuric acid).⁽⁵⁾

The problem is linked to the high humidity level in the premises surrounding the excavation, where the lab has been set up. As we could not alter the general climate, we enclosed the coins singly inside small containers with transparent closures, glued shut once the contents were inserted (micro mount containers). The small boxes were then enclosed in similar, but larger containers, this time in greater numbers, separated according to their trench provenance. In this way we created a sort of controllable micro-climate: both containers have a false bottom with silica gel and, as already mentioned, can be hermetically sealed. Naturally such a system works if periodically controlled (monthly) and the silica gel replaced; the time involved, however, is amply rewarded by the results.

In concluding this report, we would like to emphasise the simplicity of the measures adopted in the course of the conservation interventions on the excavation -- both those described here and others not considered useful to include.

This simplicity is doubly significant because the methods used proved efficacious and because of the modest expense involved. This, in view of the comments above about the proportion of conservation costs to administrative costs on the excavation, demonstrates, we hope, not only that it is feasible to have a conservator in the field and that his level of productivity is high, but also that he contributes to the output of scientific research.

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Figure 1. Overall view of the site.



Figure 2. Wall of mudbrick laid in clay. General view showing the temporary shelter of metal tubing, corrugated plastic and bamboo screening. This roof serves to keep off rainwater and to limit insolation, overheating and drying of the clay. The wall is about 4 m high. Photo: author.

Figure 3.
Detail of the wall exposed to
environmental agents. Photo:
author.



Figure 4.
Detail of the wall excavated
during the conservation
intervention. The structure has
maintained its original texture
and consistency. Photo: author.





Figure 5. The "drop-by-drop" wetting system enabled the archaeologists to deepen the trench prior to a consolidation intervention, and kept the wall from drying out and running the risk of contraction, crack formation or total collapse. Photo: author.



Figure 6. Consolidation with infiltrations of a clay solution combined with 10% hydraulic lime. Photo: author.



Figures 7-8. Coins were enclosed singly with silica gel inside small containers with transparent closures and glued shut; the small boxes were then placed in similar, but larger, containers, with silica gel and an air-tight seal. Photo: author.

EXCAVATED WALL PLASTERS: CONSERVATION PROBLEMS

Andreina Costanzi Cobau*

SUMMARY

This report describes some conservation interventions on wall paintings and plasters discovered in situ at the Crypta Balbi excavation in Rome.

The following cases in particular are analysed:

- wall plasters on structures of tuff and travertine with problems of rising damp, water infiltration from the rear, and biological attack;
- consolidation of mortars used as rendering on niches;
- conservation assistance during excavation of frescoes on site;
- sampling of plasters.

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This paper will describe some conservation interventions on wall plasters and mural paintings discovered in situ at the Crypta Balbi excavation, which has been initiated in the urban centre of Rome⁽¹⁾. In the general ambit of the research, based on collaboration between archaeologists and restorers, we would like to emphasise how the factors that condition the conservation interventions are affected by the schedule and requirements of the excavation, in addition to the climatic and structural characteristics of the finds themselves.

The first intervention presented is related to structures excavated inside a semicircular area (an exedra), enclosed by a wall of the Augustan period in opera quadrata made of travertine and tuff, with later additions, and by another rectilinear wall in brick.

A temporary roof protects the area from rainwater, and a gutter system prevents the collected water from falling where the roof slants down above the rectilinear wall. The roof, in plastic material, is raised some two meters above the brick wall in order to allow air to circulate inside and avoid the formation of a "greenhouse effect". Nevertheless, the exedra walls require constant control and biocide treatments. Infiltrations of water from surrounding environments - to the east an embankment almost as high as the circular wall, to the west an uncovered excavation trench - together with rising damp favour the settlement and development of algal cells on the tuff and the wall plaster. This is a biological alteration that appears as a thin adherent green patina extended over various parts of the wall⁽²⁾.

We managed to limit this algal growth by controlling the adjacent environments. Along the east side we filled all the ditches next to the wall, creating a slight slope that keeps the water from stagnating next to the masonry; then with a lime/sand mortar we closed the cracks that offered preferential routes to the water infiltration.

The same precautions could not be taken along the western side because the area borders another excavation zone and is therefore subject to variations in the ground level. In this case the biocide treatment was applied to both sides of the cross-wall that separates the exedra from the other trench.

As one can see, the conservation problem of the exedra is concentrated along its perimeter: the roofing protects the zone from atmospheric agents without creating the danger of condensation in a closed environment, thus limiting the rising damp to the moisture content of the ground; in contrast the walls, and especially the one in opera quadrata, are at risk in acting like membranes towards the outside.

The tuff wall, so far excavated on only one side, has become a filter for the water coming from the bank behind it: a filter, however, unable to stop the soluble salts transported by the water, with the most obvious consequences⁽³⁾. The tuff has formed scales, more or less concentrated in the zone retaining fragments of wall plaster; some of the scales are as much as 30 mm thick.

An area of about 4 m² of the tuff wall is covered with wall plaster. A few traces of fresco decoration allow us to identify different facings on the same wall. The most extensive remains appear to be the first layer, corresponding to a phase after the Roman monument was abandoned. This is a plaster 15-20 mm thick, a light-coloured mix based on marble dust. The decoration must have been of a regular composition, but only a few traces remain of a red design on a white background. In a few places the surface has a finish that recalls the politiones cited by Vitruvius⁽⁴⁾, but most of the paint layer is abraded.

Upon excavation, the plaster's cohesive properties had been lost: it was powdery and any attempts to clean it were a serious threat to the few remaining traces of colour.

For this reason we decided not to remove the thin layer of dirt (a few millimeters) that still adhered to the surface, but to leave it while the humidity in the plaster evaporated, in order to create a new surface level. This way the soluble salts borne by the water coming from the support would not crystallize next to the paint film but on the other side of the dirt.

During the weeks following the excavation, we noted different rates of evaporation between the plaster and the tuff wall; the latter was much slower. Due to the pore size characteristics of the tuff, this material holds water longer and consequently takes longer to dry⁽⁵⁾. In the case of the wall, complete drying of the tuff is impeded by the constant humidity arriving from the bank behind: thus apart from working on a wet object it was also necessary to carry out interventions that did not obstruct the passage of water.

After removing the thin layer of dirt⁽⁶⁾ we proceeded to in-depth consolidation with a material as close as possible to the porosity of the plaster, capable of setting even in a damp environment: for this we chose the grout developed by the ICCROM Research Team, based on the use of hydraulic lime and brick dust added to a fluidifier and an acrylic emulsion⁽⁷⁾.

By consolidating the areas of detachment between plaster and tuff, however, we did not remove the cause of the deterioration: the water infiltration from behind the wall. The plastered area, in relation to the water evaporation front, becomes a preferential zone and the cause of disequilibrium over the entire wall. The scaling on the tuff along the edges of the plaster can be traced directly to this. The same hydraulic consolidant was used to fix the scales, as it also had adhesive properties for tuff⁽⁸⁾.

To reduce the danger of losing fragments along the plaster edges, it was felt necessary to protect them with a thin coating (a film of 10% Paraloid B72 in trichloroethane). This intervention was restricted to a narrow perimeter strip in order not to create an impermeable barrier over the whole fresco area, whose thermo-hygrometric behaviour, as mentioned above, differs from the surrounding area.

In order to equilibrate the entire wall surface there was a proposal to plaster or coat the tuff blocks. In any case, the bank behind the wall will eventually be excavated, and this itself will be a definitive conservation intervention.

In a situation where the cause of deterioration is not immediately removed, one can see how the conservation of an artifact becomes more complex and delicate, given that we wish to keep the painted plaster fragments in situ; this is the sole testimony of the building's decorative system, which we can only partly interpret today.

In a niche on the brick cross-wall of the exedra, we discovered a plaster with regular imprints of elements that have disappeared and with amphora fragments still in situ, irregularly placed. Subsequent excavation of other niches along the same wall revealed the same type of facing. This is the setting bed of an opus sectile decoration, where the amphora fragments were used to level the mortar at the moment the marble slab was applied⁽⁹⁾.

A survey at 1:5 scale made after cleaning permitted us to locate both the position of the slabs (through the remaining imprints) and the progression from bottom to top of the mortar in even horizontal bands (by means of the mortar joints); on the basis of the same survey we mapped the state of pre-conservation at the time of discovery as well as subsequent interventions.

In order to conserve the remains of the lost decoration in situ, we decided to intervene on this setting bed, treating it as if it were the complete decoration.

The conservation intervention involved the upper part of the niche. Excavation, by eliminating the dirt filling the niche, had caused an increase in the areas of detachment between plaster and support, with a consequent danger of collapse.

The intervention began with the help of J. Malliet of the ICCROM Research Team, using the hydraulic consolidant mix described above. This mix gave good results and its characteristics make it suitable for the first aid frequently needed on an excavation worksite. Often, because of the requirements of excavation, one must intervene on a plaster that has not yet lost the humidity of the ground. Or one must deal with the upper part of a plaster while the remainder is still buried.

In May 1985, excavation began along the eastern side of a medieval wall⁽¹⁰⁾ that bore traces of a frescoed facing.

In several places the plaster was completely detached from the support and some large plant roots had infiltrated. Elsewhere this wall had fallen and only the plaster remained, supported by the earth.

Thus a consolidation intervention was necessary prior to excavating the entire fresco. This operation was indispensable for fixing the edges of the plaster.

At the time of excavation the environmental situation of the medieval wall was exactly opposite to that of the opera quadrata wall described above. In this case the back of the wall had already been excavated, down to the foundations. It had had an opportunity to dry out and its constituent materials - brick and mortar, along with structural details - had permitted balanced evaporation of the moisture content.

The buried face of the wall would be exposed with the new excavation, and we expected evaporation phenomena limited to the moisture contained in the plaster or due to rising damp. As we could not predict how deep the fresco might go, or what the covering earth might contain, we imagined the most complex of possibilities, thus taking precautions against every eventuality.

Together with the archaeologists, having analyzed the stratigraphic conditions of the trench, we decided to excavate the area to within 155 mm of the fresco. The remaining dirt layer serves several purposes: as a sacrificial layer, permitting water to evaporate gradually as the excavation level deepens without influencing the plaster's state of conservation, and also as protection against possible digging accidents. Moreover the final operation to excavate the painted plaster is made easier and safer: when the moment comes, the final dirt layer can be removed from the front of the wall instead of from above, as happens when a fresco and the surrounding area are excavated together. There one runs the risk of scratching the surface already exposed. Perhaps this precaution seems useless, but with a simple intervention one helps the fresco to a gradual transition from the constant humidity of the ground to the thermo-hygrometric variations of exposure to the open air.

Finally, we would like to mention a system for taking samples of the plasters which was adopted in order to develop a useful archive of the types of fragments discovered during an excavation. The difficulty of cataloguing plasters is often due to the impossibility, with a fragment, of identifying structural characteristics such as the preparatory layers, the type of mix, or the type and grain size of the filler without resorting to chemical or physical analyses.

Taking as our model the technique of cross-sections⁽¹¹⁾ used for observation of the strata of the paint layer, we took plaster sections varying in thickness from 5 mm to 50 mm. Each fragment was set in epoxy resin⁽¹²⁾, sectioned and polished. This provides easy-to-manage samples that permit typological comparisons with plasters in situ. The samples were inventoried in such a way as to produce two catalogues: one arranged according to typology and the other according to the provenance of the various fragments. On the basis of this sampling one can recognize the need for chemical analysis of the most characteristic fragments, using an appropriate methodology⁽¹³⁾.

As one can connect some technical data to historical data, it is possible to interpret information that otherwise might have been lost.

An intervention of conservation in situ on a wall plaster is only the first link in a chain to which one must join all the other data pertinent to the history of the building. If one cannot make all the connections today, the work of sampling and cataloguing the fragments, which should soon be standardized, can become the key to understanding tomorrow.

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- 10) Trench XII, conducted under the supervision of M. Ricci.
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Figure 1.
Plaster on tuff: application of
tissue for temporary consolidation
of perimeter strip. Photo: author.

Figure 2.
Area under excavation: the
archaeologists leave a dirt layer
covering the frescoed wall in
order to avoid crystallization of
soluble salts on the paint layer.
Photo: author.

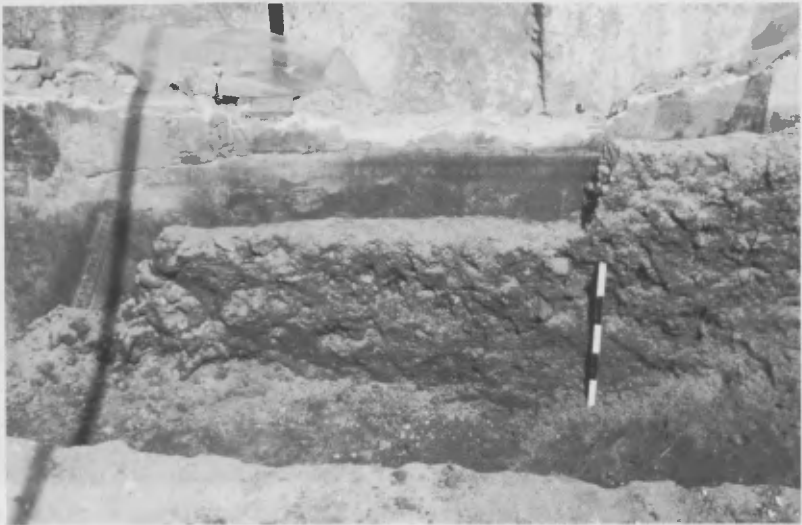




Figure 3. Frescoes being excavated: removal of vertical dirt layer. Photo: author.



Figure 4. Cleaning: the intervention is restricted to removal of dirt residues from the painted surface. Photo: author.

PROTECTION OF SITES UNDERWATER

PROTECTION DES SITES SUBAQUATIQUES

THE EXCAVATION, ANALYSIS AND CONSERVATION OF SHIPWRECK SITES

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SUMMARY

The wreck site of the iron steam-ship *Xantho* has provided a model for how an underwater archaeological site can be managed. Pre-disturbance surveys of the marine biology and the electrochemical and physical environment of the site established reference criteria for monitoring changes in the site conditions. Installation of a sacrificial anode system prevented further deterioration of the historically significant engine whilst conservation facilities were being constructed. Measurements made after excavation of the engine established that the removal of this massive structure did not significantly change the microenvironment of the remaining parts of the vessel.

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Fig. 1. Location of the wreck of the SS *Xantho*, 28°11.2'S, 114°14.1'E.

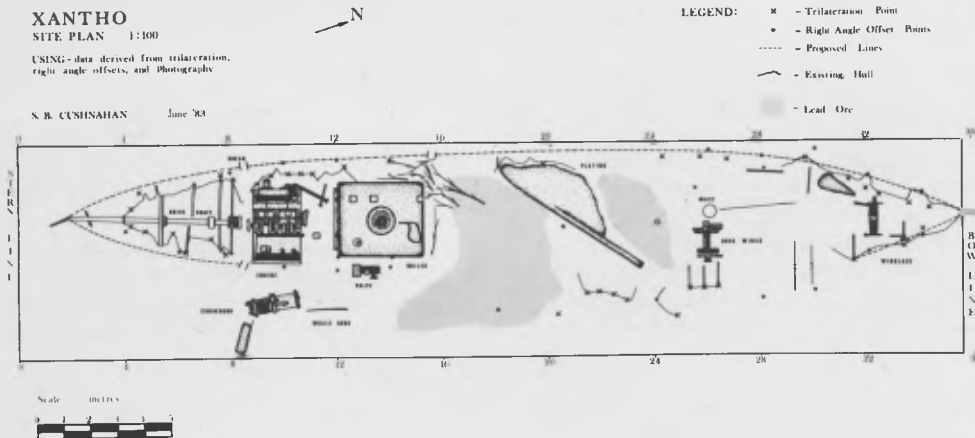


Fig. 2. Plan of the wreck site as examined during the predisturbance survey. The item noted as a condensor was later identified as a steam water heater.

INTRODUCTION

Apart from their intrinsic merit as archaeological sites, shipwrecks provide a wealth of information about how the vessels and associated artefacts interact with the environment. In the tropical to sub-tropical waters of Western Australia very few wooden structures survive the ravages of wood-boring organisms; it is only when timbers are buried under coral debris, ballast mounds or sand that any significant structure remains. Examples of these environments are seen with the sites of the *Batavia* (1629), *Rapid* (1811) and *James Matthews* (1841) respectively. In order to properly understand the factors governing the degradation processes that occur on underwater sites, conservators must work in very close collaboration with maritime archaeologists. Conservation staff must dive and be able to perform a range of in situ measurements if the maximum benefit is to be gained from an excavation. As well as routine photographic documentation of the distribution of artefacts, the on-site recording of corrosion phenomena is vital since many degradation products undergo marked and irreversible changes once they reach the surface. The majority of conservation staff first see artefacts in an isolated context, often months after an excavation, and this presents many problems. Interpretation of corrosion and other degradation phenomena as well as the choice of the most appropriate treatment are fraught with difficulty if the archaeological context of the artefacts is not known.

Six years ago the wreck of the iron steamship *Xantho* was discovered by a group of volunteer archaeologists, some 550 km north of Perth, near the fishing settlement at Port Gregory (Fig.1). A brief wreck inspection by a group of museum divers confirmed that it was the site of Western Australia's first screw-driven steamship which had sunk while carrying a cargo of the locally mined lead ore, galena. The most significant aspect of the site was that it was essentially untouched and as such presented an excellent opportunity to examine the physical, chemical and biological condition of an iron shipwreck in its undisturbed condition. Such studies have intrinsic merit in terms of pure scientific research but they are invaluable when applied to the excavation and conservation of historic shipwrecks.

This paper will report on all three phases of excavation from the pre-disturbance surveys in 1983 through to the final recovery of the *Xantho* engine. After the initial survey a cathodic protection system was installed to protect the historically significant steam engine from further corrosion. A second inspection showed that the site had been buried by four metres of sediment in only eight months. The third excavation season took place in April 1985 in an environment that had essentially returned to that which was initially observed. During the most recent season the engine was removed from the ship's structure and successfully brought ashore. It is now undergoing conservation treatment in the laboratories of the Western Australian Maritime Museum. Data obtained from other wreck sites will be utilized in the interpretation of phenomena on the *Xantho* site.

Detailed reports on the archaeology of the excavation of the *Xantho* site and the specialized techniques used in the recovery operation are to be found in reports by the project leader, and maritime archaeologist Mike McCarthy of the W.A. Maritime Museum (McCarthy, 1985).

PRE-DISTURBANCE SURVEY - MAY 1983: Marine Biology

In terms of basic research into the microenvironment created by a shipwreck the *Xantho* appeared to be an ideal long-term experiment in marine fouling and artificial reef formation. Although completely submerged at all times, part of the wreck stood three metres above the seabed with large quantities of cast iron,

steel, copper, brass and some white metal exposed to colonization and subsequent growth by marine organisms. Since parts of the boiler and engine were well above the sand level, they provided a chance to look at the interaction of marine growth and metal corrosion. With the time span of more than 100 years it was an ideal opportunity for looking at the effects of long-term interaction of wreck material with its environment. A plan of the wreck site is shown in Figure 2.

Initial inspection of the marine biology of the Xantho site showed up significant differences in the ecosystem compared with a nearby reef which was dominated by eel-grass communities with a large fauna of carnivores feeding on the organisms that lived in the grass. The shipwreck site was a tunicate-dominated community with sedentary filter feeders being the major colonizing organisms, with upright and encrusting sponges and a few encrusting bryozoa. Small chlorophytans (algae) were found in the light-rich areas (water depth 2.9 - 3.3 m) while large phacophylans were abundant in water deeper than 3.3 metres. The ship's boiler provided very good areas for studying the effects of the current on the marine growth since its long axis was essentially parallel with the direction of the strong current which ran at between 3 and 5 knots (1.5 - 2.6 m/sec). The boiler was approximately 3.2 m long, 2.8 m wide and 2.6 m high. A photograph of the boiler viewed from the port side is shown in Figure 3.

The observations on the biology of this structure are summarized below.

Top of boiler: surge perpendicular to current, approximately 0.5 m in amplitude. Apart from small tunicates living in the shelter of the remains of the steam dome, the top was encrusted with sponges and small green algae. Lower sections of the rounded top were colonized by large brown algae.

Forward side: periodic current fluctuations with a distinct demarcation of growth at 4.1 m depth. Above this line the growth was the same as on the top of the boiler but below, there were large tunicates (100 - 150 mm c.f. 70 - 100 mm in steam dome) and large upright sponges (50 - 100 mm high).

Port side: at depth less than 3.7 m the biological growth was similar to that of the top where the full force of the current is experienced. Between 3.7 m and 4.2 m depth there was a band of large brown algae down to the seabed at depth of 4.9 m.

Starboard side: the current runs along the plane of the face with large tunicates and small sponges covering the area between 3.3 and 4.0 m depth. The same organisms covered the remaining side to the sandy bottom at a depth of 4.7 m but with a much lower density. Above the 3.3 m level the growth was the same as at the top of the boiler.

Aft side: the water flow was irregular and the fauna was more varied than on the other parts of the boiler. The close proximity of the engine caused periodic backflows of water. The surface was covered with large brown algae from the 2.9 m to 3.7 m depth level where the sandy bottom had covered the lower parts of the fire box. Some feather worms and crinoids had colonized the interior of the exposed 70 mm diameter boiler tubes.

From the above observations it was apparent that the current exerts a marked effect on the growth of the marine organisms on the wreck. The strong current carried a large amount of weed and sea-borne grit which gave a turbidity of 2.5 to 3.0 metres at best but often it was less than one metre. There appeared to be a marked change in the colonization of the boiler at a depth of 4.2 ± 0.1 m, the

significance of which was to emerge in the second season. The chemical environment was typical of the coastal waters of Western Australia with a salinity of 37.53 parts per thousand and the pH of the sea water was 8.1 with a water temperature of 23°C. No thermal gradient was observed during our measurements in the 3-6 m range between 5th and 9th May. Although no direct measurements of dissolved oxygen were made it is reasonable to assume that because of the strong current and shallow depth it was close to 100% saturation.

METAL CORROSION

Previous experience on sites such as the *Rapid* (1811) had shown that electrochemical measurements of parameters determining metal stability could be effected either on site or immediately the objects were raised (North, 1976 and MacLeod, 1981). The knowledge of parameters such as the pH and electrochemical potential of a metal combine to provide a very handy guide as to whether there have been changes in the microenvironment of a metal, whether or not it is actively corroding and whether any solid metal remains. Since the *Xantho* was the first iron steamship to be systematically examined by the Western Australian Museum, it was decided in conjunction with the project leader that an electrochemical survey of the site be made before any disturbance occurred. By examining the wreck prior to excavation we had access to a 100 year controlled corrosion experiment. Simulation of long-term marine corrosion phenomena in a laboratory situation is very difficult and there are many problems involved in the extrapolation of data from short term studies (Taylor and MacLeod, 1985).

When metals are placed in oxygenated sea water they will begin to corrode. Positively charged ions are produced as the metal oxidizes and precipitated in the surrounding concretions or disperse in the sea. Each metal corrodes at a rate that depends on variables such as temperature, dissolved oxygen, salinity, water movement and the inherent reactivity of the metal in relation to water. Some metals react explosively with water, others corrode at a steady rate while yet other metals remain largely unaffected by immersion in water. Examples of these three categories are sodium, iron and silver, respectively. A convenient way of comparing such phenomena is to measure the voltage of a metal in equilibrium with a standard solution of its salts dissolved in water. Reactive metals give negative voltages, compared with the standard voltage of zero for hydrogen in an acid solution, whilst noble metals such as copper have positive standard voltages, E° 's or standard reduction potentials.

Since we are concerned with metals in a marine environment, the solutions under consideration pertain more to sea water than to standard acid solutions. Because chloride ions alter the rates of many electrode processes (e.g. metal oxidation - metal reduction) the standard electrode potentials (E° 's) of the metals in "standard sea water" are different from those in ordinary water. Iron and, less commonly, copper and its alloys are often covered with a layer of marine growth which effectively places the metal in an environment which is different from normal sea water (North, 1976; MacLeod, 1982). Such environments tend to have a higher chloride concentration and lower pH and much lower oxygen concentration than ambient sea water since the concretions act in many ways as a semi-permeable membrane which inhibits rapid transport of some ions and gases.

When a metal is corroding, one of two processes limits the rate of the corrosion reaction: it is either the rate of the cathodic process (which is commonly called oxygen reduction) or the rate of the anodic process (metal dissolution). Other cathodic processes include the reduction of hydrogen ions to hydrogen gas and the

reduction of sulphate to sulphide ions. For most cases involving concreted metals the rate of oxygen reduction is the controlling factor that determines how fast the object will corrode. The voltage of a metal object in the sea will be dependent on how fast the metal is corroding and this is interdependent on the pH of solution adjacent to the corroding object. If we have a knowledge of the pH and the voltage of the corroding metal (commonly called the corrosion potential, E_{corr}) we can tell whether the metal is immune (cannot corrode), is passive (very slow corrosion) or if it is actively corroding. Since the voltage is dependent on both the metal oxidation and cathodic reduction processes the voltage is also known as a "mixed" potential. Such electro-chemical data are conveniently presented in a Pourbaix diagram (Pourbaix, 1974).

XANTHO DATA

The corrosion potentials were measured in situ using a high impedance digital multimeter (Fluke 8010A), a platinum electrode (0.8 mm thick) housed in an epoxy body and a silver/silver chloride reference electrode (Titron model No. 211). Subsequent measurements were performed using a different silver chloride reference electrode (DIMET). Sea water was used as the reference solution. The procedure consisted of drilling into the concretion (using a 1/4" masonry bit and a hand drill) and placing the platinum electrode into the hole while pressing firmly to establish good electrical contact; the reference electrode was placed adjacent to the concreted metal surface and the voltage measured. For the resistance survey the reference electrode was replaced with a stainless steel probe (see Fig.4) and both were brought into contact with the holes drilled in the metal concretion.

A summary of the results of the survey are shown in Table I and also in a diagrammatic way in Figs. 5 and 6 which show the Pourbaix diagrams for iron and copper in sea water. Although in situ pH measurements were not done on the wreck material, we have estimated the pH of the metal under concretion on the basis of our previously published data on iron and copper-based concretions (North, 1976, MacLeod, 1982). When the iron concretion was being drilled bubbles of escaping gas were occasionally observed - the gas is mainly hydrogen and light-weight hydrocarbons that are formed as a result of the corrosion process (North, 1982). Inspection of the Pourbaix diagram shows that the potential of the frame plates lies on the hydrogen discharge line, viz. at such potentials and pH, water is in equilibrium with one atmosphere of hydrogen gas. Seventeen of the twenty-five sites measured had a corrosion potential of -0.268 ± 0.004 volts vs NHE (or -0.0539 vs AgCl seawater); in effect this shows that they are all in essentially the same corrosion microenvironment. From the observed relationship between corrosion currents and voltage in laboratory experiments, the standard deviation of 6 mV means that the rates of corrosion are within thirty percent of each other. The difference of 113 mV between the corrosion potentials of the deck winch and the frame plates near the stern reflects a ten-fold difference in their relative corrosion rates. The value of -0.103 volts for the windlass is typical of potentials where no solid metal remains and this was indicated when the drill bit penetrated to a depth greater than 100 mm without striking solid metal.

All the potentials observed for the non-ferrous fittings showed that they are all in the immune (for copper and brass) (Fig.6) or passive zones (white metal on crankshaft bearings). The corrosion potentials of the brass steam cocks and valves are largely determined by the iron corrosion potentials since the objects are in electrical contact with the iron metal which has a much larger mass and surface area. Although the copper and iron fittings on the engine have the same potential the results are different; copper and brass will not corrode while iron is actively

corroding. The concretion layer observed on the brass and copper fittings was a few mm thick and consisted of a dense white calcareous deposit. Because of the galvanic protection provided by the corroding iron, the copper based alloys act as cathodic sites in the corrosion cell and this causes the surface pH to increase and inorganic calcium carbonate as calcite/aragonite precipitates on the metal. Once this "protective" layer of CaCO_3 covers the biologically toxic metal corrosion products, the surface is then subject to normal colonization by marine organisms. The CaCO_3 layer appeared to act as a barrier to oxygen diffusion since under its protection some of the Cu_2O on the metal surface had been converted to Cu_2S through the action of sulphate reducing bacteria. The less negative potential for the copper tubes and case on the steam water heater is simply due to the relatively small mass of iron attached to the copper tubing which has a large surface area.

Although the corrosion potential of the white metal bearings on the crankshaft is -0.268 volts vs NHE is outside the immunity range for lead it is in a region of stability of passivation through lead sulphate (anglesite) formation. On-site inspection suggested that the 2.5 mm film covering the bearings was a mixture of anglesite and calcite (PbSO_4 and CaCO_3 respectively).

SUMMARY

The electrochemical survey on the metal structures of the shipwreck gave us three parameters that are directly related to the condition of the underlying metal, i.e. corrosion potential, presence of entrapped gases and the depth to solid metal. The engine and the boiler are in relatively good condition with low potentials, no significant gas evolution and solid metal relatively close to the original surface. The non-ferrous components of the engine and boiler are in excellent condition with potentials too low for active corrosion. The hull remains were in a fair condition with the amount of corrosion attack being higher in the forward areas than in the stern. The windlass is very badly corroded with the concretions alone retaining its shape - very little solid metal would remain. Similarly the iron steam fitting attached to the copper coils appears to be in an extensively corroded condition.

MINERALOGY OF ORE CARGO

Samples of the galena (lead sulphide) ore were taken for examination under a scanning electron microscope. Mineralogical analysis of the original high purity ore showed that small amounts of minerals other than galena were associated with the deposit, namely lead carbonate, zinc blende, iron pyrites, blue slaty clay and quartz (Wilson, 1926). Since there were no arsenic or mercury compounds in the galena it is unlikely that there was any marked influence on the marine ecology from material leached from the minor compounds of the galena. The SEM micrographs of the galena samples recovered in the pre-disturbance survey (Fig.7) showed that some of the mineral had oxidized. Lead had migrated out of the galena matrix to the surface where it was deposited in two forms. The spikey crystals are phosgenite ($\text{PbCl}[\text{CO}_3]0.5$) and the plate-like crystals growing into cubes are the hydroxy carbonate hydrocerussite $\text{Pb}_3(\text{OH})_2(\text{CO}_3)_2$ (Thorner, 1985). A sample of iron concretion downstream from the mound of galena had 162 20 ppm lead while a sample of concretion from Vergulde Draeck (1656) which carried general cargo, was 61 ± 6 ppm. The significance of the solubilization of lead from the cargo (Mann & Deutscher, 1980) on both the corrosion rates and marine biology is yet to be determined. The amount of lead in the concretion from the Vergulde Draeck (1656) site probably reflects uptake of lead in seawater by marine organisms such as coralline algae (Stenner and Nickles, 1974).

EXCAVATION AND INSTALLATION OF CATHODIC PROTECTION SYSTEM

In order for the archaeologists to make detailed drawings of the historically important engine, it was necessary to remove a lot of the living marine growth from the engine. Only loosely attached material was removed since the hard calcareous concretions over steel and cast iron protects the underlying metal from accelerated corrosion (North, 1982). The surface cleaning also revealed many bright brass fittings which would attract the attention of a sports diver. The electrochemical survey had also resulted in many small holes having been drilled into parts of the structure. It was decided to install a sacrificial cathodic protection system to protect the engine from further corrosion.

In general terms a sacrificial cathodic protection system consists of a highly reactive disposable metal which is in electrical contact with a less reactive metal. This forms a galvanic couple with the more reactive (and expendible) metal suffering increased corrosion attack and the less reactive metal, usually steel, being protected against corrosion. Details on cathodic protection are readily available in standard text books on the subject (Shrier, 1976).

There are several desirable effects that could be obtained from installation of a cathodic protection system for the Xantho engine. Apart from corrosion control the action of cathodic protection generates alkali at the metal-seawater interface and thus raises the pH of the sea water which causes calcium carbonate to precipitate. The white calcareous deposit would hide bright copper/copper alloy fittings under a paint-like layer and so help to protect them from theft by divers. The cathodic protection system would also tend to block up any of the holes drilled during the potential survey. Under normal site conditions copper artefacts tend not to be concreted, owing to the toxic nature of their surface. Under cathodic protection the toxicity of the metal is greatly diminished and colonization by marine organisms is not impeded (MacLeod, 1982).

DESIGN AND INSTALLATION

In order to be cathodically protected, the object must be in metal-to-metal electrical contact with the anode. An electrical continuity survey was performed by measuring the electrical resistance between different points on the engine, boiler and drive train. Because of the electrical conductivity of sea water it is difficult to establish which pieces of metal are in metal to metal electrical contact since the value of a metal/sea water/metal pathway may also be very small. There is also the problem of making good contact between components and so one of the resistance probes was always in contact with either copper, brass or white metal in an attempt to minimize such problems. The survey showed that the engine formed a single conducting unit which was also electrically bonded to the propellor shaft. Most of the copper pipe work was in electrical contact with the engine but there was no apparent metal-metal contact from the engine to the hull remains or to the boiler or the steam water heater.

It was decided to install two protective anodes on the engine. Each anode consisted of a 2 kg magnesium anode welded to a 25 kg aluminium anode. Sufficient cable was used to place the anodes outside the hull remains and at a sufficient distance from the engine (3-4 m) to give a good current spread. The anode cables were welded to a clamp system which was bolted onto the propellor shaft and onto a white metal bearing on the crankshaft. Each clamp was individually designed to fit the particular part of the engine. Before attaching the clamps each point was deconcreted back to the original metal. No apparent problems occurred during the installation.

SITE DISTURBANCE - 1984

As a result of the initial survey the boiler and the engine had been cleaned of the bulk of the marine growth and a cathodic protection system had been installed on the engine. It was planned to check the regrowth on the engine and the functioning of the cathodic protection system after eight months of operation. It was presumed that the warmer spring and summer months of October through to January would have seen significant recolonization of the engine. Since the boiler and engine were not electrically connected a comparison of the regrowth on these objects would have given information on the effect of cathodic protection on the marine ecology. Physical inspection of the site showed that the seabed conditions had altered markedly since the pre-disturbance survey.

The whole engine was covered in sand and only the top 1.5 m of the boiler was exposed. Skeletal remains of surpulid worms, coral, bryozoans and assorted molluscs were still attached to the surfaces of the boiler but no animals remained. The top 0.9 m of the boiler had an extensive growth of green filamentous algae with some small brown and white banded fan seaweed and light brown banded ribbon seaweed approximately 75 mm long. The lower 0.6 m of the boiler had only a small growth of green filamentous algae. These observations, when combined with the reports of local divers, suggest that until a few weeks before our return trip the whole site had been completely buried for some time. The current began to scour the site and exposed the top 0.9 m of the boiler in the last week of 1983 and further began to clean away the next 0.6 m in the first two weeks of January 1984. Periodic burial is the obvious explanation for the marked change in colonization of the boiler at the 4.0 ± 0.2 m depth that was observed in the initial survey (see Fig.3). Any comparison of regrowth with and without cathodic protection was made impossible by the burial. After removing the metre-thick overburden of sand from the engine (using water dredges manned by the archaeologists) corrosion potential measurements were made on the anode attachment bracelets. The bracelet on the crankshaft bearing was only -0.450 volts vs hydrogen whereas effective cathodic protection is only obtained with voltages as low as -0.540 to -0.610 volts vs SHE (Wilkins, 1982). The bearing itself had a potential of -0.264 volts which indicated that there was poor electrical contact between the bracelet and the object (see Table II). Although the 5 mm thick white calcareous deposit on the bracelet indicated that the anodes had been working, it was readily apparent that they were not functioning under several metres of sediment. The bracelet on the propeller shaft showed even less apparent protection than the fitting attached to the crankshaft.

The following day, attempts were made to excavate the anodes but the fine sand gave way, only one metre down below the current seabed, to a mixture of fine sand and clay. This matrix could only be shifted by breaking it up with a geopick. Equipment and personnel constraints meant that the anodes had to remain buried. Aluminium anodes are designed to function in open sea water and although they can perform satisfactorily under one metre of fine sand they cannot function under a metre of clay which is overlaid with three metres of sand.

The apparently anomalous marine ecology of the Xantho site as first observed can readily be understood in terms of the burial phenomena described above. The "newness" of the biological environment on the wreck site compared with the surrounding reef is most probably due to the fact that the whole site is periodically buried under several metres of sand. It may be that such burials are due to the scouring of the upstream beaches during heavy winter storms. Apart from killing all the colonizing marine animals, the burial causes the site to change from an aerobic to an anaerobic one. The mixed cuprite (Cu_2O)/chalcocite (Cu_2S) patina observed under the thin layer of calcite on some of the brass pressure relief

valves (on top of the trunks) is readily explained by periodic changes from aerobic to anaerobic environments.

Examination of a polished specimen of copper wire from inside a water spray device, found lying proud of the seabed in the 1979 wreck inspection tour, showed up a typical banded formation with layers of the copper sulphide chalcocite (Cu_2S) (Fig.8). Such banding is consistent with the periodic exposure to anaerobic/aerobic conditions over the last 110 years that would occur each time the site was buried/exposed.

Since the pre-disturbance survey had indicated that the engine appeared to be in a remarkably good condition, the archaeologist in charge of the project decided to attempt to recover the engine for the purposes of research and display. As the only remaining example of the first mass-produced marine steam engine, the Xantho is of prime importance to industrial archaeologists. In order to minimize any damage to the site, excavations of the seabed were made only in the vicinity of the four steel bearers on which the engine was supported. A thermal lance was used to cut through the badly corroded iron beams and this let the engine settle onto a support system of 100 mm square blocks. Details of this phase of the excavation have been reported elsewhere (McCarthy, 1985). The engine was partly disguised with rocks in an attempt to make the structure less obvious when viewed from the surface.

RECOVERY OF THE ENGINE - APRIL 1985

Before commencing any dredging operations the site was inspected and shown to be in a similar physical condition to that found in the initial survey in May 1983, except that the current was greatly diminished. Corrosion potential measurements showed that no change had occurred in the microenvironment of the metal in the boiler. The fact that the potentials were the same indicates that the concretion layer tends to insulate the metal from changes at the sea water-concretion interface (see Table II). The water temperature was 21.5°C and the salinity at the 7 m level was 37.3 parts per thousand which is essentially the same as during the initial inspection. The areas of the brass steam valves and tool box by the propeller shaft that had been exposed to bare metal were repatinated with a thin layer of calcareous material. Potential measurements showed that they had the same potentials as the iron objects in the immediate vicinity. The deposition of calcium carbonate on the exposed areas of the brass fittings was more probably due to the protection gained from the iron itself rather than from the sacrificial anode system. Measurements of the corrosion potentials of the anode bracelets showed a small improvement in the propeller shaft potential (towards protection) but a lowering of the extent of protection on the crankshaft bearing when compared with the previous readings fifteen months previously (see Table II).

During the clearing of the surrounds of the engine, the anaerobic nature of the seabed material was noted through the rapid tarnishing of sterling silver rings on the divers' hands and poisoning of the silver/silver chloride reference electrode with hydrogen sulphide. The regrowth on the boiler was about half as intensive as during the initial inspection of the site which may indicate that we had seen two years' marine growth in the first instance. Typical fouling rates in shallow and warm coastal waters can be up to $20 \text{ kg/m}^2/\text{year}$ depending on current, supply of nutrients and the season (De Palma, 1982).

The team leader, two riggers, one photographer and a video cameraman formed the crew that raised the engine from the seabed and recorded the exercise. Details of the techniques used in raising the 7.8 tonne artefact can be found in forthcoming

reports - the basic procedure consisted of attaching several air bags to the engine using heavy-duty, 5 cm thick, synthetic rope and broad-woven lifting strops with lifting capacities of 1 tonne per thickness. The engine was cushioned from localized lifting pressure by distributing the load with sandbags (Fig.9). After clearing the site, the engine was towed to a steel sled in shallow water. The sled was then raised and attached to the engine before both were gently lowered to the seabed by deflating the lifting bags. One day after removing the engine, and immediately prior to its being brought onto dry land, the corrosion potential was remeasured at the same reference point. The voltage was the same as found on the initial survey (within experimental error) and 121 mV more positive than before the cable from the anode was cut (see Table II). Although the anodes were not operating at full efficiency, the observed swing of 121 mV in the steel potential would have caused a reduction of approximately 90% in the iron corrosion rate, i.e. the anodes gave effective protection to the engine. The potential of the boiler and the copper steam water heater were remeasured on the main site and found to be unchanged by the removal of the engine, i.e. we were able to demonstrate that extraction of the engine caused no immediate changes in the microenvironment of the remaining artefacts.

The sled and engine were brought ashore by pulling the sled along the seabed with chains attached to a bulldozer and an articulated front-end loader. The sled was dragged along the beach and up onto level ground where it was secured. After being photographed, the engine was saturated with fresh water then covered with a layer of sodium carbonate (dense soda ash) before being wrapped up in wet hessian. The hessian was covered with a layer of a polymeric gel material (Erosel, a polyamide) which effectively stopped the engine drying out. The hessian was covered with a heavy-duty black plastic membrane and this was overlain with a tarpaulin. Despite the strong easterly winds and high daytime temperatures (30°C), the engine remained wet between the daily "baths" of fresh water* which was poured over the hessian. Although the hessian would tend to dry out, the gel coating stopped any significant evaporation of the underlying material and so maintained a moist alkaline environment for the engine. The use of sodium hydroxide solutions was ruled out because the brass and white metal components would have corroded. The health hazard created by a strongly caustic solution oozing onto a public car park also precluded its use at the holding site. Before transporting the engine to Perth it was again uncovered and photographed using specialized survey equipment (stereographic photographs from four sides using full-sized glass plates) so that a three dimensional record would be retained in the event of damage to the engine on its road journey. After five days on land the engine was lifted by a crane and placed on a bed of sandbags over the forward section of an articulated heavy haulage vehicle. A plastic membrane placed under the bags was sealed with tape to a similar covering over the engine. Before the final seams were taped, 200 litres of fresh water was poured into the giant plastic bag - this kept the engine wet until we reached our overnight stop. The following day more water was added for the second leg of the 550 km trip to the laboratories in Fremantle. Inspection of the engine at the end of the road trip showed no apparent damage to the protective concretion layers and there were no tell-tale red-brown rust spots on the artefact which would have indicated fresh corrosion attack. The engine was lifted by a crane and lowered into a specially-built steel treatment tank some 3 m x 3.5 m x 2 m deep.

The storage, deconcretion and conservation of the engine will be reported in later publications. Some idea of the scale of the exercise is seen in the quantities of materials involved in the treatment. A total weight of 1.8 tonnes of concretion has

* Although in limited supply the local tap water was used to wet the engine; the chloride level was 897 ppm.

been removed and after only three months of treatment more than 10 kg of chloride ions have washed out from the engine into the 14 m³ of 1 wt% sodium sesquicarbonate solution. Test drillings into the cast iron fittings show corrosion depths of between 1 mm and 3.5 mm which correspond to corrosion rates of 100 to 32 µm/year. The average corrosion rate for iron in a marine environment is 100 µm/year with a range from 25 to 190 µm/year (La Que, 1975) so the observed values for the engine fall within the range of other long-term studies. More research is needed to establish whether or not the engine was protected in part by preferential corrosion of the hull plates and other parts of the ship's structure. The cyclic changes of the site from aerobic to anaerobic conditions is probably the most significant factor in determining the extent of corrosion on the engine.

SITE PROTECTION

It is planned to raise the stern section of the hull in 1986. The rudder, propellor and two frames being removed from the site will be transported in a similar fashion to the engine. Since the stern is one of the strongest parts of a steam ship, its removal could cause the collapse of any remaining structure. To prevent such an occurrence, concrete sections will be laid in situ to act as a retaining device for the hull. Sacrificial anodes will be attached to the remaining sections of the hull to minimize further corrosion. Concretion samples will be taken from the areas upstream and downstream from the lead ore and analysed to further clarify what effects the galena has had on the corrosion and colonization processes. The site will be periodically inspected by members of the excavation and conservation team to see what effects the removal of the engine has on the nature of the site. Since the massive boiler bears the brunt of the current, it is anticipated that the sections of the wreck aft of the engine will not be adversely affected by this first stage of excavation. Sufficient ship's structure remains for the site to be immediately identifiable as that of the SS Xantho. Souvenir clothing and spoons, marked with the excavation logo, are available at the local shop and this practice has resulted in a greater public awareness of the site. The local fishermen now keep a watchful eye on the site to protect it from being damaged by divers.

CONCLUSION

The work on the Xantho has shown how a wreck site can be managed so that the maximum benefit can be obtained from an excavation.

The close co-operation between maritime archaeologists, conservators, biologists and corrosion scientists enabled a pre-disturbance survey to be carried out prior to any effective excavation. On the basis of measurements made during the survey, it was decided to raise the historic, horizontal trunk steam engine and to transport it over 550 km to the laboratories for treatment. A sacrificial anode system was installed to protect the engine from further corrosion whilst treatment facilities were being constructed. Dramatic changes in site conditions resulted in a poorer performance by the anode system than we had hoped for but measurements showed that the system had worked. Monitoring of the site during and after excavation of the engine showed that the operation had been effected without any damage to the engine itself or to the remaining structures. The experience gained with the Xantho has already been applied to excavations in remote locations where a large anchor from HMS Sirius (1790) was protected by sacrificial anodes whilst awaiting construction of a treatment tank (MacLeod, 1985 b). The possibility of treating large metal structures "in situ" has major implications for preserving underwater archaeological sites.

ACKNOWLEDGEMENTS

We are most grateful to Mike McCarthy, the project leader, for the chance to participate in the excavation programme. His encouragement and enthusiasm have been instrumental in overcoming many problems. The use of SEM and XRD facilities at the Mineralogy Laboratories of the CSIRO at Floreat Park (Perth) is gratefully acknowledged.

TABLE I: Corrosion potentials of objects on the SS Xantho site, before disturbance.

| | E _{corr} ⁺ , volts vs SHE | Observations |
|--|---|--|
| Propellor shaft, crankshaft, plating near stern, engine block connecting rod, stuffing box, etc. | -0.268 ± 0.004 | some gas evolution on penetrating 22 mm concretion |
| Boiler | -0.270 ± -0.283 | concretion 4-12 mm |
| Deck winch | -0.216 | gas evolved, concretion 50 mm |
| Windlass | -0.103 | no solid metal, drill in 110 mm |
| Brass steam cocks | -0.266 | very thin concretion |
| Frame plates | -0.280 | gas bubbles |
| Steam water heater (copper coils) | -0.163 | not much solid iron |

⁺ Potentials were measured with a platinum electrode using a Ag/AgCl sea water reference which was calibrated using the voltage of the platinum electrode in a pH 4.0 solution saturated with quinhydrone.

TABLE II: Corrosion potentials of the Xantho engine before and after excavation.

| Object | Corrosion potential, volts vs SHE* | | |
|--------------------------------|------------------------------------|-----------------------------|------------------------------|
| | Pre-disturbance | Anode connected 8 months | Post excavation 23 months |
| Propellor shaft | -0.269 | -0.295 | -0.319 |
| Crankshaft bearing | -0.268 | -0.450 | -0.395 |
| Boiler** | -0.270 | (-0.270) | (-0.270) |
| Copper/iron steam water heater | -0.163 | - | -0.159 |

* Voltages were measured using Ag/AgCl sea water reference electrodes which were calibrated against a platinum electrode in a quinhydrone solution at pH 4.0.

** Potential measurements on the boiler were unaffected by the sacrificial anodes since it was not in direct electrical contact with the engine.

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Fig. 3. The *Xantho* boiler as viewed from the port side during the predisturbance survey. The inside measurement of the square grid scale against the boiler is 1.0 metres. Photo: Pat Baker.



Fig. 4. Drs. MacLeod and North measuring corrosion potentials on the *Xantho* site during the predisturbance survey. The concretion on a piston is being drilled so that the potential measurement on the underlying material can be made. Photo: Mike McCarthy.

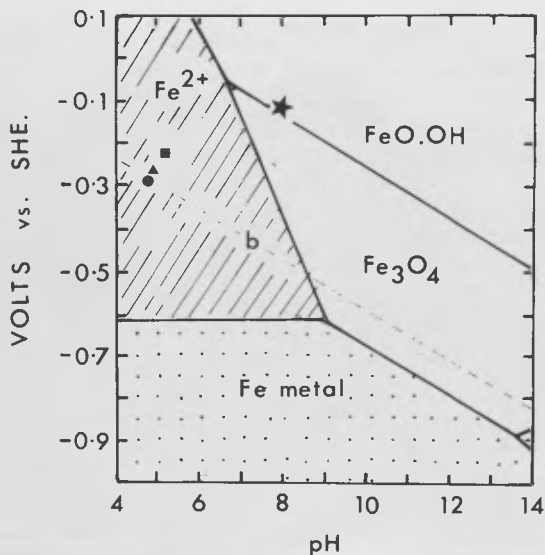


Fig. 5. Pourbaix diagram for iron in equilibrium with a 10^{-6}M Fe^{2+} solution showing on-site corrosion potentials for various parts of the engine. ★Windlass, ■deck winch, ▲mean potential of sixteen objects, ●frame plates, b represents the equilibrium line for water and one atmosphere of hydrogen gas.

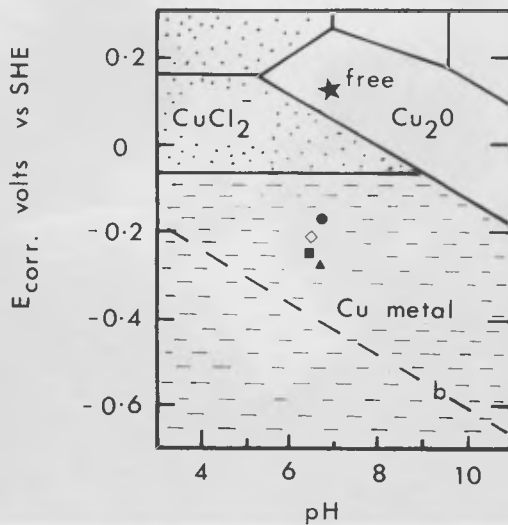


Fig. 6. Pourbaix diagram for copper in sea water in equilibrium with a 10^{-6}M copper solution. The on-site corrosion potentials illustrated are for ★free copper pipe between the boiler and the engine, ●unidentified copper fitting on engine, ◊steam pipe on water heater, ■small copper pipe on engine and ▲for brass steam cocks attached to the engine.



Fig. 7. Scanning electron micrograph of the oxidized galena ore. The spikey crystals are phosgenite ($\text{PbCl}(\text{CO}_3)_{0.5}$) and the plate-like crystals are hydrocerussite, $\text{Pb}_3(\text{OH})_2(\text{CO}_3)_2$ which overly the present galena crystals. Full width of the photograph is $750\mu\text{m}$.

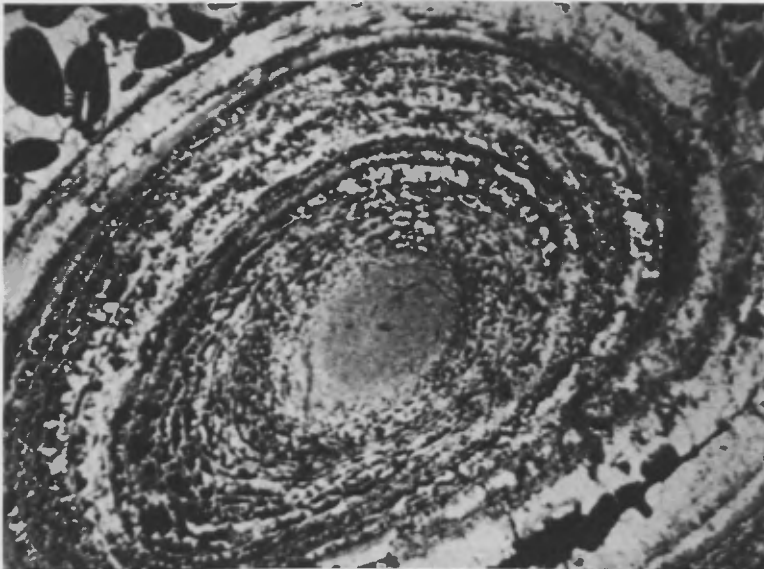


Fig. 8. Scanning electron micrograph of a mounted cross-section of mineralised copper wire. The light grey material is the copper mineral chalcocite (Cu_2S) while the black material is predominantly calcium carbonate. The banded formation is centred around a core of residual copper oxide. The full width of the photograph is 2.6mm .



Fig. 9. Raising the *Xantho* engine. Photo: Pat Baker.

PROTECTION OF AUSTRALIA'S UNDERWATER SITES

Michael McCarthy*

SUMMARY

The vast majority of Australia's known underwater sites are shipwrecks, and 50% of those declared historic to date are iron hulls or steam ships.

This paper will examine some specific case studies and general programmes in Australia, aimed at reducing natural degradation of these sites and at minimizing the negative effects of human activity before, during and after excavation. Also examined, in the light of the above, is the need to make specialist conservators a part of the underwater team itself. The need for routine pre-disturbance analysis of sites, public involvement and education programmes is also discussed.

Finally, in examining the author's excavation of the iron-hulled SS *Xantho*, the results of a pre-disturbance analysis on site and the continued use of specialists throughout this project, the benefits of the application of some of the above ideas become apparent.

This paper is allied to that of MacLeod, North and Beegle, also published in this volume.

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INTRODUCTION

The Western Australian Museum's Department of Maritime Archaeology was established by Jeremy Green in 1971, primarily to manage the sites of four Dutch and one English East Indiamen of the 17th and 18th centuries. That department has expanded its field of interest and involvement into Colonial period wrecks and the restoration of historic vessels under Graeme Henderson, and lately into the fields of display, public and professional education.

Part of the reason for this broad range of interest and involvement is that the department is well staffed and, more importantly, is "museum based" with public education and display a part of its acknowledged task. Other Australian maritime archaeological units are also museum-based and/or serve a local region or state.

With this regional or museum orientation, the need for public sympathy and involvement are, along with professional attempts at site stabilization, key considerations for maritime archaeologists in the protection of Australia's underwater sites.

Following is a discussion of four factors seen to be of importance in minimizing the effects of human interference on wreck sites. Allied are a number of case studies outlining attempts to minimize the above and the forces of natural degradation on site.

PRE-DISTURBANCE ANALYSIS

From a reading of specialist papers (e.g. MacLeod & North, 1980; Robinson, 1981) dealing with the conservation of shipwreck structures, there appears a need for routine physical, biological and chemical pre-disturbance analyses of all submerged sites being considered for excavation. Apart from MacLeod (1981) and North (1982), most of the papers are based on excavation reports and the examination of wrecksite material on land.

In 1982 following discussions with staff of the WA Museum's Department of Material Conservation and Restoration, the author (then in charge of the WA Museum's Wreck Inspection Program) advocated the inclusion in future site inspection reports of data:

"seen of importance where conservation of marine artefacts or even of the site itself is to be undertaken".

The required data was then selected by specialists in the conservation of submerged iron, non-ferrous metals and organic materials: Drs Neil North, Ian MacLeod and James Pang respectively. These were temperature, salinity, pH and dissolved oxygen content, water movement and purity, bottom type analysis, corrosion products and marine concretions. (McCarthy, 1982).

SPECIALISTS ON SITE

In order to obtain maximum efficiency and benefit in the compilation and analysis of this data, however, personnel experienced in dealing with the equipment and the analysis of the results should be involved from the outset, i.e. they should dive. Experience has shown that by working underwater, their own understanding and interpretation of this data and its ramifications are also enhanced.

In a well-staffed conservation laboratory such as that at the WA Museum and other centres around the world, there are also specialist conservators trained in the handling of specific materials and artefacts such as ceramics and glass, wood, iron, non-ferrous metals, textiles and so on. It is apparent that conservation staff could bring these specific skills and understandings to the site itself once they became competent underwater and are taught how to deal with the concretions in which these materials often appear.

With this in mind, the author, a CMAS diving instructor, offered places in his dive classes to those staff of the WA Museum's conservation laboratory who could not dive. The net result now in Western Australia is that when a site inspection reveals a predominance of any particular type of artefact or structure on site, e.g. iron hulls, the archaeologist or project director is in a position to choose his/her conservation specialist to suit.

LEGISLATION

One major effect of the enactment of the 1976 Australian Commonwealth Historic Shipwrecks Act was to rid the scene of the confusion caused by existing salvage laws. The situation is now very clear in relation to sites believed to be historic, i.e. they belong to the people through the auspices of the Commonwealth Government. Divers can expect to be rewarded or even given compensation but they have no rights to the site or its contents. Australian shipwreck legislation also assists in the prevention of intentional or unintentional human interference on wrecksites by the provision of penalties for unlawful interference, rewards for finding sites and where necessary, partial exclusion of sport divers and complete prohibition of all activity, e.g. fishing, mooring, diving, etc. (O'Keefe & Prot, 1984).

Even the act of declaring a site historic and thereby invoking protective legislation attracts public interest and, with policing problems on our vast coastline, public sympathy is a necessary adjunct to this legislation.

It is now well recognized that sites are often best protected if left alone, and searching for wrecks is seen by many professional maritime archaeologists as serving only to hasten their demise as archaeological units. Archaeologists themselves are under mounting pressure to justify their own excavations with the realization that their activities can also serve to destroy sites (Gould, 1981).

PUBLIC INVOLVEMENT AND EDUCATION

In order to minimize the dangers of intentional and unintentional human interference, public and professional education programmes and public involvement have long been recognized as matters of legitimate concern for maritime archaeologists (Roper, 1978). Amateur archaeological associations have flourished in Australia with many even preceding the establishment of their professional wing. The involvement of such associations is the subject of debate but it is clear that underwater archaeology (by nature of its medium) requires the use of a large pool of capable volunteers. If used it is clear that they must be trained before they appear on site in the skills and philosophies of underwater archaeology.

The most tangible results in the use of volunteers are reduced costs and greater diver time spent underwater. An obvious but not so visible result is the channelling of often very capable and motivated wreck hunters into the more accepted areas of survey, excavation under direction, cataloguing and drawing, etc.

The WA Museum has embarked on many public education programmes, notably displays, seminars, conferences, illustrated talks, open days and so on. The many sports divers on our shores, however, require more than static land activities and many are not interested in being involved in maritime archaeology. To this end, the Rottneest Wreck Trail pilot study was instigated by the author in 1979.

THE UNDERWATER DISPLAY CASE

This pilot study involved the marking of wrecks underwater with glass plaques and on land with brass information plaques and the provision of an historical pamphlet giving details and directions to the sites (figs.1-2).

As such, it is a mixture of ideas from a similar trail in operation at the Fathom Five Provincial Park in Canada and an underwater nature trail at the Virgin Islands.

It differs in its application to divers and non-divers alike, with an associated land trail, local island museum exhibition and visits to some of the wrecks by glass bottomed boat and lately, a semi-submersible. Diver and public reaction has been positive and they see the archaeologists actively assisting them in the development of the underwater wreck resource for the good of all.

The lesson has not been lost on the legislators, for the ideas embodied in the Rottneest pilot saw the addition of the criteria for protection of sites under the Historic Shipwreck Act increased to add those of sites with educational and recreational value (Amess, 1983). The author is currently responsible, amongst other things, for the WA Museum's amateur wing (the Maritime Archaeology Association), site inspection and public education and was also able to bring the museum's weight behind schemes to scuttle obsolete vessels in attractive underwater areas, accessible to divers.

The Rottneest pilot project is being examined in other Australian States with South Australia and Victoria now also inviting the public onto selected sites and others planning to follow suit. The net results of these schemes is to take pressure off historic wrecks in that newly qualified sports divers have invited access to a selected number of accessible sites. Following this formative and very active period in their underwater life, newly qualified divers either stop diving altogether, dive at a much reduced rate or go on in rare cases to become real enthusiasts.

It is hoped that by giving divers, the diving shops and boat charter firms invited access to some attractive sites, they will see the efforts of the maritime archaeologist in a better light and thereby develop positive attitudes to the protection of underwater sites.

SPECIFIC CASE STUDIES

Site stabilization and consolidation in Australia.

(A) WOODEN HULLS

Day Dawn (1886)

In 1976 the buried hull of this mid-19th century ex-American whaler was accidentally discovered by a dredge lowering the sea floor at Careening Bay, Western Australia. A rescue plan was drawn up by maritime

archaeologist Scott Sledge and the dredging contractors, who only three years previously and in the absence of protective State legislation, removed a similar hull from the same area, using explosives.

A deep trench was dug alongside the wreck allowing it to move slowly sideways and downwards, to finish up on a sloping bank below the harbour datum (Sledge, 1980). The site was then excavated, recorded, identified and the interior covered to prevent further degradation.

One side of the hull remained unsupported but protected from marine organisms by its copper alloy sheathing.

That has since begun to strip off, however, and the situation has worsened due to undermining from the recent effects of propellor wash from large vessels (e.g. tugboats) moored overhead. An attempt to alleviate the situation was made by dropping tons of seabed sand onto the site from large 'clam' type barges. That idea failed due to the dispersal of the sand sideways as it hit the seabed. Further feasibility studies are underway involving the building of an artificial wall or reef around the exposed hull, using either tyres, sandbags or cement-filled bags. The latter idea is similar to that planned for stage 5 of the SS *Xantho* excavation and centres on the ability of cement to set in an underwater environment.

Rapid (1811)

The accepted and general procedure on wooden ship excavation has been to backfill the excavated site with the original overburden, e.g. ballast, sand, coral, etc. There are problems, however; even though the backfill is the same as the original material, it is initially rarely as impervious to marine organisms and oxygen as before.

One solution is that attempted by Dr Neil North, formerly of the WA Museum's Department of Material Conservation and Restoration, during Graeme Henderson's excavation of the American China trader *Rapid* (Henderson, 1983). North proposed the covering of projecting frames and keelson with a chemically impregnated cloth (hessian with tributyl tin oxide, TBTO). This was then placed on the timbers and the lot sealed with the original overburden (in this case the rock ballast).

Diver reaction to handling the cloth was adverse despite the use of protective gloves, and fears were raised about the possibilities of swallowing or ingesting the toxic substances.

Despite these apparently unfounded fears, the cloth was successfully applied and again covered with many tons of ballast over a period of three working days. The site is in a remote location (over 1000 kilometres from the WA Museum) and the results are yet to be evaluated.

Sydney Cove (1897)

The protective seagrass cover on the wreck of this early Colonial trader in Tasmania began to erode following trial excavations and natural occurrences. The main area of concern centred around an exposed cylindrical bilge pump shaft which was apparently causing local eddies resulting in seabed disturbances. An ex-oilrig diver, Colin Lester, assisting Ms Shirley Strachan (the archaeological director) suggested the application

of a system used during his work on North Sea oil rigs. In order to stabilize oil pipe lines laid on the sea bed, sand bags were laid on the sea floor in the form of an undulating mound with the pipe in the centre and below the highest point of the mound. This allows for a smooth flow of water over the pipe. The idea was applied with success to the *Sydney Cove* case and resulted in a reduction of the scouring (Strachan, in press).

William Salthouse (1841)

Victoria has a large diving population surrounding the shores of Port Philip Bay and their activities have forced the declaration of a partial exclusion zone around this particular site. These activities and natural processes have produced scouring around and denuding of the protective layers on top of the site.

An adaptation of the 'sand drop' method used on the *Day Dawn* was attempted using tons of seabed sand with successful results. The team led by Mark Staniforth, of the Victoria Archaeological Survey, was successful in reducing the effects of natural scouring around the bow of buried hull. Their efforts involved the filling of the scour pits with plastic bags filled with sand and debris and this served to successfully modify the current flow (Staniforth, 1984). The erection of underwater "fences" designed to trap seaweed, sand and other seabed debris with a view to altering current flow also proved successful.

(B) IRON HULLS

About 50% of Australia's historic shipwreck sites are iron-hulled or steam-driven vessels and so it is not surprising that a beginning has recently been made on the excavation of such sites.

Apart from the enactment of legislation to prevent vessels anchoring or trawling or being otherwise engaged to the detriment of these sites, e.g. SS *Yongala* (1912) Queensland, *City of Launceston* (1865) Victoria, Submarine I 124 (1942) Northern Territory, and various sites in New South Wales, little in the way of physical or chemical protection has been attempted on iron vessels except in the case of the SS *Xantho* (1872) in Western Australia.

SS *Xantho* (1872)

In the author's excavation of this iron-hulled steamship, the first attempted under the WA Museum's Colonial Wreck Program, it was clear from the outset that the techniques, methods and assumptions applied to the excavation of submerged wooden sites may not be applicable to the iron ship or steamer.

The adaptation of existing recording and excavating methods to suit the needs of the iron-hulled steamer, however, was not difficult. The main problems were seen to centre around two related issues and ones that could not be solved by the archaeologists alone, i.e.:

1. the need to assess the relative importance of the physical, biological, chemical and electrochemical environment of iron wrecks in contrast to the wooden hulls;

2. the relevance of these findings to the future safe treatment of artefacts and structures, involved in the study and excavation of iron hulls and steam ships in general and the SS *Xantho* in particular.

Diving corrosion specialists, biologists and organic chemists were obvious choices for the examination of this aspect of the SS *Xantho* project.

Their study took the form of a pre-disturbance analysis in May 1983 and a series of re-assessments in January 1984 and in May 1985. Their electrochemical analysis of the site, its machinery and fittings, the application of protective anodes to the site in 1983 and their on-site conservation methods, especially those applied to the engine, were three of the many notable features of this study. These appear in the paper by MacLeod, North & Beegle, also published in this volume.

Of importance to the archaeologist on site, however, was the immediate availability of data and informed opinion on the strength, integrity, present and future stability of the wreck, its fittings and machinery.

Here lies the first of the major differences between the iron and wooden wreck. Unlike wood, which can in some cases last for centuries in anaerobic conditions, iron hulls, engines and fittings, even with their layer of concretion, continue to corrode and therefore in many cases have a much shorter life.

That life is even more greatly reduced by the removal of the protective layer of concretion without the intervention of immediate chemical treatment. In many cases the concretion itself serves to be the only physical remains left to indicate the presence of long since totally corroded artefacts or fittings.

CONCRETIONS AND THE RECORDING OF IRON HULLS, THEIR MACHINERY AND FITTINGS

The SS *Xantho* engine was covered in a 20-70 mm layer of concretion which was later found to account for over 25% of the total weight of 7.4 tonnes. Large fittings such as the pumps were virtually unrecognizable and accurate measurement was impossible.

To remove the concretion for the sake of measurement and study would have constituted an unwarranted attack on the integrity of the artefact and at the pre-disturbance analysis in 1983, the author decided solely upon the removal of loose marine growth and the recording of the engine using stereo cameras and manual means.

The results of the latter appear in Fig.3 and are a masterpiece of underwater manual recording and a credit to my assistant, Geoff Kimpton, who spent the entire two weeks of the survey on this task.

Conditions were often very poor and the results show what can be done in such cases without interfering markedly with the site or its fittings. Similar results are being obtained in deep water by John Riley of New South Wales, who specializes in the rapid illustration of underwater sites in the form of isometric drawings, which have proved useful for pre- and post-dive briefings and general illustrative purposes.

As with wooden hulls, film, video and photographic records, including stereo photography and the manual recording such as those of Riley and Kimpton above, will and should suffice in the vast majority of iron and steam ship excavations to record the concreted hull, fittings and machinery. In order to examine detail such as

plating, rivets, etc., the archaeologist need only remove some small sections of detached hull, leaving the rest intact. These samples can then be examined under laboratory conditions after appropriate on-site conservation. This is currently being done in the various stages of the SS *Xantho* excavation.

The excavation attracted archaeologists and specialists from all over Australia and was run (in April 1985) concurrently with an on-site practical and theoretical seminar on iron and steam ship archaeology and conservation. The engine, believed to be one of the first mass-produced marine engines, was cut free using thermal lance equipment (which can produce a surprisingly neat cut), raised and towed to a prefabricated sled lying in shallow water. The sled was then attached to the engine and the lot lowered the 30 cm remaining to the bottom and removed from the sea (fig.4). Reports on this and all other aspects of this as yet unfinished project are in the various stages of planning, preparation, or in press (McCarthy, in press).

In the *Xantho* case, the historical, physical and chemical data all combined to show that the engine could be raised for further study and conservation and that a display of this and other material from the site was a desirable outcome, especially for the people of Western Australia. This was weighed against the issues of diver access and enjoyment and site integrity, and a decision was made to go ahead and remove the engine in the context of the planned excavation of the site and examination of the vessel, its machinery and fittings, and hull.

Unless we were able to show that the engine was in an exceptional physical and chemical condition capable of being raised, conserved and displayed, then it would, of necessity, have remained concreted and on site.

The excavation will resume as soon as possible and within the next few years it is hoped to finish stage 8 of the project and thereby be able to present, to the public and professional alike, the results of this work in display, written and audiovisual form.

We also hope to leave the site as the WA Museum has done in the past, with the excavated wooden VOC ships *Batavia* (1629) and *Vergulde Draeck* (1656) and the American China trader *Rapid* (1811) as a permanent monument for the future and an educational and recreational dive for today.

It is our policy to try to leave all underwater sites, even after excavation, as intact, stable and visually attractive as before.

Cannon, anchors, ballast, machinery and fittings are then often left untouched and in situ.

To this end, Australia's underwater sites (of which those above are but a few examples) can be not only a present and future archaeological resource, but also an educational and recreational asset.

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Figure 1. An underwater information plaque on the Rottneest Wreck Trail. Photo: P. Baker.



Figure 2. A land information plaque on the Rottneest Wreck Trail. Photo: P. Baker.

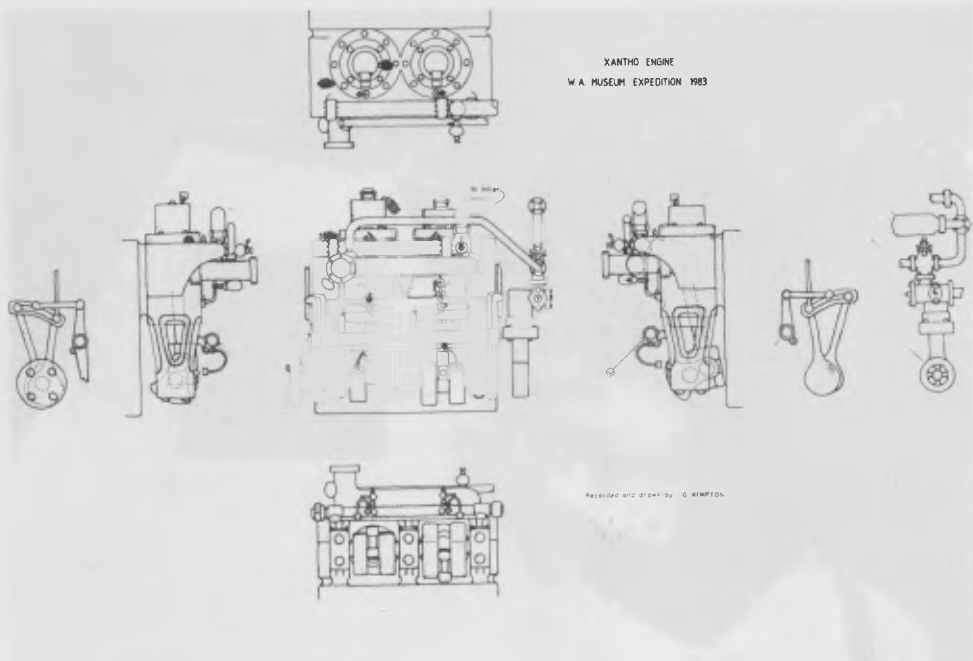


Figure 3. The SS Xantho engine before deconcretion. Drawing by Geoff Kimpton.

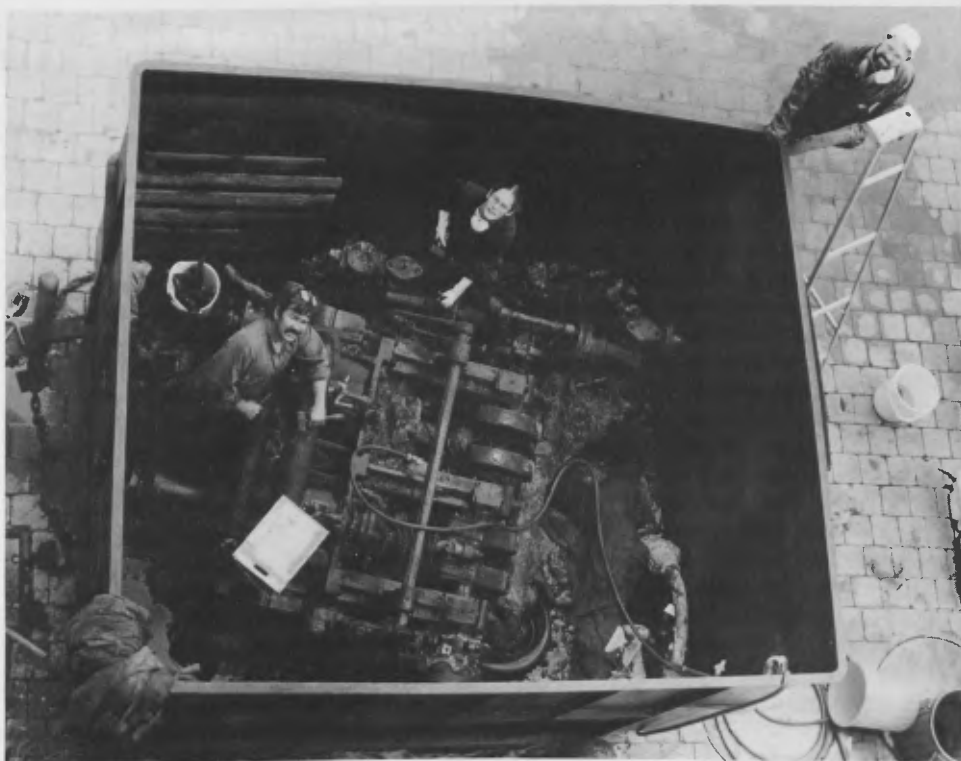


Figure 4. The engine in the process of deconcretion. Photo: Western Mail.

EXTENDED STORAGE OF WATERLOGGED WOOD, WHEN EXCAVATED AND IN SITU

Kirsten Jespersen*

SUMMARY

During recent years much attention has been devoted to the problem: how can we protect archaeological finds awaiting conservation years ahead?

This paper presents our experiences in Denmark with re-burial and storage of two cog wrecks in selected natural sand-soil layers, as well as examples of covering wrecks in situ with sandbags on the sea floor.

The paper includes a short presentation of different attempts and experiments related to the topic, such as ecological cleaning of water tanks by means of fish or snails, by deep-freezing or by the use of fungicides.

Some combinations of initial conservation and extended storage in nature are mentioned.

Furthermore the importance of collaboration between archaeologists and conservators both during excavation and afterwards is emphasized. In Denmark such team-work came into practice during the excavation of the "Maglebraende" site in 1983. It proved to be beneficial for everybody concerned, and especially for the wooden artefacts, which urgently require protection from the moment they are discovered.

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EXTENDED STORAGE OF WATERLOGGED WOOD, EXCAVATED AND IN SITU

At the Grenoble meeting of the ICOM Waterlogged Wood Working Group last year it was reported how the Danish National Museum protected excavated archaeological wooden objects by re-burial in natural layers of marine sand. It is a pleasure for me to present here an up-to-date report on the experience we have gained in this respect.

Previous to the first deposition in December 1981, a medieval wreck of the well-known cog ship type, much work had been carried out to find proper ways and means to protect large quantities of wet wood. At the waterlogged wood conservation laboratory in Brede, north of Copenhagen, we normally keep the wood, awaiting conservation, in water-tanks. In the mid-1970's we had space enough to house around 25-30 m³ of wood. Then in 1975 the *Lynes*, a beautiful ship from the Middle Ages was excavated and brought to Brede. Its seven tons of wood occupied two of the three available tanks. One year later another ship turned up, the *Vejby* cog, dated at about A.D. 1375 with all its lower frames and planks preserved, representing about 26 tons of wood. The wreck was brought up intact in the summer of 1977 and transported to one of the quays in the harbour of Copenhagen near an old storehouse (fig.1). The wreck was dismantled and placed in plastic-lined wooden tanks, unfortunately situated on the fourth floor in the storehouse.

As one more wreck of a cog was found in 1978, the *Kollerup* cog (fig.2), representing 34 tons of wood, it became obvious that it would be impossible to conserve all this wood within a reasonable time-span, with our present capacity. To keep the wood in water for many years was not considered safe on the basis of previous experience with the planks of the Skuldelev ships, as toolmarks on these planks had almost disappeared during storage. The most natural idea was - after full-scale documentation and sampling had taken place - to bury the wood again under conditions as in situ. From that point of view it was decided in 1979 that the Conservation Department and the Institute of Maritime Archaeology in cooperation should find a long-term storage in nature with optimal preservation conditions for waterlogged wood. From many years' experience dealing with waterlogged wood, we were able to recognize the differences in the deterioration of wood coming from various environments. Therefore, the first thing to do was to take core samples from sites where wrecks had been found. The examination of the core-samples was undertaken by the Institute of Environment, Technology and Society at the University Centre in Roskilde (RUC) during the summer of 1980. Fifteen samples from five localities were taken with a special corer, the "Kyholm Corer", in one-metre long transparent plastic tubes. From these samples all relevant information could be obtained on chemical and bacteriological conditions at the sites.

On the basis of the investigations we decided to seek our depot in marine sandlayers and preferably on land below a stable groundwater level. Several localities were considered but left again for one reason or another. Finally a beach area at Koge Bugt, in Vallensbaek, was inspected and found to be the right place. From the Danish Railways geotechnical laboratory and the Soil Test Company we received their sedimentation tests for this area which confirmed deposits of enormous quantities of marine sands (fig.3). The area of 5000-6000 m² was owned by the municipality of Vallensbaek and was intended for open green-belt meadows. Topsoil was very thin and even in dry summers the groundwater level does not sink to more than 50-80 cm below the turf. What we then needed was to carry out biological analysis to compare the effect of the decomposition respectively in soil and in our water tanks in Brede. Therefore a number of wood-samples were buried at the site in the wet sand at two metres depth in a well set on the spot. The samples, besides different test pieces of archaeological wood, also included samples of fresh

wood, paper and cellulose-gauze bandage - a total of 15 samples in each portion - two for the well and one for the water tank. At intervals of some months the samples were taken up, biologically tested and compared with those from the water tank. All results are presented in a report (prepared by biologist Jens Glastrup) in which the conclusion showed small differences between the two ways of keeping the wood. Some points speak in favour of burial, as for example the constant low temperature at 4-8°C, a lowered redox-potential and anaerobic conditions.

The first deposition was executed on 2 December 1982, when about 24 tons of wood from the *Kollerup* wreck found a second grave - in pure cold and wet sand. The rest of the wreck, about 10 tons, went to Brede for conservation. Some days before the deposition, the contractor set up a sub-soil water-draining unit with 30 suction tubes along the edges of the hold, 10 x 4 m and 3 m deep. Aided by the excavator as a crane, the biggest pieces were lowered and the timbers packed closely together in sand. A nylon net placed beneath the wood was large enough to be closed over the top and thus wrapped the whole batch for easy recovery. The second deposition took place on 6 May 1985, comprising all timbers from the *Vejby* cog which has suffered from miserable storage conditions over eight years - altogether about 28 tons of wood.

There are some aspects in connection with this kind of work that I would like to call attention to. First, we have not yet solved the problem of managing very heavy pieces in a proper way (the *Vejby* keelson for example weighed 800 kg; second, there is a strict limit of time. Work must be finished in less than three hours, before sand and water flow into the excavation, and therefore the working tempo is much speeded up. In some situations where there are no compelling reasons for removing shipwrecks found on the sea floor, other methods for protection against exposure and demolition have been adopted in Denmark. One example is the 13th century wreck of the *Kyholm*.

After excavation and recording of the wreck underwater in 1978, some parts of the wreck were taken up for conservation and the rest was covered with sandbags on the spot. The reconstruction of the foreward part of the *Kyholm* is based on a detailed underwater survey of details which make these drawings reliable.

The most common way to store waterlogged wood awaiting conservation is submergence in water basins - in spite of drawbacks such as growth of bacteria and fungi, bad smell and the problems of cleaning the bottom. To minimize these drawbacks we started 15 years ago having a few small fish swimming around in each watertank, and these have certainly been most useful.

During the Ottawa conference in 1981, we had the opportunity to visit the Canadian Conservation Institute where three colleagues showed their experiments on cleaning wood and water tanks by means of snails. This proved quite successful in comparison to other inhibitory systems. Water-soluble biocides and fungicides are most commonly added to water storage tanks. In my opinion this is a bad habit and should be avoided by all means, as illustrated by another case history from the Ottawa meeting.

Colleagues reported on a large-scale treatment of the *Machault* ship excavated in 1969-1972. The quantity of wood was estimated to be about 90 m³. At the end of 1971 it was decided to retrieve a cross-section of the *Machault* together with its rudder and other timbers for display. Various conservation treatments for the massive oak section were considered but the final decision was to try a cheap method which had not been tried out before: a slow drying by burial in sand.

A double-walled insulated building of 18x9x2.4 m was constructed and supplied with hot air. The sand burial was meant to retard the drying and to support the timber. A floor of coarse gravel provided drainage. A large sandwich consisting of sand, timbers and the fungicide sodium pentachlorophenate was created right to the top of the walls. Two ventilation holes in the roof were made for the water evaporation. It was estimated that in this way the wood could reach a moisture content of 13% over a two-year period.

In practice it went differently. During the first five years the moisture content was recorded to be about 65% at each check. Apparently the ground water was drawn up at the same rate as the evaporation took place from the top of the sand. In January 1977 this method of conservation was finally given up. From this pilot project much useful information can be gained about the problems of excavation - burial - re-excavation and how to get rid of the fungicides, in concentrations from 60 - 8600 p.p.m., both in wood and in 200 m³ of sand.

Information from Holland ought to be mentioned about protection of shipwrecks in situ by local raising of the subsoil water level in a vertical plastic enclosure. Mr Reinder Reinders's graph illustrates the working method:

- digging a trench around the shipwreck;
- putting earth from the trench and surroundings on top of the wreck;
- placing plastic foil vertically around the shipwreck and on top of the wreck with a hole in the middle at the lowest point;
- filling the trench and covering all the plastic foil with earth;
- digging a small ditch around the protected area to prevent mechanical damage.

Mr. Reinders emphasizes that the method only "works" if there is a thick layer of clay below and around the shipwreck.

At conferences for conservators, we often discuss the question of whether or not conservators should participate in excavations. In many countries archaeologists dislike the idea of having a conservator permanently working at a site. Well, they do call for assistance to bring up delicate objects, but it would be wiser to work together throughout an excavation. In 1983 and again in September 1985, I went with the team from the Viking Ship Museum that was excavating a site containing a shipyard of 1100 A.D. at Maglebraende, Falster.

I am quite sure that proper treatment and protection right after the discovery left our 420 objects in a better state than they would otherwise have been. Extremely fragile objects, appearing every moment, could be released and secured rapidly. Last but not least the important packing for transport could be carried out in an ideal way.

For the archaeologists my responsibility for all excavated objects was a great relief and they gained more time to excavate.

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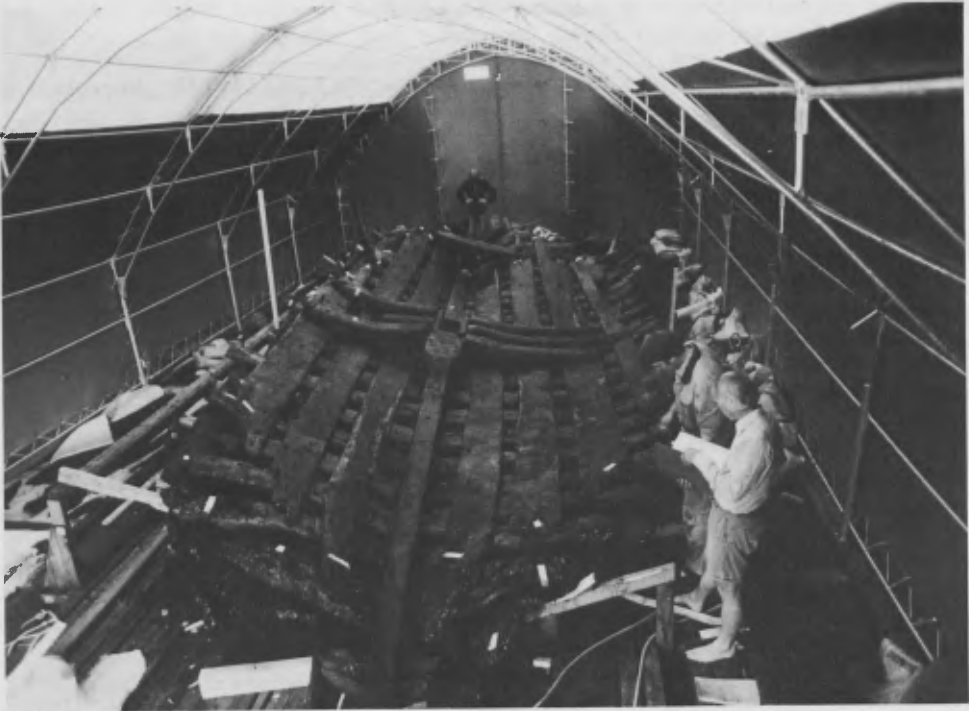


Figure 1. The Vejby-cog placed in a temporary tent at one of the quays in the harbour of Copenhagen, 1977.



Figure 2. A close-up view of the Kollerup-cog timber, excavated in 1978.

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Farsøvej 4
4800 Søge
Tlf. 003 99 00 97

Kote = 0,0

Sag nr: 77104 dato: 1977.05.23

Navn: T. Sørensen Vand

Adresse: Katrinebjergvej 25

Matr.nr.: 11⁸², Vallensbæk by

Kote 10

Vingeforsøg:

Jordsætning:

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| +8,0 | -7 | | Sand og mergel |
| +9,0 | -8 | | sand og tørv |
| +10,0 | -9 | | sand og tørv |
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*påle
forsøg med dybde*

Figure 3. Sedimentary column from Vallensbæk.



Figure 4. The suction-tube system along the edges of the deposition pit.



Figure 5. Closing the waterlogged wood depot with nylon net and sand.

LE BATEAU ARABE-NORMAND DE MARSALA.
LA PROTECTION IN SITU

Costantino Meucci*

SUMMARY

This XII century ship was discovered in 1983. It lies 2 metres deep on a sandy seabed, about 50 metres from the beach at the centre of the main seaside resort. The integrity of the wreck is threatened with rapid degradation, due to the lowness of the seabed and to the changing of the stream which endangers the wooden frame, periodically burying and unburying it.

Thence arose the need to protect the frame by covering it with a layer of silicone rubber for mouldings, polymerized in loco in panels of the size of 100 x 50 cm. A thixotropic catalyst, which gives the elastomer peculiar structural properties, enabled us to keep the timbers, the keel and the remains of the hull tightly assembled, in order to preserve the whole wreck from the damaging action of the sea and of man.

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1. LE SITE

L'épave, de quelque 15 mètres de longueur et d'une largeur de 3 mètres, est couchée sur un fond mixte de tuffeau et de sable à une profondeur de 2 mètres environ, quelque 50 mètres au large du Lido Signorino, une plage localisée à près de 2 km au sud de la ville de Marsala. Il s'agit d'une côte exposée surtout aux vents du Sud et de l'Ouest, qui produisent des courants marins très forts et, par conséquent, le déplacement continu du sable du fond, ce qui peut causer l'exposition occasionnelle de l'épave.

Ce phénomène périodique a produit une certaine désagrégation des éléments de la structure due à la fatigue; d'autre part les changements continus des caractéristiques du milieu ambiant ont affecté directement la rapidité du processus d'altération chimique et biologique des matériaux.

2. L'ÉPAVE

Le bateau, que l'on peut dater du XII^e siècle (1,2,3), est entièrement monté avec des clous et des chevilles de fer, qui joignent le bordé a paro à la charpente, dont il reste la quille, 36 varangues et quelques mètres de carlingue.

Tous les éléments en fer présentent une corrosion très avancée due à l'apport continu d'oxygène par l'action des flots et des courants, et à la couche de sable au-dessus. La corrosion des clous de fer diminue considérablement la compacité de la structure entière; c'est pourquoi la plupart des varangues flottaient librement à mesure que les fouilles avançaient. Au contraire, la section de proue du bateau est dans son ensemble assez solide soit parce que les varangues sont maintenues en place par le poids de la carlingue, qui est encore unie à la quille par des chevilles métalliques, soit parce que les planches du bordé résiduel sont en bon état de conservation.

3. LES ESSAIS SUR LES MATÉRIAUX

Au cours des fouilles de 1984 on avait échantillonné quelques éléments de l'épave, en particulier des varangues et des planches du bordé. Les échantillons ont été testés au laboratoire dans le but à la fois de caractériser l'essence des bois, et de déterminer les espèces microbiologiques fixées dans le bois même.

Ainsi on a constaté l'utilisation de bois de chêne (*Quercus sp.*) et de châtaigner (*Castanea Sativa*) pour les varangues, alors que le bordé est constitué de planches de sapin (*Abies Alba*). Les analyses chimiques et morphologiques des matériaux montrent une dégradation très différenciée des structures microscopiques des bois: on observe notamment qu'alors que les parties les plus internes des éléments gardent presque inaltérée la morphologie caractéristique du bois, au contraire les surfaces les plus extérieures, qui ont été en contact avec la boue du fond, ont perdu leur consistance, dans quelques cas sur une épaisseur de quelque 10 mm.

Ce phénomène est directement lié à la pollution marine particulière de l'endroit: les eaux de décharge des industries vinicoles de la zone introduisent dans l'habitat des sels de soufre, qui ont permis aux colonies de bactéries minéralisatrices du soufre organique de bien se développer sur la surface extérieure du bois et de s'établir dans la boue du fond, directement en contact avec l'épave. C'est l'activité métabolique de ces bactéries qui cause la dégradation progressive des bois attaqués. Enfin, il faut bien remarquer l'absence totale dans les échantillons testés de toutes espèces qui métabolisent la cellulose (4).

4. LA PROTECTION

Les caractéristiques particulières du site et la décision de ne récupérer l'épave qu'après avoir achevé son étude et, surtout, après avoir mis au point en grande partie l'intervention de conservation nous ont imposé la nécessité de fixer à leur place tous les éléments mobiles et de protéger le site au cours et à la fin des fouilles.

La fixation des varangues aux planches du bordé a été simplement réalisée en introduisant des chevilles de bois tendre, de 5 à 8 mm de diamètre et 50 à 80 mm de long, dans des trous pratiqués dans les éléments par des carottiers métalliques de même diamètre. Les chevilles étaient logées dans les trous après y avoir coulé un mastic de silicone, qui avait la fonction de créer une couche souple entre la cheville et le bois ancien, dans le but d'éviter tous dommages par fatigue. Cette opération nous a donné la possibilité de tenir les éléments flottants pendant les fouilles, au cours des phases de documentation du site et jusqu'au moment de la protection définitive de l'épave.

La protection de l'épave a été réalisée en utilisant un caoutchouc de silicone pour moulage, que l'on a choisi en fonction des résultats d'une recherche spécifique visant à déterminer le catalyseur le meilleur et le temps de vulcanisation optimal. Le caoutchouc sélectionné, qui donnait les résultats les plus satisfaisants, a été le RHODORSIL RTV 1600, produit par Rhône-Poulenc Italia, auquel on ajoutait le catalyseur W TIXO BLEU à raison de 5% du poids (5).

Il s'agit d'un élastomère silicique thixotropique qui possède des propriétés spécifiques de résistance au maintien de la forme et de flexibilité et qui, dans la phase de vulcanisation et de formation du réseau moléculaire, subit un retrait linéaire minimal, que l'on peut estimer à environ 0,1%, de sorte qu'il n'y a aucune tension mécanique sur la surface de l'élément moulé. Une limitation à l'utilisation du RTV 1600 provenait de la valeur optimale de la température de vulcanisation (entre 20° et 30°C); cependant des essais expérimentaux sous-marins, réalisés pendant l'hiver, ont démontré que l'élastomère ne modifiait pas ses propriétés en vulcanisant à une température un peu inférieure aux 20°C théoriques. Dans ces conditions de travail, le catalyseur choisi réalisait la formation complète du réseau moléculaire de caoutchouc de silicone en à peu près 60 minutes, ce qui nous assurait le temps suffisant pour mélanger les produits et pour appliquer l'élastomère sur les structures in situ.

La protection a été effectuée en étalant une couche de quelque 5 à 10 mm d'élastomère sur des toiles de chanvre de 50 x 70 cm; les toiles étaient alors appliquées sur la surface extérieure des bois de l'épave. La mise en oeuvre de plusieurs toiles superposées nous a permis d'obtenir une couche continue de caoutchouc de silicone, qui adhérerait très bien aux éléments de l'épave sans s'y coller. En milieu sous-marin, en effet, c'est l'eau même qui gorge le bois, ce qui explique l'utilité de détacher l'élastomère de la surface du bois.

La couverture définitive du site, enfin, a été réalisée en superposant sur les structures de l'épave traitées avec le caoutchouc de silicone des sachets de PVC de dimensions différentes remplis de sable: les plus petits (de 150 mm de diamètre) étaient logés entre les varangues, les plus grands (de 50 x 70 cm) formaient une couche continue au dessus du site. A ce point on déposait sur le site une couche de sable d'environ 20 cm afin de le protéger de l'action de la mer et de l'homme.

5. CONCLUSIONS

L'utilisation d'un caoutchouc de silicone pour la protection d'une épave en milieu sous-marin nous donne plusieurs avantages. Avant tout, l'opération est très simple à réaliser, ce qui baisse le coût global de la protection: dans le cas de l'épave de Marsala on a utilisé 120 kg de caoutchouc de silicone, en appliquant quelque 2 kg par m², soit un coût d'environ 60.000 liras par m². Le temps global de travail peut être évalué à 15-20 minutes par m² de caoutchouc de silicone appliqué.

D'autre part il faut considérer que ce produit est tout à fait inaltérable dans l'habitat sous-marin et que, par conséquent, il ne modifie pas ses caractéristiques de flexibilité et de résistance mécanique dans les conditions spécifiques du site. Le RHODORSIL RTV 1600, enfin, est compatible du point de vue chimique avec nombreuses résines synthétiques, que l'on pourrait utiliser pour obtenir des moules rigides, dans le but de faciliter le renflouement de l'épave. De plus l'élastomère vulcanisé montre une bonne résistance à l'action chimique de plusieurs solvants organiques, ce qui pourrait donner la possibilité de l'utiliser comme "cuve de traitement" où réaliser toutes les opérations de restauration.

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PROTECTION OF SITES ON DISPLAY
ROOFING AND IN SITU PRESENTATION: NEW TECHNIQUES

PROTECTION DES SITES EXPOSES
TOITURE DE PROTECTION ET PRESENTATION IN SITU:
NOUVELLES TECHNIQUES

Jean Vouvé* et Jacques Brunet**

RESUME

Les auteurs abordent dans cet article le problème de la protection des oeuvres pariétales dans les grottes préhistoriques d'une part, dans les gisements archéologiques et monuments historiques d'autre part. En effet dans le monde les exemples concrets sont hélas très nombreux: actes de vandalisme, rythme de fréquentation touristique élevé, aménagements inexistantes ou maladroits des accès aux cavités, etc.

Toutes ces perturbations conditionnent la sauvegarde du patrimoine culturel. A cette protection, circonscrite au monument lui-même, s'ajoute la prise en compte du monument dans son environnement naturel et/ou urbanisé, cet environnement pouvant être aérien ou souterrain.

Dans cet esprit, J. Vouvé et J. Brunet développent deux notions fondamentales. La première révèle l'importance du doublet "site-monument". Celui-ci constitue un ensemble indissociable dans le sens de la protection des oeuvres préhistoriques et historiques. Cette protection doit s'exercer à deux niveaux:

- au niveau scientifique et technique d'une part,
- au niveau juridique et administratif d'autre part.

La seconde évoque la vulnérabilité des doublets. Celle-ci se traduit par:

- une estimation qualitative et quantitative des dégradations et altérations réelles et possibles;
- la cartographie des zones plus ou moins vulnérables, celles-ci étant dessinées sur des fonds topographiques et/ou de cadastres.

Elle est matérialisée par trois périmètres de protection (périmètre immédiat - rapproché - éloigné) dont le degré de vulnérabilité est décroissant.

Ainsi pour chaque site, nous proposons qu'une charte ou un code soit préparé et rédigé en tenant compte des faits d'expérience et de ceux qui sont prévisibles. L'exemple de la grotte préhistorique de Combarelles en Dordogne est développé par les auteurs.

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1. INTRODUCTION

Notre action pour la sauvegarde des monuments préhistoriques, entreprise depuis plus de 20 années déjà, est basée sur le principe de l'identification des interactions naturelles et artificielles au niveau du doublet "*site monument*", que nous étendons présentement à la cible "*site-gisement et fouille archéologiques*".

La finalité pratique associée à ce concept élargi se traduit par:

- des actions de *protection directe* sur les mobiliers et les oeuvres (en milieu aérien, subaquatique et souterrain)
- l'identification de zones à degré de vulnérabilité variable, matérialisées par des périmètres de protection et associées à la *protection active*.

La reconnaissance légale de ce découpage géographique permet son inscription dans les plans d'occupation des sols (P.O.S.) qui régissent l'activité présente et future des communes françaises.

La transposition à tous les pays est possible sur la base d'organigrammes évolutifs à adapter en fonction:

- des contextes politiques, juridiques, socio-économiques spécifiques d'une part,
- des cadres climatiques, topographiques, orographiques d'autre part.

2. DES FAITS CONCRETS

Nous évoquons dans les lignes qui suivent quelques exemples représentatifs de ce que peuvent être les *protections directes* dites également *protection de proximité* à l'encontre des malversations et vandalismes humains d'une part, à l'encontre de la présence de l'homme en tant que visiteur d'un site, d'autre part.

Ce sont les grottes ornées qui ont été choisies pour illustrer nos propos.

2.1 A propos de la protection directe

Nous allons distinguer globalement deux cas opposés - 2 pôles - entre lesquels il y a une multitude d'intermédiaires.

A un pôle, mentionnons des cavités ornées très proches d'un village telle que celle de "Font de Gaume"⁽¹⁾, aux abords mêmes d'un centre d'animation telle que la cavité de "Pech Merle" qui jouxte le Musée A. Lemozi; à l'autre pôle évoquons la situation de réseaux isolés sur les plateaux karstiques à la périphérie du Massif Central tels que "Ebbou", "Chabot" dans les gorges de l'Ardèche, "Baume Latrone" dans les gorges du Gardon. Si dans le premier cas la fréquentation est contrôlée, dans le deuxième cas elle a été clandestine et s'est traduite par de nombreux actes de vandalisme et des déprédations variées. Nous pouvons citer "les charbonnages" des traits gravés de la grotte "Chabot", le vol de fragments d'une frise de mammoths gravés toujours à "Chabot", le jet de boulettes d'argiles, les maculations de noir de fumée, les graffiti, la destruction de fragiles tracés digitaux à "Baume Latrone", la surcharge au crayon gras de couleur de chevaux de la grotte de "Labastide". Cette lamentable énumération serait sans fin.

(1) Pour la localisation précise de toutes les grottes ornées françaises, nous renvoyons le lecteur à "l'Atlas des grottes ornées paléolithiques françaises" publié en 1984 par le Ministère de la Culture.

Face à cette situation, que faire? A "Baume Latrone" deux décennies de négligence et vandalisme avaient laissé des traces jugées longtemps irréparables. Pour cette cavité, une porte commandant l'accès du réseau a été renforcée par une grille à l'entrée; les agressions contre ce type de protection ont diminué, mais se produisent toujours au rythme de deux par an environ. C'est un cas extrême, mais combien révélateur de l'urgence d'assurer des moyens de protection.

Nous venons d'évoquer l'intérêt de la dissuasion des visites clandestines, "sauvages" des galeries ornées, et pour d'autres cavités heureusement le légitime désir de connaissance du public peut être satisfait. Dans les cavités de "Rouffignac", "Gargas", "Cognac", "Villars", "Niaux", les guides et gardiens assurent une protection rigoureuse lors des visites, mais compte tenu de la spécificité propre à chaque cavité il est cependant délicat de définir des consignes identiques pour toutes.

Pour les cavités visitées par le public, se pose le problème de concilier les impératifs de la conservation tout en facilitant ou maintenant l'accès aux touristes. A partir de ces deux extrêmes que sont conservation et fréquentation touristique, aux actions antagonistes, il convient de trouver une solution les prenant en compte et les satisfaisant toutes les deux.

Nous avons remarqué, lors d'études de cavités, qu'un guide ne pouvait assurer un commentaire de bonne qualité que si l'effectif du groupe ne dépassait pas 20 à 25 personnes au maximum; au-delà, la qualité des explications peut en souffrir.

Depuis des années, un système de visite a été mis au point à "Font de Gaume" et il donne satisfaction du point de vue de la conservation des peintures et de l'accès des visiteurs. C'est une cavité en forme de couloir, de largeur moyenne, ne dépassant pas 2,50 mètres dans la partie ornée; le problème a été résolu en instaurant des groupes de 20 personnes encadrées d'un guide et d'un "serre-file" qui s'assure que les différents groupes ne se mélangent pas dans la cavité et que les visiteurs ne touchent pas aux parois ornées. Ces conditions permettent d'assurer la visite de manière acceptable.

2.2 A propos de la protection naturelle et des perturbations occasionnelles

A l'expérience, nous nous apercevons que dans le milieu souterrain, le maintien en bon état des oeuvres rupestres est dû à une protection naturelle qui s'est maintenue durant des milliers d'années.

Cette protection est assurée par des conditions favorables tant du point de vue biologique, climatique (température, humidité), etc... issues d'échanges avec le milieu externe.

Toute modification des paramètres perturbera la stabilité du milieu et aura des conséquences fâcheuses sur la conservation et la protection des témoins de cet art.

2.2.1 Cas des facteurs biologiques

Les micro-organismes peuvent trouver dans les grottes des conditions favorables à leur développement; en effet, l'air est humide par suite d'infiltration d'eau, des mécanismes de condensation et aussi par la vapeur d'eau dégagée par la respiration des visiteurs (il faut rappeler que chaque personne rejette en moyenne 40 grammes de vapeur d'eau par heure). Des quantités importantes de matières organiques sont également apportées par l'haleine, la sueur. Bien souvent, en période estivale, l'éclairage est pratiquement permanent en raison du rythme soutenu des visites; il facilite le développement de ces micro-organismes.

Si ces effets sont minimes au niveau de chaque individu, ils deviennent importants par accumulation à l'issue de la saison touristique.

Toutes les cavités possèdent une flore et une faune naturelle, et heureusement les phénomènes d'auto-épuration limitent aussi bien qualitativement que quantitativement le développement de ces micro-organismes. A un moment donné, cependant, il apparaît que ces mécanismes d'auto-épuration n'interviennent plus ou, du moins, plus assez efficacement. Et, si actuellement, les résultats des contrôles effectués sont satisfaisants, il faut s'attendre, en tenant compte de l'augmentation régulière du nombre de visiteurs, à atteindre des valeurs où la perturbation biologique produite ne s'éliminera plus toute seule. Les capacités d'auto-épuration ou d'auto-régulation auront été alors dépassées.

Pour assurer la protection du milieu souterrain donc des oeuvres rupestres, l'élimination de ces végétaux est faite par pulvérisation de liquides biocides. A titre d'exemple le programme d'entretien des cavités ornées d'Aquitaine (grottes de Font de Gaume, Teyjat, Villars, Pair-non-Pair, Combarelles) permet d'assurer de bonnes conditions de conservation et de protection.

2.2.2 Cas des facteurs physiques

La Grotte de Lascaux, depuis sa découverte, a subi de nombreuses vicissitudes associées à un programme d'aménagement touristique en plusieurs phases dont la finalité nous apparaît, avec le recul du temps, assez éloignée des meilleures conditions de conservation. Les aménagements maladroits réalisés pour faciliter la visite de la cavité ont rendu l'ensemble de la Salle des Taureaux et du Diverticule Axial plus sensible aux influences externes qu'il ne l'était au moment de la découverte en 1940.

En voici, brièvement, l'historique: (figure 1A-1B-1C)

- De septembre 1940 à 1941: découverte et premiers aménagements. Creusement d'un puits dans les éboulis d'entrée pour accéder plus facilement à l'intérieur. Les premières visites ont lieu.
- De fin 1941 à 1948: de nouveaux aménagements sont prévus et réalisés. Nouveau creusement du cône d'éboulis à l'entrée, électrification de la cavité, mise en place de la porte externe et, déjà, d'un sas.
- 14 juillet 1948: début des visites touristiques.
- 1958: l'afflux des visiteurs entraîne de nouveaux travaux importants, pour éliminer le gaz carbonique et la vapeur d'eau ainsi produits. Conditionnement de l'enceinte souterraine; machine à recycler l'air de la cavité; mise en place de gaines dans le sol pour la distribution de l'air plus frais et, à nouveau, creusement du cône d'éboulis.
- 1963: alerte à la conservation des peintures, reconnaissance et prolifération de colonies d'algues sur les parois. Ordre administratif de fermeture au public.
- 1964-1969: recherches fondamentales et pluridisciplinaires.
- 1969-1985: suite de la détermination des conditions favorables à la conservation des oeuvres préhistoriques. Restitution et maintien de ces conditions.

Les parois de la Salle des Taureaux et du diverticule axial sont recouvertes d'un mince concrétionnement servant de support aux peintures et qui a sans doute contribué à leur conservation. En milieu calcaire, le concrétionnement est lié aux conditions régnantes et sa stabilité dépend de la présence d'eau, de calcium et de gaz carbonique. Il pourra y avoir des phases de corrosion; ces dernières étant dues à l'action simultanée du phénomène de condensation sur les parois et de la présence de l'anhydride de carbone. De plus, de rapides modifications de température à la surface de la roche et dans l'air ont pour conséquence immédiate les phénomènes d'évaporation ou de condensation. Ce phénomène de condensation est capable de dissoudre le carbonate et, par ruissellement, d'entraîner les pigments, ce qui est très préjudiciable au bon état des peintures.

Un système de climatisation utilisant les échanges qui se font naturellement par convection dans la cavité entre la salle des machines (S.M.) d'une part et la partie axiale (P.A.) d'autre part a permis d'éliminer la possibilité de condensation sur les parois ornées et, au contraire, de la favoriser sur un point froid artificiel présent dans la salle des machines (figure 2). Il s'agissait de maintenir à proximité des surfaces décorées une tension de vapeur d'eau dans l'air inférieure à celle correspondant à la température de surface de la roche.

En pratique, nous provoquons la condensation de l'air de la cavité sur deux échangeurs thermiques reliés à des groupes réfrigérants externes, alors que la roche de la Salle des Taureaux, encore froide par suite de la lente progression des ondes thermiques hivernales dans le sol, est soumise à l'influence de l'air venant des parties plus exposées aux variations telles que la salle des machines.

Prenons l'exemple du cycle climatique 1981-1982. Ces documents montrent que de juin à fin décembre, les conditions hydriques, après une série de mesures journalières, sont réajustées par M. Marsal, autour de (figures 3 et 4) valeurs qui ont été reconnues comme les plus aptes à assurer la meilleure conservation des peintures. La souplesse du mécanisme qui s'exerce uniquement dans la partie axiale permet de contrôler l'humidité de l'air à tout moment et à aucune période il n'y a possibilité de condensation. Pour faciliter ce contrôle, la cavité est isolée de l'extérieure par une série de cloisons isothermes et de sas empêchant les échanges directs d'air.

Si cet exemple est significatif des mesures de protection aptes à assurer l'instauration de bonnes conditions climatiques de conservation, il est cependant exceptionnel; dans le domaine des interventions de ce type il faut être prudent, car la plupart du temps les facteurs ne sont pas toujours maîtrisables.

3. DE L'UTILITE D'UNE PROTECTION ACTIVE ADAPTEE

3.1 De la notion de doublets "sites-monuments" et "sites-gisements et fouilles archéologiques"

Les gisements aériens, sous-cutanés, souterrains, sub-aquatiques (eaux douces et salées) ainsi que les monuments ornés constituent spécifiquement un doublet avec les sites naturels qui leur sont géographiquement associés.

Il s'agit en fait d'un "ensemble bimodal indissociable" dans la mesure où les actions de toute nature qui s'exercent sur l'un, entraînent des réactions sur l'autre.

Celles-ci peuvent aider à la conservation comme à la destruction partielle ou totale d'un témoin de notre passé (cf. figures N°5 à 10). C'est dans l'esprit de destruction potentielle que nous développerons notre travail.

Notre longue expérience associée à la sauvegarde du patrimoine préhistorique national et international nous permet d'affirmer que certaines interventions, naturelles ou humaines, ces dernières pouvant être dans certains cas involontaires, impliquent des désordres ou dégradations même mineures qui peuvent mettre en péril la sauvegarde du gisement, de la fouille et du monument ou faire perdre une information précieuse aux chercheurs.

Ainsi, en milieu continental (terrestre, lacustre ou fluvial), les perturbations peuvent se manifester:

- au niveau de la cohésion et de la teneur en eau du sol et du sous-sol (érosion s.l.)
- en ce qui concerne le régime des eaux de surface (ruissellement) et du vent, avec perte de substance dans les deux cas (effet climatique indirect)
- quant aux modalités de circulation des eaux souterraines, quant à leur régime et à leur qualité physico-chimique (effet climatique induit).

En milieu subaquatique marin, on retiendra surtout l'action évolutive de la courantologie naturelle ⁽¹⁾ et celle provoquée par les aménagements de l'homme le long du littoral qui peut avoir des conséquences néfastes.

C'est le cas des travaux portuaires, de rejets de produits solides de poses d'émissaires avec rejets d'eaux usées etc.

Globalement, on retiendra que chaque événement ou phénomène dynamique est porteur d'un certain degré de nocivité, variable en fonction de la latitude (donc du climat dominant), du cadre naturel (géomorphologie - présence ou absence de couverture végétale - cohésion des matériaux - degré de saturation etc.); à cela viendront s'ajouter des phénomènes naturels exceptionnels (tornades, cyclones, crues, séismes, incendies, etc.).

Quant à l'action de l'homme, elle est des plus variées et aux conséquences souvent inattendues, en tous lieux (même désertiques), en liaison avec une progression et une mutation technologique mal contrôlée, qui peut prendre en compte aussi bien un chantier de grands travaux (barrage hydroélectrique) que le détecteur individuel de métaux manipulé par des vandales.

Parmi les innombrables actions engendrées par cette technologie effrénée, nous évoquerons le déboisement, l'agriculture et l'élevage industriels, l'exploitation de carrières, l'industrialisation (s.l.), l'urbanisation immodérée sans oublier le profit frauduleux (vente des pièces originelles).

Cette évolution nous a amenés depuis de nombreuses années à développer la notion de protection des doublets associée à l'inventaire réel et prospectif des altérageⁿs ⁽²⁾.

(1) On notera que certains facteurs peuvent avoir une double finalité; ainsi un courant peut révéler un gisement aux plongeurs après déplacement du sable; à l'inverse il peut masquer un autre gisement après envasement du site. Le vent joue le même rôle en milieu désertique (champs de dunes mobiles).

(2) *altérageⁿ*: toute substance ou tout facteur provoquant une altération de l'environnement (extrait du vocabulaire pour l'environnement et les nuisances - du Conseil International de langue française - Mai 1971).

Ce que nous avons réalisé en France sur des *cibles* archéologiques précises peut bien entendu être repris ailleurs. Nous suggérons que cette notion soit prise en considération par les organismes internationaux et puisse s'inscrire dans le domaine du droit à l'environnement qui prend corps depuis quelques années en Europe et dans tous les pays industrialisés.

3.2 Méthodologie de la protection

Il s'agit en quelque sorte de rassembler un faisceau de données scientifiques et techniques permettant d'établir un état réel des lieux (aériens et souterrains) ainsi que les mutations possibles et probables.

Les questions primordiales associées à cette *étude d'impact* sont de deux ordres:

- recherche des limites spatiales extrêmes du motif et du gisement qui lui est associé au-delà desquelles une quelconque perturbation n'a plus d'influence néfaste.
ex.: - la surface d'alimentation (ou impluvium) associée à un réseau souterrain orné ou à une fouille archéologique
- la distance au-delà de laquelle l'exploitation d'une carrière par explosifs n'offre plus de danger pour une grotte ornée en raison des vibrations.
- inventaire sous la forme d'une liste non exhaustive d'événements à conséquences réversibles ou irréversibles dans le sens de la dégradation de la *cible*.
ex.: inondation du site amont d'un barrage qui serait susceptible de receler des gisements archéologiques.

Pour donner une vue plus complète de l'objectif à atteindre, nous donnons ci-après (cf. tableau N°1) un exemple correspondant à l'étude d'impact associée à la grotte à gravures de "Combarelles" et les conséquences qui en résultent quant à la vulnérabilité.

4. ACQUISITION D'UNE DOCUMENTATION CARTOGRAPHIQUE CENTREE SUR LA NOTION DE VULNERABILITE

4.1 Préambule législatif

Pour évoquer ce que nous connaissons le mieux, nous rappelons que la France possède une législation qui confère à l'Etat, par des limitations à l'étendue du droit de propriété des biens immobiliers, les pouvoirs nécessaires à la protection du patrimoine archéologique.

Dans cet esprit, trois textes principaux concourent à la protection des gisements, des monuments et des oeuvres artistiques:

- la loi sur les monuments historiques (31 décembre 1913): elle s'applique aux immeubles et aux objets. Elle contribue à la protection de l'art rupestre et des gisements préhistoriques.

- la loi sur les monuments naturels et les sites (loi du 2 mai 1930) renforcée par la loi du 7 janvier 1983. Elle protège les monuments naturels et les sites et, à ce titre, l'Etat dispose d'un droit de surveillance sur les aménagements pouvant intervenir; les cavités appartenant à ces ensembles bénéficient dans ce cas d'une protection.
- loi sur les fouilles archéologiques du 27 septembre 1941, validée par une ordonnance du 13 septembre 1945.

4.2 De la notion de zonage des risques (vulnérabilité)

La sensibilité des doublets à toute espèce de dégradation dépend de facteurs multiples, les uns naturels, les autres hérités de l'activité humaine.

Sur le plan fondamental, les caractéristiques associées au couvert végétal, à la pédologie, à la géologie, à la géomorphologie, à l'hydrologie etc... constituent des critères d'aptitudes quant à la protection des *cibles*.

Sur cette base, nous avons rassemblé les facteurs d'un classement dépendant des résultats de l'inventaire réel et prospectif des altérages ainsi que des mutations possibles et probables (ex.: développement d'infrastructures routières - habitat secondaire etc.).

Pour cela, nous nous sommes interrogés sur les fonctions essentielles et leur importance pour tel ou tel *doublet*.

Nous prendrons quelques exemples simples:

1) pour les gisements et fouilles archéologiques:

- l'enfouissement associé à la saturation ou à la désaturation du milieu et de l'objet (conséquences possibles: vieillissement accéléré, disparition, fantomisation);
- les risques d'érosion et de déclenchement de la météorisation.

2) pour les monuments ornés:

- l'hydrochimie qui engendre la disparition des peintures par concrétionnement (grottes);
- la microclimatologie associée à la présence de visiteurs qui accélère la calcification ("maladie blanche") et le développement algal ("maladie verte");
- la végétation aux-dessus des cavités qui par l'intermédiaire de l'évapotranspiration équilibre les échanges hydriques vers la profondeur (infiltration) et vers l'extérieur et par là même le climat souterrain.

A ce titre nous signalerons que le régime actuel de cet écosystème semble satisfaisant pour la conservation des oeuvres rupestres alors que toute déforestation à proximité immédiate et rapprochée du monument présenterait un danger associé à un déséquilibre du bilan hydrique.

4.3 Bases scientifiques de cette protection

La protection des monuments ornés implique en priorité celle du site surincombant et environnant dont les dimensions sont chaque fois un cas d'espèce.

Ces dimensions sont à rattacher à l'évolution paléo-génétique des lieux (âge, origine du creusement ou de l'évidement du réseau souterrain, de l'abri, de l'à pic, du bloc etc.).

A cela, il faut ajouter une bonne connaissance de la dynamique climatique et microclimatique actuelle: ensoleillement - froid - transferts hydrologiques (en milieu aérien), hydrogéologiques (en milieu souterrain) - ventilation.

De la sorte, il est possible de déterminer, par le calcul comme par la mesure expérimentale, les temps de transfert des calories, des frigories, les volumes d'eau infiltrée, les taux de pollution physicochimique, organique et microbactériologique, lesquels, on le sait, peuvent par leur présence excessive ou déficitaire perturber l'équilibre naturel de la paroi, de la peinture et/ou de la gravure qui la recouvre.

A partir de ces mesures brutes, des prévisions qui peuvent être faites et de la cartographie des paramètres, il est possible d'établir synthétiquement pour chaque cas un découpage géographique révélateur de la vulnérabilité à l'égard des altérages.

Celle-ci est circonscrite à l'intérieur de *périmètres de protection*.

4.4 Un cadre et des commentaires succincts

Nous avons envisagé jusqu'à ce jour des découpages géographiques à trois modules de dimensions croissantes, deux de ces périmètres pouvant être dissociés le cas échéant en sous-ensembles.

Le périmètre de protection immédiate occupe au sol la surface la plus restreinte; il englobe en général le territoire immédiatement circonscrit au monument. Les règles qui le régissent sont les plus contraignantes.

Le périmètre de protection rapprochée intercepte au sol une aire altimétrique plus élevée que le monument, aire en-dessous de laquelle une pollution est susceptible de se transmettre rapidement au niveau des peintures et/ou des gravures et sculptures. Le délai peut varier entre quelques heures et quelques jours (8 à 10 environ).

Les contraintes associées à cette protection comportant des interdictions et des autorisations sans condition ou assorties de conseils selon la nature et la géométrie de l'environnement aérien et souterrain.

Le périmètre de protection éloignée englobe toute la surface au sol intégrée dans le bassin versant topographique ou impluvium.

Il s'agit en fait de l'aire au-dessous de laquelle la pluie après ruissellement et infiltration est susceptible d'émerger un jour au contact des peintures et des gravures après un temps de transfert souterrain plus ou moins long et inférieur en général à 12 mois.

Les contraintes associées à cette protection ne comportent que des réglementations et des recommandations.

4.5 Bilan

A ce stade de l'enquête, nous proposons un tableau de dénominations équivalentes, que chaque responsable et spécialiste ou *gestionnaire du risque* (cf. conclusion) pourra adapter selon l'impact qu'il souhaitera donner à son projet.

| périmètres de protection | degrés de vulnérabilité | - équivalences des dénominations dans la zonation (application du site souterrain de Combarelles) |
|--------------------------|-------------------------|---|
| périmètre immédiat | vulnérabilité "forte" | - zone "rouge" - sous-zone "jaune" ou "orangé"; c'est-à-dire (cad.) aires très exposées avec risques multiples à caractère irréversible et redoutable Combarelles = aires N°1 et 3 |
| périmètre rapproché | vulnérabilité "moyenne" | - zone "bleue" - sous-zone "bleu clair"; cad.; aires exposées à des risques moindres et à caractère réversible Combarelles = aire N°4 |
| périmètre éloigné | vulnérabilité "faible" | - zone "blanche" - sous-zone "grise"; cad. aires présumées à faibles risques prévisibles Combarelles = aires N°2 et 5 |

5. PROTECTION ZONALE DU DOUBLET

5.1 Application à la grotte ornée de Combarelles

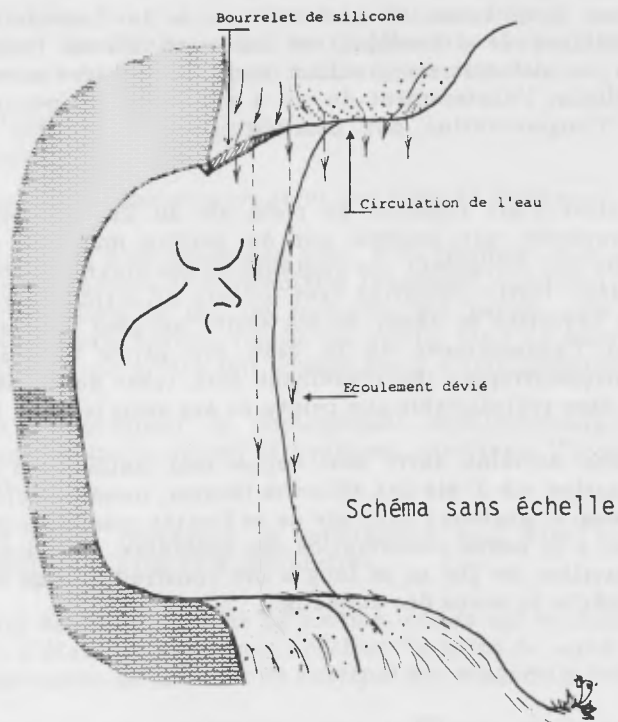
A la suite du développement de cette étude des risques, applicable à n'importe quel doublet, nous sommes en mesure de cartographier la cible et de délimiter au sol les zones et sous-zones témoins d'une vulnérabilité variable et évolutive dans une vision prospective des problèmes.

Nous illustrons nos propos par l'exemple d'une grotte ornée de gravures, la grotte de Combarelles qui se situe dans la commune des Eyzies (cf. fig. N°11 et 12 et tableau N°1 déjà cité).

5.2 Facteurs limitant dans la protection des oeuvres (ex. choisis)

5.2.1 Protection contre l'eau en excès en climat humide tempéré ou tropical par exemple

Sous diverses latitudes, l'eau peut être un agent dégradant des oeuvres rupestres par effet de ruissellement. Actuellement, le contrôle hydrologique n'est pas envisageable en raison de surfaces à traiter toujours importantes (quelques centaines à quelques milliers de m²). Il est préférable de s'orienter vers des actions ponctuelles tel que le drainage par microforages ou la pose de gouttières (Fig. 13).



COUPE TRANSVERSALE D'UN ABRIS PEINT

Le bourrelet empêche l'eau de ruisseler sur la peinture rupestre.

FIG.N° 13

Ces procédés sont délicats à mettre en oeuvre et doivent être adaptés en fonction de la nature et de la fissuration de la roche.

Le premier cas a été mis au point dans le "salon noir" à Niaux par nos collègues du C.N.R.S. de Moulis. Cette technique a permis de maîtriser l'excès d'eau qui provoquait le lessivage des traits peints.

Le second cas a été appliqué dans l'abri du site de "Walga Rock" en Australie occidentale sous la forme de bourrelets d'élastomères qui font obstacle au ruissellement.

Une opération similaire a été réalisée à titre expérimental sur les parois rocheuses en bordure de l'oued Timenzouzine (Algérie) en climat désertique.

5.2.2 Protection des oeuvres à l'encontre des hommes et des animaux

Les aménagements destinés à faciliter les conditions de visite et à améliorer la protection des peintures peuvent avoir des effets contradictoires. A la grotte de Niaux, déjà citée, l'abaissement du sol au niveau du "Salon Noir" par les découvreurs (Cartailhac - Garrigou - Molard) fut bénéfique dans la mesure où il mettait hors de portée les principaux panneaux décorés. A l'inverse, cette action eu des retombées négatives par suite de la destruction des niveaux de sol préhistoriques dont les portions immédiatement en contact des parois possèdent des "gravures sur argile".

Ces niveaux, jusqu'à une décision récente de la Commission Supérieure des Monuments Historiques de consolider ces surfaces, furent l'objet d'un véritable "grignottage" par les visiteurs s'approchant trop près des ces gravures. Toujours au "salon noir" de Niaux, l'abaissement du sol a certainement perturbé les conditions climatiques par l'augmentation des possibilités de circulation d'air. C'est une hypothèse.

Dans les sites d'art rupestre de plein air du Tassi N'Ajjer en Algérie, la protection de proximité est assurée par de petites murettes de pierres sèches d'équilibre instable qui dissuadent les visiteurs de les enjamber pour voir et toucher les parois décorées. Cette initiative très louable et efficace présente après coup l'inconvénient de favoriser le dépôt de sol éolien au pied des parois pouvant aller jusqu'à provoquer l'ensablement de la base des parois décorées et en cas de précipitations pluviométriques (heureusement fort rare) de constituer une réserve hydrique pouvant être préjudiciable aux peintures des abris (cf. fig. N°6 et 14- ABCD).

En Australie certains abris sous roche sont entourés d'une barrière pour assurer leur protection vis-à-vis des animaux (bovins, moutons, chèvres, kangourous, etc.). En effet ceux-ci avaient l'habitude de se frotter contre les parois. Ces actions sont préjudiciables à la bonne conservation des peintures. Sur le site de Walga Rock (déjà cité), une barrière de 200 m de long a été construite à une centaine de mètres de l'entrée et empêche la venue des animaux.

CONCLUSIONS

Dans le domaine archéologique (s.l.) nous pensons que la protection des oeuvres et des sites est un tout et que cette protection doit s'envisager à deux niveaux (la *protection active* et la *protection directe* ou *p. de proximité*) et à deux degrés d'urgence (le sauvetage et l'action programmée).

La *protection active* vise (selon la nature des sites, la géométrie du monument, l'activité des lieux, etc...) à définir des zones de vulnérabilité et à interdire certains phénomènes redoutables pour la conservation des témoins archéologiques. Elle vise également à contrôler et réglementer les autres phénomènes moins nocifs, tout ceci devant être intégré dans le cadre de la loi pour être opposable aux tiers (cf. législation française).

Quant à la *protection directe*, et selon la stratégie que nous avons mise au point, nous suggérons une intervention pratique sur le témoin archéologique menacé ou susceptible de le devenir et non plus au lieu de départ du phénomène et/ou de l'altérage.

Cette action nécessite le contrôle en même temps des conditions d'évolution du risque comme par exemple la fréquentation touristique de la grotte, du gisement, etc.

Dans cet esprit nous agissons en tant que gestionnaire du risque et à ce stade il est indispensable que nous ayons les moyens (légaux, scientifiques et.. financiers) d'agir et d'utiliser au mieux les outils de prévention.

La multiplicité des cas que nous avons eus à traiter par le passé nous a amenés à codifier les actions (de l'intervention de routine à la sauvegarde d'urgence) et à alimenter une banque de données selon un double processus:

- rigoureux (fichier étalon)
- souple (fichier évolutif)

afin que nous-mêmes et nos successeurs aient des états de référence.

Ainsi la découverte d'un monument orné, d'un gisement doit-elle être associée à un programme de recherches et d'inventaire favorisant en priorité la prospection à distance ou téléprospection du sol, du sous-sol, des parois, afin que les témoins fragiles (empreintes de pas, foyers, tracés sur argile, etc.) ne soient pas détruits et que l'ambiance initiale d'une grotte soit connue avant d'être perturbée.

Ces actions comprennent la photographie multispectrale, la géophysique, l'investigation thermique (infra-rouge) et hydrique, carottage, l'emploi de périscopes et de microcaméras, etc.

A ce stade de la recherche le programme peut être commun aux sites récemment découverts et à ceux déjà inventoriés.

Dans le cadre des interventions de routine, celles qui excluent toute urgence, il est indispensable d'établir ce que nous appelons "le bilan de santé d'une cible" tant au niveau aérien (synonyme de plein air ou externe) que souterrain (ou interne).

Cette approche est réalisable sur la base d'enquêtes géologiques, hydrogéologiques, climatiques, chimiques étalées sur la durée d'un cycle climatique (11 à 13 mois en général et quelle que soit la latitude des lieux).

Les données acquises doivent alors être transférées sur des fichiers qui constituent les dossiers d'archives.

En raison de la multiplicité des cas de figure dans le monde, il est illusoire de vouloir imposer un modèle de fichier exhaustif comme cela a été proposé lors de certaines réunions.

Pour la France et en ce qui concerne la protection et la conservation de l'art rupestre, nous avons conçu un modèle ou "fichier étalon". Il s'applique uniquement au site de Lascaux pour lequel une focalisation scientifique, technique et financière exceptionnelle a été réalisée (travaux en cours).

Dans le même temps nous avons mis sur pied un "fichier évolutif" à partir duquel chaque spécialiste pourra, en fonction des cas à traiter, faire preuve de réalisme et d'initiative en fonction des critères régionaux, locaux, ponctuels.

C'est l'analyse de tels fichiers qui permettra demain ou plus tard de comparer l'état d'une oeuvre, d'un gisement, d'une fouille entre deux périodes plus ou moins longues et le cas échéant d'établir des priorités d'intervention dans un domaine où le recul scientifique est très court, ne l'oublions pas, et ne date que d'une vingtaine d'années si l'on prend l'année 1963 comme référence (premières recherches entreprises à Lascaux).

TABLEAU N° 1

| N° | SITES | CODES | POSITION GÉOGRAPHIQUE PAR RAPPORT À LA GROTTE | APPARTENANCE HYDROGÉOLOGIQUE | DISTANCE EN M | VULNÉRABILITÉ POTENTIELLE ESTIMÉE |
|----------------------------|------------------|-------|--|---------------------------------|------------------|---|
| LIEUX CONSTRUITS | | | | | | |
| ① | Les Combarelles | N.H. | Aval | Indépendante | 5 | Nulle |
| ② | Les Combarelles | H. | Aval | Indépendante | 110 | Nulle |
| ③ | Les Combarelles | H. | Aval | Indépendante | 275 | Nulle |
| ④ | Combarelles-haut | E.R. | Amont | Indépendante | 225 | Nulle |
| ⑤ | Hollandais | R.A. | Amont | Indépendante | 500 | Nulle |
| ⑥ | Fontenelle | E.R. | Amont | Indépendante | 475 | Nulle |
| ⑦ | Trémoulède | H. | Amont | Dépendance indirecte | 1475 | Très faible |
| ⑧ | Le Repaire N. | H. | Amont | Dépendance indirecte | 1000 | Très faible |
| ⑨ | Le Repaire S. | H. | Amont | Dépendance indirecte | 1150 | Très faible |
| ⑩ | Fontenelle-bas | E.R. | Amont | Directe | 775 | Notable |
| ⑪ | | H. | Amont | Directe | 400 | Notable |
| SURFACES NATURELLES | | | | | | |
| | Aire N° 1 | | Amont - boisée | Directe | | Forte |
| | Aire N° 2 | | Amont - boisée | Indirecte | | Faible |
| | Aire N° 3 | | Amont - cultivée | Directe | | Forte |
| | Aire N° 4 | | Amont - boisée | Indirecte | | Moyenne |
| | Aire N° 5 | | Amont - cultivée | Indirecte | | Faible |

① H = habitée - N.H. = non habitée en 1977 - E.R. = en ruine - R.A. = reconstruction en cours

② Plus courte distance calculée par rapport à l'entrée de la grotte

③ Pol. Pot. estimée dans l'hypothèse de projets de construction de maisons secondaires ou d'exploitations agricoles.

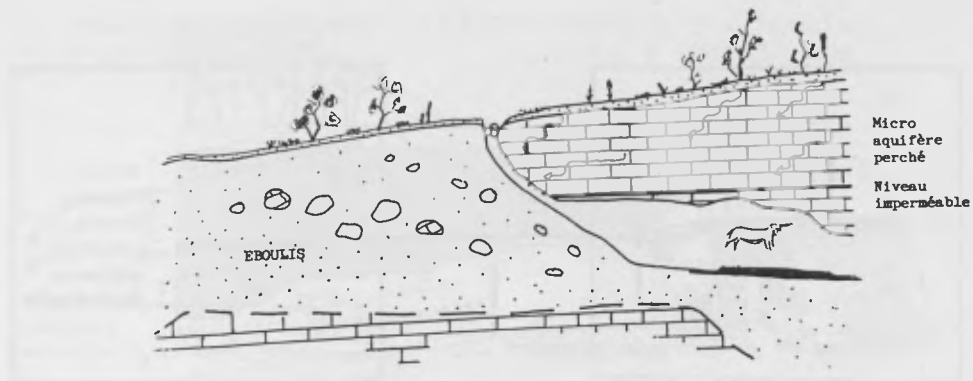


FIG. 1 A - RECONSTITUTION DE L'ETAT DE L'ENTREE DE LA CAVITE EN 1940

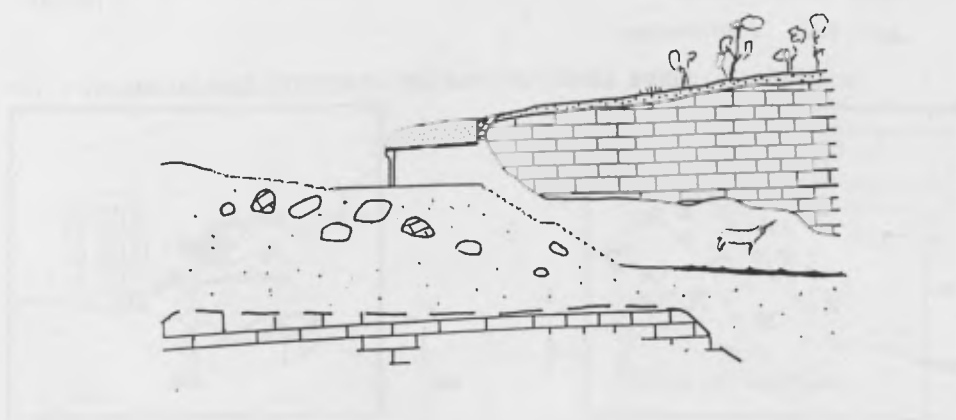


FIG. 1 B - RECONSTITUTION DE L'ETAT DE L'ENTREE DE LA CAVITE EN 1948

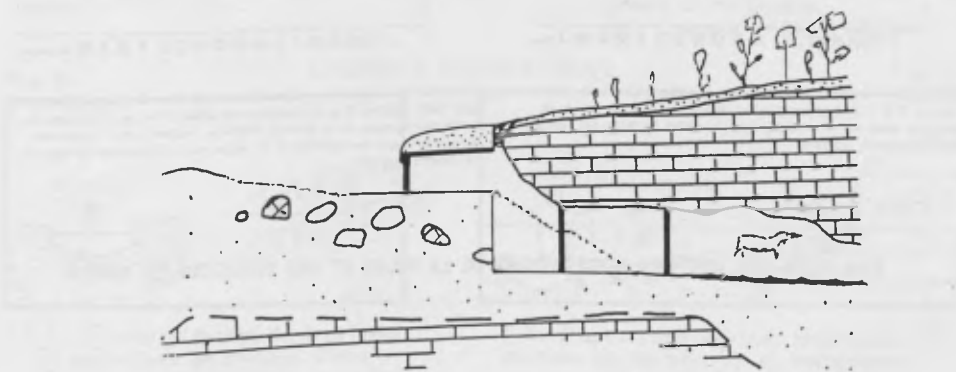


FIG. 1 C - RECONSTITUTION DE L'ETAT DE L'ENTREE DE LA CAVITE EN 1958

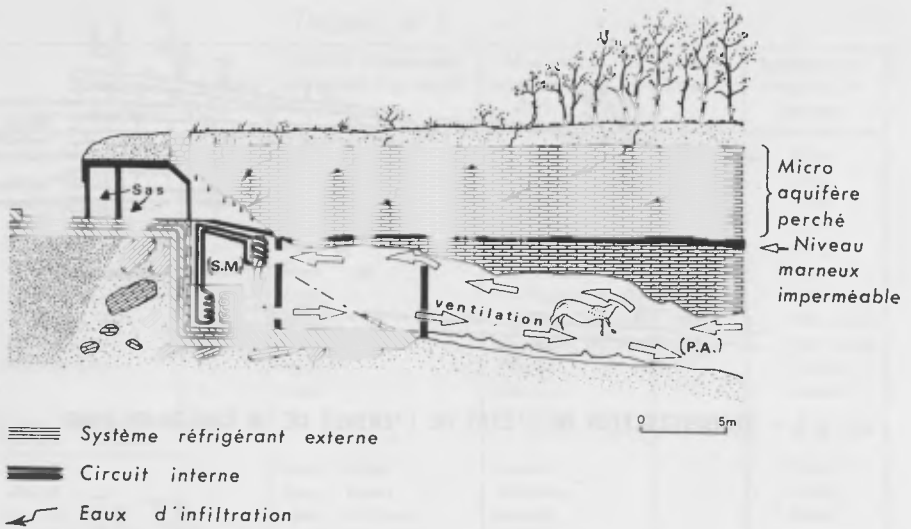
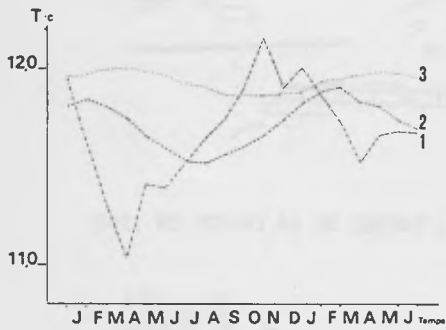
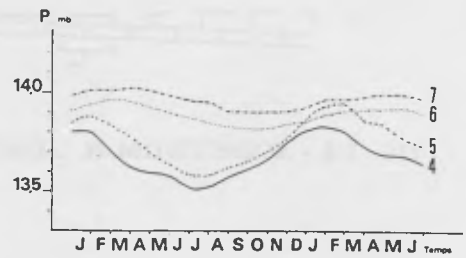


FIG. 2 COUPE LONGITUDINALE DE LA GROTTÉ DE LASCAUX



Variations thermiques de la roche de janvier 1981 à juin 1982. Les courbes 1, 2 et 3 sont respectivement représentatives des points de mesure à la voûte de la Salle des Machines, dans la Salle des Taureaux et dans la galerie latérale.

FIG. 3



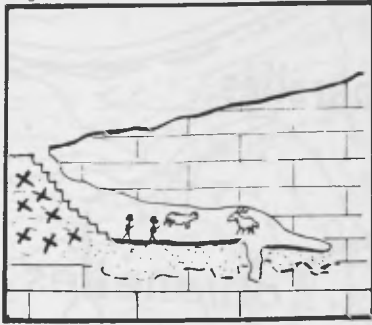
Evolution de la tension de vapeur d'eau dans l'air de janvier 1981 à juin 1982. Courbes 4 et 6 : pression de vapeur d'eau de l'air dans la Salle des Taureaux et la galerie latérale. Courbes 5 et 7 : pression de vapeur d'eau équilibrante de la roche dans la Salle des Taureaux et la galerie latérale.

FIG. 4

EVOLUTION CYCLIQUE DES TEMPERATURES DE LA ROCHE ET DES PRESSIONS DE VAPEUR

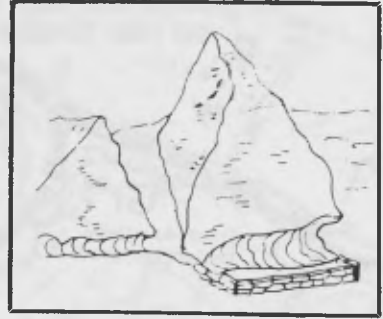
DOUBLETS SITES-MONUMENTS, GISEMENTS, FOUILLES ET ALTÉRAGÈNES

Fig. 5 GROTTTE ORNEE



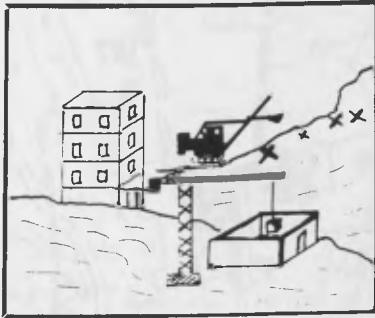
f.d.: facteurs dégradants (f.d.):
tourisme et voiture - aménagements - agriculture - carrières - explosifs

Fig. 6 ABRIS SOUS ROCHE



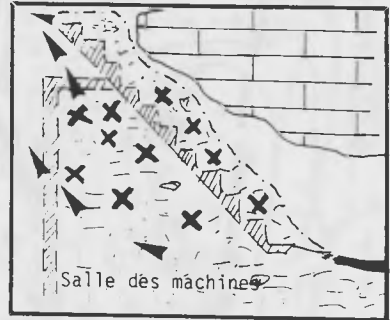
f.d.: désertification - érosion éolienne - tourisme.

Fig. 7 GISEMENT DE PLEIN AIR SUPERFICIEL



f.d.: décapages sauvages pour aménagements par ruissellement - urbanisation - détecteurs de métaux.

Fig. 8 FOUILLE SOUTERRAINE

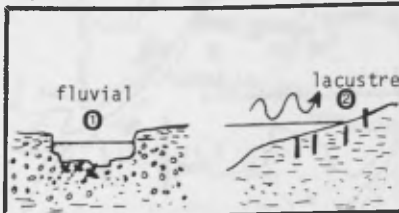


f.d.: extraction de matériaux avec mobilier préhistorique non identifié préalable à l'aménagement d'une grotte (ex. Lascaux - 1948 à 1952)

Fig. 9

GISEMENTS SUBAQUATIQUES

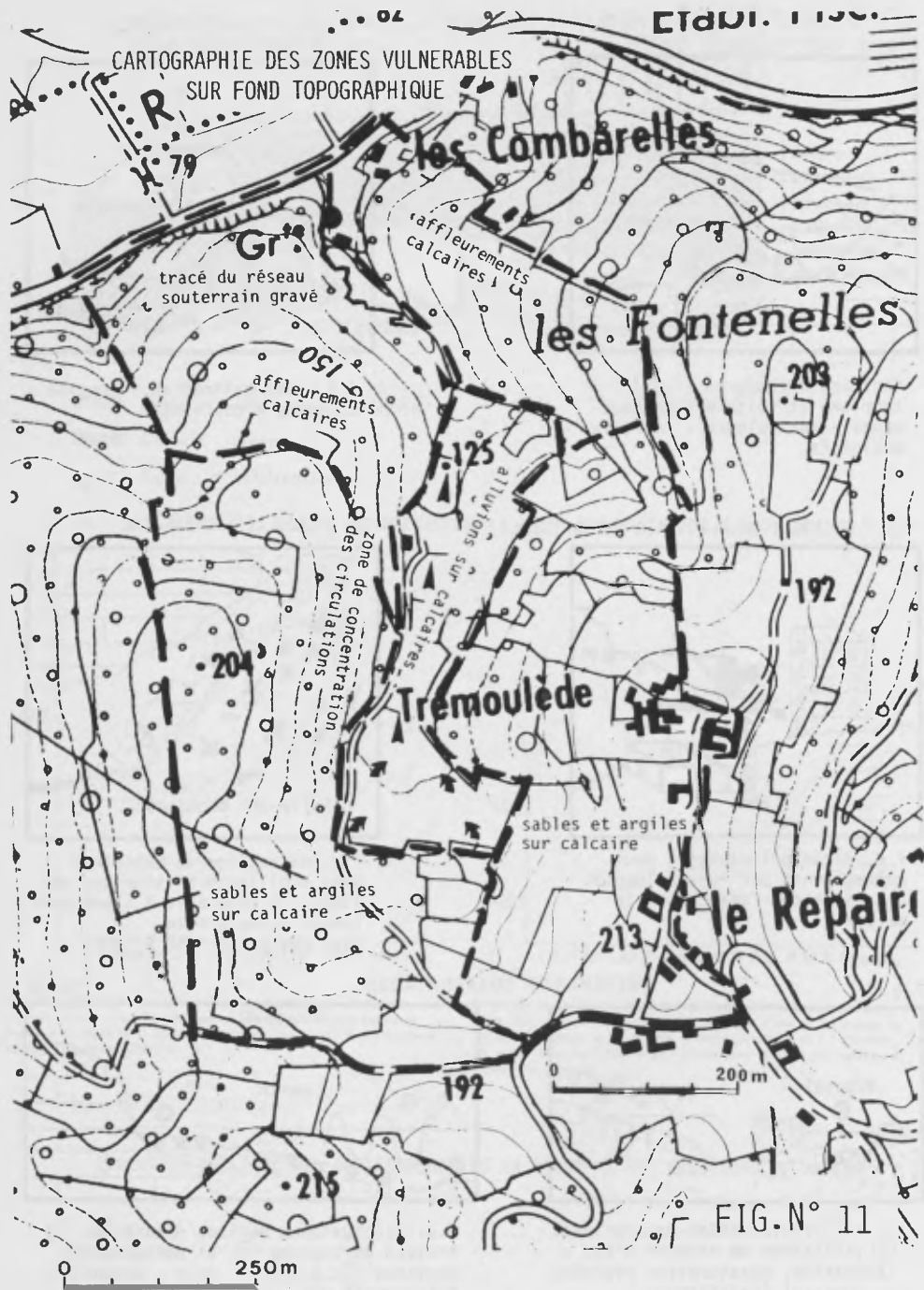
Fig. 10



f.d.: ① exploitation de gravières
② variations de niveaux d'eau ; saturation, désaturation répétées du sous-sol (Palafittes).



f.d.: fluctuations marines naturelles ① travaux portuaires ② et aménagements sauvages ③ (jetées - épis - extensions d'aéroports etc...).



CARTE DE VULNERABILITE
SUR FOND CADASTRAL



FIG. N° 12



FIG. 14 A

ETAT INITIAL DE L'ABRI



FIG. 14 B

CONSTRUCTION D'UNE MURETTE DE PROTECTION

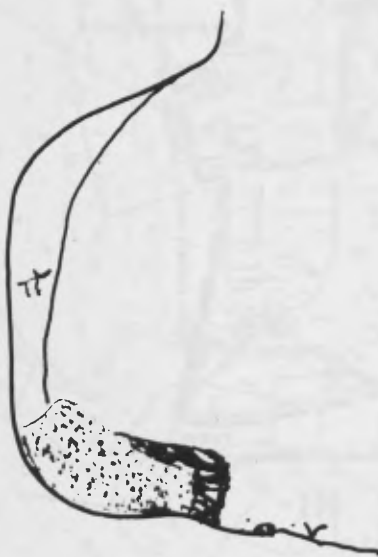


FIG. 14 C

ACCUMULATION DE SABLE AU PIED DE L'ABRI



FIG. 14 D

EN CAS DE PRECIPITATION, POSSIBILITE DE REMONTEES D'HUMIDITE

ARCHAEOLOGICAL CONSERVATION IN THE CASTLE OF KRUJA

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Although there was a certain amount of archaeological activity in the past, the scientific protection of historic monuments in Albania started and developed only after the Second World War, without having any past theoretical or practical tradition. Archaeological conservation, as one of the sharpest questions of an active protection of monuments, is for understandable reasons still younger - it has existed in our country for approximately three decades. Thanks to the favourable conditions created by the State for the protection, preservation and presentation of monuments of culture as a whole, achievements in archaeological conservation of sites and objects are visible today.

Given its small territory, Albania has a remarkable number of archaeological sites from all periods, the overwhelming majority of which are still unexcavated. The right to declare an archaeological site in Albania and to undertake excavations and conservation belongs only to the State, which exercises this right through a technical and scientific staff specialized in history, archaeology, architecture, art, engineering and other auxiliary disciplines. From the organizational point of view, this activity is directed through the cooperation of two scientific research institutes, which have their headquarters in Tirana: the Archaeological Research Center (QKA) and the Institute of Cultural Monuments (IMK), together with sub-centres in different areas of the country. In their archaeological conservation activity, the Albanian specialists have kept in consideration the theoretical and practical experience of the specialists of ICCROM, as well as that of the countries most advanced in this technico-scientific field. The 1956 Unesco Recommendation on International Principles Applicable to Archaeological Excavations has served especially as a point of support. With the intensive work done over the last three decades for the excavation and conservation of sites such as Epidamnus, Apollonia, Buthroton, Lissus, Scodra, Antigonea, Nikea, Bylis, Amantia, Dimalum, etc., quite a rich native experience has now accumulated. This theoretical and practical experience of archaeological conservation is in conformity with the scientific level of the country and the intellectual interests of the society. A typical case of the Albanian experience in the field of archaeological conservation is that of the practice applied in the medieval castle of Kruja.

Kruja, situated around 30 km north of Tirana, is one of the four medieval towns of Albania that have been declared historic towns, because of their historical, urbanistic, architectural, artistic and engineering values. Its castle was built over a natural rocky crest, which dominates the whole of today's town (fig.1). An episcopal center from the 9th century, in the 12th century Kruja became the capital of the principality of Arber, the first Albanian medieval state formation. It reached its political apex in the 15th century, when it became the capital of the Albanian state of Gjergj Kastrioti Skënderbeg, the legendary leader of the epic liberation struggle of the Albanians against the armies of the Ottoman Empire. But it paid dearly for this brilliance, with the great destruction it suffered a number of times during the military clashes of the Middle Ages, and especially with its complete destruction in 1478, when it fell definitively into the hands of Mehmet II. From that time on, the fortified town of Kruja lost the material evidence of its medieval civilization. The passage of time covered its ruins with the usual accretion of centuries. With the exception of the structures of the entrance, of the donjon and some fragments of its surrounding walls, nothing else was visible on the surface of this accretion, made partly by earth and partly by buildings of the last two centuries. Besides this poor aspect of the medieval ruins on a surface of 4 ha of the castle, there was an even greater lack of historical written sources on the life of the medieval town. Due to this lack of documentation, many scholars were of the opinion that the numerous wars had left the castle of Kruja without any evidence of its medieval culture.

Among them, the Austrian medievalist Th. Tippen, who visited the castle in 1907, wrote that the history of the castle of Kruja would remain dark forever, suggesting that not even the interventions of the archaeologist could change such a situation. In spite of that, the castle of Kruja was one of the first archaeological sites to be placed under tutelar state protection, and was immediately submitted to conservation policy.

1. Field practice has proved that whatever the state of archaeological sites may be, whether excavated or covered with the historical accretion of centuries, once their value is traced, that is once it is declared tutelar, they must be put under conservation. Even when there is no plan for any immediate excavation, there is still place for conservation interventions. In such a stage the site must be protected from the presence of deep-rooted plants, from the heavy vehicles that may circulate on its surface, from landslides and many other things. Until excavation of the site has started, all the historic accretion, which serves as a natural preservation of the underground archaeological material, is conserved. Under such conditions, the conservation of an archaeological site implies precisely the conservation of its "historical accretion". Therefore to declare a site under protection means to start its conservation. From that moment on, conservation becomes a continuous process, closely connected with the existence of the values of the site. In every case, responsibility for conservation of archaeological sites is entrusted from the very beginning to IMK.

For over thirty years the castle of Kruja was kept under control and conservation measures for its historical appearance. Several preventive measures were adopted which served to preserve the still unexcavated archaeological material: among these were continuous consolidation of those unknown stoneworks which came to the surface; prohibition of any underground installation, any new construction within it, or cultivation of the land; keeping out livestock; eliminating any occasional late construction; cutting of big trees situated near the surrounding walls; continuous clearing of seasonal vegetation, etc.

An important problem treated in this early stage of conservation was the study of the stability of the rocky crest on which the site of Kruja stands. A simple look at its northern and eastern sides shows that the rock, made of a calcareous formation, is rapidly decomposing. Apart from the big blocks that had fallen off some time ago, there are still many deep cracks in different directions, which indicate the likelihood of further major rock falls. Among them, in the most advanced state, was that of the north-eastern corner of the castle (with a volume of nearly 3,000 m³), the separation of which would have caused serious damage to the site. A number of projects were considered for its stabilization. At first, attempts were made for a concrete reinforcement within the rock, but because of interior decomposition of the rock, such a reinforcement was abandoned as damaging. The safest and most practical intervention was considered to be the utilization of spoil from the excavations in the acropolis. This was done: about 800 m³ of earth were compressed like a slope into the base of the rocky block.

2. The great historic value of the castle of Kruja on one hand, and the great poverty in documentary evidence on the other, dictated the necessity for immediate archaeological excavations, considered as the birth operation of the site, the act of bringing it to society's cultural life. Obviously it is the most critical moment of its active protection, which is why it is accomplished through a preparatory stage. IMK does not permit any attempt on the part of QKA to start excavations, without having done a preliminary archaeological-conservation study of the site and without preparing the necessary means for the prophylactic care of the archaeological material. From this moment on, the site is kept under study by a team of specialists,

who base their work on the close collaboration of the archaeologist with the conservator. Their work in this stage aims at the drawing up of the archaeological-conservative cartography of the whole site and of the excavation programme. The cartography contains, on one hand, the archaeological data ensured through the written historical sources and through the survey accomplished in the field, while, on the other hand, it also contains conservation data about the kind and state of archaeological material, the approximate topography of the basic area of the site, climatic characteristics, relative humidity, frost occurrence, water overflow, predominant wind direction and frequency, characteristics of the traditional building materials still in use in the inhabited area around the site, etc. The programme contains the areas chosen for excavation in the studied site, the excavation planning strategy, the transport to the site of the necessary means for conservation and also the bilateral funds.

During the drawing up of the cartography, done in 1976-1978, it was understood that the ground of the castle preserved evidence of the medieval town. There were fixed traces of a number of architectural works, and the situation of some archaeological pits with a clear and rich stratigraphy. Although the archaeologists were interested in frontal excavations in the whole uncovered area of the castle, the excavation was permitted and programmed only in three of its zones (representing nearly 25% of the surface): in the SW, where was to be uncovered the fortified yard which served to defend the drinking water spring of the castle; in the centre of the site, where were to be found elements of the urban nucleus of the town, together with its aqueduct; in the NE side, for excavation of the acropolis of the castle (fig.2). The programme was to respond to three conditions:

- a) the archaeological material that was to be excavated in these three zones was to be sufficient to throw light on the medieval history of the site;
- b) the conservation resources were to be capable of facing any problems created.
- c) an untouched archaeological area should be left for the excavations of future generations.

3. Excavation is considered as a temporary intervention in the permanent process of conservation of an unexcavated site. But the relatively short period of time of its accomplishment and the consequences it brings to the archaeological material by destroying its century-long equilibrium, demand from the conservator the most intensive attention and energetic action, maybe more than in any other stage of the existence of the site. In an archaeological excavation we do not divide responsibility for success or damage between the excavator and the conservator. It stands as a duty and common responsibility to resolve urgently each of the many conflicts that arise during the excavations between the passion of an archaeologist for operations and the insistence of a conservator to preserve every part of the ruins and objects, and this must be done for the benefit of the fullest possible preservation of the context of archaeological material. As a consequence, the dynamic of excavations is characterized by an elastic exchange of criteria, passing from the criterion which suits the conservator, and vice versa, according to immediate needs as work goes on. The excavation is considered successfully concluded when the conservation of all the archaeological material is ensured (both site and objects), be it even provisionally.

The excavations in the three zones of the castle were accomplished during 1979-1983. In the SW side some important finds were made as a result of the investigation of the architectural ruins, but at the same time their conservation was

accomplished. Thus we attained full discovery of the constructions left from towers of the walls of the fortified yard, accompanied by a number of consolidation interventions. Conservation was also done on this side for the walls and towers of the castle, and for a byzantine chapel of the 9th century, the remains of which were covered with a protective sheeting of traditional materials. (figs.3-5).

Valuable urbanistic evidence was found in the excavation of the central part of the site. The conservation interventions performed in due time saved many fragmentary traces, structurally weak, of the two early stages of the main street of the castle, the ruins of some buildings, the architectural remains of a mosque, fragments of the 15th century aqueduct, etc. (fig.6). Not dwelling at length on the great number of problems that arose and were solved during the archaeological-conservative process on the site, we will concentrate only on the methods of conservation during excavation in the acropolis of the castle.

When the cartography was being drawn up, we already knew about the existence of the acropolis wall, connected in the north with the donjon and in the south with remains of another unexcavated tower (fig.7). The pickets were even fixed for the ruins of a church in its interior. It was this knowledge that oriented the excavation strategy. The work started with the excavation of the acropolis wall, going from the donjon to the southern tower (fig.8). The wall, nearly 5 m wide, was made from four curtains of closely-fitted walls, built in different periods. The second wall in line (on the side of the attack), connected with the substructures of the donjon, was older and belongs to the 12th century. The three others are supported on it on both sides, one on the side of the attack (with a slanting face), the other two on the interior side of the acropolis; these seem to have been constructed during the 15th century. The southern tower was also of the same time. Because of the weak building material (weak lime mortar) mainly of the 15th century walls, the excavation of the acropolis wall was accompanied by consolidation at every step (fig.9). In its sides, at different heights, appeared voids in the form of pits in the masonry, which were filled on the spot, thus eliminating the danger of demolishing the overlying structures.

The excavations continued in the inner space of the acropolis, in an area of 160 m², around an archaeological pit found during survey (fig.10). As it had no architectural ruins, the excavations were carried out by the archaeologists. A rich variety of objects from all periods of the Middle Ages was put under conservation in the field. In the NW side of the area, already excavated, in the foundations of the acropolis wall the remains of a small apse were found, covered with painted wall plaster, which indicated the existence of an unknown chapel. As all the remains of the chapel, with the exception of the apse, lay under the foundations of the acropolis wall, its conservation took priority and the excavations were interrupted. The season of the excavation of the chapel was postponed until the conclusion of the respective conservation study, and the exposed apse was backfilled with earth.

The conservation work was further concentrated on the excavation of the remains and objects from the church near the donjon, of which some of the elements of the plan were known. For the preliminary elucidation of the stages of the construction, and of the state of the ruins, and with the purpose of creating greater possibilities for props and the fixing of pillars for provisional covering of the sanctuary, the excavation was first accomplished from its four exterior sides (fig.11). From this stage of fieldwork it became clear that we had to do with the remains of two churches, situated almost one over the other. The ruins of the bottom church belonged to the 10-11th century, while those of the church above to the 15th century (Latin rite). The west walls of the 15th century church presented many conservation problems. Consolidation had to be done from the very first steps of

excavation, whether by filling the vertical cracks or by reinforcing its very weak structures from above. On the other hand, as its foundations were not completely supported by the substructures of the older church, a whole system of props was put in to support it from the outside until the foundation could be reinforced. The foundations of the SW corner of this church were also over unstable earth. The need to go deeper with the excavation at this point led to the fixing of a definitive metallic beam, etc. in the foundations of the ruin.

Before starting the excavation in the interior of the churches, a temporary roof of wooden rafters and corrugated asbestos-cement was erected to cover the whole excavated area (fig.12). The advance in the excavation of the interior was done in three transverse zones, because of the completion part by part of the foundation of the western wall. It was traced through the matrix and grid system, so as to record every fragment of the painted wall plaster which had fallen in the interior of the sanctuary, but which was found to be heavily damaged due to burning. Some fragments of the painted wall plaster were consolidated. At the same time all the wall tops of the remains were reinforced with mortar (fig.13). Meanwhile, the planning for the excavation of the remains of the chapel situated under the acropolis wall was prepared (fig.14). In a situation where it was necessary to preserve at the same time the acropolis wall and the remains of the chapel, while also aiming to excavate it, we were obliged to make the excavation of the chapel during the process of conservation. Without verifying the archaeological relationships between the architectural remains of the chapel and the walls of the acropolis, a liberation in height and width of its structures would have been mistaken. This is why at the beginning only the part of the foundations of the two 15th century curtains was opened in the form of a gallery in the acropolis wall. From the space created, all parts of painted plaster were removed in a ruinous state, and at the same time they were recomposed on a special frame or panel of clay. On the basis of the archaeological material, the chapel was dated to the 6th century (paleo-Christian). Going further in the interior, the remains of its walls were preserved in almost all their height and were incorporated in the transverse section of the acropolis wall. For the further removals needed to make the chapel more evident, it was decided to leave them after assessing the historical values of the site and the definitive conservation (fig.15).

4. Conservation fieldwork in the excavation stage is considered accomplished when all the urgent needs that come up are stabilized, and when conditions ensure that all the remaining problems of further conservation of the site and its objects can be solved in tranquillity. The planning of conservation after excavation is done on the basis of a definitive archaeological and conservation survey of everything that has come from the excavations, on the basis of an objective and comprehensive evaluation of remains and objects that deserve to be preserved and displayed. This evaluation aims first to ensure the consecutive archaeological evidence for historical periods of the site, and second, to underline the evidence belonging to the most important period of the site. After this common evaluation, the site remains solely in the hands of the IMK. Conservation after excavation aims to be as definitive as possible, in the sense of making another intervention of this kind unnecessary or as distant in time as possible (figs.16-17).

Certainly, considering it as one of the most valuable elements of evidence for the history of the site of Kruja, the discovery of the remains of the chapel took priority. It was agreed to liberate the structures situated over it but only for the two curtains of the 15th century, without piercing the wall of the acropolis from one side to the other. A simple shed covered with corrugated asbestos-cement was put over the remains of the chapel, visible only from the interior of the acropolis. Some spontaneous and very late architectural ruins, left during excavation, were removed.

All the wall tops of the excavated ruins, as in the whole site, were connected with a line of stones and mortar rich in lime mixed with 5% cement; this was an intervention of a consolidation nature and at the same time understandable for local scholars. Also indispensable was the permanent shelter covering the ruins of the churches near the donjon. An open shelter would have been sufficient to secure them, but such a solution was superseded in favour of enclosing them completely because they met the conditions needed to function as a site museum. This is why the definitive conservation intervention in the ruins of the churches of the donjon was left to be accomplished at the display stage (fig.18). Last, the archaeological objects were evaluated and divided into two groups according to their value and their conservation needs. The majority were kept in secure premises near the site, while the others were sent to the laboratory.

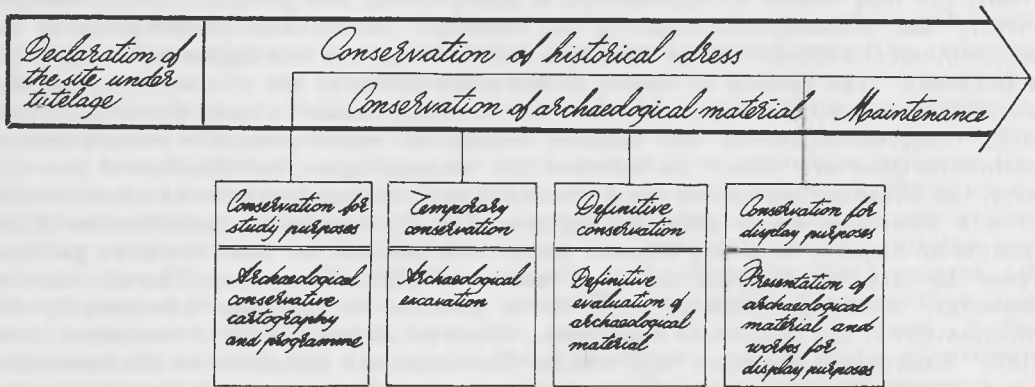
5. The excavation and conservation of archaeological sites, as with all protection of monuments in Albania, is not done in any case to ensure material profits. The State funds, the only source of expenditure in this activity, are given for the interests of history and patriotic education of the society. This is why presentation of the archaeological evidence of the site, in a cultured way and intelligible to the public, is a necessity. The placing of boards at different points of the site with explanations about the excavations is still effective and is widely used. To make the architectural ruins comprehensible for the visitors, sometimes some complete restorations or reconstructions are done. To increase the archaeological information of the site, even the Albanian specialists seem to accept and put into practice the establishment of site museums, which provide conditions for the continuing maintenance of the objects on display. Not only because within this museum the objects will be gathered from the site, but because there, by means of different graphical means, such as drawings, sketches, models, etc., it is possible to increase considerably the information of the context of many ruins, often incomprehensible to the visitor in the field. Such a site museum, with similar functions, can eliminate at the same time much of the damage and costly expenditure that an intervention for their restoration in the field would have entailed, when these restorations are not dictated so much by the needs of conservation, but by needs of improvement of display of the site.

The task of making the archaeological material on the Kruja site (remains and objects) legible for the public led to some other conservation works. To make it possible to read the building stages of the acropolis wall, the masonry of the second curtain, which in its height was linked with the wall of the donjon, was made more evident by raising it with three courses of stones. Complementary restoration work of the masonry was done on three faces of the southern tower, so as to make its form readable. The temporary shed over the remains of the churches near the donjon was transformed into an enclosed field museum. It was erected over the remains of the 15th century church, following its plan but not pretending to be a reconstruction, and was modelled with a wooden framework, covered from outside with laths and plastered, and covered with panels inside. Its roof was constructed with wooden rafters and traditional tiles. Windows on both sides provide light and air. To increase the volume of the museum and to choose the materials used for that purpose, it was kept in mind that it had to have a natural visual integrity within the site of the castle, without spoiling its general historical contours, it had to be reversible and to have a fully justified function. Another conservation intervention for the visitors' benefit was the restoration of the donjon, according to its aspect and function during the last centuries as a watch tower. The creation of a path for visitor circulation in the acropolis, the planting of lawns in suitable places, etc., were some of the last measures to enhance public access.

6. After this work done with due quality, the archaeological material of the site of Kruja was put under continuing post-excavation maintenance. On the other

hand, the unexcavated area remained always under protection for the conservation of all historical accretions. As for all the archaeological sites in our country, so also in Kruja, depending on the size and the problems of maintenance and conservation, a team of five persons, including skilled craftsmen and workers, remains permanently at the site. Their work is planned from time to time, by conservators of IMK. To guard the site, from the moment of its being declared under protection, there is a site custodian employed by the IMK who is also connected with the local state authorities. Another guard is employed in the museum of the site of Kruja.

If we can summarize the stages of active conservation of the site of Kruja, where archaeological excavations are accomplished, we shall give in general lines this scheme:



The archaeological conservation activity at the site of Kruja gave satisfactory results in excavation and protection of the new documentary evidence of its history. The application of traditional methods and materials was another successful step for our specialists in archaeological conservation.

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L'APPRECIATION DES VESTIGES ARCHITECTONIQUES DES MONUMENTS DE L'ANTIQUITE ET DU MOYEN AGE EN ALBANIE

Valter Shtylla*

Un travail considérable est effectué en Albanie pour protéger et conserver des vestiges architectoniques des monuments de l'Antiquité et du Moyen Age. Une section des Monuments de l'architecture antique et moyenâgeuse fonctionne déjà auprès de l'Institut des Monuments Culturels à Tirana. L'Institut s'occupe des fouilles, de l'étude, de la conservation et de la restauration des monuments. La section prend soin de 600 monuments environ, dont un certain nombre sont conservés à l'état de ruines, quelques-uns mis à jour après les fouilles archéologiques et une partie conservée en surface à l'état de ruines.

Pour cette catégorie de monuments, ainsi que pour ceux qui sont intacts, l'Institut des Monuments fait preuve d'une sollicitude particulière. Notre travail de conservation est constant tant aux centres archéologiques bien connus, que sur les ruines architectoniques de n'importe quelle période historique, indépendamment de leur valeur historique et architectonique. Nos restaurateurs se basent sur des critères justes et une méthodologie scientifique. Toujours en collaboration avec l'archéologue, une fois terminé le nettoyage de l'objet, on procède à une observation scientifique et à la définition des phases de sa construction.

Le travail dans les ruines se base toujours sur le rapport et le projet relatif. L'envergure du travail sur les monuments est toujours orienté sur les critères tendant à conserver dans son état original l'objet, sa structure, sa forme et la technique de sa réalisation. En général, on entreprend le travail dans la partie supérieure du mur en vue de le consolider et le protéger des agents atmosphériques en faisant des anastyloses aux murailles antiques en blocs et une liaison en mortier avec les murs moyenâgeux. On entreprend des travaux pour obturer les creux et les cavités, uniquement au cas où ceux-ci mettent en danger la résistance de la muraille ou bien quand ils sont de petites dimensions et que leur remplissage donne une vision plus nette de la ligne planimétrique. Afin de distinguer la partie réparée de celle originale, nous avons utilisé des morceaux de vitre entre les deux parties où on a accentué la ligne réparatrice. Sur les monuments en ruines nous n'avons pas construit de toit (couverture), sauf en présence de peintures murales, comme la chapelle de l'amphithéâtre de Durres. Sur les objets en ruines, où le plancher possède des mosaïques, celles-ci sont couvertes de sable, tandis que les eaux sont évacuées par de minuscules fossés creusés en marge des mosaïques.

Grâce aux travaux de conservation dans les grands centres archéologiques de Butrint et d'Apollonie, les ruines architectoniques sont bien appréciées. Au Théâtre de la ville de Butrint (III^e siècle avant notre ère) on a entrepris des travaux de conservation et de réparation en vue de construire des arcs de briques pour éliminer la dégradation ultérieure des colonnes de la scène, de parfaire des corniches et niches

imbriquées conformément aux lignes originales existantes. Tous ces travaux améliorent l'ensemble en allégeant la construction originale. De même à Butrint, sur la basilique paléochrétienne des IV^e et VI^e siècles, on a parachevé des arcs imbriqués sous les murailles qui séparent les nefs de l'église, structures nécessaires à la conservation de cette ruine architectonique. Les murailles des ruines de la ville antique de Butrint sont constamment consolidées, et en outre ce centre est systématiquement soumis aux travaux de nettoyage. A Apollonie, des travaux de nettoyage, de conservation et de restauration sont régulièrement effectués sur les diverses ruines mises à jour.

D'importants travaux d'anastylose à Apollonie portent sur le monument des Agonothètes (I^{er} et II^e siècles) où on a employé les éléments originaux, et, à la leur défaut, en vue de parachever la structure de la façade originale, du matériel de construction moderne comme le béton-armé et des profilés métalliques recouverts. A l'Odéon de la ville, outre les travaux de nettoyage et d'aménagement des pierres originales des gradins, on a restauré le mur supérieur ainsi que le canal des eaux. Tous ces travaux étaient nécessaires pour protéger l'ouvrage des éboulements et du débordement des eaux des collines. A Apollonie on a bien conservé la promenade de la ville avec des niches en blocs de pierres (IV^e siècle avant notre ère). Un bon nombre de murailles de diverses ruines sont consolidées. Apollonie, ville antique célèbre, riche en monuments en ruines, est soigneusement conservée grâce aux soins constants des restaurateurs de l'Institut des Monuments de la Culture.

D'important travaux de conservation sont également exécutés dans les ruines architectoniques des monuments antiques et moyenâgeux de Durres, un des plus grands ports de la Méditerranée. Un des monuments majeurs de la ville est l'amphithéâtre (II^e siècle) où sont effectués des travaux de consolidation des gradins, tels le remplissage des cavités dans les galeries qui soutiennent les gradins, la réparation des murailles délabrées et lézardées des galeries, quelques réparations des arcs des galeries, etc. La chapelle byzantine du X^e siècle ornée de mosaïques murales et de traces de fresques est couverte de plastique ondulé sur des armatures métalliques.

Outres ces centres bien connus, des travaux de conservation portent sur d'autres ruines et centres antiques, tels les théâtres de Klos et Bylis, sur des objets de Bylis et de Dimal, les stations thermales de Durres et de Bradashesh, etc.

Des travaux de conservation sont aussi effectués en Albanie dans les ruines architectoniques médiévales. De nombreuses basiliques paléochrétiennes (IV^e - VI^e siècles) datant de la basse antiquité et du haut Moyen-Age ont été découvertes ces dernières décennies par les archéologues albanais: la basilique de Lin (Pogradec), de Tepe (Elbasan), de Ballsh (Fier), de Arapaj (Durres) et d'autres. Dans ces basiliques, toutes conservées à l'état de ruines, avec des murailles basses et des planchers décorés de mosaïques de pierres, des travaux de conservation sont effectués sur les murs intérieurs, sur les planchers et leurs annexes, etc. La mise à jour de basiliques paléochrétiennes à mosaïques et des toitures constitue un problème pour l'avenir.

Dans les ruines médiévales on a également pris soin des ponts en pierre; à Poshnje de Berat, on a parachevé l'arc de briques, et ainsi on a consolidé ce pont datant du V^e-VI siècle. Le pont en ruines de Kasabash à Skrapar, ouvrage de l'architecte albanais bien connu du XVII^e siècle Kasem, fera bientôt l'objet de travaux supplémentaires sur l'arc pavé de pierres, qui sera protégé d'une dégradation ultérieure.

Le traitement scientifique de conservation des ruines architectoniques des monuments antiques et moyenâgeux en Albanie, considéré justement comme un important processus dans toute l'activité de conservation et restauration de tous nos monuments, est régulièrement programmé dans les plans annuels de l'Institut Albanais des Monuments de la Culture.

En outre, sur les grands centres antiques et moyenâgeux tels Butrint, Apollonie, Durres, Lezha, Bylis, Shkodra, Gjirokastra, Tepelena, etc., des équipes de nettoyage, de maintien et de conservation travaillent toute l'année.

La recherche, l'étude et la procédure de protection, de conservation et de restauration des ruines sont décrits dans les publications scientifiques de l'Institut.

Les monuments culturels en ruine en tant qu'important matériel documentaire pour l'histoire de la culture de notre peuple, sont protégés et conservés systématiquement par l'Etat socialiste albanais.



Figure 1. Kruja: the castle.

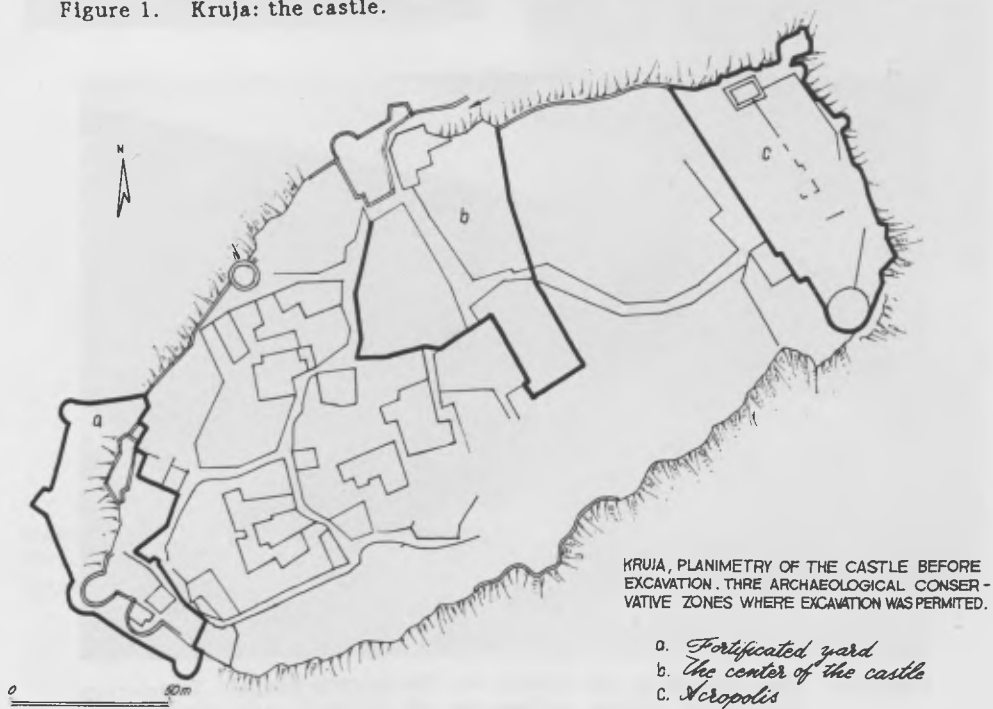


Figure 2. Plan of the castle before excavation. Three archeological zones where excavation was permitted: a) fortified yard; b) the center of the castle; c) acropolis.

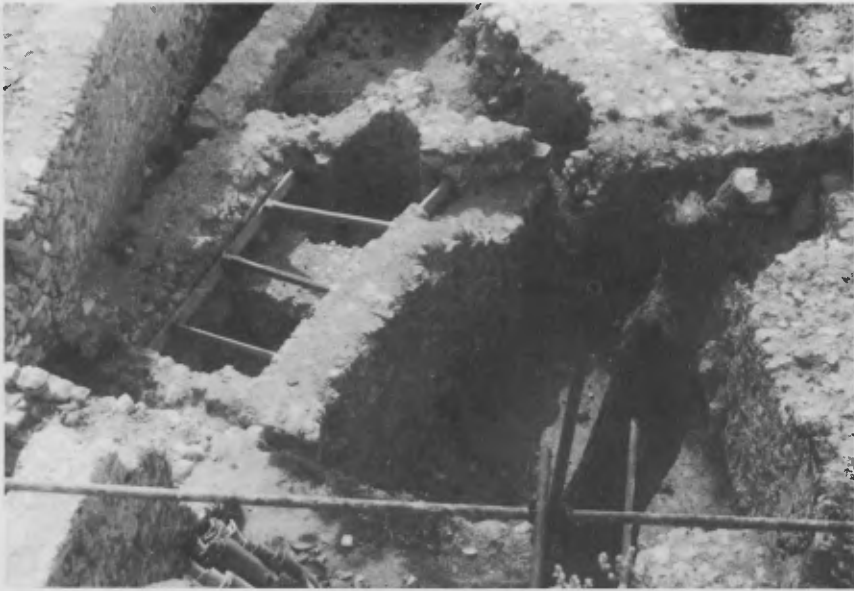


Figure 3. The SW side of the castle: the 9th century chapel during excavation.



Figure 4. The SW side of the castle: the 9th century chapel. Temporary protection during excavation of painted wall plaster was provided by a very simple shed with corrugated asbestos cement.



Figure 5.
The SW side of the castle: definitive
conservation of the 9th century
chapel, re-creating spatial volume.



Figure 6.
The centre of the castle:
conservation during excavation.



Figure 7.
The acropolis of the castle:
prior to excavation.



Figure 8.
The acropolis wall during
excavation.



Figure 9. Acropolis: consolidation during excavation of its curtains and the southern tower.



Figure 10. Acropolis: excavation in the inner space.



Figure 11. Acropolis: the start of excavation of the church near the donjon.



Figure 12. Acropolis: temporary roof before starting excavation in the interior of the churches near the donjon.



Figure 13. Acropolis: consolidation during excavation of the remains of walls and painted wall plaster of the churches near the donjon.



Figure 14. Excavation of the remains of the chapel situated under the acropolis wall.

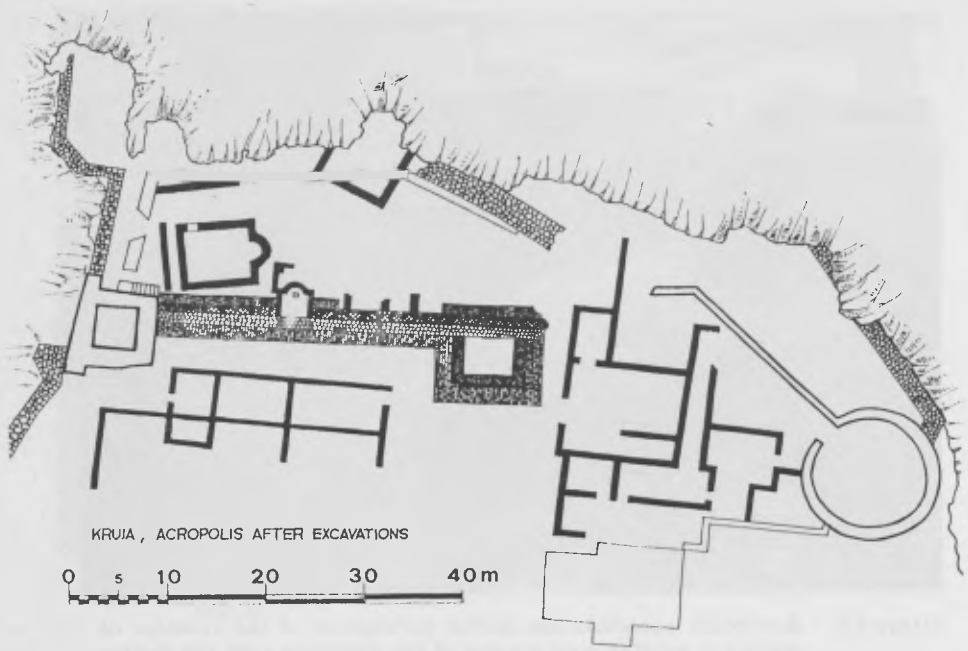


Figure 15. The acropolis after excavation.

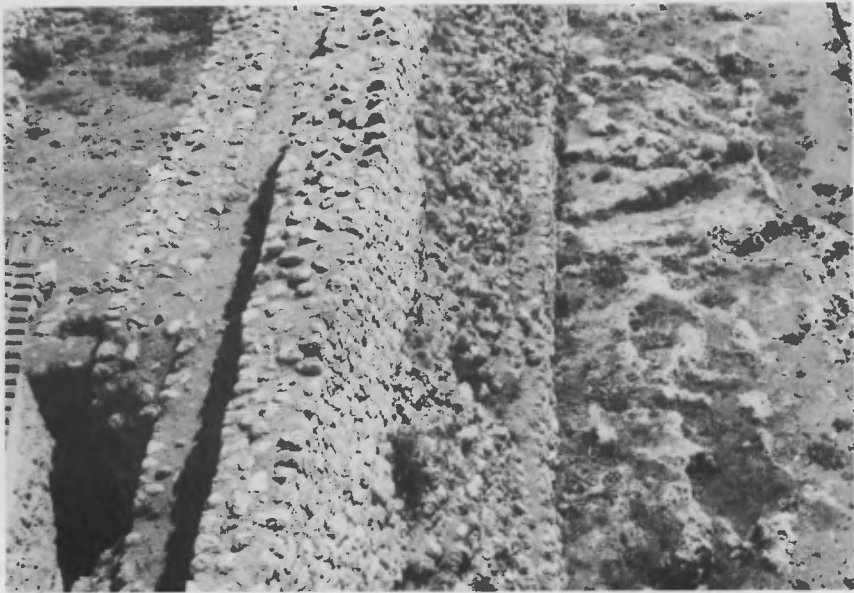


Figure 16. Fragment of acropolis wall after the definitive conservation in the display stage.



Figure 17.
Acropolis: the definitive
conservation of the southern
tower.



Figure 18.
Acropolis: the site museum.

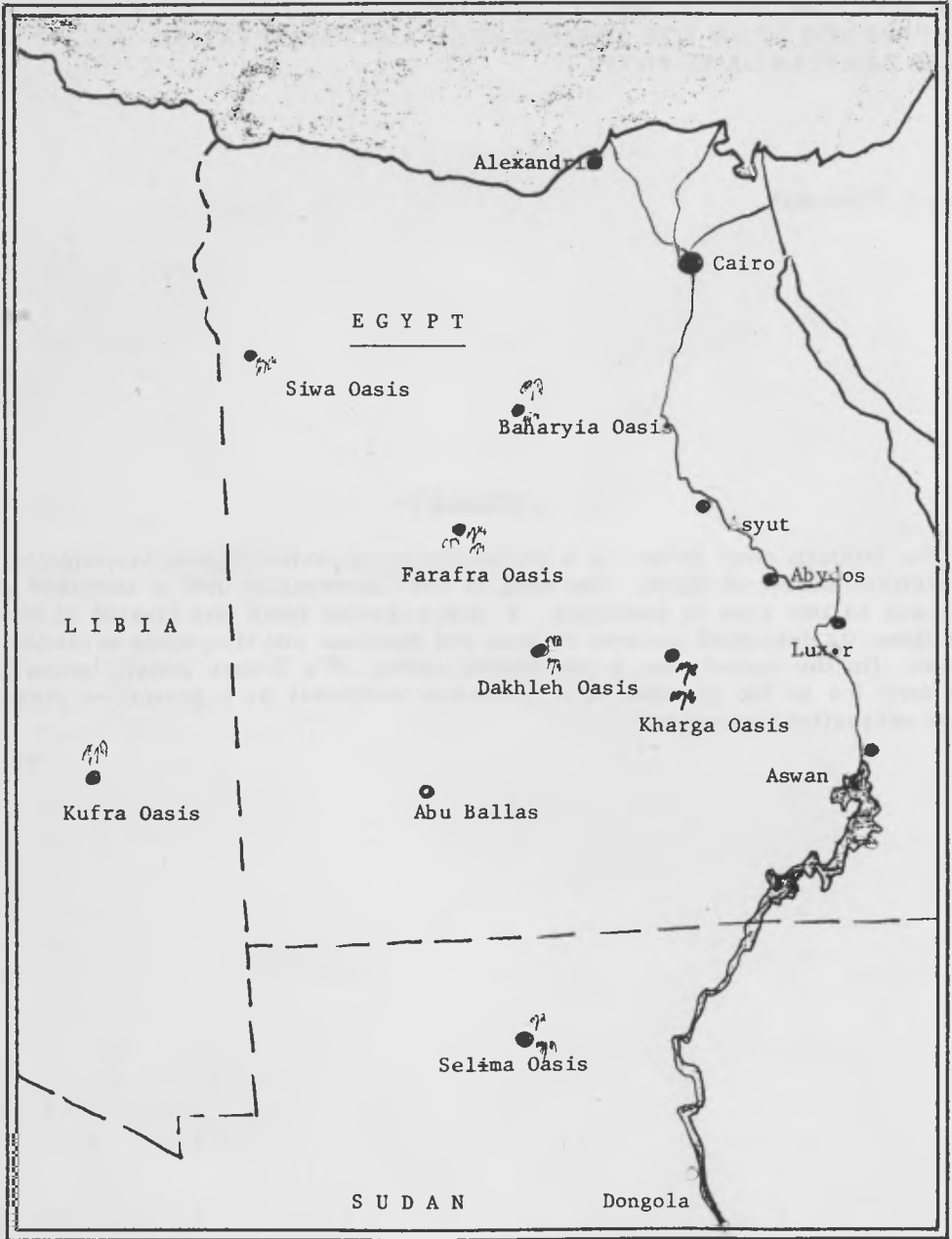
CONSERVATION UNIT OF THE DAKHLEH OASIS PROJECT:
AN APPROACH TO ON-SITE CONSERVATION AND PRESERVATION
IN THE DAKHLEH OASIS, EGYPT

Adam K. Zielinski*

SUMMARY

The Dakhleh oasis project is a multidisciplinary archaeological investigation in the Western Desert of Egypt. The work of the Conservation Unit is described with reference to two sites in particular. A Greco-Roman tomb was cleared of recent accretions, its decorated surfaces cleaned and moulded, and then made accessible to visitors. On the second site, a preliminary survey of a Roman temple buried in a sand dune led to the planting of a protective windbreak as a preventive measure before excavation commenced.

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1. HISTORY OF THE PROJECT - CANADIAN CONCESSION IN THE DAKHLEH OASIS IN WESTERN DESERT

The birth of the Project goes back to 1974 when Ahmed Fakhry, famous Egyptian archaeologist, suggested to Mr Geoffrey Freeman of the Society for the Study of Egyptian Antiquities in Toronto that he work in the Western Desert and, if possible, in Dakhleh Oasis. A preliminary reconnaissance was made and in 1977 a concession was issued to Mr G. Freeman by the Egyptian Antiquities Organization. That year, after a trip to the site, Mr Anthony Mills of the Royal Ontario Museum in Toronto was appointed the project director. It was the beginning of a fruitful relationship which gained momentum a year later in 1978 when the second phase of the enterprise was completed. That phase consisted of an archaeological survey of the whole area. So, in 1978, convinced by the success of the operation so far, the team adopted a new structure for what became known as the Dakhleh Oasis Project and included both the Royal Ontario Museum and the Society for the Study of Egyptian Antiquities, the two organizations sharing research, financial and administrative responsibilities. A generous contribution from the Social Sciences and Humanities Research Council of Canada gave a good start to the project. In autumn 1983 the Project began to undertake the third and last phase of its activities: the excavation as such. This phase will last for many more years.

2. THE DAKHLEH OASIS IN THE WESTERN DESERT

The Oasis is situated about 600 km southwest of Cairo and it is topographically isolated, although modern access is by paved road either from Assiut via Kharga Oasis to the east or from Cairo via Farafra Oasis to the north. It is the largest oasis in the Western Desert of Egypt. It is a sausage-shaped area some 80 km long and 25 to 30 km wide, which lies under the south face of a 500 m high limestone escarpment. The Oasis is the result of a combination of two major elements. The flat cultivable land is composed of rich clay soil, the remains of an old lake bed. More important, however, in this rainless desert is the underground water, which comes to the surface by an artesian process and irrigates the land. Recently, extensive development of deep drilled wells has resulted in the production of large amounts of water, much more than is necessary for agriculture. This new environmental phenomenon seriously influences the Oasis as surplus water has to be stored in artificial evaporation lakes.

The Oasis has been inhabited for 100,000 years, since the period of the hunters of the Old Stone Age. So far, three distinct prehistoric periods have been identified: the Epipalaeolithic, the Aceramic Neolithic and Ceramic Neolithic. Thereafter, in order, the main historic periods of the Oasis are as follows: the Pharaonic period, the Roman-Christian period and the Islamic period.

During its history the Oasis has known many changes of fortune. The Stone Age hunters became farmers and craftsmen. During the Pharaonic era the Oasis was a place of exile and banishment. The Romans established an important agricultural settlement of which many ruins still remain. The Christian era, although short-lived, brought important visitors. It is believed, for example, that Patriarch Athanasius of Alexandria visited Dakhleh during one of his numerous periods of exile and that the heretical Patriarch Nestorius of Constantinople resided in the area after his banishment in A.D. 436.

3. MULTIDISCIPLINARITY OF THE PROJECT

The D.O.P. research team is composed of two major sections:

- the environmental studies group consisting of a geomorphologist, a palaeobotanist and palaeontologist;
- the archaeological studies group consisting of specialists in Egyptology, ceramics, prehistory, classics and epigraphy. The most recent addition to the Project's structure is a conservation unit, acting in close relation with both groups.

In general terms, the Project is an archaeological enterprise with the broad objective of reconstructing and explaining human cultural adjustment to changing environmental and economic circumstances. The Dakhleh Oasis has been selected because it has not yet been greatly affected by modern technological developments. It is large enough to have had a continuing, independent life of its own, yet it is not too large to be an unwieldy subject for intensive study.

4. NECESSITY FOR AND ORGANIZING OF THE PERMANENT CONSERVATION UNIT

Apart from traces of a great number of monuments of all ages, no fewer than 25 temples have been identified. They are all from the Ptolemaic or Roman periods. Some are still decorated with murals and their state of preservation varies enormously. Apart from the temples, more than half a dozen mud brick churches have been uncovered and must be studied. A multitude of fragments and undamaged pots have been uncovered which explains the evolution and needs of man through ages. Mention must be made of an important discovery in 1982 on the Amheida site - a large Roman town in the western part of the Oasis. The whole area covers some 55 hectares and almost all the area is covered with structures. During the test excavation a room was found in one of these Roman structures which was entirely decorated with multicolored mural paintings depicting mythological scenes.

These finds go together with the discovery of tools from prehistoric to modern times. Finally, one cannot speak about Egypt without mentioning sarcophagi, of which the Project has an imposing collection.

The Project is now moving from the archaeological survey of the Oasis to the next stage of investigations, that is, of excavations. This new and more specific archaeological activity requires the preservation and conservation of finds and sites. The abundance of finds, enormous number of sites, variety of occupants at a site, variety of materials and technologies employed and various states of preservation of materials and structures resulted in organizing a conservation unit as a permanent branch of the Project. The unit has been organized to carry out a variety of preservation, conservation and prevention treatments. Also, the present Egyptian regulations for archaeological excavations require preservation of excavated sites and finds.

5. CONSERVATION UNIT OF THE PROJECT

The demands of modern archaeology divide the activities of the unit into two main areas:

- field conservation - preservation treatments on site of artifacts and monuments (the Project archaeologists soon realized that some sites could not be excavated without conservator assistance, that some objects could not be moved without preliminary preservation treatments and that some monuments and sites would disappear if their preservation were neglected);
- collecting data, carrying out observations and studies to provide adequate information to understand the process of deterioration of materials as well as to understand ancient technologies.

The general conservation problems encountered can be divided into two main groups:

- monuments (stone structures, mud brick structures, composite structures);
- artifacts in a variety of materials.

In the course of its work the unit will deal with these material groups:

- masonry;
- ceramics;
- organic materials;
- metals;
- multi-material objects.

Members of the unit carry out inspection visits to sites being surveyed, to study the present state of preservation of a given site, to understand its past and to observe the environmental phenomena of this site. Such a visit is always supported by the presence of an archaeologist, who knows the site and its past, and the ensuing discussion on site is of great importance for future conservation-preservation plans. Such discussion, when it takes place somewhere in a quiet university or museum room, even illustrated with slides, is in most cases only half as successful as one on a site.

Also, the environmental studies and observations are a serious part of the unit's activities. Such phenomena as deterioration of the original bedrock of the Oasis, movements of sand and sand dunes, distribution of water wells and irrigation canals and distribution of salty swamps are observed and studied and the conclusions become an important part of the unit's reports concerning the conservation of a given site or monument. Regular meteorological observations are a vital part of our daily work. These provide important information concerning daily, weekly and monthly variations in relative humidity, temperature and wind direction.

The presence of other scholars allows us to discuss problems arising on site and answers questions which often used to be unanswered when the season was over and such conversations occurred at the university.

The entire archaeological policy of the Project is discussed with the conservator, and the conservation treatment is also subject to archaeological needs and requirements. Two recent projects of the unit were based on such a practical approach. First was the complete conservation of a Roman sandstone tomb and the second one is a long-term excavation-conservation program for a late Roman sandstone temple. The restored tomb is the tomb of Kitinos and is located in the village of Bashendy in the eastern part of the Oasis. The Roman temple is presently a site entirely buried in a huge sand dune, and is also located in the eastern part of the Oasis near an old well called Ein Birbiyeh.

6. COMPLETED PROJECTS AND PROJECTS IN PROGRESS

- *Tomb of Kilinos*

This tomb is one of a group of at least eight Graeco-Roman tombs at the north end of the village of Bashendy. It is built of local sandstone and consists of a square superstructure about 10x10 m standing above ground. Parts of the tombs are decorated with raised relief and with a minimum of preserved painting.

In 1982 the Project was approached by local Antiquity Organization authorities with a request to clean up the tomb and make it more attractive for visitors. Ahmed Fakhry records that the tomb was inhabited when he first discovered it in 1947. Although he discovered it then, nothing was done to the monument until 1972 when he cleared the sanctuary and built a pair of protective gate pillars and installed doors to safeguard the interior.

The condition of the tomb could be described as poor when we completed our inspection in 1984. All surfaces had been blackened by a coating of soot and other matter from cooking fires; it was filled with debris; there was virtually no light inside to enable the visitor to see the monument; and there was a modern village house built on the top of the tomb roof. Much of the stone used in the construction was of poor quality and, for example, several roofing slates had cracked.

In the course of an organized and planned operation, the conservation unit completed the task in six weeks' time, handing the key of the completely restored monument to the representative of the Egyptian Antiquities Organization.

The modern house was demolished as well as parts of the west and north walls and the south-east corner, which had been all rebuilt during the tomb's use as a dwelling and storage space. Also, the protective pillars built by Fakhry as temporary structures were demolished and the original surface exposed. The subfloor burial pits were investigated in each room. With the archaeological work completed, the restoration of the monument could begin.

The treatment proposed and subsequently employed was based on results of tests carried out on samples of deposits covering the interior surfaces of the tomb. The rebuilding of the damaged parts of the walls, additional roofing and installation of a door and skylights were proposed to enable the visitor to realize the sequence of the complete structure as an architectural unit.

The entire operation was divided into two parts:

- structural restoration of the tomb (repair works);
- cleaning of the interior surfaces.

Both parts were carried out together in order to complete the project in one working season. All materials used during the entire project were local, purchased in the Dakhleh Oasis or in Cairo. They were natural materials apart from the iron doorway and glass for skylights. These materials were used so that the natural balance of the tomb structure would be disturbed as little as possible and the original fabric of the tomb preserved to the highest degree.

One of the burial pits was left open to enable the visitor to get an idea of the substructure of the tomb. All the other pits were refilled and their floors have been made up with a layer of rough stones buried in clean yellow sand. The floors are now easy to keep clean and blend with local tradition.

Some 50 cm of sand and debris were removed from the floor of the doorway, down to the original floor of the tomb. The bottom two courses of the original jambs were revealed and bear well-cut decoration and inscription. Missing tomb walls have been rebuilt with stone. A large quantity of stone, much belonging to the original structure, was recovered during the cleaning of the tomb. All our stone additions (new repairs) have been pointed with regular lime mortar and can be easily distinguished from the original masonry as this was built without mortar. The exterior of repaired walls has been built up to the level of the cornice with mud bricks to prevent access to the roof of the tomb. This has been plastered with mud-sand plaster to blend with local traditions.

The tomb, of course, never had windows. The electricity supply of Ezbet Bashendy is only available during the evening hours. In order to provide some light for visitors, small skylights were installed in newly rebuilt walls. None of the windows is visible from outside the tomb and they are too small to permit access. An iron door (according to Antiquity Organization security regulations) and frame have been installed. The door opens inwards and has been so fitted that the vibrations caused by its operation should not be transmitted to the fabric of the tomb.

The second part of the treatment was to clean the interior surfaces of the tomb: walls and ceiling. This was accomplished by the application of mixtures of organic solvents and then removal of softened deposits.

In the season the work in the tomb was confined to making latex moulds for a cast of the decorated chamber and its doorways, which will be reconstructed in the new Egyptian Galleries at the Royal Ontario Museum in Toronto. As in the previous season, all our supplies were purchased in Cairo or in the Oasis and the technology employed was developed under laboratory conditions and entirely focused on what was available in Egyptian markets. This work was completed in a five-week period by a crew of two enthusiasts and the final product was 45 m² of latex moulds of 6 - 8 mm in thickness reinforced with fine cloth and burlap.

- *Roman Temple in Ein Birbiyeh*

The site is called Ein Birbiyeh after a small spring nearby. Largely disregarded in the past, because it was felt to be the ruins of a Roman stone fort, the site proved on testing in 1983 to be an almost complete Roman temple buried to the roof in a large sand dune. The present plan must be seen as a preliminary drawing because it only records the structure at the present ground level. From this plan it can be seen that the temple building measures about 21x25 m and seems to be situated within a mud brick temenos which is entered at the east through a stone gateway. The temple, in addition, is more closely surrounded by a heavy stone wall on three sides, which forms an ambulatory around the inner building.

The temple complex was built on a sand-clay-mud soil and presently is covered by a coppice dune. Visible stone elements, that is roofing slabs and wall tops, are poorly preserved due to physical decay and decomposition of stone matter. The dune is littered with a large number of broken stone elements, many of which are misshapen and in most cases beyond recognition.

The site is located in the vicinity of abandoned cultivation areas. It is in the path of constant north winds, which come from the escarpment making the north boundary of the Oasis. These prevailing winds very often blow at gale force. Transects surveyed across the site suggest that the temple is probably built on the top of a very slight hill which slopes away from it in all directions. It is well above the present water table.

The results of survey testing in 1983, test exposures in 1985 and laboratory research suggest that some parts of the temple will have to be dismantled, the damaged elements repaired where possible and then the structure reassembled. It is proposed that the excavation of this monument will commence in the 1986 season. An essential part of the excavation program will be to undertake conservation and preservation measures as the excavation proceeds. The poor quality of the stone on the surface of the site makes it imperative that the conservation program be developed prior to unearthing the temple. It was necessary to understand something of the structural nature of the masonry as opposed just to the material. To this end, two small test pits were dug in the sand fill adjacent to the wall of the temple. The pits were refilled immediately after examination.

A permanent windbreak - protection for the exposed temple has been designed. Sandstorms infesting the oasis could result in a short time in serious damage to the temple. The windbreak will be a strip of shrubs and trees planted some 100 m from the site on the windward quarter. The planting proposed will include tamarisk for good ground cover, casuarina which grows quickly and acacia, which should remain in place for a century or more. Also, the water needs of the proposed plants are less than modest which is important in the Oasis.

With our existing knowledge of the state of preservation of stone material and of site conditions, the proposed main steps of the treatment would be :

- organizing storage space and working area;
- creation of a protective windbreak around the site;
- removal of all stone elements, presently covering the surface, to a proper storage area;
- dismantling the damaged or unsafe parts of the structure;
- repair of damaged stone elements;
- reassembling.

The proposal is based on observations made on, and conclusions from, site visits around Egypt, as well the present site. The proposed treatment has been discussed on site with the highest officials of the Egyptian Antiquities Organization and our approach to the problem is fully supported by the Organization. Also, the procedure is based on local supplies, obtainable on markets in Egypt, focused on natural materials which have proved durable and stable in local conditions and are able to survive the harsh climate of the Oasis.

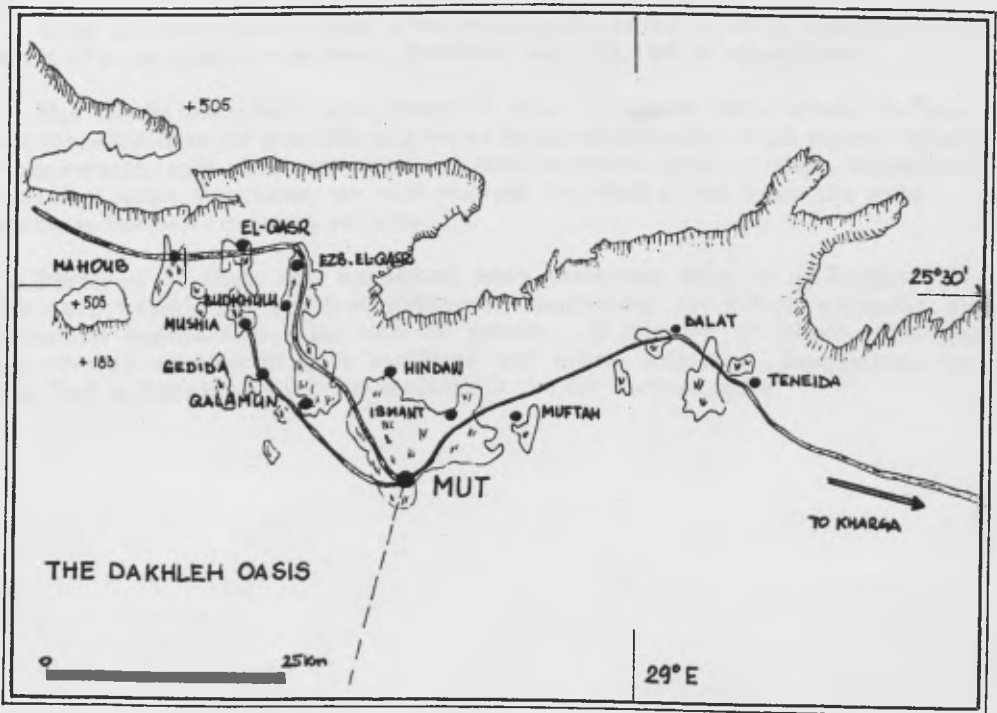
CLOSING REMARKS

The Conservation Unit is the youngest branch of the Dakhleh Oasis Project. It was organized as result of the development of the Project. With the archaeological survey almost completed, the detailed investigations of selected sites are the next step, which in terms of archaeological practice means exposure of investigated sites, removal of finds and study of exposed sites.

Several test excavations demonstrated the archaeological richness of the site and the need for conservator assistance. The main bulk of finds are those related to funeral customs and the known structures are of religious, agricultural and urban character. Some of the finds have to be removed, some of the structures have to be left exposed. All that requires close co-operation between archaeologist and conservator, detailed planning and an efficiently operating conservation workshop. The Conservation Unit will have to deal with objects and structures.

In most cases the objects will be protected against detrimental agents in their new environment with the prospect of future treatment under museum laboratory conditions, but exposed structures have to be completely treated in order to prevent damage caused by the harsh climate. Among many preventive measures during excavation, properly executed backfilling is considered as a very reasonable measure. Another important preventive measure is properly designed landscaping of the site, in order to protect the exposed site against strong winds, blown sand and sun as most of the sites are located on the desert part of the Oasis. Use of soil removed from the site, planting of trees, and very strict control of irrigation canals should slow down the wind yet still allow proper ventilation of the site and protect the structure against the detrimental action of water.

In conclusion, the phenomenon of the Dakhleh Oasis Project in its present form gives the rare opportunity to properly protect the archaeological site, and to co-operate from the very beginning with the person who decides to unearth the site.



THEFT PROTECTION OF ARCHAEOLOGICAL EXCAVATIONS: A TEST CASE STUDY

Adalberto Biasiotti*

SUMMARY

Scientists and archaeologists are often more concerned with site protection against weather and climate than man-organized attacks.

Open air excavations pose a difficult problem to security specialists, due to extent of area, lack of man-made defences, and high cost of surveillance.

Due to the extremely wide range of local situations and available facilities (or lack thereof,) it is not possible to give an in-depth coverage of all aspects of security arrangements, so a different approach was selected. After a short introduction on general security principles, we will examine in detail a test case: the Park of Latin Tombs, in the eastern Rome suburbs.

Problems of theft and vandalism were overcome with an up-to-date security plan that caters for physical defences, specialized electronic defences and an innovative approach to the role of guards. A number of illustrations gives a step-by-step account of past problems and actual solutions. Suggestions are also presented on suitable security measures for similar environments.

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1. THE PECULIAR REQUIREMENTS OF ARCHAEOLOGICAL SITE PROTECTION

My paper will address the theme of site protection against pilferage, vandalism and theft, more than weather or conservation defences.

Site protection may be grouped in two broad categories:

- localized protection
- area or perimeter protection.

It is not possible to define in general terms which one is more suitable to a specific environment. As a broad rule, I may list the following instances of recommended protection, but such a classification is by no means exhaustive or binding.

Recommended localized protection:

- very large site with few scattered buildings or interest areas;
- shrubs, trees or fog in the area;
- site near town or villages;
- limited access possibility to protected area.

Recommended area protection:

- flat areas with unobstructed view;
- site far from town and villages;
- presence of artefacts not easily transported.

A combination of both protections may be employed in special sites, where a mixture of the conditions described above may be encountered.

The type of defence to be selected may be classed as follows:

- physical defences;
- electronic defences;
- guards and patrols.

The first type of defence is relatively cheap, but may be easily overcome with simple tools. Also no warning is given of an attack in progress and we must be sure that the time interval between patrolling watches is equal, or less, than the time required to penetrate defences and escape with stolen artefacts.

As an example of the time required to penetrate some typical physical defences, with simple tools of the trade, here follows a list:

- | | |
|--|------------|
| - iron gate with 1 inch bars, spaced 10 inches apart, 3 metres high | 10 minutes |
| - brick wall, standard thickness | 10 minutes |
| - steel-reinforced concrete, 10 inches thick | 30 minutes |
| - heavy padlock with chain | 3 minutes |

Of course attackers may also jump the barrier, but such a penetration may pose problems for the theft of heavy items. If jumping is a concrete opportunity both for penetration and escape, the times indicated should be reduced sharply. Electronic barriers do not prevent penetration, but may send a warning signal to patrolling

guards, that may effectively deter intrusion by reducing drastically the time available to attackers for a successful penetration and escape.

No defence should ever be used, unless a manned control and intervention post is operative.

The potential for arresting the intruder is a prerequisite for any defence system and the more skilled and fast is the response of the guards, the more effective will be the protection afforded. We should not forget that criminals are very good risk-managers and they would never attempt theft if the probability of being caught is heavily weighted against them.

The best protective solution will be based on a correct mix of the above-mentioned defences, bearing in mind that the most effective solution should be determined case by case, with help from experts in the field.

2. THE REQUIREMENTS OF A PERIMETER DEFENCE

The physical layout of a perimeter defence is often dictated by cost and effectiveness requirements.

So a brick wall of three metres height may be quite secure, but is often unacceptable on aesthetic grounds. The same applies to iron grilles and high-rise steel bars.

The advantage of an electronic perimeter defence, even if more expensive (but not always), lies in its much more discreet appearance, or total invisibility in some instances. Also the electronic defence may be tailored to surround high risk zones, within a much larger area, in order to concentrate cost and protection where it is most required.

The advantages of localized protection and of area protection may be mixed in a properly balanced and executed system design. A detailed example will be given at the end of this paper.

In order to be effective, an electronic defence system must comply with a number of evaluation parameters, which are listed below.

- High detection probability (PD)

This parameter is defined as the ratio between a number of detected intrusion attempts, as against the attempted ones.

The ratio is always less than one, one being applied to a system 100% successful in detecting an intrusion attempt.

Typical system PD ranges from 0.5 to 0.9.

Due regard must be given to the type of penetration attempt.

For instance, a taut wire system is quite good at detecting climbing attempts, but is totally ineffective against jumps over the fence. For each system a table may be constructed, listing the PD factor applicable to various types of penetration attempts.

- Low ratio of false and nuisance alarms - (FAR) and (MAR)

Perimeter protection being essentially an outdoor system, the causes of nuisance and accidentally tripped alarms are quite high, ranging from animal trespass to leaves and branches transported by wind.

Snow and sand storms, rain, hail, etc. may also trigger accidental alarms, which are quite dangerous in terms of system credibility and reliability. The patrolling team, after a number of interventions triggered by false alarms, may become less responsive and alert to real intrusion alarms. Thus a very good FAR index must be specified for the system, particularly when the system is quite large. One false alarm per month per 100 metres of perimeter protection may appear to be attractive, but it gives rise to a very disturbing ratio of one alarm per day on a three kilometre long perimeter.

- High sabotage protection

The best protection system, according to the parameters just shown, may be totally ineffective if easily compromised.

As a proof of that fact, we cite the taut wire sensor, highly praised in the past, but now much less so, due to an intrinsic weakness to sabotage attempts, performed with two locking pliers.

Other radioelectric systems may be masked during the day, and become ineffective when operated at night.

- Highly stable performance

All the evaluation parameters, good as they may seem, must remain constant over a period of time, with no appreciable decline.

This fact often is not sufficiently appreciated, and many apparently good systems are, after some time, left inoperative due to an unacceptable rise of the false alarm ratio and subsequent lack of credibility.

The parameters to be used in assessing the performance of a perimeter protection system are more than those illustrated, but I hope that even that short description may be enough to stress the high level of skill required to select a proper system.

A further parameter, of very high importance in archaeological sites, is the modification of the landscape caused by the system, whether physical or electronic, which may often be totally unacceptable.

I might add, on my own, the imperative need to make the system impervious not only to sabotage attempts, but also to accidental damage from passersby, visitors, workers and vehicles operating on the site.

3. A TEST CASE STUDY: THE PARK OF LATIN TOMBS IN ROME

Among the many cases that my experience may select, I decided in favour of this one because a number of relevant factors are grouped in a single environment - factors that are not normally found all together.

The Park of Latin Tombs is located in downtown Rome, between the city boundaries and the Alban Hills, near the Appian Way.

The attached layout (fig.1) gives a clear idea of the site, which is bordered by a heavy traffic road, a minor road and some football playing fields.

The site is fully contoured by a brick wall, ranging in height from 1 to 1.5 metres, with a steel bar palisade, reaching up to 2.5 metres.

A warden house is located near the west entrance, with at least two guards on duty at night and up to three during the day.

We experienced problems of vandalism, due to the vast area and the practical impossibility of carrying out continuous surveillance day and night; there were also repeated cases of theft of statues and marble columns, always at night.

The theft pattern is quite standard, performed with a cut of one or more bars (fig.2), a penetration, a lift of the heavy artefacts and a quick escape through the surrounding football fields, assisted by a car or a pick-up truck.

The main areas to be protected are the following:

- St. Stephen basilica;
- Pancrazi Tomb;
- Valeri Tomb.

The tombs are mostly underground and a number of highly interesting statues and wall decorations are stored inside. The area is not lighted at night and wardens are often quite unhappy to perform night watches and patrolling, due to their not being armed and to the high crime rate of the area where the park is located. Even during the day, we recorded a number of instances where thugs challenged the guards.

The physical protection is by all standards and by proof of experience quite ineffective. Therefore we decided not to reinforce it, but to add an electronic defence, with additional protection for the guards themselves, in order to boost their confidence and security.

An electronic perimeter defence was ruled out because of the high cost and the fact that sites to be guarded are scattered, but localized in the eastern part of the park.

The perimeter system should be totally invisible, and be fully protected against tampering, mostly because young boys often use the park as a playground during the day. Therefore we selected a buried system, sensitive to pressure exerted on the ground. Such a system detects the slight pressure variations and vibrations of the ground, caused by the intruders trying to walk, run, crawl or jump through the protected area (figs.3-4).

The defence perimeter was set around the basilica of St. Stephen, which is near the property border and was pinpointed as a favorite target for burglars. The remaining tombs are made of very substantial walls, about one metre thick, and do not give easily to penetration attempts, except at the main entrance, now protected by a substantial iron gate.

Therefore we decided to install an infrared-ray barrier, just behind the gate pillars, in order to protect the transmitter and receivers from tampering during the day, and to give early warning of penetration attempts as soon as a leg or arm tries to penetrate through the bars of the gate.

All the intrusion detectors are thus completely invisible and are connected to the guards' house with a buried cable duct. A wall display allows quick identification of the alarmed zone. On alarm, the guard may react by calling the police on a direct phone line.

In order to give additional protection against false alarms, we decided to set a different procedure. In case of alarm, one guard goes out to investigate. In case of a suspect situation, or worse, a penetration attempt, the guard may send a discreet radio call to a receiver located in the guards' house. The second guard can easily summon help. The transmitter is quite small, of the "cigarette pack" variety.

Even during the day, one guard remains on duty at the main entrance in the guards' house, acting as an entrance surveyor. The other one may wander freely through the park, being in constant radio contact, in case of emergency, with the colleague who can summon help at any time. Vandals or thugs do not need to be challenged directly - that could be dangerous - but the police can be called in if needed.

The overall layout is quite effective because it satisfies the following basic requirements.

- unobtrusive installation;
- protection against vandals and sabotage;
- reasonable cost;
- excellent probability of detection, with a low false alarm rate;
- investigation possibility on alarm, without endangering the guard security.

4. FINAL REMARKS

The problem of site protection against thieves and vandals is quite complex. The test case submitted to your attention must be regarded as an example of the many possible solutions and the multifaceted requirements of a typical installation.

Due to budget shortages, cost and reliability factors are often more important than maximum detection effectiveness, and a careful, balanced solution must be worked out.

Also, due consideration must be given to the guards' personal security and safety, to increase their job effectiveness.

Additional advantages may be found in selecting systems that may be put on site in a temporary way to protect work in progress, and that may be retrieved and reinstalled elsewhere.

We strongly recommend that any such protection plan be carried out with expert consultancy because of the relatively high expenditure involved and the very specific type of knowledge required.

I hope that your approach to site protection will be, in the near future, more open-minded, with due consideration given to protection against criminals, and not only to atmospheric conditions, which are often much less unpredictable and dangerous than man-created hazards.

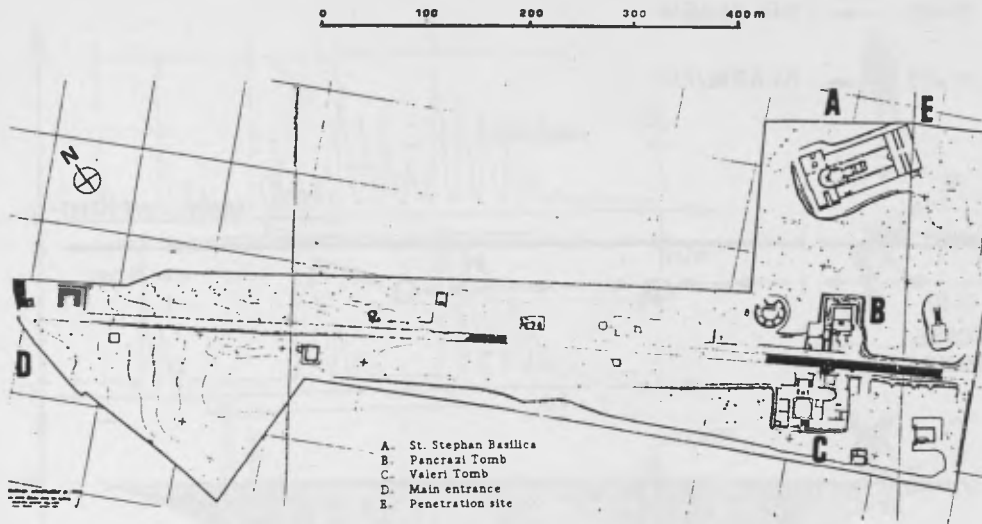


Figure 1. Plan of the Park of Latin Tombs.

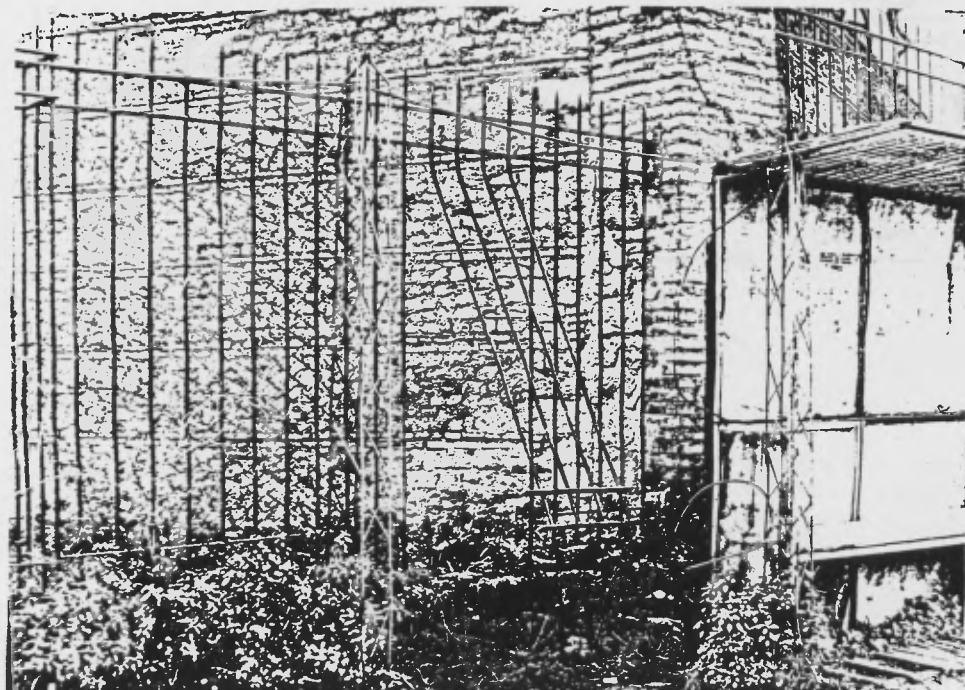


Figure 2. An attack on steel bars.

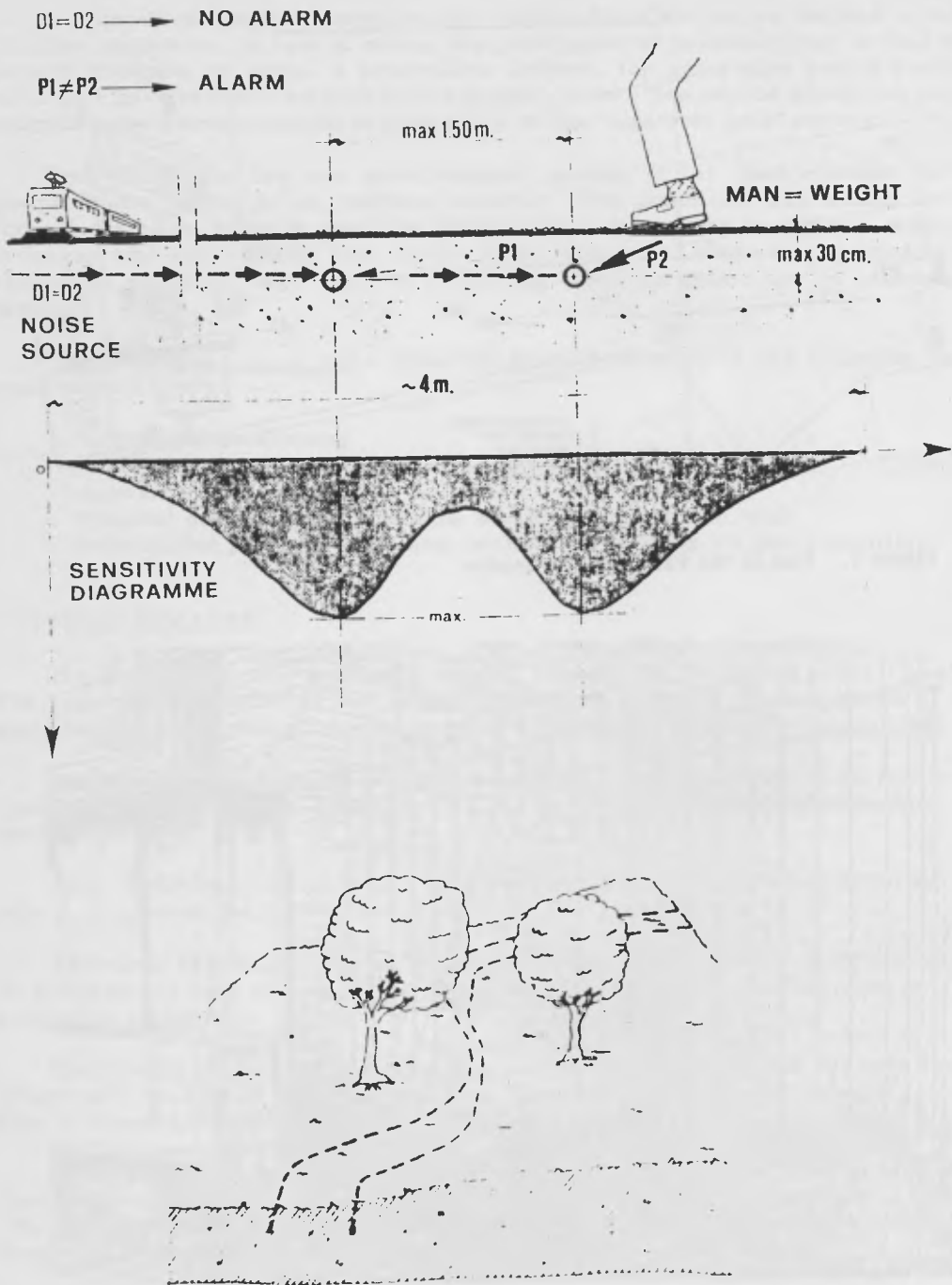


Figure 3. Buried protection schematics.

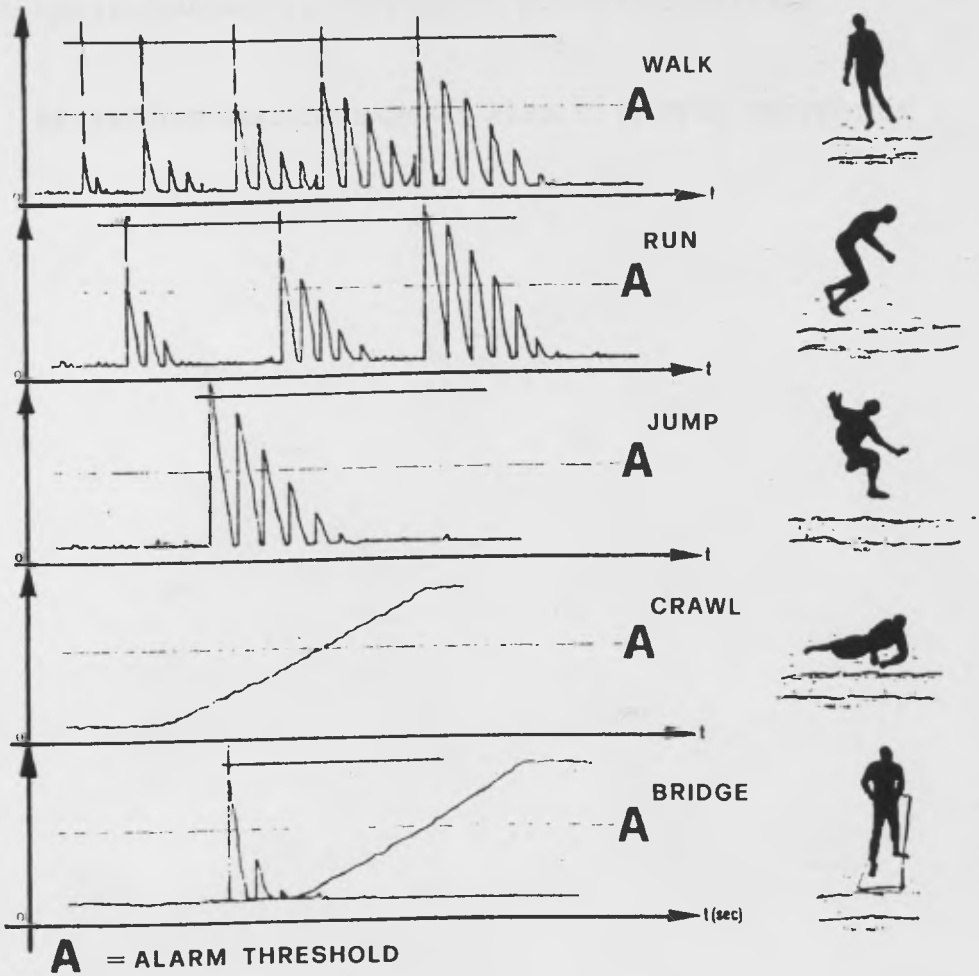


Figure 4. Signals given by penetration attempts.

PROTECTION OF SITES ON DISPLAY: ROOFS AND SHELTERS

PROTECTION DES SITES EXPOSES: ABRIS ET TOITS DE PROTECTION

STRUCTURES NOUVELLES DE PROTECTION DES SITES ARCHEOLOGIQUES DU TIERS MONDE

André Stevens*

RESUME

A l'aide de nombreux exemples pris au Moyen-Orient, en Chine, en Afrique ou en Amérique, l'exposé fera un bref bilan des systèmes apparents de protection - architecture ou construction - adoptés jusqu'à présent dans les pays du tiers monde. L'accent sera mis sur la difficile coexistence des structures nouvelles avec les vestiges architecturaux, spécialement dans le cas des sites archéologiques où prédominent les constructions en briques crues. On traitera d'autre part de quelques mesures de protection en rapport avec l'aménagement d'un site, son équipement, sa présentation au public, ses constructions nouvelles, en insistant sur l'aspect plastique de tout équipement nouveau, trop souvent considéré comme provisoire ou tout simplement déconsidéré. Protection et embellissement ne sont pas contradictoires mais bien complémentaires. Enfin, on proposera des idées nouvelles en matière de couvertures partielles ou totales de la fouille, en s'inspirant des réalisations de grande portée dans d'autres domaines comme les halles d'exposition, les complexes sportifs, les hangars, etc.

Un projet particulier sera étudié plus en détail: la couverture du Temple d'Ishtar à Babylone au moyen d'une structure textile de protection qui rehausse, par le contraste des formes et des matières, la dignité authentique des ruines et de leur environnement immédiat. L'idée maîtresse de la conférence sera de démontrer que, dans certains cas, il est admissible de "prolonger" les vestiges du passé par une architecture contemporaine de qualité qui concilie protection et respect des lieux.

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ROBE / TERRE / CIMENT / PLEXIGLAS

Avant d'envisager la couverture des vestiges découverts au moyen d'une structure apparente de protection - toits protecteurs - évoquons brièvement une technique de recouvrement des vestiges eux-mêmes, appliquée avec succès - n'était le coût prohibitif de l'entreprise - sur le site de *Aruda* le long de l'Euphrate en Syrie.

Au début des années 70, deux temples du 3ème millénaire furent découverts sur les flancs de la vallée par une mission hollandaise, les murs de briques crues étant conservés sur une hauteur de deux mètres environ. Pour freiner la dégradation des parois mises au jour et dans l'attente de mesures plus définitives, les responsables entreprirent de recouvrir les vestiges par un enduit traditionnel en terre séchée peint à la chaux. L'objectif était d'enrober les temples d'une nouvelle gangue terreuse mettant à l'abri des intempéries les structures d'origine, tout en conservant l'aspect général de ruines présentées à ciel ouvert. Dans ce cas bien précis, la couverture épouse chacun des vestiges qui deviennent le support immédiat du matériau de recouvrement. Cette solution, accompagnée d'un bon drainage des espaces mis au jour, conserve toute sa valeur là où on décide de mettre l'accent sur le jeu des parois d'origine. Malheureusement cette solution s'est révélée très chère et a dû être abandonnée. Une expérience similaire fut tentée sur le site de *Tepe Nush-i Jan* en Iran où les murs furent recouverts d'un enduit traditionnel (kaghel) mais où, cette fois, la fouille était recouverte d'une structure métallique.

D'autres matériaux furent expérimentés, tant pour le recouvrement du sommet des murs que pour celui des parois. Comme les enduits de protection ne sont pas l'objet de cet article, nous nous limiterons à deux exemples significatifs.

En Iraq sur le site de Kalkhu (actuellement Nimrud), on recouvrit les murs par un mortier de terre trop riche en ciment, ce qui déboucha sur de nombreuses fissures, rendant la protection du mur toute illusoire. En outre cet enrobage donnait au site l'aspect d'un chantier de construction nouvelle. Toute authenticité était rejetée au profit des arêtes alignées et des surfaces planes. Dans ce cas on pourrait dire qu'il y a rejet de la "robe" par la structure d'origine toujours en mouvement.

Autre exemple en Sicile. Construite vers 335 av. J.C., la fortification de *Gela* constituée d'un soubassement de pierres et de briques crues était enfouie sous une dune de 300 m de long et 8 m de haut. Les parois en briques ont été protégées par un revêtement de plaques en plexiglas, tandis que la fortification elle-même était recouverte d'un auvent métallique particulièrement apparent. Devant les difficultés de mise en oeuvre d'un tel matériau, on peut concevoir son utilisation dans certaines situations spécifiques, par exemple certaines fresques à *Pompéi*. Son utilisation à grande échelle semble plus contestable, sauf peut-être dans le cas de la *Piazza Armerina* en Sicile. (Voir les actes de la 1ère conférence).

TOIT / MODULE / ARCHITECTURE

En matière d'interventions nouvelles de protection, comme la construction de toits protecteurs, les bons exemples sont très rares, du moins ceux qui se distinguent par une architecture de qualité appropriée au site, ou ceux qui représentent quelque audace dans l'utilisation de matériaux et techniques contemporaines. Le site n'appartenant plus aux seuls archéologues, il devient un domaine où l'architecte paysagiste - ou l'architecte qui n'est pas seulement restaurateur - a son rôle à jouer dans la protection comme dans l'embellissement des lieux historiques.

Ce fut l'une des recommandations du symposium international sur la conservation des structures en briques crues qui s'est tenu à Ankara en 1980. On suggéra d'entreprendre l'étude d'un projet de systèmes modulaires pour la construction d'abris de protection d'un prix modéré, et permettant une fermeture complète ou partielle. On proposa en outre que la conception des abris soient développée par des spécialistes de différentes disciplines (architecture, archéologie, conservation) et que le projet soit expérimenté par eux sur le terrain, avec une attention particulière pour les matériaux disponibles sur place. Nous ajouterons que les systèmes dits "parachutés" ne sont pourtant pas à rejeter. Certains sites du tiers monde se prêtent parfaitement aux tentatives originales de protection, dans le cadre d'un processus général de développement où conservation et développement peuvent aller de pair.

TOIT / METAL / ELEMENTS PORTANTS

Au vu de quelques exemples représentatifs des tendances de ces 20 dernières années, l'aspect esthétique est souvent relégué à l'arrière-plan des préoccupations immédiates. Par exemple: les systèmes utilisés pour la protection de quelques salles du palais d'Assurnazirpal II à *Kalkhu* en Iraq. L'une des salles fut recouverte par une structure combinant poutrelles métalliques et matériaux traditionnels. Des poutrelles renforcées à l'approche des murs reposent sur les murs de briques crues rehaussés pour l'occasion. Des rondins portent d'une ferme à l'autre et supportent des nattes sur lesquelles s'étend une couche de ciment armé. Au sommet des murs entre chaque ferme, une ouverture est ménagée pour amener la lumière et ventiler la salle. Une formule plus élégante se rencontre dans une autre salle où les poutrelles métalliques sont soutenues en leur milieu par un pilier en briques crues élevé dans l'axe de la salle. Les murs sont ici rehaussés jusqu'au toit et la lumière pénètre par une bande zénithale qui souligne dans le sens de la longueur la structure employée.

A *Ninive*, le palais de Sennachérib a été en partie restauré vers 1967. Dans ce cas, le toit métallique (poutrelles et tôle ondulée) repose sur des montants métalliques insérés directement dans les murs de briques crues rehaussés. Cette technique permet un large débord des parties recouvertes, surtout quand il faut protéger la paroi extérieure du mur qui peut contenir, comme à *Ninive*, de magnifiques ortostates. Malheureusement le voisinage des colonnes métalliques et des briques crues entraîne des fissures dans les murs, essentiellement dues aux différences de comportement à la chaleur et au manque d'adhérence entre matériaux nouveaux et traditionnels.

Signalons encore la présence d'une structure métallique de protection sur le site de *Tepe Nush-i Jan* en Iran (protection combinant enduit traditionnel et structure indépendante des vestiges), sur le site d'*Akrotiri* à Santorin (fermes et montants en treillis), à *Roselle* en Toscane (colonnettes et poutrelles; voir le rapport de la 1ère conférence) et en Crète sur le site d'*Aghia Triada* où un palais minoéen a été recouvert en partie par une structure métallique avec une couverture en éléments de plastique transparent (on se soucie de la qualité de la lumière) et sur le site d'*Amnisos* près d'Heraklion.

TOIT / BETON / MATERIAUX LOURDS / FORME

Béton armé et brique crue font souvent mauvais ménage. Des travaux de restauration entrepris en Iraq entre 1956 et 1971 témoignent toujours d'une marque presque ineffaçable. A *Ninive*, les ruines de la porte monumentale "*Nadad*"

furent recouvertes par une ossature en béton armé (colonnes et poutres) autour de laquelle on tenta d'élever un voile en briques crues, reprenant en gros la forme supposée d'origine. Des différences de tassement entraînèrent la fissuration des voiles et même l'écroulement d'une partie de la structure nouvelle sur celle que l'on voulait précisément protéger. Cette réalisation date de 1968 et offrait en 1979 un spectacle désolant. Un exemple plus réussi serait celui de la restauration de la porte monumentale "*Maski*" entreprise en 1971. La nouvelle ossature est constituée de murs en briques crues (épaisseur: 1m20) raidis en hauteur tous les mètres à peu près par un cadre en béton armé (largeur: 20cm), lui-même raidi horizontalement par des barres d'acier qui se croisent dans les piliers en briques crues élevés à l'intérieur des 2 tours qui flanquent le passage voûté. L'enveloppe finale est en briques mi-cuites (largeur: 1 brique et demie), ce qui ne demande aucun enduit de finition. Quant à la porte "*Mergal*" reconstruite en pierres de taille vers 1956, elle présente, à la différence des deux autres, un petit musée installé à l'intérieur de ses tours.

A plus petite échelle, sur le site de *Kalkhu*, les portes d'entrée de la salle du trône (palais d'Assurnazirpal II), décorées de lourds ortostates, furent recouvertes par une sorte d'auvent en béton armé. Cette construction est manifestement trop présente par rapport à la finesse des pierres sculptées qu'une telle présentation allourdit inutilement. La protection est aussi affaire de présentation. Un exemple similaire se rencontre à *Kara-Tepe* en Turquie (voir le rapport de la 1ère conférence). On ne s'étendra pas sur le cas des couvertures en béton armé reposant sur des murs portants, qu'ils soient en briques crues comme ceux du temple d'*Emah* à Babylone ou qu'ils soient en pierres comme ceux du fort de *Quryat* en Oman; de part et d'autre ils provoquèrent l'écroulement partiel des murs, faute de coffrage et de chaînage approprié.

TOIT / MATERIAUX TRADITIONNELS / PROVISOIRE:

En ce qui concerne les courtes portées, les matériaux traditionnels jouent un rôle dans la protection des vestiges découverts. Le temple de *Nabu-Sha-Mari* découvert en 1979 à Babylone - conservé sur une hauteur de plus de 5 mètres - a été aussitôt recouvert par une structure traditionnelle faite de rondins, de nattes et de terre, et reposant directement sur les murs d'origine. Il faut dire que la salle principale contenait des parois décorées de motifs peints et qu'il convenait de les soustraire rapidement aux effets des intempéries. Système toujours provisoire, dans l'attente d'une solution qui recouvrirait le temple d'une seule toiture en matériaux nouveaux. Des structures en bois ou en jonc, combinant la terre séchée ou les gerbes de paille, furent utilisées sur le site de *Chan-Chan* au Pérou pour protéger les frises en adobe de l'un des temples. On ne faisait ainsi que reconstruire une structure qui existait déjà à l'origine. Des systèmes analogues - auvent à un seul pan - furent utilisés pour la protection des bas-reliefs des palais royaux d'*Abomey* au Bénin, pour celle des sculptures en terre armée de jonc qui ornent les piliers-stupa des villes anciennes de *Yar* et de *Qotcho* dans l'oasis de Turfan (Xinjiang chinois). Quant aux hauts murs en briques crues du temple de *Wiraqocha* au Pérou conservés sur plus de 6 mètres de haut, ils furent recouverts par un toit à double pan directement ancré au sommet des murs, technique habituelle pour la protection du sommet des murs en briques crues ou pisé.

Sur le site de *Cochasqui* situé à 3000 mètres d'altitude dans les Andes de l'Equateur, les archéologues découvrirent au sommet de l'une des pyramides (construites en blocs de "*canguha*") les vestiges d'un observatoire astronomique. Pour protéger les structures mises au jour, ils élevèrent un toit à double plan fortement incliné et constitué d'une structure portante en bambous assemblés au moyen de

cordes végétales, dont les montants évitent soigneusement les points sensibles de la fouille. La couverture est en plaques de tôle ondulée sur lesquelles on voulait primitivement accrocher des gerbes de paille. Cette structure se révèle très sensible au vent. L'espace protégé n'est pas entièrement clos contrairement à la fouille de *St. Mary* dans le Maryland aux U.S.A. où la structure en forme de tente est constituée de fermes en bois et d'une couverture en toiles de plastique qui enferme totalement le site fouillé. Après des vents violents, il n'est pas rare de devoir réaccrocher des éléments de couverture. Cette solution, aux yeux des responsables actuels, est toute provisoire, mais on a voulu à cette occasion retrouver certaines techniques de construction propres aux indigènes, ce site faisant l'objet d'une mise en valeur de type "social", à l'écart de toute ambition touristique. Cette construction nouvelle, située au sommet d'une pyramide de terre dans un paysage hors du commun, prend une valeur plastique telle qu'elle devient un "objet architectural" parmi d'autres plus anciens. On souhaiterait dans ce cas exceptionnel que la solution retenue fasse l'objet d'études approfondies - pourquoi pas l'organisation d'un concours d'architecture - un tel site méritant une intervention qui soit à la hauteur du cadre grandiose qu'avaient choisi les bâtisseurs de l'époque. Dans un tout autre domaine - construction d'un club sportif sur une colline - des architectes brésiliens réalisèrent une structure à coupoles jumelées qui soit aussi un nouveau point de repère architectural sur les collines de São Paulo.

Un toit protecteur omniprésent ne s'impose pas toujours, par exemple lorsque les pluies sont très rares. A *Lothal* comme à *Chan-Chan*, des montants en bois sont fichés dans les sol, là où certains vestiges exigent une protection accrue. En cas de brusque pluie, les gardiens accrochent à ces poteaux une toile protectrice imperméable qui joue un rôle limité dans le temps. Dès le soleil revenu, la couverture est retirée; le principe du parapluie. Signalons que sur le tell *Mosân* en Syrie, les fouilleurs se protègent du soleil en s'abritant sous une toile tendue entre quatre poteaux munis d'une poulie à leur sommet. Un abri "voyageur" existe au musée de *Khartoum*. De petits temples en pierres provenant des forteresses à moitié noyées par les eaux du barrage d'Assouan et installés en plein air peuvent, en cas d'alerte, être recouverts par un abri "gigogne", composé de trois portiques métalliques glissant sur des rails. En cas de "repos", ils s'emboîtent les un dans les autres à quelques mètres des temples déplacés (Temple de Buhen, Semna et Kumma).

MATERIAUX NOUVEAUX / STRUCTURE ET ARCHITECTURE / 7 CAS

L'utilisation de matériaux nouveaux peut se justifier lorsqu'il s'agit de recouvrir de grandes étendues, ou tout simplement si leur choix provient d'une volonté délibérée, par exemple en voulant faire oeuvre d'architecte contemporain. Fermes métalliques de grande portée, portiques en métal ou en bois lamellé, structures textiles ou tridimensionnelles en forme de tente, coupole ou toiture plate, telles sont quelques techniques récentes à la portée des décideurs d'aujourd'hui amenés à s'occuper de la protection des sites, que les vestiges soient en partie ou en totalité protégés ou qu'ils soient au-dessus du niveau du sol ou à moitié enterrés.

Les vestiges de la *Casa Grande* (Arizona), considérée comme un témoignage culturel des Etats-Unis - une architecture de terre crue de plan plus ou moins carré -, ont été recouverts par une élégante structure métallique composée de quatre fines colonnes fichées légèrement de biais dans le sol et d'une couverture qui affecte la forme d'une pyramide très aplatie. La construction nouvelle est totalement indépendante des vestiges et sa présence toute aérienne fait songer à un bel objet délicatement posé sur le sol et "prêt à s'envoler".

Par contre la structure métallique de protection des fortifications de *Gela* (Sicile) est nettement plus présente. Une procession de pylônes en treillis métallique longe un côté du rempart et supporte l'auvent qui suit le sommet du mur à une distance respectable. L'ensemble est raidi par des cables d'acier fichés dans le sol de part et d'autre du rempart.

Dans le cas de vestiges enterrés ou à moitié enterrés, la structure de protection peut se limiter à un seul toit protecteur reposant soit directement sur les vestiges, essentiellement les murs, soit sur le sol au moyen de montants dépendants ou non des vestiges. Plusieurs cas viennent d'être évoqués en Iraq ou en Iran. Ces tentatives ont le mérite d'exister, mais des solutions plus hardies ont été néanmoins expérimentées sur d'autres sites.

A *Mari*, site archéologique sur l'Euphrate en Syrie, une tentative originale de protection fut réalisée en 1975. Une partie du palais présargonique (2400 av. J.C.), dont les murs étaient conservés jusqu'à 5 mètres de haut, fut recouverte par une toiture légèrement inclinée constituée d'éléments modulaires de plastique posés sur de fines charpentes métalliques. On reconstituait ainsi l'espace principal du sanctuaire où différents niveaux d'occupation restent visibles. Les montants furent ancrés dans la structure d'origine au moyen de blocs en béton. Des problèmes subsistent: le drainage des eaux de toiture autour de l'aire protégée, l'assèchement rapide des parois intérieures qui tombent en poussière, l'entretien de la toiture maltraitée par le passage des animaux ou des enfants. En revanche, cette réalisation représente le signe d'une architecture contemporaine en milieu archéologique, respectant l'environnement par une intégration relativement neutre et instaurant une forme de coexistence entre les structures nouvelles et anciennes.

A côté des formules de recouvrement partiel subsistent les solutions de "mise en cocon" où une aire choisie est enfermée à l'intérieur d'un espace-abri, une halle, un musée ou un autre édifice.

A *Cusco* au Pérou, lors de la restauration du couvent Santo Domingo partiellement détruit à la suite d'un tremblement de terre, on décida de mettre en valeur les vestiges d'un temple Inca (Temple de Coricancha en excellent état de conservation) sur lequel le couvent avait été édifié. Pour ce faire on n'hésita pas à l'insérer dans l'une des quatre ailes du couvent dont l'espace sous toiture restait entièrement libre. Deux poutres maîtresses de 35 m de long, l'une en treillis en K l'autre en treillis en N (treillis en montants verticaux statiquement déterminés), furent lancées par-dessus le temple dans le sens de la longueur et s'appuyant sur des murs transversaux. Pour compléter la charpente, des fermes triangulaires reposent d'une part sur la façade reconstruite côté patio, et d'autre part s'assemblent en leur centre aux deux poutres maîtresses, de manière à présenter une toiture en porte-à-faux par-dessus le temple. L'espace est clos par une paroi en éléments de verre qui s'élèvent au-dessus des murs en pierres sèches, libérant le temple de tout élément porteur de sa couverture. Une prouesse technique pour un résultat brillant où s'intègrent harmonieusement les colonnades espagnoles, les murs incas et les prolongements contemporains: fermes métalliques et parois de verre.

Sur une butte dominant le village de *Banpo*, proche de la ville historique de Xian (Shaanxi, Chine), on découvrait en 1953 l'un des plus importants sites néolithiques de Chine, sur une zone d'environ 50.000 mètres carrés. C'est sur le site

même que l'on construisit en 1958 le musée archéologique de Banpo qui comporte un ensemble de halls, séparés du bâtiment principal, et où se trouvent conservés, en l'état, 3.000 mètres carrés de fouilles. Une galerie en surplomb fait le tour des halls dont le périmètre en dents de scie enferme les découvertes les plus significatives. Deux espaces de plan plus ou moins carré sont reliés entre eux par un troisième plus petit. Les halls les plus vastes sont recouverts par une toiture à deux versants reposant sur des fermes triangulaires d'une portée de l'ordre de 40 mètres, dites fermes "mixtes" car elles sont constituées de tirants horizontaux en acier (traction) et d'éléments en bois pour la partie de la charpente en compression.

L'une des halles les plus vastes est sans doute celle élevée au-dessus du champ de fouilles du tombeau de l'empereur Qin Shi Huang, situé non loin de *Xian* en Chine. C'est en 1974 que les archéologues chinois mirent au jour près de 6.000 statues en terre cuite de guerriers et de chevaux attelés à des chars, en grandeur nature et disposés dans une fosse longue de 210 mètres et large de 60. En 1976 on entreprit la couverture du site (14.000 mètres carrés) par une gigantesque toiture en forme de berceau dont la structure est composée de 17 arcs en treillis métallique (arc à 3 rotules) d'une portée de près de 70 mètres, la portée entre les arcs étant de l'ordre de 13 mètres. Cette technique est proche de celle utilisée au début du siècle pour la construction de gares ferroviaires (voir le magnifique exemple de la gare d'Anvers en Belgique). La solution retenue dans ce cas accentue encore l'importance du site par ses dimensions hors du commun. La hardiesse de la structure est ici à la mesure des découvertes exceptionnelles dont la plupart restent visibles dans l'état de leur mise au jour à partir de galeries qui surplombent le site. Outre son rôle de protection des vestiges, cette halle permet aux archéologues chinois de continuer leurs recherches à l'abri des intempéries; seule une petite partie des 14.000 mètres carrés avait été fouillée en 1981.

Toujours en matière de halle de dimension moyenne, analysons une réalisation européenne exemplaire: le *musée des Thermes* aux Pays-Bas, le cas du *Fishbourne Palace Museum* (Sussex, Angleterre) ayant été évoqué lors de la première conférence de Chypre.

En 1940 on découvrit dans la ville de *Heerlen* aux Pays-Bas les fondations d'un grand bâtiment thermal de l'époque romaine. Ces vestiges particulièrement intacts furent aussitôt recouverts de 2.000 m³ de sable fin, dans l'idée de les dégager à nouveau en des temps meilleurs. Ce n'est qu'en 1975 que le dernier projet prit la forme d'un musée archéologique. Au cours du projet du musée, on envisagea différents types de structure à grande portée. Cependant la taille réduite des maisons avoisinantes et les volumes relativement modestes des annexes du Musée rendaient cette solution difficilement acceptable pour des raisons architecturales. Afin de ne pas trop souligner les dimensions et la forme des thermes, on choisit finalement une charpente tridimensionnelle de toiture qui recouvre l'ensemble des vestiges, et forme un tout aussi bien du point de vue architectural que du point de vue structural. La charpente au-dessus des thermes couvre une surface de 2.640 m² (48 x 55 m) et repose sur 4 colonnes distantes de 26,40 x 36,00 m d'axe en axe. La structure se compose de 4 treillis tridimensionnels soutenus par des cadres en acier. Les contre-ventements et les 4 colonnes qui soutiennent le plafond sont formés des mêmes profilés. Pour éviter tout dégât aux thermes, le manque de place empêchant d'autre part d'amener sur le chantier des grues mobiles, le montage de la charpente s'est fait sur échafaudages. Pour le visiteur, les vestiges forment un contraste saisissant avec le plafond en tubes d'acier et avec l'ossature peinte en jaune.

Pour information, évoquons quelques structures contemporaines de grande portée, comme les hangars d'aéroport, les constructions industrielles, agricoles ou sportives, les halles d'exposition, qui pourraient utilement inspirer les responsables de la protection des sites archéologiques.

Quelques projets en milieu archéologique sont restés lettre morte. Début 1980, les autorités irakiennes envisageaient la protection d'une nouvelle fouille, le temple de *Nabu Sha Hari* à Babylone, par une coupole destinée à recouvrir une aire de 2.500 m². Le projet d'une structure textile fut envisagé d'autre part (il sera étudié dans les pages qui suivent). Vers 1976, il fut question d'entourer l'*Erechtéion* par un cube en matière plastique où serait entretenue une atmosphère climatisée, tandis qu'une partie de l'*Acropole* serait recouverte par un globe en plexiglas pour la soustraire à la pollution atmosphérique. On peut se faire une idée de ce projet en se référant au pavillon des Etats-Unis construit en 1967 à l'exposition universelle de *Montréal*. Le pavillon se présente sous l'aspect d'une coupole géodésique de 76 m de diamètre et de 61 m de hauteur, construite en charpente tubulaire tridimensionnelle. La peau qui la recouvre est un assemblage de panneaux en plastique acrylique transparent revêtus d'un matériau teinté rendu réfléchissant par une mince pellicule métallique. Visité en 1980, il avait été en partie détruit par un incendie; la structure spatiale à présent découverte renfermait les restes calcinés des escalators et ascenseurs, un spectacle presque fantastique où couverture et vestiges formaient la plus futuriste des ruines contemporaines. Une autre structure fut imaginée pour l'*Acropole* par un grand constructeur métallique. L'affiche publicitaire de cette entreprise présente les différentes constructions recouvertes par une gigantesque nappe tridimensionnelle qui semble flotter en l'air, dans l'attente de retrouver les éléments portants! Le styliste s'est bien gardé de les dessiner; c'est bien évidemment là, au niveau du contact de la structure avec le sol, que se pose une grande partie du problème. Signalons à l'affiche des réalisations de cette entreprise une structure spatiale de grande portée abritant 20.000 m² et reposant sur 4 montants, chacun constitué de 4 colonnes (Projet RAI à *Amsterdam*).

Parmi les toitures circulaires de très grand diamètre, il y avait en 1974 dans le monde entier plus de 40 arènes circulaires couvertes dont le diamètre dépasse 90 mètres, la plupart aux *U.S.A.*, mais on en trouve également en Europe occidentale, en *U.R.S.S.*, au Japon, au Brésil, en Thaïlande. Le forum de Los Angeles qui peut contenir 13.460 places a un diamètre de 124,5 mètres. Le "Oakland-Alameda county coliseum" de Californie a quant à lui un diamètre de 128 mètres, tandis que le dôme de l'auditoire de Pittsburgh d'une hauteur de 33,25 m a un diamètre de 127,2 mètres. L'astrodome de Houston-Texas construit en 1963 peut contenir 47.000 personnes sous une coupole de 195,68 mètres de diamètre. Mais c'est le "Wayne County Stadium" de Detroit qui possède sans doute la coupole la plus vaste au monde d'un diamètre de 265,78 mètres. En 1983 et 84 a été construite et mise en place en un temps record la plus grande charpente de toiture en coupole du Sud-Est asiatique pour le stade national circulaire "Negara" situé au sommet d'une colline en plein centre de Kuala Lumpur, capitale de la *Malaisie*. Cette structure, qui épouse la forme d'une coupole de 15 m. de haut ou plutôt d'une calotte, présente un diamètre de 92 mètres et couvre une surface au sol de 6.600 m².

Question toiture plate de grande dimension, les portées peuvent aller jusqu'à 90 mètres et plus. Le hangar de manutention de ALITALIA à Rome, dont la charpente est constituée de poutres triangulées, mesure 116 x 90,40 m et 25 m de hauteur. De moindre portée, le hall d'exposition de *Denver*, constitué d'une ossature métallique en tubes carrés, mesure 208,90 x 73,20 m, et le hangar métallique de *Brize Norton*

dont la toiture est constituée de poutres en treillis mesure 318,70 x 65,60 m. La patinoire artificielle de *Eindhoven* aux Pays-Bas, construite en 1980, est recouverte par une structure métallique en forme de poutres triangulaires de 52,80 m de portée. D'une hauteur théorique de 3 m et d'une largeur de 3,60 m, elles sont placées avec une entre-distance de 9,60 m d'axe en axe. La distance de 6 m entre les fermes a été directement couverte au moyen d'éléments en tôle d'acier profilée, de sorte que les pannes n'étaient pas nécessaires.

Un exemple intéressant, combinant coupoles et toiture plate, est celui d'une nouvelle construction sur les hauteurs de *São Paulo* au *Brésil*. Suite à la demande du club "Paineiras do Morumby" qui projetait la construction d'un vaste complexe sportif, les architectes imaginèrent une structure à 2 coupoles jumelées à une nappe, chacune formée de 2 icosaèdres avec recouvrement constitué de panneaux-sandwich. Dans le monde sportif, une entreprise suisse propose des coupoles sur plan carré capables de recouvrir deux courts de tennis. Réalisée au moyen d'une charpente légère composée d'un réseau d'arcs en bois, chaque coupole enjambe 56 m dans le sens diagonal et 40 m sur le côté, soit une aire au sol de 2.240 m². L'avantage réside dans le fait que plusieurs coupoles peuvent aisément être reliées entre elles, un désavantage serait l'importance des fondations en béton armé qui occupent tout le périmètre, du moins en cas de site archéologique où il convient de minimiser les effets du contact de la structure nouvelle avec le sol fouillé.

Quant aux structures textiles, l'une des plus connues - à part celle récente de l'aéroport de *Jeddah* en Arabie saoudite - est sans nul doute le pavillon de la République fédérale d'Allemagne à l'exposition universelle de *Montréal*. Une aire au sol de 120 x 90 m est couverte par un treillis en acier auquel est suspendu un mince voile transparent de 1,6 mm d'épaisseur, ce qui donne l'aspect d'un filet de pêche drapé sur des mâts hauts de 36,60 mètres. La résistance de la structure est assurée pour des vents de 160 km/h. Si l'architecte Frei Otto est célèbre dans le monde de l'architecture du textile, un autre artiste ne l'est pas moins, mais dans celui de la sculpture du textile, il s'agit de Cristo dont le prochain spectacle urbain sera l'emballage du Pont-neuf à *Paris* au moyen d'une toile en polyamide. Intervention réversible qui met en évidence le rôle de l'artiste d'aujourd'hui en milieu historique ou archéologique dont il assure une forme de promotion qui pourrait, dans certains cas, aller de pair avec la protection du site.

UNE TENTE-ABRI A BABYBLONE / PROJET STEVENS 1979 / RAPPEL

M'appuyant sur une expérience personnelle, je soumets à la réflexion une méthode originale de protection des sites culturels, basée davantage sur un effort d'imagination créative plutôt que sur la répétition de modèles surannés. En tant qu'architecte, je ne peux me contenter d'un tableau noir ou d'un tableau blanc, encore me faut-il accrocher un autre tableau à la cimaise du paysage, sans quoi cette communication n'aurait aucune signification.

Cette méthode que j'ai suggérée pour la protection de certains vestiges du site de Babyblone repose sur le principe de la construction nouvelle en milieu ancien, et son esprit est susceptible d'être appliqué en tout lieu, pour autant que règne une conjoncture favorable alliée à une volonté politique.

Après avoir visité les principaux sites archéologiques de l'Iraq - excepté l'ancien pays de Sumer - à l'invitation du département des Antiquités nationales (en 1979), j'ai suggéré un système de protection destiné aux ruines les plus significatives, et plus précisément les plus friables comme les vestiges en briques crues.

L'objectif primordial était de créer une structure contemporaine de protection, qui rehausserait, par le contraste des formes et des matières, la dignité authentique des ruines et de leur environnement immédiat. Très rapidement, mon choix se porta sur une structure légère et tendue entre quelques mâts, réduisant au maximum les points de contact avec le sol. Le temple d'Ishtar à moitié enterré allait servir de cobaye dans le parc monumental de Babylone. La forme générale de la structure découlerait du prolongement architectural des espaces d'origine, l'enveloppe protectrice s'élevant et s'abaissant en fonction de la hiérarchie des espaces à couvrir, tout en maintenant le caractère évident des ruines conservées ou restaurées.

La tente-abri apparaissait comme la forme qui pouvait animer avec le plus de justesse le paysage particulièrement plat de Babylone. Acceptons d'en faire l'éloge, n'a-t-elle pas convaincu plus d'un bédouin! Toiture élémentaire simple, elle enveloppe plus qu'elle ne couvre. Elle rejette les eaux de pluie en dehors de la fouille, elle limite l'action des vents violents, elle tire parti des courants d'air et de lumière. En s'élevant au-dessus des lieux, elle situe les vestiges enfouis et souligne l'importance d'une fouille, d'abord soustraite aux regards, puis lentement découverte et appréciée. La fonction des espaces couverts est perceptible dans la forme aérienne qui les survole. La forme générale précisée par la membrane, ses arêtes et son faite, allège les espaces occupés et disparaît au profit de la matière allégée, les cables et pylônes métalliques.

Les espaces intérieurs, délimités par les structures d'origine, se diluent dans l'unique espace supérieur contenu par la membrane protectrice. Les murs en briques crues conservent leur force de mur plein et les sols retrouvent leur fonction de libre passage. Ni les murs, ni les sols - à quelques exceptions près - ne sont entamés par la structure étrangère qui met l'accent sur ce qui est à protéger. La structure d'origine, nette et distincte de la couverture, précise les espaces à l'état de leur découverte. Le visiteur n'est pas induit en erreur, il fait spontanément la différence entre l'authenticité des lieux et leur prolongement à l'état actuel. Des éclairages différents - la couleur de la membrane pouvant varier dans ce sens - révèlent les diverses fonctions des espaces originels. Les espaces sont à l'abri des fortes chaleurs et lumières qui généralement aveuglent le visiteur, décolorent toute matière et dépouillent les espaces de leurs dimensions. L'ambiance toute en douceur met l'oeil au repos et se prête aux commodités du corps, permettant au visiteur d'apprécier les lieux et de participer davantage à leur nouvelle mise en condition, le bien-être physique n'entravant pas les mouvements de la pensée.

Le cheminement des visiteurs emprunte le parcours d'origine, les espaces étant découverts dans l'ordre issu du plan, depuis la porte d'entrée jusqu'aux espaces les plus sacrés. Grâce au plan aisément perceptible, le visiteur prend conscience de la hiérarchie des espaces qui n'ont rien d'un labyrinthe. Le remplacement de la fonction d'origine (temple, palais, etc.) par une fonction actuelle (musée de plein air, exposition d'art contemporain, etc.) assure le maintien des valeurs spirituelles. Celles du passé, irremplaçables, ouvrent la voie aux nouvelles valeurs, attachées à la qualité de l'ambiance, et leur permettent de se révéler, au fil des jours, plus dignes de l'authenticité des lieux.

Avant toute intervention de ce type, il faut distinguer les zones principales du site - site de grande étendue - qui demandent une protection de choix, et les zones secondaires qui se contentent d'un traitement moins strict ou différent. Un même site pourrait offrir des parcours différents: romantique, classique, historique, actualisé, etc. La désignation d'un périmètre de sauvegarde implique très souvent

des mesures préjudiciables pour l'environnement immédiat de la zone préférée. Ce n'est pas une raison pour oublier de se soucier de tout l'équipement indispensable pour amener le visiteur à respecter les lieux sans qu'il ne s'en rende compte. Parmi ces équipements dont le choix devrait relever d'un plan d'ensemble dit d'aménagement, citons, outre celui destiné à abriter une fouille, les panneaux explicatifs (Ex.: ruines de Pécos au Nouveau-Mexique), une tour d'observation (Ex.: Alacahoyuk), la maison de fouille (Ex.: mission américaine dans la vallée de l'Assassif en Egypte), l'équipement HORECA (Ex.: hôtel Zénobie à Palmyre), l'équipement Sons et Lumières (ex.: Persépolis), les passages pour visiteurs (Ex.: Huaca Juliana à Lima), l'équipement récréatif (Ex.: une piscine non loin de la pyramide du soleil à Trujillo au Pérou), les installations de commodité, etc. Les quelques exemples relevés plus haut sont particulièrement significatifs à cet égard.

STRUCTURE TEXTILE A BABYLONE / ESTIMATION DU COUT /1980/ RAPPEL

En 1980, la firme Stromeyer de Constance établit un devis estimatif du projet de protection du temple d'Ishtar à Babylone au moyen d'une structure textile. Sur base d'une aire couverte de 2.000 m² (40 x 50 m), l'estimation se montait à 600.000 DM incluant la réalisation des éléments de la structure au-dessus du niveau des fondations en béton (coût non inclus dans l'estimation), mais sans les taxes et les frais de douane. Ce prix inclut l'élaboration technique comme les calculs statiques, plans d'exécution des mâts et autres pièces comme la membrane. Il faut ajouter à ce devis 30.000 DM pour l'avant-projet incluant la réalisation d'une maquette, 42.000 DM pour le transport (40 tonnes) des pièces vers Babylone au moyen de trois poids lourds, et 50.000 DM pour la surveillance du chantier par deux spécialistes pendant un mois. En plus le client met à la disposition de l'entrepreneur 20 manoeuvres et l'équipement nécessaire au montage de la structure.

CONCLUSION

En matière d'abri protecteur de vestiges archéologiques, la plupart des réalisations de ces trente dernières années paraissent peu convaincantes aux yeux d'un architecte d'aujourd'hui. Les réussites dans ce domaine restent isolées, tant l'introduction d'une architecture contemporaine en milieu archéologique se heurte encore à de nombreux préjugés. Dans bien des cas on s'est en effet contenté de construire un abri sommaire - faute de moyens financiers, il est vrai - sans trop se soucier de l'intervention nouvelle que l'on pratiquait ainsi sur un site historique. Néanmoins toutes ont le mérite d'exister même si bon nombre sont restées au stade du laboratoire d'essais in situ; aux responsables de la protection des sites d'en tirer les leçons.

Aujourd'hui un site archéologique n'a plus la même signification qu'auparavant. Une question se pose: comment tirer parti d'un patrimoine culturel en l'associant aux préoccupations de notre temps par le moyen d'interventions nouvelles, fruits de l'art et de l'architecture d'aujourd'hui, tout en préservant son identité comme sa personnalité profonde? Le site remarquable devient alors le champ des activités humaines qui allient protection des vestiges et promotion des arts. En cela il mérite les plus grands égards des créateurs les plus authentiques associés aux spécialistes de la protection et de l'aménagement des sites. La notion d'abri protecteur évolue vers celle d'oeuvre d'architecture, pourquoi pas de monument, le terme n'étant pas nécessairement synonyme de gigantisme où de mégalomanie.

A cette occasion, les auteurs de projet agissant en artistes professionnels démontrent leurs capacités à créer des espaces appropriés aux vestiges découverts, afin de donner une nouvelle signification à l'héritage culturel tout entier. La structure qui en découle, loin d'être considérée comme un gadget moderniste ou un geste architectural gratuit, peut se concevoir comme une association abrupte avec le passé ou, selon l'expression consacrée, l'affirmation de notre temps par la concrétisation d'une proposition hardie. En matière de protection des sites, l'audace peut ne pas manquer de respect.

Pratiquement, une solution, significative et d'esprit contemporain, serait l'introduction d'une structure légère - il faut limiter les dégâts en cas d'écroulement - qui enferme partiellement ou totalement les vestiges, en manifestant un maximum d'indépendance par rapport au site protégé, par exemple en réduisant le plus possible les points de contact entre la nouvelle structure et le sol d'origine, sans pour cela abuser des structures à grandes portées. C'est au niveau du choix de ces contacts comme des éléments de liaison que l'on appréciera les qualités d'intégration ou de contraste de la structure nouvelle. On se souciera en outre de sa présence plastique sur le site au même titre que celle de tous les équipements indispensables au respect des lieux, dans le cadre d'un plan particulier d'aménagement.

Sans tirer de conclusion définitive, une formule pourrait résumer l'idée maîtresse: pas de conservation sans actualisation des lieux au travers d'un signe du 21ème siècle!

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Figure 1. Syrie. Nouvelle couverture du coeur sacré du palais du 3ème millénaire à Mari. (1975) Photo: auteur.

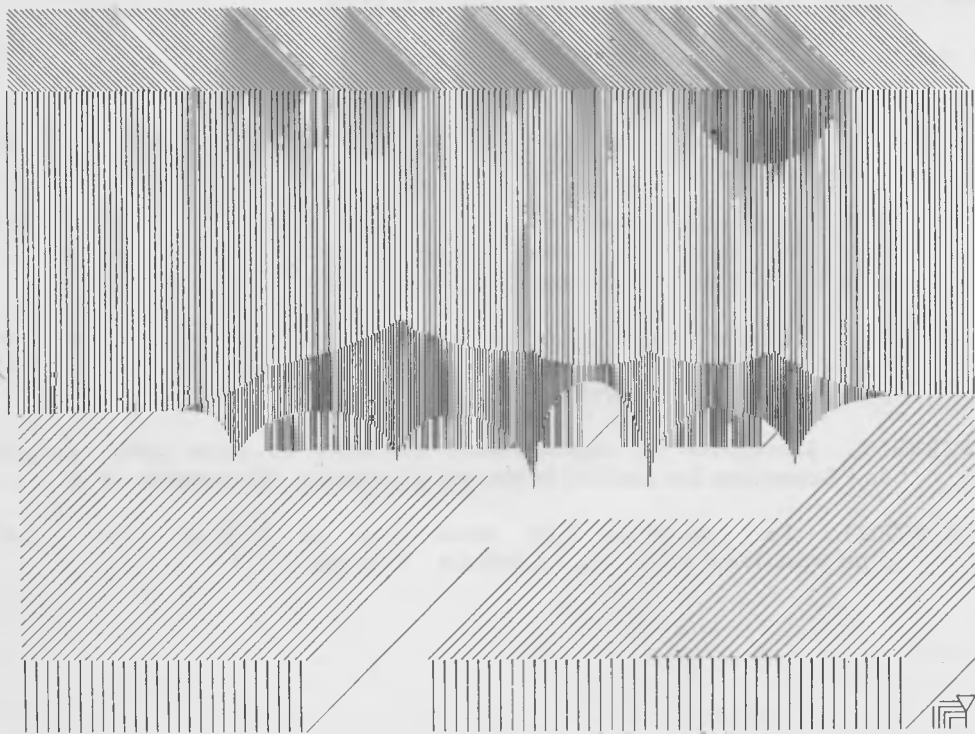


Figure 2. Iraq. Babylone. Structure de couverture légère, tendue et réversible, qui n'altère en rien l'authenticité des ruines. Projet d'André Stevens, 1979.



Figure 3. Canada. Le pavillon des Etats-Unis à l'exposition universelle de Montréal (1967). Exemple de coupole géodésique. Photo: auteur.



Figure 4. Grèce. L'Acropole d'Athènes. Affiche publicitaire d'un grand constructeur métallique des Pays-Bas, spécialisé dans la fabrication et le montage de structures spatiales de grandes portées. (Bailey, revue Acier 2/82 avec permission).

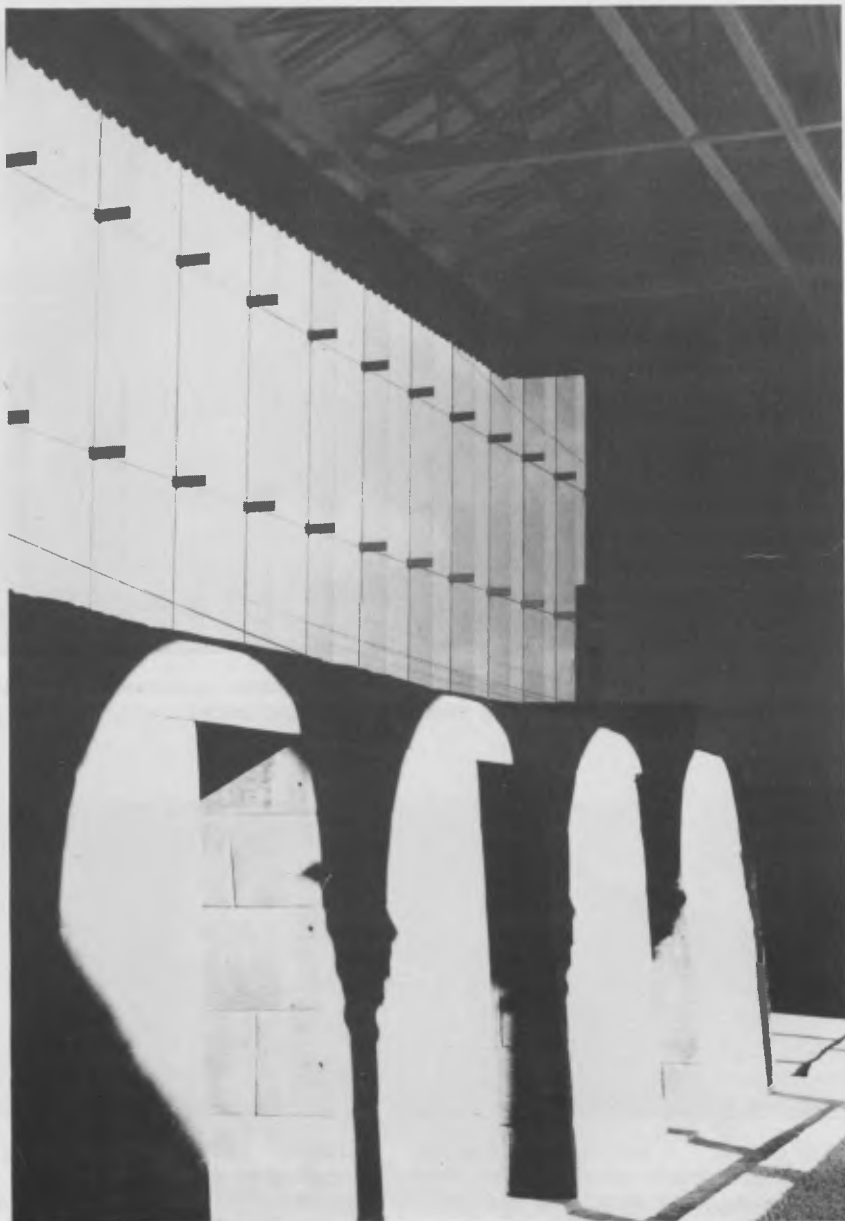


Figure 5. Pérou. Intégration du temple de Coricancha dans le couvent Santo Domingo à Cusco. Photo: auteur.



Figure 6. Equateur. Cochasqui. Structure de protection en matériaux appropriés au sommet d'une pyramide en 'cangahua'. Photo: auteur.



Figure 7. Chine. Protection du tombeau de l'empereur Qin Shi Huang (à Xian) par une vaste halle de 70 x 200 m. Photo: source chinoise.



Figure 8. Hollande. Heerlen. Le musée des Thermes recouvert par une charpente tridimensionnelle de toiture. (Revue Acier, 1/80 avec permission).



Figure 9. Turquie. Tour d'observation à Alacahoyuk. Photo: auteur.

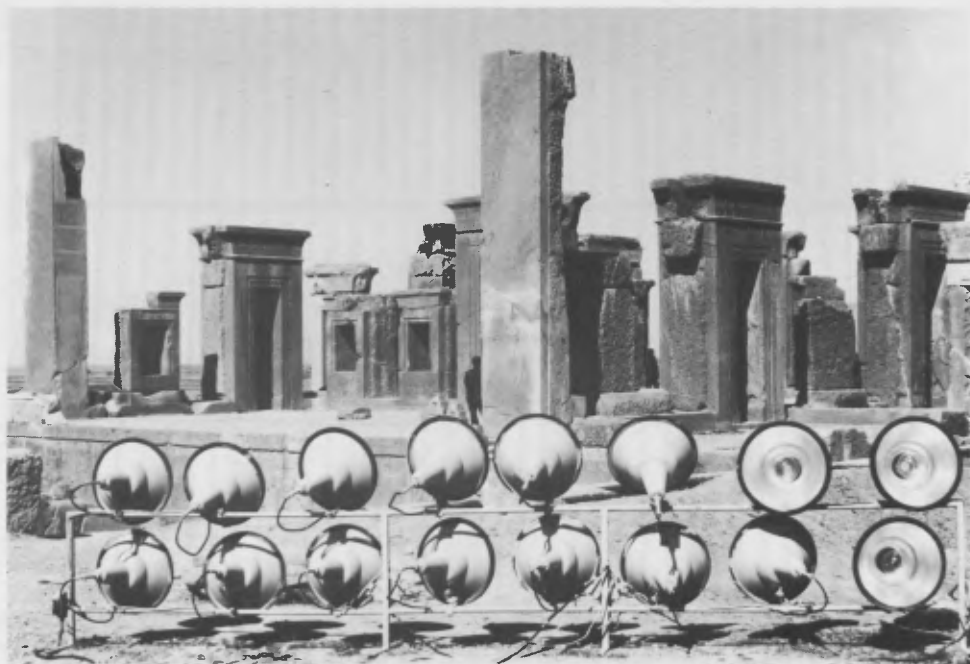


Figure 10. Iran. Sons et lumières à Persépolis. Photo: auteur.



Figure 11. Un Chinois à Montréal. Le pilier-stupa de Yar (Oasis de Turfan) à l'abri du dôme géodésique de Montréal. Montage photographique d'André Stevens.



Figure 12. Egypte. Ecran métallique anti-pigeons de l'ensemble d'Hathor à Dendérah. Photo: auteur.

ROOFS AND SHELTERS:
THE TANZANIAN EXPERIENCE

S.A.C. Waane*

SUMMARY

Tanzania's prehistory is best known for the palaeontological archaeological richness of Laetoli, Olduvai, Ndotu and Isimila - Stone Age sites. The first three sites are within the Olduvai "area" and have contributed substantially to the understanding of hominid evolution, not only in East Africa but also in the world as a whole. The latter site is an extensive Acheulian site. At the various sites within the Olduvai Gorge and at Isimila, attempts were made to present and protect excavated areas as "on the spot museums", while it is the intention of the Tanzania Government and the whole scientific community to preserve and protect the Laetoli footprints while exposing them to the scientific world and tourist alike.

This paper reviews briefly the prehistory of Tanzania, focusing primarily on the above four sites. Then it describes and illustrates Tanzanian efforts to protect and preserve various significant sites within them. Finally it shows why these attempts have failed so far to achieve the destined end, due to a low level of technology which did not take into consideration the nature of the artifacts being preserved when these on-the-spot museums were built. It also tries to explain why, so far, the Laetoli bird and animal footprints are still under a canvas cover and cannot be seen.

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1. INTRODUCTION

The main theme of this conference is of utmost importance to Tanzania for several reasons. First and foremost because archaeology as a discipline and profession is fairly young in Tanzania; serious archaeological research did not start in Tanzania until the 1950's. Therefore, there is much that Tanzania can learn, by our participation in this conference, from countries which have much longer experience. Secondly, despite this, within the thirty years of serious archaeological research in Tanzania, important archaeological discoveries have been made which have had and are bound to have considerable impact in archaeological circles for some years to come. Notable among these are the stratigraphy, palaeontological and hominid finds from Olduvai; the Laetoli footprints within the Olduvai Gorge system; the Ndotu Skull from Lake Ndotu; iron smelting sites in Bukoba, Northwestern Tanzania; and the equally important Isimila Acheulian Site in Iringa. It is also important to mention the many rock-art shelters of Central Tanzania. The conservation of these sites, archaeological and prehistoric phenomena is of primary national and world necessity, for they constitute a very vital stock of our national and world heritage.

The main objective of archaeology is to reconstruct the cultural history of man's past in an attempt to understand and explain how this history affects present societies culturally and technologically. In order to achieve this, in most instances, the archaeologist has to "expose" through digging the cultural, faunal and floral remains of past human/climatic environments. With systematic excavations, and at times luck, one may find butchery sites, tool/implement factories, occupation floors, irrigation channels, paintings, etc. which may be scientifically and archaeologically important enough to warrant permanent conservation and protection (both legal and physical), so that other people can come and see such archaeological occurrences and phenomena in the future.

Of the sites mentioned above, roofs and shelters have been built at Isimila, Olduvai and various rock-art shelters in Central Tanzania; some protection has been undertaken at Laetoli and Kemando Bay, Bukoba, Northwestern Tanzania. Various publications have already appeared regarding the sites mentioned above:

- Isimila (Howell, 1957, 1958; Keller and Hansen, 1969, 1970; Kleindienst, 1971, 1979 (a), 1979 (b);
- Bukoba (Schmidt 1978);
- Central Tanzanian Rock Art ((M.D. Leakey, 1983).

Isimila Stone Age site will be taken as a typical example of the problems of protection, conservation and development of our cultural heritage in Tanzania.

2. THE ISIMILA STONE AGE SITE

2.1 The Site and Archaeology

The Isimila prehistoric site (see photo 5) is within a small stream in the drainage basin of the little Ruaha, about 14 miles south of Iringa town at about 55°30'E and 7°54'S. Originally the site was known as MacLennan's Gorge. Geologically the gorge was formed by down-faulting and tilting during the Pleistocene with subsequent changes in the drainage pattern. During this faulting, the valley was blocked, resulting in a small, more or less permanent body of water. This mass of water was infilled with sediments to a depth of over sixty feet. These sediments consist of silt and clays with intercalated beds of coarser sandy and silty sediments, with the coarse sediments containing rich implement-bearing horizons representing occupation of the site by prehistoric peoples (Howell, 1959:482).

Archaeologically, the site falls within the late African Acheulian (Stone Age) period, comparable typologically with the hand-axe industry present at Olduvai Gorge Bed IV, Ologesailie, Kariandusi and Sewa in Northern Tanzania and Kenya. During this period man must have used the lake and stream as a watering place and hunting grounds and made his tools there. The tool assemblage includes hand-axes, various types of flakes, lanceolates, ovates, discoids, cleavers, knives, scrapers, chisels, pushplanes, choppers, pebbles and chunks made primarily from cataclasites, quartz and quartzite (Kleindienst 1962, table 1:101). The volume, occurrence and types of artifacts on the surface at Isimila are unique in the world. At four excavated areas the type and range of implements and palaeontological occurrences warranted (then and now) conservation, protection and presentation as on-the-spot museums (see N°s 1-4 on map).

2.2 What was Conserved and Protected

Excavations were carried out at various parts of the Korongo between 1957 and 1970. Four areas were isolated for conservation and protection (physically) as on-the-spot museums. The first area, marked 1 on the map (see photos 3, 6, 10, 11), had remains of a hippopotamus skeleton; most of the bones have now disintegrated. The second area, marked 2 on the map (see photo 8), has an occupation floor with stone tools and rubble left in position as they were found during the excavations. Preserved also at this museum are the eastern and southern walls of the excavations which show the clay and sand deposits referred to earlier. Of the other two areas, marked 3 and 4 respectively on the map (see photos 1, 2, 4, and 7), 3 is an exposed old land surface with all the tools that were found left in position, while 4 is a 30 x 15 m rectangle

"from which all stones which have not been worked by man have been removed. Those that remain are all tools, or flakes which have been struck off in the process of making tools. They have been preserved in this way in order to give an idea of the density of man's relics on the site" (Chittick, 1963: 5).

3. PROBLEMS OF ARCHAEOLOGICAL CONSERVATION: ROOF AND SHELTERS AT ISIMILA (AND IN TANZANIA)

3.1 It is my belief that the conservation of archaeological sites of whatever type has two primary objectives; first, to maintain (through conservation and restoration) the archaeological record and evidence as the archaeologist found it during excavation by giving it permanence and durability; second, to present this record and evidence to the general public and future generations by making it accessible. Given these two objectives, what has been our experience in Tanzania?

3.2 Accessibility

For obvious reasons, most archaeological sites are located outside any sizeable population concentrations, except for those colleagues who may be working in an urban/small island environment. This is true of all the sites mentioned above. Olduvai Gorge and Laetoli are more than 30 miles from the headquarters of the Ngorongoro Conservation Area; Isimila is about 14 miles from Iringa town, while Kemando Bay is about 15 miles from Bukoba township.

Thus our main problem in Tanzania is to make these museums/sites accessible from the main/feeder roads. The cost of maintaining all the roads to and within the site (as is the case of Olduvai) falls on the Antiquities Department whose

conservation budget is less than US\$10,000 per annum, allocated to service and maintenance of over 20 protected archaeological, historic and natural sites. The net effect of this situation is that most sites remain 'closed' to the general public during the main part of the year. For example, the road to Olduvai during the rainy season is hazardous, and Laetoli is inaccessible. Fortunately, Isimila is on the main road from Dar-es-Salaam (Tanzania) to Zambia; therefore it may be visited throughout the year.

3.3 Erosion

Olduvai, Laetoli and Isimila are in arid areas with scrub and scanty secondary vegetation (the latter is true of Isimila); therefore wind and water erosion is fairly extensive. However, although this erosion does not directly affect the artifacts and bones in the various on-the-spot museums, it greatly erodes the roads to and within the sites, making them not easily accessible by car and further aggravating erosion within the site. To the average archaeologist, for example, working at such sites as Olduvai, this may be a blessing in disguise because then it is possible to locate archaeological/palaentological materials eroding away. But to the Archaeologist and Conservator of Antiquities it is a big problem. At Isimila, we have managed to contain the erosion by not maintaining the road from the main road to the site and the access path from the guide's post to the Korongo. However, there is still an ongoing process of rolling of the artifacts down the valley and sides of the Korongo. At Olduvai, the roads to some on-the-spot museums are so eroded that visitors find it very difficult to get to them.

Other than this surface wash erosion, the two museums at Isimila are either on the slopes or at the base of the Korongo. As a result, both downward percolation of water and its accumulation within the clayey silty soils make the surface on which the artifacts/finds rest damp and wet, particularly during the rainy season, causing decay and disintegration of the artifacts being conserved and protected, especially those of bone and wood.

3.4 Rainwater and Variations in Temperature

The walls of both structures at Isimila and those at Olduvai Gorge were built and plastered with mud to about 1 m high, with relatively high roofs. This kind of architecture at most times allows the rain and sunlight to enter directly into the shelter, thus aggravating the dampness and decomposition mentioned earlier. This is more so with the extreme variations in temperature between the wet and dry seasons and night and day temperatures which cause very high seasonal and diurnal ranges.

3.5 Insects and Low Technology Levels

In all the on-the-spot museums where stone artifacts were left in situ, e.g. at Isimila, these artifacts have withstood weathering (relatively) well. Whereas where bone material was left in situ, as is the case with one museum at Isimila, most of the bone has been decomposed and is fast being destroyed by insects. The main reason for this, climatic factors aside, is the fact that none of the artifacts or the occupation floors underwent reasonable scientific treatment and conservation either during or after the excavation, to make sure that they withstood the hazards of weather and time. This is not a judgement against the good intentions of the archaeologists who built these museums, but an observation of the state of the science and technology of conservation that was then available to them and to Tanzania in general. Probably it is for this reason that the Laetoli footprints and the iron-smelting sites of Bukoba are still hidden from the general public. At these two sites the features have been covered with tarpaulins and the area backfilled.

CONCLUSION

What this brief review has attempted to show is that we do have, at places like Olduvai and Isimila, roofs and shelters, which I have referred to here as on-the-spot museums, and that the artifacts conserved in these museums are fast disappearing with time and weathering. Finally, it is better, for the moment, to keep under cover whatever archaeological phenomena we deem fit to conserve until and unless we get access to the appropriate technology.

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Figure 1. Fenced area to show density of stone tools at Isimila trench.



Figure 2. Stone tools scattered in trench area through water action in rainy season.



Figure 3. Scattered fossil faunal remains left as "on-the-spot" museum; note decay of stone tools in situ.



Figure 4. Detail of stone tools in situ.



Figure 5. The site of Isimila from the east.



Figure 6. On-the-spot museum - a poorly built shelter that causes decay of fossil fauna, mainly in rainy seasons.



Figure 7. Stone tools in situ, with fence preventing access.



Figure 8. Artifacts displayed in situ in on-the-spot museum; note decay of wall base.

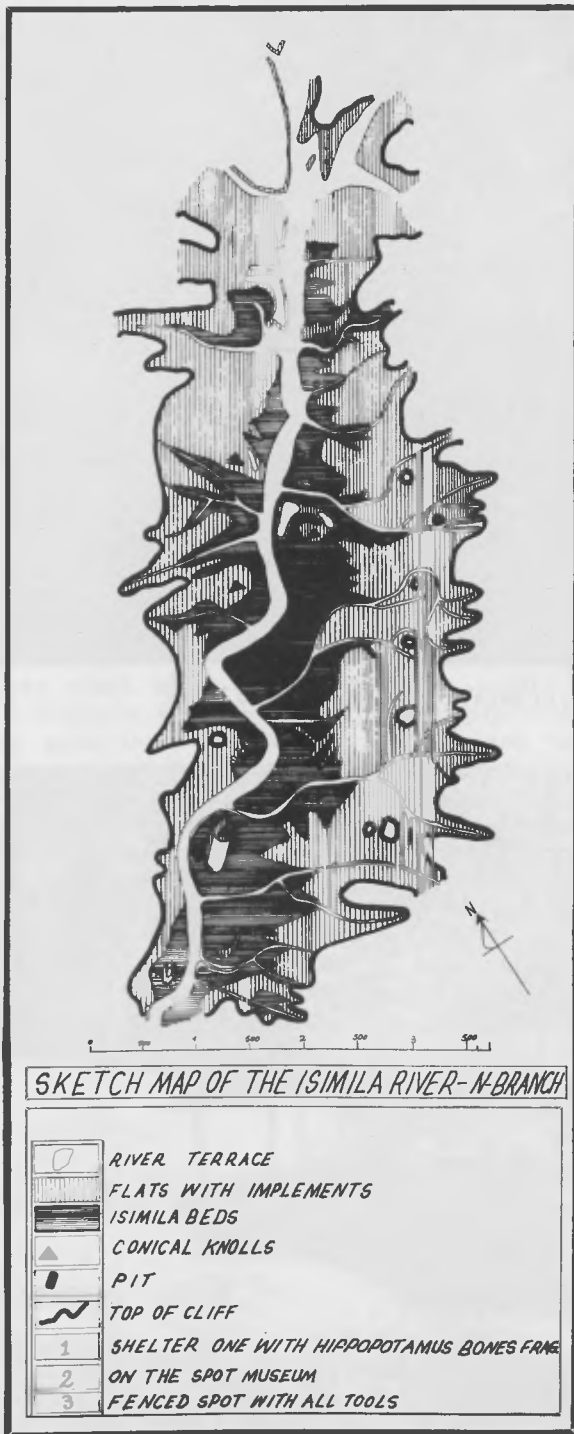




Figure 10. Detail of decay of poorly preserved bones.



Figure 11. On-the-spot museum at Isimila.

A CASE STUDY OF A PALAEOLOGICAL SITE - THE NEED FOR PLANNING AND PROTECTION

Neville Agnew and Mary Wade*

SUMMARY

The needs and methods of protection of palaeontological and archaeological sites have common denominators. The Lark Quarry dinosaur trackways site in central Queensland was excavated in the late 1970's by stripping off the overburden of country rock to expose part of a track-bearing layer 210 m² in area. The site contains some 4000 dinosaur tracks in soft arkosic mudstone. They date from the mid-Cretaceous and are about 100 million years old.

For two to three years while funds were being sought to provide physical protection from the elements and animals, serious deterioration occurred. During this time the only protection was plastic sheeting and hay on the surface. Subsequently, during construction of a roof, the straw and plastic caught fire and caused further damage. Animals, human interference and environmental factors have all played detrimental roles and have degraded the quality of this important palaeontological site, necessitating expensive restoration and preservation work. A case is made for the need for thorough planning and funding before excavation of such sites is undertaken. Likewise, communication and co-operation between the various disparate groups and individuals - palaeontologists, conservators, statutory authorities, architects, construction workers - who may become involved in protecting a site are essential. Where independent and sometimes arbitrary decisions are taken in regard to protective measures, the inevitable result will be damage to the site.

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Figure 1. Lark Quarry is about 100 km south-west of Winton in Central Queensland.

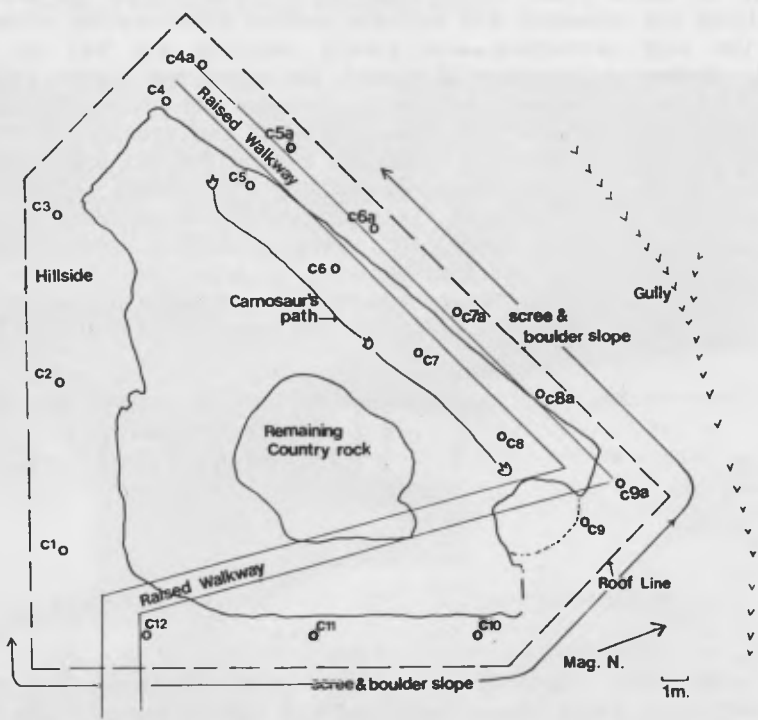


Figure 2. Lark Quarry site plan. C numbers denote the positions of the columns supporting the pentagonal roof.

INTRODUCTION

One does not usually think of palaeontological field sites as necessarily being in need of protection. Palaeontological sites contain fossil remains which, if sufficiently important or otherwise significant, are excavated and the material so obtained is further prepared for study in the laboratory. Yet, as has been pointed out by Mossman and Sarjeant, (1983), most extinct vertebrates are known not from their fossilized remains but only from their prints and tracks. That this should be so is, of course, not surprising because while an animal leaves only one set of remains when it dies, during the course of its life it leaves many sets of tracks or other traces of its movements. Consequently, the likelihood of preserved tracks being found is much greater than that of fossilized remains being discovered.

In the public eye palaeontology is a fascinating subject, especially where dinosaurs are concerned. The drama of the subject has depended in no small way on the discovery of fossilized remains, and the excavation, reconstruction and display of the material. But, increasingly attention has turned also to the study of preserved tracks and prints of extinct animals and the information it can yield.

Analysis of tracks can provide information on the size, speed and behaviour of the track makers. A trackway usually cannot be removed in its entirety to the laboratory or museum because of its size and extent. It thus poses particular problems of preservation in situ - problems that arise through weathering, vandalism, "souveniring" and, not least, well-intentioned but poorly co-ordinated and executed protective measures.

The Lark Quarry dinosaur trackways site, located in central-west Queensland south of the town of Winton (Fig. 1), has been subject to most of these vicissitudes. The site, in Cretaceous sediments about 94 million years old, is of world-wide palaeontological significance because (i) it shows nearly all the tracks presently known of running bipedal dinosaurs; (ii) it records a stampede of small dinosaurs - some 130-150 in number of two kinds - coelurosaurs and ornithopods - by a large carnosaur; (iii) there are roughly 4000 tracks presently exposed and the full extent of the trackways has not yet been uncovered.

We can anticipate in future an increase in the discovery of tracks and trackway sites world-wide. Not all track sites to be discovered will necessarily be of importance great enough to demand the application of elaborate preservation techniques. Some finds, however, undoubtedly will be sufficiently significant to justify such measures. The Lark Quarry dinosaur trackways may well become, therefore, a prototype of the preservation needs of sites yet to be discovered.

THE SITE

Evidence of fossil tracks was first found close to Lark Quarry in the early 1960's (2), and in 1976-77 the Queensland Museum excavated the site with the assistance of a large team of volunteers. A roughly triangular area of 210 m² was cleared of sedimentary overburden. Figure 2 shows the site plan. At the south-western end the trackways horizon, which is nearly horizontal and dips on average only by about 4°, extends into the hillside. In this area about one metre of overburden was removed. Hence, the full extent of the trackways is not presently exposed, or known, and any future excavation into the hillside will require, progressively, removal of more overburden. Furthermore, the carnosaur's trackway (of which 11 tracks survive) swerves to the right near roof column 5 (Fig. 2) into an area that is now an eroded gully.

Figure 3 is a tracing of part of the photomosaic of the trackways. It shows that the smaller animals, which ranged in size from that of a bantam to that of an ostrich, streamed in one direction only and several of the carnosaur tracks are over-trodden by small footprints. The interpretation of events on the site, which probably occurred over a time span of only a minute or two, is that the predator herded the animals against a shallow lake, and when the prey had been selected and perhaps seized, the others broke out in wild panic. The firm, plastic mud in which the tracks were made shows slip-marks as the animals bolted. Palaeontological work and a detailed analysis of the trackways was carried out by Wade and Thulborn (3-6) and their definitive paper (6) has yielded information about the size of the animals and speed at which they were running.

Because of the scientific importance of the site an area of 374 hectares of surrounding country was declared and named the Lark Quarry Environmental Park in 1982, a special reserve gazetted under the Queensland *Land Act* (1962-81). The Park is administered by the Queensland National Parks and Wildlife Service. Environmental parks are similar in many respects to national parks except that they are placed under the control of appropriate statutory bodies through trusteeships. Several organizations may have responsibilities for an environmental park by this arrangement. For Lark Quarry Environmental Park, the following roles have evolved for the organizations involved: Queensland National Parks and Wildlife Service (QNPWS): administration; assist trustees to plan manage site, supply signs, produce brochures, provide development funding as necessary and available. Queensland Museum and Winton Shire Council (QM and WSC): as joint trustees the former is responsible for technical information, scientific study, conservation; the latter for site surveillance and regular maintenance activities.

CHRONOLOGY - (relevant to conservation)

| | | Organization Involved |
|------------|--|--------------------------|
| Sept. 1976 | Preliminary excavation and casting of surface. Site recovered with pebbles and soil. Soil washed off over summer. | QM |
| May 1977 | Main excavation and casting of surface. Site left uncovered for examination by QNPWS; remained uncovered for 2 winters and 1 summer. | QM |
| Mid-1978 | Protection of surface with straw and plastic. | QNPWS |
| 1979 | Construction of roof and fire. | QNPWS |
| 1980 | Roadwork to site. | WSC |
| 1981 | Involvement of conservator; photographic monitoring started; preliminary conservation plan initiated. | QM |
| 1982 | Steel walkway erected. | QNPWS |

| | | |
|---------|--|-------------------|
| 1983 | Preservation work - infilling and repair with polyethylene foam and silicone resin. Fence erected. | QM QNPWS |
| 1984 | Buttressing edges to prevent further breaking away. | QM |
| 1984/85 | Restoration of individual tracks with silicone resin. | QM |
| 1985 | Interpretive signs. Shade cloth on fence. | QM/QNPWS QNPWS |

EXCAVATION OF SITE

The Lark Quarry site was excavated by Queensland Museum workers and volunteers in 1976 and 1977.

In the first season a preliminary excavation was carried out and the following year the main excavation was done by a team of 20 or more museum workers and volunteers who completed, within 2-3 weeks, the removal of the overburden of sandstone over 210 m² of the site. The overburden was up to one metre thick at the up-hill or southwestern end of the site and it is estimated (6) that about 60 tons of sandstone was removed. Fortunately, the sandstone cleaved cleanly from the trackbearing mudstone layer and it was possible to use robust techniques such as crow bars to prise it loose. After the excavations had been completed, a small team of skilled preparators meticulously cleaned out the sandstone infilling from about 4000 prints using small blunt awls and hand-tools (Fig.4). The site was then vacuum cleaned and a cast taken in latex.

SUBSEQUENT HISTORY OF THE SITE

The exposed trackways site was covered in 1978 with hay and plastic sheeting to prevent weathering and the site remained like this while funds were sought from the State Government to erect a protective roof. Finally, in late 1979 the roof shown in Fig. 5 was erected at a cost of some \$50,000. This construction work was done without supervision and, during welding, the plastic and hay caught fire and apparently burned unchecked over the site. It is not clear whether the construction workers were indifferent to the site or believed no damage could be done to the rock or whether it was impossible to put out the fire, but no attempt was made to pull off unignited plastic. No reliable first-hand report exists of the fire's intensity or duration. As a consequence, however, much of the surface was discoloured a blue-black and the thin limonite layer covering the surface has cracked off (Fig.6) extensively where the fire is thought to have burned most fiercely. Fortunately, in some areas where a pebble and soil cover had remained from the 1976 excavation, the surface was protected from damage by the fire.

THE ROOF

The flat, pentagonal steel roof with a central skylight, erected in 1979 has served to keep the site reasonably dry. It has not prevented wind-driven rain from flooding the site, and, being open on the sides, it has not prevented dust from

collecting in the tracks. In addition there is evidence of damage to the surface during erection when the 12 support columns were set in concrete (Fig. 7). Kangaroos also found the shelter attractive in hot weather, and several died on the site during the 1982 summer drought. Consequently the site had to be fenced.

In every aspect of the design and erection of the roof, there have been deficiencies which could have been anticipated or at least remedied quickly once they had been identified and noted.

THE WALKWAY

A raised steel walkway over the site was erected (as shown in Fig. 7) in 1982. Prior to this visitors had walked on the surface itself. Again, this was installed without supervision and damage to the site occurred. It has, however, been effective in encouraging visitors not to walk on the surface.

DETERIORATION OF THE SITE

In mid-1981 one of the present authors (NA) visited the site for the first time at the invitation of the co-author (MW) in order to attempt to assess the deterioration which was occurring. The soft sediments with high kaolin and iron content were weathering, and the deterioration was alarmingly advanced for a surface that had been exposed for only some four to five years.

As a result a conservation programme was initiated. Details of this have been published (7). In outline, the conservation strategy endeavoured to do the following:

- (i) Document the deterioration.
- (ii) Identify all the parameters responsible for the deterioration
- (iii) Examine the various facets and input of professional and technical advice and expertise relating to the site since the excavation.
- (iv) Photographically monitor selected points on the surface.
- (v) Do research on suitable restoration and preservation materials and techniques.
- (vi) Carry out a restoration programme.

These various components of the overall project have now, in mid-1985, by and large, been implemented (8).

SUMMARY OF CAUSES OF DETERIORATION

Environmental Factors:

Thermal shock during summer rain storms.

Expansion of joint planes and cracks by rain and mud flooding on to the site.

Fire leading to discoloration and exfoliation of limonite layer.

Dust accumulating in tracks and cracks - creating mud when wet and thus widening the cracks.

Kangaroos and wallabies congregating in shade of the roof - droppings, urine, scratching surface; animals dying on the surface.

Human Factors:

Walking on surface - cracking layers and dislodging loose fragments of surface.

Souveniring.

Vandalism.

Unknown Factors:

Effects of removal of overburden - possible stress relief causing opening of joints and cracking.

DISCUSSION

The problems that have arisen over the period - now nearly 10 years - since the excavation could, with hindsight, have been anticipated. The lessons to be learnt are clear, and were the site to be excavated today, the adoption of the measures discussed below would go far towards preventing the deterioration which subsequently was to necessitate costly conservation work.

First, appoint a field conservator with a specific brief to examine from every angle and to be concerned with all possible causes of deterioration of the site. This professional would have a continuing involvement with the site and would play a key role in preservation especially during the early stages of excavation. The conservator should be involved with the architect or designer of the protective shelter, roof, walkway and so on to ensure that the extraneous object to be erected will conform to the preservation requirements of the site.

Second, in a case such as Lark Quarry where disparate statutory authorities are involved - each accustomed to acting more or less independently within its own field of expertise - it is essential to establish a standing committee composed of members from each organization. This committee would be responsible for all decisions, plans and so forth relating to the site. It would control every aspect of the scientific work, the preservation, management, and development of the site. The committee's most important role would be during the early phase of work on the site when important decisions were being made regarding, for example, planned measures of physical protection, visitor access to the site and so on. The function of the committee would become less crucial after the initial decisions had been taken and implemented but would be essential during the early stages. The committee could be scaled down, if need be, to a simpler management committee when the site had been stabilized and construction work completed. As mentioned above the three organizations involved at Lark Quarry were QNPWS, QM and WSC. It is a matter of record that each one of these has at some time acted independently of the other two; occasionally arbitrarily, but more usually because the need to communicate had simply not been envisaged. To be specific - the erection of the roof was undertaken by the QNPWS without ensuring that a conservator, or indeed any staff member either from that organization or the QM or WSC, was on hand to safeguard the delicate surface of the site and prevent construction workers from damaging it.

Third, the field conservator should be appointed to the standing committee with a brief to liaise between the bodies. The conservator should be a member with some authority on the committee - it being understood that he would be the "link man" between the organizations. Likewise, contact persons within each organization, should be appointed to the committee. They would be au fait at all times with current decisions and policy.

Fourth, excavation should not proceed without assured funds becoming available within a specified period to enable protection and preservation to be undertaken. When funds have been allocated, it is advisable to plan or schedule protective measures to proceed as nearly concurrently as possible with the excavation.

Where the extent of an excavation cannot be known in advance - as was the case at Lark Quarry - temporary, but adequate, protection must be planned and designed. At Lark Quarry, shallow reburial with soil and pebbles at the end of the 1976 casting work proved inadequate as the soil washed off. After the May, 1977 excavation and casting, the site was left uncovered so that it could be examined by QNPWS with a view to possibly accepting responsibility for it. It was anticipated that prompt covering of the surface would occur once this important decision had been made. As it happened the surface was left uncovered for over a year (two winters and one summer) before it was covered with plastic sheeting and hay.

It may be argued, with justification, that the significance of a site such as Lark Quarry cannot be known until after it has been excavated and that, therefore, it is unrealistic to make financial provision, in advance, for large capital and maintenance expenditure. Nonetheless, it is essential that, at the very least, adequate temporary protection be afforded a site once evaluation has established its importance, and that swift moves be set in train for permanent measures. Indeed, the temporary protection provided at Lark Quarry in mid-1978, although late, was probably sufficient for the purpose - the site, as already stated, was covered with plastic sheeting and hay. The material, as it turned out, was to have to serve for another year before the roof was erected, and it was during the welding by construction workers that it caught fire and apparently was allowed to burn unchecked on the site. No conservator or representative of any of the three trustee organizations was present on the site when the fire occurred and it is this experience that gives emphasis to the final recommendation:

- (vii) only during the presence of the conservator should construction or other work by persons unfamiliar with the stringent preservation requirements of the site be permitted. The conservator must have vested authority to veto any harmful practices.

The proposed measures outlined above may be thought to be over-elaborate and even cumbersome for what after all may be seen as a matter of common sense and requiring only co-operation between the responsible authorities. Our experience indicates that the contrary is true and that a logical operational framework with defined roles and functions should be agreed at the earliest possible stage. Where the roles of the statutory bodies are allowed to simply "evolve", the situation is fraught with possibility for independent and arbitrary decision and action and, indeed, disaster for the site.

There is another more quantitative measure which one can apply to a site such as Lark Quarry when discussing the need for structured planning, and that is cost. Figures for the total expenditure over the 10 year period of excavation, preservation and development have not been compiled and it would be difficult to do so accurately because of the large component of hidden costs in wages and travel to and from the

site. Nonetheless a rough estimate, which is probably conservative, of around \$A350,000 may be made. Of this an amount of about \$A100,000 went towards capital expenditure (roof, walkway, fencing); \$A200,000 towards operating expenses (wages, travel costs to and from the site); and \$A50,000 for preservation work attributable to deterioration that would have been largely avoided had immediate protective measures been available when the site was excavated.

CONCLUSION

Lark Quarry is logistically a difficult and expensive site to work on. It is in a remote area two full days' drive from Brisbane. The cost of a visit to the site can run to \$A1,000 and a week must be allowed for even the most cursory inspection of the surface. Thus, for a visit to be co-ordinated with staff from another organization usually requires considerable advance planning. These factors, contributory to the lack of adequate co-operation and supervision on-site at Lark Quarry, should be seen as ones which typically will arise in a palaeontological or archaeological field site, especially in a country as large as Australia. Thus, it is important that factors such as remoteness and cost be recognized when putting together an integrated preservation plan.

At Lark Quarry some serious oversights were made and it is to be hoped that these, if discussed and recognized frankly, will serve to prevent similar mistakes' being made elsewhere.

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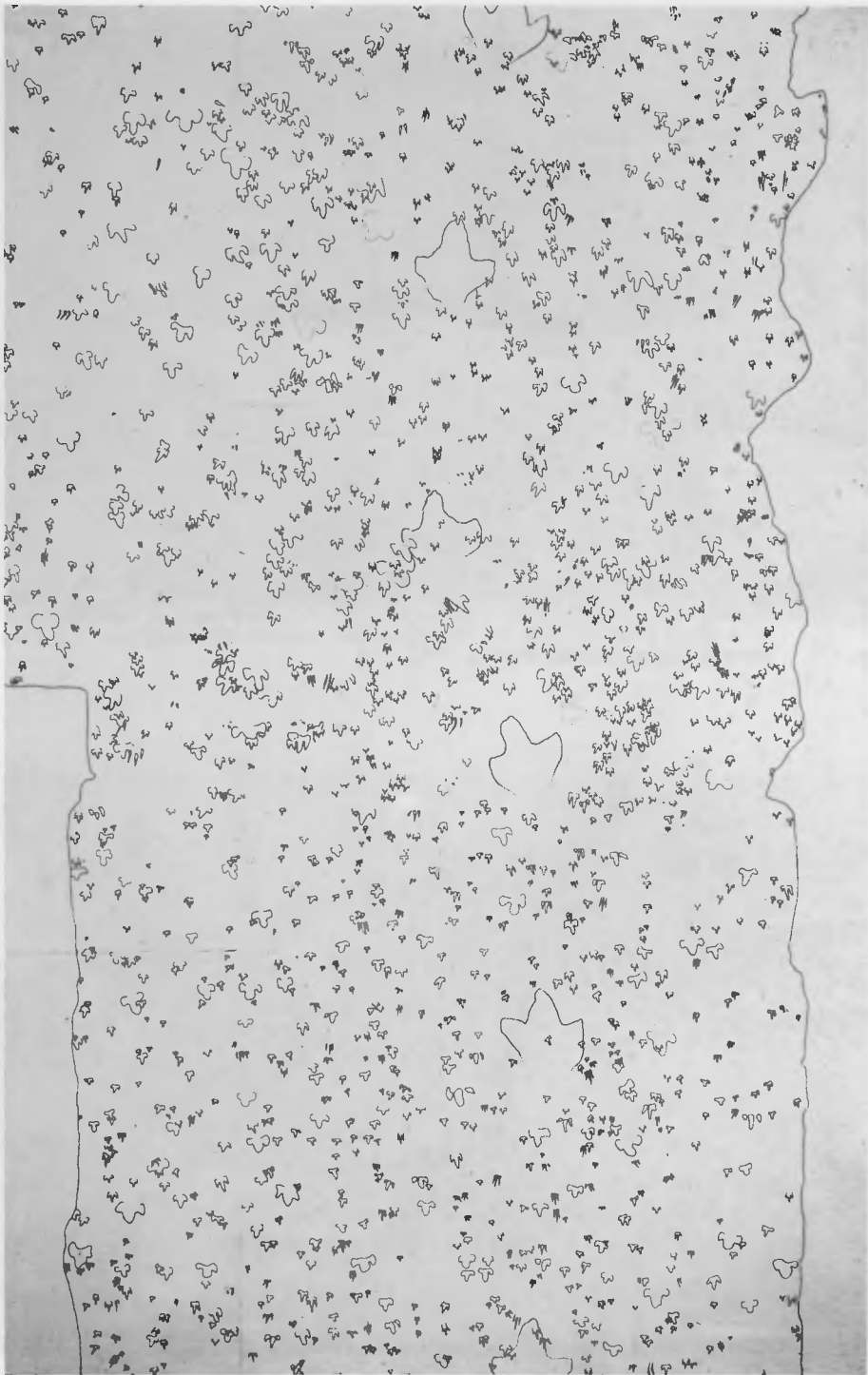


Figure 3. Tracing of part of the photomosaic of the site.



Figure 4. Excavating individual tracks, 1977.



Figure 5. Roof, walkways and fence around the site. Scree slopes were formed from overburden of sandstone excavated to uncover the tracks.



Figure 6. Cracks in the surface and lifting of the thin limonite layer.



Figure 7. Visitors on the walkway. Note the roof columns and walkway supports embedded in the surface.

ROOF OVER A MONUMENT SRI LANKAN EXPERIENCE

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INTRODUCTION

In the process of understanding civilizations, many efforts have been made to interpret architecture and its relation to human experience. Some define architecture as the expression of the spirit of the period, or that "architecture is the matrix of civilization", etc. To such definitions, it may be added that, viewed historically, architecture remains the principal visible and material record through the ages of man's intellectual evolution. Each great cultural movement has made its own particular contribution to art and architecture so that the aspirations of the people, and even their way of life, stand revealed in substantial form for all to see. The products of art and architecture that serve to commemorate, to remember and to understand the happenings of the past may each be considered a monument, for they can be as small as a piece of carving, or as complex as a city.

Buildings were normally designed and constructed with roofs, but many an old building remains today without a roof. The roof would have decayed and fallen, destroyed by natural causes or by man, exposing the superstructure and the works of art to natural elements. There were instances when people re-constructed different roofs to those which preceded them, without any sympathy to the original architecture of the monuments, due to lack of interest, ignorance or lack of money for construction. Sometimes, even monuments which were designed and constructed to perform their functions without roofs were later covered with protective roofs to prolong their life spans. There are also those instances where the original roof was intact but failed to perform its function and therefore a secondary roof was constructed for greater protection. When monuments are unearthed during archaeological excavations, temporary covers are generally necessary to protect them from the sun and rain until they are conserved. But, sometimes, a roof may have to be permanently fixed over the excavated area for the protection of the excavated material on a long-term basis. Construction of a temporary roof becomes necessary to protect the monuments only when the conservation work is in progress.

ROOF OVER A STUPA

A stupa was originally a funeral mound or tumulus, erected by Buddhists either to enshrine a relic or to commemorate some sacred site. In Sri Lankan religious architecture, the stupa was given an important place and constructed as the over-powering architectural element in religious complexes. The height of the stupa varies from 1 - 125 metres. All important architectural monuments in the country were products of many successive rulers, continuing to exist as original contributions or as improvements to previous structures. The construction of a roof over an existing monument was not a new concept in the history of Sri Lankan architecture. The construction of a roof over an existing Stupa "*Jumparama*" constructed in the 3rd century B.C. was carried out by King Vasabha (170 - 126 B.C.).

It would have been a magnificent roof supported on four concentric circles of stone columns. The original form of the roof is still controversial. Some scholars are of the opinion that the central roof of the two-tiered structure was domical, while others consider that it was conical in shape and covered with clay on bronze tiles. This construction of a roof over the existing stupa brought in a new style in Sri Lankan Buddhist architecture identified as "*Vatadagē*". There are more than thirteen *Vatadagēs* in Sri Lanka but the roofs of the earlier structures have decayed (fig.1). Construction of a roof over an existing stupa was a protection to the monument, and also considered as a further contribution in honour of the Buddha.

ROOF OVER A STATUE

The contribution of sculpture to Sinhalese art is commendable, and varies from a small ivory or gold carving, to a very large statue cut out from a living rock. Most of these statues that were found have been carved out of granite, limestone or made in brick. In time, the buildings that were protecting these statues have decayed and the statues were exposed to hot sun and heavy rain. With the clearance of jungle and archaeological explorations carried out in the 19th century, these statues were brought to light. Ensuing public opinion initiated measures to prevent further decay, and attempts were made to cover them with protective roofs.

Religious groups also pressured the Department of Archaeology to construct roofs over important Buddha statues of religious and aesthetic importance.

A seated Buddha in limestone, carved in the 3rd or 4th century A.D., was found at Abhayagiri Monastery. It was one of the best sculptures in the ancient city of Anuradhapura, depicting the Buddha in a state of deep meditation and popularly known as "*Samadhi Buddha*". A need for protection for the statue was stressed by the public and, as a result, a flat concrete roof supported on columns at four corners was constructed. It was a challenge to the Department of Archaeology to construct a roof without disrupting the artistic and archaeological values of the statue and keeping it in the openness of its surroundings. After the roof was added, the view of the sculpture among the large trees of the surrounding park was lost, in response to the fulfilment of a technical need.

Construction of concrete roofs over ancient stone sculpture did not stop there. Different types of concrete structures were constructed for the protection of such monuments. A limestone statue, popularly regarded as King Dutugemunu and found near the *Ruwanweli* Stupa, was brought under a concrete shelter, and now accepted as being technically valid.

A colossal 5th century sculpture of the standing Buddha at *Aukana*, carved out of granite, was another interesting monument that was subjected to religious-cultural demands for a protective roof (fig.2). The statue was carved out of a monolithic rock to a height of about 12 metres, with the remaining part of the original rock in the background. The plinth of the original Image House has remained although no indication of the architectural form of the building was found. The statue would have been left exposed to sun and rain for a period of more than 1,000 years, until a temporary canopy over the head was constructed out of steel in the form of a cantilever, fixed onto the background rock by the workmen who were engaged in construction of a new railway line to Anuradhapura in the latter part of the 19th century.

A few years later, the canopy disintegrated and, falling on the statue, damaged its head.

A critical press roused public opinion against the apparent lethargy of the Department of Archaeology to take measures against the resultant exposure of the statue to the elements. A National Committee was appointed by the Government to advise the Commissioner of Archaeology in arriving at a suitable solution for the protection of the monument. Advertisements through the mass media called for suggestions from architects, archaeologists, art historians and the general public. There was little or no response. The Department of Archaeology was left to find its own solution. The height of the monument was the main guiding factor for the protective enclosure. It had to provide shelter to both head and body. A design concept for an enclosure was based on the existing remains of the brick image houses of the 12th century found at Polonnaruwa.

An arch was built out of common bricks, using the principle of every upper layer cantilevering from the edge of the lower layer, till they met at the top of the arch. The shape of the arch was copied from the *Thuparama* image house at Polonnaruwa, but finished with broken brick edges. The ultimate product was an over-powering mass of brickwork which completely over-shadowed the magnificent scale of the statue (fig.3).

The brash, raw brickwork provoked criticism from art historians, but this mass has mellowed somewhat over the succeeding years.

An image house was one of the most important building types in Sri Lankan Buddhist architecture that flourished for more than 2,000 years. Foundations of buildings with stone columns and large stone images of the Buddha and *Bodhisatva*, are the only remains today of this important ancient form of Sinhalese architecture. Presently, all these statues are directly exposed to the hot sun and rain without any protection (fig.4). The most notable of these are three statues of Buddha, one reclining, one standing and the other seated, carved out of rock at *Gal Vihara*, Polonnaruwa. These are considered very important in terms of their artistic and religious values. Another proposal was mooted by the Department of Archaeology, for a brick arched roof similar to the one at *Aukana*. Religious-cultural aspects may weigh more heavily, in fact, than mere technical needs in crystallizing such solutions.

It is obvious that stone or brick masonry, when exposed to direct sun and heavy rains in tropical climates, undergoes accelerated deterioration, and a roof cover may protect the monument, although its effects on artistic and archaeological values are questionable.

ROOF OVER A BRICK MONUMENT

The most outstanding achievements of Sinhalese architects during the Polonnaruwa period (11th and 12th century A.D.) are the massive image houses with vaulted roofs of brick construction. These edifices have moulded bases and the exteriors of their walls are ornamented with pilasters supporting horizontal cornices. Between pilasters are facades of miniature edifices, in which are stucco figures of deities. Friezes of animals and miniature divine figures called "*Ganas*" adorn the plinth and cornices. Both internal and external walls are decorated with paintings. The materials of construction and the decorative artwork in these buildings are such that the fate of a monument of this nature without a roof can easily be imagined.

There are three examples of this type of vaulted shrine at Polonnaruwa. *Lankatilake* and *Tivanka*, the first two, housed two colossal standing Buddha images of brick and stucco; the third, *Thuparama* had a seated Buddha image. It is only at *Thuparama* that the vaulted roof remains. In *Lankatilake* and *Tivanka*, the roofs have fallen in. The remaining structures measure nearly 40 x 20 x 18 m and 41 x 20 x 15 m respectively. *Thuparama* was 25 x 16 x 13 m. The two earlier monuments have remained without a roof for nearly 700 years. In both edifices, the decorative stucco work remains, but the wall paintings have survived only at *Tivanka* image house. These 12th century paintings are the best preserved of the period in spite of remaining exposed to the weather. Exploration and excavation work at *Tivanka* commenced in 1885, and intervention therefore has recurred over nearly a hundred years. The Department of Archaeology has constructed many temporary roof canopies over the remaining painted plaster work, but the broken walls are still exposed to monsoon rains and direct sunlight still continues to fall on the painted surfaces. There is now a final realization that only a proper protective

roof could adequately preserve these unique 12th century paintings and the remaining stucco sculptures as a matter of great urgency. There are, however, many important factors that a designer may have to take into consideration, such as:

- (a) Imbalances to environmental equilibrium;
- (b) Extent of intervention;
- (c) Method of support;
- (d) Effects of new micro-environment created;
- (e) Reversibility;
- (f) Durability of materials used;
- (g) Prevailing cyclonic effects on the area;
- (h) Protection of artwork on external facades;
- (i) Economic feasibility of the proposal; etc.

There were two proposed solutions to the above problem put forward recently, one by the Department of Archaeology and the other by a conservation architect. The proposal put forward by the Department was to construct a timber-framed roof, supported on the walls of the monument at different levels and sloping in different directions. The other proposal was to construct an independent roof on a timber framework supported on timber columns running outside the monument and clad with translucent fibreglass sheeting. No steps have been taken so far to implement either of these solutions.

Another brick image house of the same architectural character was built in the mid-14th century and known as *Lankatilake Vihara* of Gampola. It was found that the brick vaulted roof had not functioned effectively due to a number of reasons such as location in the wet zone of the country, the poor quality of material and technology used in construction, etc. Due to the unsatisfactory performance of this vaulted roof, the edifices were covered in the mid-15th century with a complicated clay tile roof. The timber framework of the roof was supported on existing vaults. The addition of this roof evolved a new architectural style, which still remains as a significant contribution to Sri Lankan architecture.

ROOF OVER A STONE BUILDING

In the mid-14th century, a new architectural form and style was used in the construction of Buddhist image houses. It was a direct application of South Indian stone architecture, developed in an environment where the rainfall is sparse. There is no doubt that the stone roof had not functioned satisfactorily in the hill country with a considerably higher rainfall. In the mid-15th century, a tiled roof, similar to the previous one, was constructed over stone roofs and domes to give protection to the monument. The image house at *Gadaladeniya* is a good example of this type. At the *Gadaladeniya* image house, the secondary roof remained until some archaeologists of the Department removed it completely in the mid-20th century. It may be considered destruction in the guise of conservation resulting in the decay of painting and sculpture in the chambers below by penetrating water and damp. Similar new protective roofs may also be found at places such as *Adāhana Maluwa*, Kandy; and *Kobbekaduwa Vihara*.

TEMPORARY ROOF OVER MONUMENTS UNDER EXCAVATION

The process of archaeological excavation is a time-consuming and slow process. When architectural monuments are exposed in excavation, their consolidation and conservation must follow up immediately.

Archaeological materials preserved naturally under cover of earth have acquired a certain equilibrium within the micro-environment around the monument. With their exposure to atmospheric conditions, this equilibrium is disturbed and consequently deterioration sets in. Construction materials like brick, mortar, stucco, pigments, timber, adobe, etc., cannot survive in excavated conditions if exposed to direct sun and rain. A temporary roof cover has to be constructed, depending on the conditions of the monument unearthed, the duration that it is going to be left in the same condition without proper conservation, importance of the monument and the extent of the monument. With the undertaking of excavation of large areas under the Unesco-Sri Lanka Cultural Triangle Project, a large number of monuments were exposed. It was not economical to bring the whole of this area under a single temporary roof cover. A set of selected monuments were initially covered with temporary roofs in cadjan [matted palm-leaves] or corrugated iron sheets. But conservation did not proceed at an accelerated pace, resulting in roof collapse and damage due to this and exposure. Temporary roofs over monuments under excavation should remain until conservation has been accomplished. In special cases, it may be necessary to maintain a roof over a conserved archaeological monument in respect of its long-term survival.

TEMPORARY ROOF OVER MONUMENTS UNDER CONSERVATION

In the event of architectural conservation, it may be necessary to expose certain parts or areas of a monument to environmental conditions different to those to which they were subjected earlier. It may become necessary, for instance, to dismantle the roof or to remove certain protective coverings.

When a conservation project which requires a temporary shelter has been identified, one has to consider the following aspects before any roof is designed: (a) the life-span of the material and structure in relation to the required performance period; (b) the maintenance of the roof structure; (c) possible hazards; and (d) the cost. In architectural conservation work carried out previously in Sri Lanka, a cadjan roof, on a timber framework known as "*Puragē*" was built covering the monument. If the *Puragē* was not maintained, the rain and sun might have destroyed the monument or it might also have fallen on the monument itself, causing damage. There was the instance when a temporary protective roof was built over the Image House at *Hindagala* Temple, and which ignited due to a bush fire started in a nearby jungle, destroying the 8th century paintings on a cave ceiling above the building that was under conservation. In spite of the high cost, galvanized corrugated roof sheeting on a steel pipe framework is alternatively being used today.

CONCLUSION

A roof over a monument may be temporary or permanent, but it must be well thought out, properly designed and constructed for the safety of the essential monument. Monuments are being conserved to help us understand the past through its cultural and historical contribution and behaviour. A properly designed roof may therefore help to extend its life span. When designing a roof for an existing monument, the aesthetic, architectural and archaeological values should be equally considered and preserved, in addition to the more obvious technical and economic validities.



Figure 1. Vatadage at Medirigiriya after roof has decayed.



Figure 2. Buddha image at Aukana before covering.



Figure 3. Buddha image at Aukana after covering.



Figure 4. Stone image of seated Buddha at Asokarama, Anuradhapura, without a protective roof.

SALT AND CRACK PROBLEMS IN THE ROMAN BATH AT HEERLEN AND THEIR THERAPY

W.O. Boekwijt*

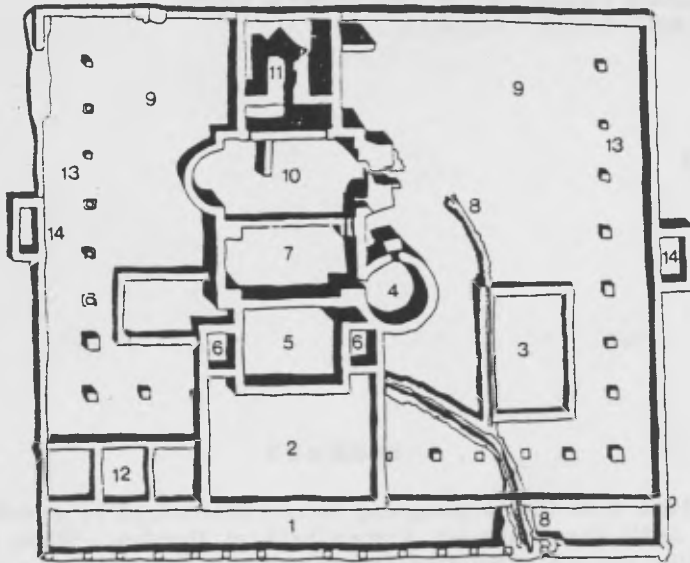
SUMMARY

It was in June 1940 that a ploughing farmer discovered by a lucky chance some pieces of the until then unknown Roman bath at Heerlen. When excavation had started and after putting a building around the ruin in 1977, some problems arose. The main problems were salt efflorescence on the brickwork and on the ground as well as the forming of big cracks in the soil which damaged the old brickwork.

In 1982, TNO did some investigations at the museum. This led to the conclusion that the ruin and the surrounding ground were drying from an original, rather high moisture content to a lower level in accordance with the new situation and that the process was far advanced already.

As no further cracking was expected, the research was directed to the salt problem. It appears that the efflorescence consists mainly of gypsum. This salt bloom is practically harmless but not nice looking and it is very difficult to remove by physical and mechanical means. Chemical cleaning is more promising. Reasonable results have been obtained with the application of EDTA paste on a pilot scale in the museum.

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- | | |
|-------------------|-----------------------|
| 1. Entrance | 8. Water drain |
| 2. Dressing room | 9. Sports-fields |
| 3. Swimming-pool | 10. Hot bath |
| 4. Sweating-room | 11. Furnace room |
| 5. Cold bath | 12. Shops |
| 6. Immersion bath | 13. Colonnade |
| 7. Tepid bath | 14. Side entrance (?) |

Figure 1. Fresh water was taken from the higher Caumerbeek and the dirty bathing water drained off through waterduct 8 to the lower Geleenbeek.

1. THE THERMAE MUSEUM AT ROMAN HEERLEN

Coriovallum, as Heerlen was called in Roman times, was founded on the highroad from Boulogne-sur-Mer to Cologne. When afterwards a route of similar importance - from Xanten to Aachen and Trier - came to intersect the former here, the place became a major crossroads. Military, travellers, and merchants in transit could meet in the thermae to take a bath, indulge in games and exercise, or simply have a chat.

The crossroad position was of course very favourable for trade in the area. On Coriovallum's regional market, domestic products were sold, such as pottery from the local factories and produce from the villae (farmsteads) in the surrounding countryside, as well as goods brought in from afar, such as terra sigillata (luxury pottery) and glassware.

Roman Heerlen was first of all a civilian settlement. But the original meaning of the name is "army camp", so that military activity cannot always have been far away. Actually, people have not known only times of quiet and prosperity in these parts. Thus the third century saw raids by Germanic tribes, who looted the countryside with its villas. Coriovallum could have been fortified then, as were other settlements along the highroad from Boulogne to Cologne. Remnants of such a fortification are defence ditches uncovered on the north and south sides of the thermae. Apart from these so-called V-shaped ditches, arms and accoutrements testify to the presence of troops. After the settlements had been fortified, peace temporarily returned to the area. But the villas in the country were never rebuilt. Finally, plundering tribes could occupy the territory when, in 402, the Roman troops were ordered back to Italy, which was threatened by the Germanic Migrations. This put an end to four centuries of Roman history in Heerlen.

The thermae, or public baths, were in those days a centre of leisure and recreation for the entire community and played an important role in social life. The establishment found in Heerlen was situated on a sloping site between two brooks, so that the water supply must have posed but little problems to its builders. The ground plan in Figure 1 gives an idea of the remains.

The visitor entered the building by a colonnade (1 - *porticus*), after which he took off his clothes in room 2 (*apodyterium* = dressing room). The floor of this apartment is composed of small bricks arranged in a herringbone pattern. Thence he went to the sweating room 4 (*sudatorium*) for a hot-air bath at 50-55°C. This was followed by a period in the hot bath 10 (*caldarium*), which contained a pool and presumably also tubs. Cooling-off, relaxing and massage took place in the tepid bath 7 (*tepidarium*). To cool down further the visitor then proceeded to the cold bath 5 (*frigidarium*), on either side of which was an immersion bath 6. The stacks of tile seen in apartments 4, 7, and 10 originally supported the floor, which thus formed an element in the heating system (*hypocaustum*). In this system, hot air from the furnace room was passed under the floor.

Initially, the large furnace room 11 (*prae-furnium*) was used. Obviously, this did not function well, since afterwards an extension to the hot bath was demolished to instal a new furnace. The sweating room 4 received its own furnace to achieve the high temperature required to heat the air.

The other amenities of the establishment show that it was more than just a public bath. On either side of the main buildings, there was a sports field 9 for exercise, ball games, etc. There is also a swimming pool 3 (*natalio*). The smaller apartments 12 in the front presumably functioned as shops, and may also have housed a small restaurant.

2. INTRODUCTION TO THE PROBLEM

In June 1940 a ploughing farmer accidentally discovered pieces of a Roman column at Heerlen (the Netherlands). This discovery led to large-scale excavations, which were continued till November of that year. During this campaign the greater part of a Roman bath-house was excavated. In November the activities were stopped and - for protection - the excavated ruins were covered with bituminous paper and straw.

The excavations were resumed in 1941 and stopped once more when winter set in. By then the complete thermae had been excavated. The site measures about 50 x 50 m² and is to be dated as far back as the 2-4th century A.D. It belongs to the so-called row types; there are two periods to be distinguished and in its construction mainly burnt materials were used for the interior walls and Kunrade stone for the exterior ones. We find some blocks of limestone as well.

When the winter of 1941-42 approached, the ruins were once more covered with bituminous paper and straw. Immediately after the discovery it had been decided that the ruins should be preserved. According to a report made by Mr F. Peutz, civil engineer, this could only be possible if they were put under a protective roof. Then rain and frost would have no influence on them and the visitor would be able to visit the thermae all year round unhindered by the weather.

Mr Peutz's report gave birth to the idea of the roofing-over, but he rightly concluded that it was impossible to realize the plans under the war conditions prevailing at the time. His advice was to consolidate some parts of the ruins immediately, promote efficient drainage of the site, and cover the ruins once more.

During the whole period of the war the thermae lay open, covered only with bituminous paper and straw, much to the satisfaction of children, who regularly came to play there, with all its consequences.

Also after the war there was no money for the roofing of the ruins. But on the other hand it was necessary to call a halt to further decay. Ultimately this resulted in 1946 in a decision to cover the ruins with 2,000 m³ of silver sand, covered with 1,000 m³ black earth to keep the silver sand in place. This state remained unchanged until in 1975 sufficient means were found to realize the plans.

On 1 November 1977, the museum was opened to the public and officially opened on 29 November 1977. One day after this event TV shots were made, which naturally required much light. During the taking of these shots a white film, lying over the whole ruins, became visible. This white film only got worse in the course of time.

In consultation with the State service for archaeological investigations in the Netherlands, in March 1978 it was decided to carry out climate recordings of the exterior and interior of the hall. Also at regular intervals colour pictures of exactly the same places were taken. From these pictures it clearly appeared that the white film expanded upwards from the bottom.

The wide cracks in the soil, in some places stretching into the masonry, caused anxiety with regard to the stability of the construction.

To prevent the site's having too low temperatures, some air heaters had been installed in the hall. These heaters were adjusted to work only below 5°C interior temperature. However this limit had never been reached. The hall is also provided with air exhaust fans.

In June 1980 TNO was engaged on account of complaints about the white film on the masonry and the soil, the wide cracks in the soil and the condensation against the inner side of the enclosure.

The ground plan in Figure 2 gives a good idea of the site. The old Roman fireplace and the furnace (south side, Fig. 2) are built of tuff and clay. The rest consists mainly of roof tiles walled with shell lime and tilegrit. The tiles are burned very hard. It was hardly possible to make holes in them with a widia drill. Although the tiles show a relatively large portion of their surfaces in the masonry, a lot of mortar was used, as Figure 3 shows.

The floor consists mainly of concrete (Roman technology!). Some parts of the floor, however, are laid with a herringbone pavement as e.g. the dressing-room at the entrance (north side).

3. THE CLIMATE

Knowing that the problems described above are closely related to moisture of the soil and the brickwork and the humidity of the air, the first step was to examine the climate of the museum hall. The combination of temperature and humidity of the inside air is the main factor affecting the evaporation from the site.

The municipal department for archaeology of Heerlen performed indoor and outdoor climate recordings at the site from March 1978 to November 1981. These figures have been processed into monthly averages as given in Figure 4 (table). These data show that it is rather cool and humid in Holland even in the southern part. Therefore heating of buildings where people work and live is a necessity during the winter.

As we have seen in the introduction, there is no heating working in the museum hall. However the average temperature there is about 8.3°C (17.9 - 9.6°C) higher than at the outside. This is not because the Romans forgot to put out the furnace as they left. The explanation is that the hall is part of a heated building and some heat leaks through partitions and from the piping system.

The relative humidity inside (79%) is practically the same as outside (82%). Vapour pressures, however, give more information about the climate than relative humidity figures do. The average vapour pressures are: inside 1645 Pa and outside 1018 Pa resulting in an inside climate more fitted for laundries, dairy-factories and swimming halls than for museums. This causes a lot of condensation on the inside surface of the building's hall, which is mainly a metal structure.

A good ventilation system can certainly lower the difference in vapour pressure between indoors and out. The museum hall has been provided with exhaust fans. Figure 5 shows that these fans have only a slight influence on the vapour pressure inside. From calculations it appears that the ventilation rate doubles from 0.15 to about 0.3 h⁻¹ when the fans are switched on. The advice to the museum staff was to keep the fans working permanently to save the building.

4. MOISTURE CONTENT AND PROPERTIES OF THE MATERIALS

The moisture content of the soil as well as the brickwork had to be known in relation to the properties of the materials involved. This is because most materials

shrink when their moisture content decreases, which can cause cracking. Moreover, salt is formed where water evaporates. In the past the evaporation took place mainly at the surface. After some time this evaporation plane will withdraw behind the surface depending on the properties of the materials. We will consider all these factors in the next sections.

4.1. The soil

With an earth drill the soil was sampled at five positions each down to a depth of 4 m. The positions are marked on the plan of Figure 2 and named after compass readings (SW, NW, SE, E) and cal. (caldarium). The moisture content of the clay was determined using calcium carbide. The results are given in Figure 6. The elevation was measured with respect to the sea level (NAP, Amsterdam). The arrows at the top end of the lines point to the local ground level. Some readings have been repeated to get an idea about the course through time of the moisture content. It appears that at the SW position between 17 October 1980 and 4 December 1981 (-412 days), about 300 kg/m^2 of water have evaporated from the ground. At that time the moisture content of the total mass of clay had reached a relatively homogeneous amount of about 12% by mass. Later readings show that the clay dries now only slightly just under the surface. The surface moisture content has come to about 4% by mass. The level of the free groundwater is about 101.9 m (+NAP), so the (freatic) groundwater is about 11 m below the surface of the site.

To understand the meaning of the moisture figures in relation to the cracking problem of the soil, a sample of clay taken from position NW was examined. Figure 7 shows a shrinking curve of this sample together with a curve for loess, which is a fertile rich loam normal for this area, and alluvial loam. It appears that the curve of the clay from the site lies between that of loess and alluvial loam. Below a moisture content of 16.5% by mass, the shrinkage is about 0.018 %/%, which is very low compared with the shrinkage in a wetter state (about 0.66 %/%).

Regarding the meaning of the kink in the curve of Figure 7, we can add that there are no more continuous water connections available between the main depositories. Most particles rest on each other and water can only move then from one oasis to another by evaporation and condensation. The clay is now of less importance as a water supply for the masonry.

We can conclude at the same time that further cracking of the soil is not expected. As salt formation appears only in the evaporation area, the rest of the bulk will not be transported to the soil surface, as the moisture content is now considerably below 16.5%.

4.2. The masonry

To get an indication of the course of the salt formation on the surface of the masonry, it is important to know the moisture content of the brickwork. Unfortunately, these data could hardly be obtained as the hardness of the stones and the mortar combined with a very poor cementation between them made it impossible to drill holes in a normal way without causing damage. Therefore drilling was restricted to a solid piece of brickwork in the round wall (caldarium, see Figs. 1 and 2) and it was only done using a domestic drill with a very slight percussion. Brick dust was taken out at four heights and the moisture content was determined by means of calcium carbide. From the results presented in Figure 8 we see that the moisture content decreases with height.

The information given in Figure 8 only has meaning if it can be related to the properties of the material. In this context it is necessary to know the critical moisture content and the suction properties characterized by the coefficient of water absorption and water penetration.

The critical moisture content is the minimum value of the moisture content at which direct water transport is possible. Samples were taken from the caldarium and the sudatorium for the determination of these properties. The results are given in Figure 9 (table). It appears that the critical moisture content is about 6% by mass while the values for the water absorption and penetration coefficients show little indication of suction.

Looking at the actual moisture content of the masonry as given in Figure 8, we see that the critical value of 6% is found near the floor level. If this is valid for the site as a whole, the conclusion would be that new salt formation is unlikely to appear. Observations on small, specially cleaned test surfaces have shown, however, that there was still a very slight salt formation, mainly on the concrete floor, but it is clearly at its end. Later readings (see Fig. 8) show that the brickwork has dried even further.

5. THE SALT PROBLEM

Salt formation has already been mentioned occasionally in the discussion about the action of moisture. This was unavoidable because both are strongly connected. In this part we will focus on the salt. Successively we will raise the matter of salt formation, damage caused, and the further handling of the salt problem.

5.1. Salt formation

Characteristic of walls sucking water from the ground is the balance of water between the amount of suction and of evaporation. If the water evaporates inside the wall it is called pore evaporation. If, however, water migrates to the surface in the liquid phase to turn into vapour, the term surface evaporation is used.

A clear distinction between these two types of evaporation is important for understanding the place of salt formation, as this happens only where evaporation occurs.

We have seen that the moisture content of the brickwork as well as the soil are decreasing and that at the surface the critical moisture content has probably been attained or already passed. Therefore evaporation at the surface will stop and the site will dry now inside at a much lower rate to a certain equilibrium. Up to then some salt formation will occur inside the materials.

To recognize the type of salt we are dealing with, some samples were taken from the sudatorium and the caldarium and examined qualitatively. There was no difference between the results of the two samples. The results were:

| | ion | amount |
|---------|-----------|--------|
| anions | Sulphate | ++++ |
| | Carbonate | + |
| | Chloride | + |
| cations | Calcium | ++++ |
| | Sodium | +++ |
| | Potassium | ++ |
| | Magnesium | + |

It appears that in both cases calcium sulphate (gypsum) is predominant. Sulphates of sodium, potassium and magnesium are less common, while carbonates and chlorides are hardly found.

The mortar in the masonry and the concrete, which contains a considerable amount of lime, is undoubtedly one of the main sources of the salinity.

5.2. Salt damage

Salt damage will only occur under certain conditions. The type of damage depends on the kind of salt, the materials involved and the circumstances. Salts can cause direct chemical damage of the materials, but the most dangerous type of damage is mechanical, by salt efflorescence. Crystals of some soluble salts can bind water molecules under certain circumstances. This hydration process occurs at constant pressure in a rise of volume $(\Delta V/V)_p$ - which is an isobaric situation - or at constant volume in a rise of pressure - which is an isochoric situation. The equilibrium expressions for calcium, sodium and magnesium sulphate are e.g.:

| Transition temp. (°C) | | Isobaric expansion $(\Delta V/V)_p$ |
|-----------------------|--|-------------------------------------|
| 130 | $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O} + 1 1/2\text{H}_2\text{O} \rightleftharpoons \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{heat}$ | 1 |
| 32 | $\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O} \rightleftharpoons \text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O} + \text{heat}$ | 3 |
| 130 | $\text{MgSO}_4 + 6\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{MgSO}_4 \cdot 7\text{H}_2\text{O} + \text{heat}$ | 3 |

From the Le Châtelier principle it is clear that the equilibrium shifts to the right when the relative humidity increases (excess of free water) or to the left when the temperature increases. The temperatures given at the left are values beyond which the equilibrium is completely at the left side, forming anhydrites. The maximum isobaric expansion when the equilibrium is completely right is given at the right side of the equations.

If expansion is hindered, an isochoric situation appears causing a pressure with magnitude up to 40 MP_a. The salt pressure is so high that the pore walls of soft-burnt bricks will collapse. However, one left-right cycle will not give visible damage. This will only happen when the process is regularly repeated, e.g. caused by changing climate conditions and if there is a certain amount of salt available.

In that case an ever-growing amount of dehydrated salt will fill the pores with an increasing salt pressure in the hydrated state as the free volume decreases then. Also non-hydrating salts can build up enormous pressures if expansion is hindered, but this is hardly important in practice as there is normally no cycling process.

When more types of salts are acting together, the whole process would become rather complicated. However for this presentation there is no need to discuss the whole theoretical salt story. We have seen that calcium sulphate is strongly predominant in our case and the bricks are hard, having an unlayered structure. Salt efflorescence does not appear at all as the temperature of transition forming anhydrites (=130°C) is much higher than the actual temperature and moreover the daily climate is practically constant. Only sodium sulphate would have a yearly cycle, but this salt is of no importance for the Thermae.

The conclusion is that we are only dealing with an aesthetic kind of damage. The masonry has a slight white bloom, but there is no risk of any mechanical damage.

5.3. Salt handling

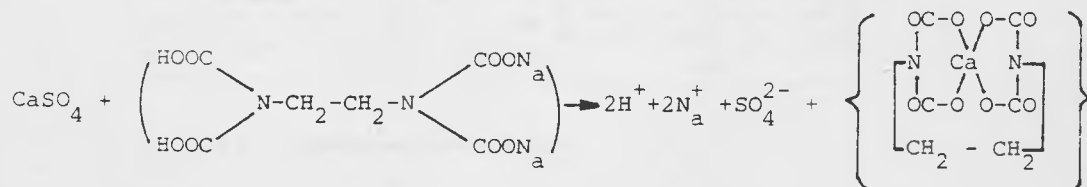
Any treatment to remove the salt from the surface is useless as long as new salt formation continues. In the previous sections we have seen that the salt formation at the site is a result of evaporation of water from the surface. The measurements presented, however, show that the drying process is far advanced already and that new salt formation is not expected. Long-term visual observations by the museum staff confirm this conclusion.

It is time now to consider the need for, and the possibilities of cleaning the masonry. The question is whether the site as it looks now is acceptable or not. Having things clean or not is a matter of personal opinion. Figure 10 gives an impression of the present situation. To help in making a sound decision we did a cleaning experiment on some horizontal test surfaces using a chemical method. We will discuss this method in more detail.

The equilibrium in the equation: $\text{CaSO}_4 \rightleftharpoons \text{Ca}^{2+} + \text{SO}_4^{2-}$

is strongly left-sided. This explains the poor solubility of gypsum into water. Good solubility can be obtained by removing the Ca^{2+} ions, causing a right-sided shift.

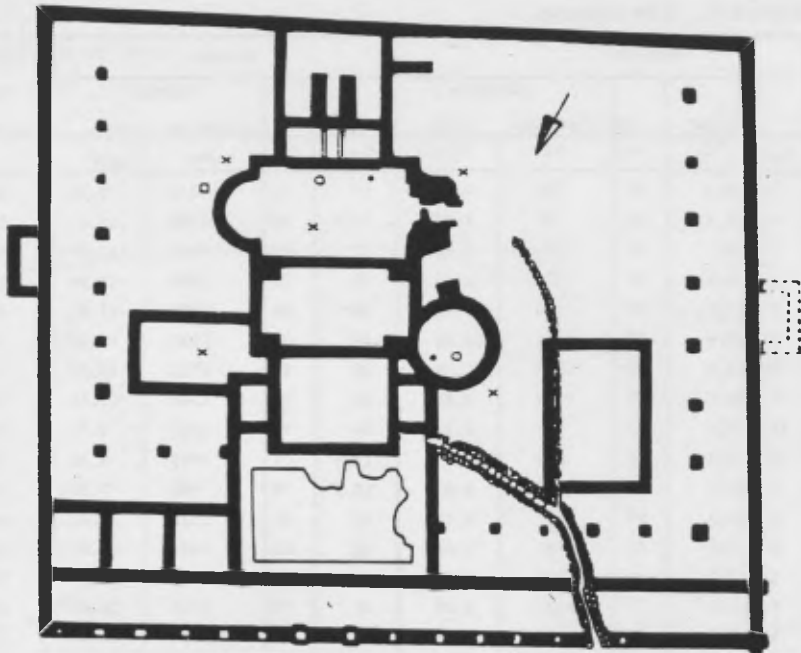
This is, for instance, the case in running water. As mechanical and physical cleaning would give more trouble than results, we turned to chemical methods. We put some EDTA paste on the surface. The reaction has the following form:



The EDTA paste (disodium salt of Ethylene Di-amino Tetra-Acetic acid) can be removed after a few days. To keep the paste from flowing down along vertical surfaces, a supporting foil has to be used. The question of whether the whole site must be treated according to this technique is a choice between acceptance of the present situation and financial means.

Acknowledgments

The author wishes to thank the directors of the Thermae Museum, Dr J.T.J. Jamar and Mr J.K. Gielen for their excellent cooperation.



x = moisture content
of the soil

o = moisture content
of the masonry

• = salt-analysis

o = properties of material

Figure 2. Position of sampling.

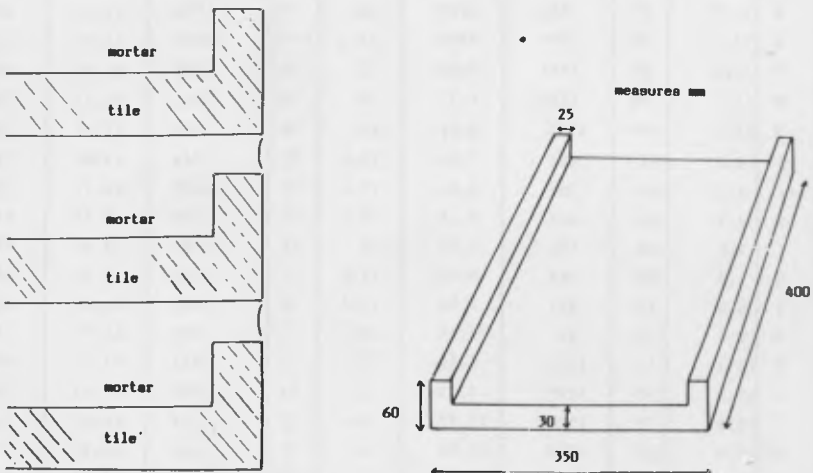


Figure 3. Typical wall construction.

Figure 4. The climate.

| | Outside | | | | | Inside | | | | Diff. in vapour- pressure (Pa) | |
|------|---------|------|------|------------------|------------------------------|--------|------|---------|-------|---|------------------------------|
| | date | temp | RH | vapour- | | temp | RH | vapour- | | | |
| | | (°C) | (%) | pressure (Pa) | conc. (g/m ³) | | | (°C) | (%) | pressure (Pa) | conc. (g/m ³) |
| 1978 | 3 | 6,3 | 83 | 792 | 6,13 | 13 | 83 | 1242 | 9,39 | 430 | |
| | 4 | 7,3 | 79 | 797 | 6,15 | 14,5 | 84 | 1336 | 10,43 | 589 | |
| | 5 | 12,1 | 83 | 1171 | 8,88 | 17 | 83 | 1607 | 11,99 | 436 | |
| | 6 | 14,9 | 81 | 1371 | 10,30 | 19 | 86 | 1889 | 13,99 | 513 | |
| | 7 | 15,5 | 82 | 1443 | 10,32 | 19 | 86 | 1889 | 13,99 | 446 | |
| | 8 | 15,4 | 83 | 1451 | 10,68 | 19 | 93 | 1823 | 13,50 | 372 | |
| | 9 | 13,2 | 88 | 1334 | 10,08 | 19 | 95 | 1753 | 13,03 | 419 | |
| | 10 | 10,7 | 87 | 1119 | 8,53 | 16 | 85 | 1544 | 11,56 | 425 | |
| | 11 | 5,4 | 90 | 807 | 6,27 | 14 | 79 | 1262 | 9,51 | 455 | |
| | 12 | 2,5 | 90 | 658 | 5,17 | 12,5 | 77 | 1115 | 8,45 | 437 | |
| | 1979 | 1 | -2,0 | 98 | 455 | 3,63 | 10,5 | 78 | 990 | 7,55 | 535 |
| | | 2 | -0,1 | 87 | 527 | 4,18 | 12 | 81 | 1135 | 6,61 | 608 |
| 3 | | 5,2 | 85 | 751 | 5,84 | 15 | 83 | 1414 | 10,62 | 663 | |
| 4 | | 7,7 | 79 | 830 | 6,39 | 17 | 82 | 1588 | 11,84 | 758 | |
| 5 | | 12,2 | 77 | 1093 | 8,29 | 19 | 78 | 1713 | 12,69 | 620 | |
| 6 | | 15,9 | 79 | 1426 | 10,68 | 21 | 77 | 1914 | 14,08 | 488 | |
| 7 | | 16,2 | 78 | 1435 | 10,74 | 22 | 81 | 2140 | 15,69 | 705 | |
| 8 | | 15,5 | 79 | 1390 | 10,42 | 22 | 80 | 2114 | 15,50 | 724 | |
| 9 | | 13,9 | 73 | 1158 | 8,73 | 20 | 80 | 1870 | 13,80 | 712 | |
| 10 | | 11,0 | 78 | 1023 | 7,79 | 19 | 80 | 1757 | 13,01 | 734 | |
| 11 | | 5,6 | 85 | 773 | 6,00 | 16 | 76 | 1417 | 10,61 | 644 | |
| 12 | | 5,5 | 86 | 776 | 6,03 | 15 | 77 | 1312 | 9,85 | 536 | |
| 1980 | 1 | 0,2 | 88 | 546 | 4,32 | 13 | 77 | 1152 | 8,71 | 606 | |
| | 2 | 5,1 | 84 | 737 | 5,74 | 15 | 81 | 1380 | 10,37 | 643 | |
| | 3 | 5,0 | 83 | 724 | 5,63 | 15 | 79 | 1346 | 10,11 | 622 | |
| | 4 | 7,5 | 76 | 787 | 6,07 | 17 | 77 | 1491 | 11,12 | 704 | |
| | 5 | 11,7 | 67 | 921 | 6,99 | 20 | 76 | 1776 | 13,11 | 855 | |
| | 6 | 14,7 | 78 | 1304 | 9,80 | 21,5 | 79 | 2025 | 14,37 | 721 | |
| | 7 | 15,5 | 82 | 1443 | 10,82 | 22 | 81 | 2140 | 15,69 | 697 | |
| | 8 | 17,1 | 78 | 1520 | 11,33 | 24 | 76 | 2267 | 16,51 | 747 | |
| | 9 | 14,1 | 81 | 1302 | 9,84 | 22 | 78 | 2061 | 15,11 | 759 | |
| | 10 | 9,0 | 83 | 952 | 7,30 | 19,5 | 77 | 1744 | 12,90 | 792 | |
| | 11 | 4,5 | 84 | 707 | 5,51 | 17,5 | 72 | 1439 | 10,71 | 732 | |
| | 12 | 2,8 | 88 | 657 | 5,15 | 15,5 | 73 | 1285 | 9,63 | 628 | |
| 1981 | 1 | 2,0 | 89 | 629 | 4,94 | 15 | 74 | 1261 | 9,47 | 633 | |
| | 2 | 1,0 | 86 | 565 | 4,46 | 15,5 | 71 | 1249 | 9,37 | 634 | |
| | 3 | 8,8 | 81 | 917 | 7,04 | 17,5 | 76 | 1519 | 11,31 | 602 | |
| | 4 | 8,5 | 76 | 843 | 6,48 | 19 | 72 | 1581 | 11,71 | 742 | |
| | 5 | 13,4 | 74 | 1137 | 8,59 | 21 | 73 | 1815 | 13,35 | 678 | |
| | 6 | 15,0 | 76 | 1295 | 9,73 | 23 | 73 | 2050 | 14,98 | 755 | |
| | 7 | 16,8 | 79 | 1510 | 11,27 | 23,5 | 77 | 2229 | 16,26 | 719 | |
| | 8 | 17,0 | 80 | 1549 | 11,55 | 24 | 78 | 2326 | 16,94 | 777 | |
| | 9 | 15,0 | 79 | 1346 | 10,11 | 21,5 | 79 | 2025 | 14,37 | 679 | |
| | 10 | 9,0 | 86 | 987 | 7,57 | 18 | 76 | 1568 | 11,65 | 581 | |
| | 11 | 6,5 | 86 | 832 | 6,44 | 16 | 78 | 1417 | 10,61 | 585 | |

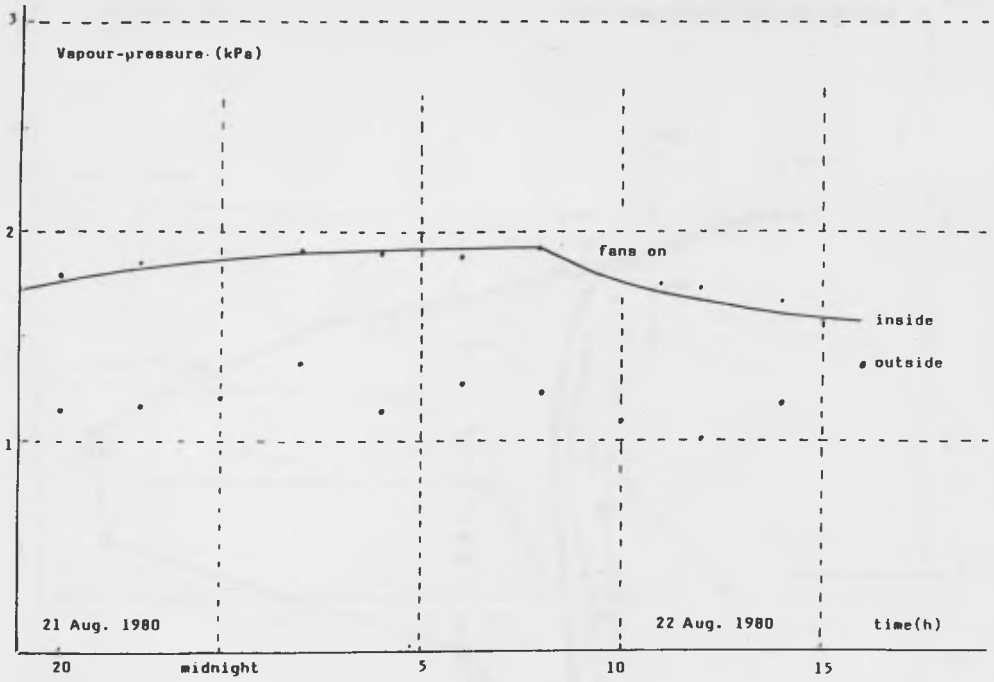


Figure 5. The impact of the fans on vapour pressure.

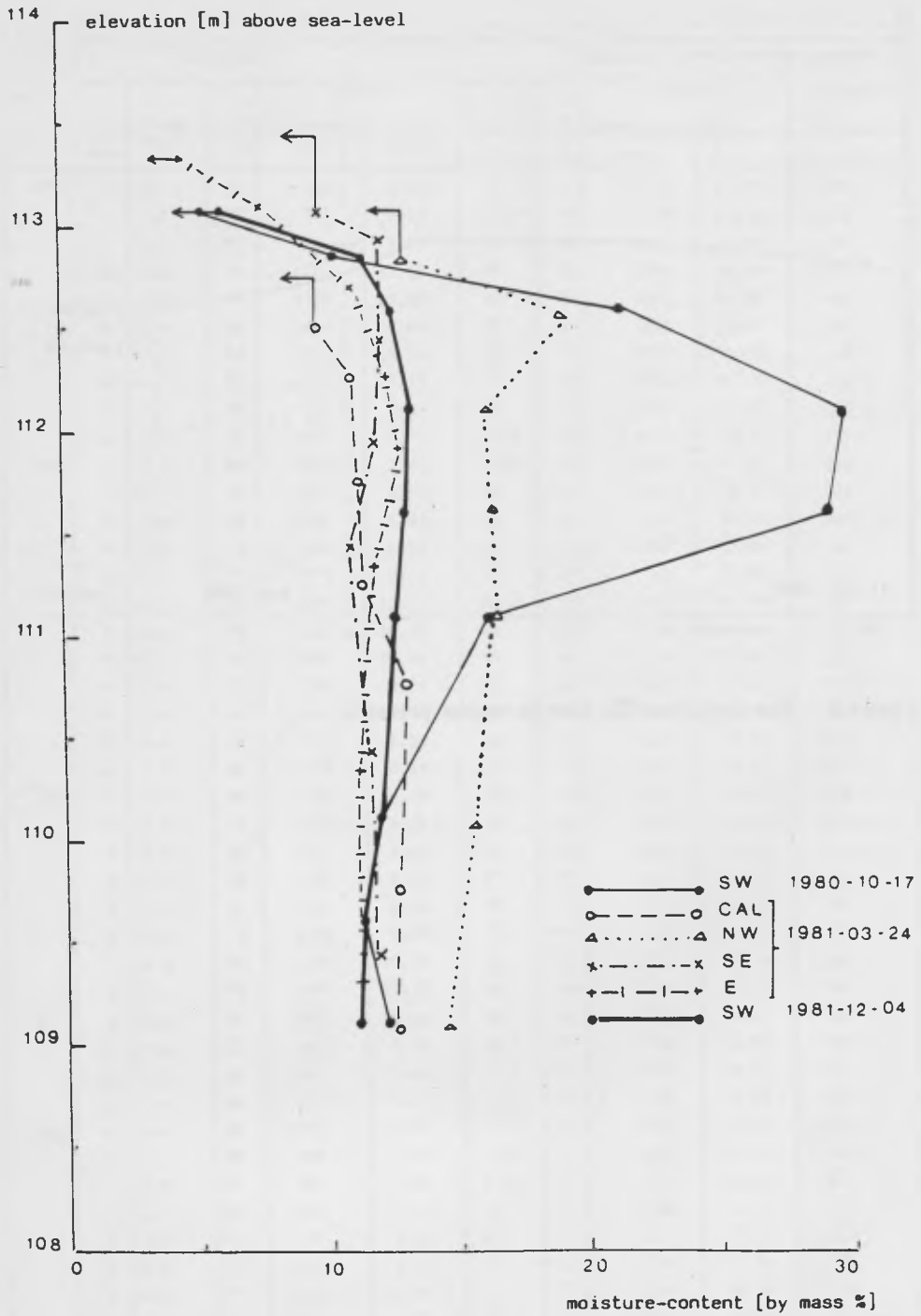


Figure 6. Moisture content of the clay.

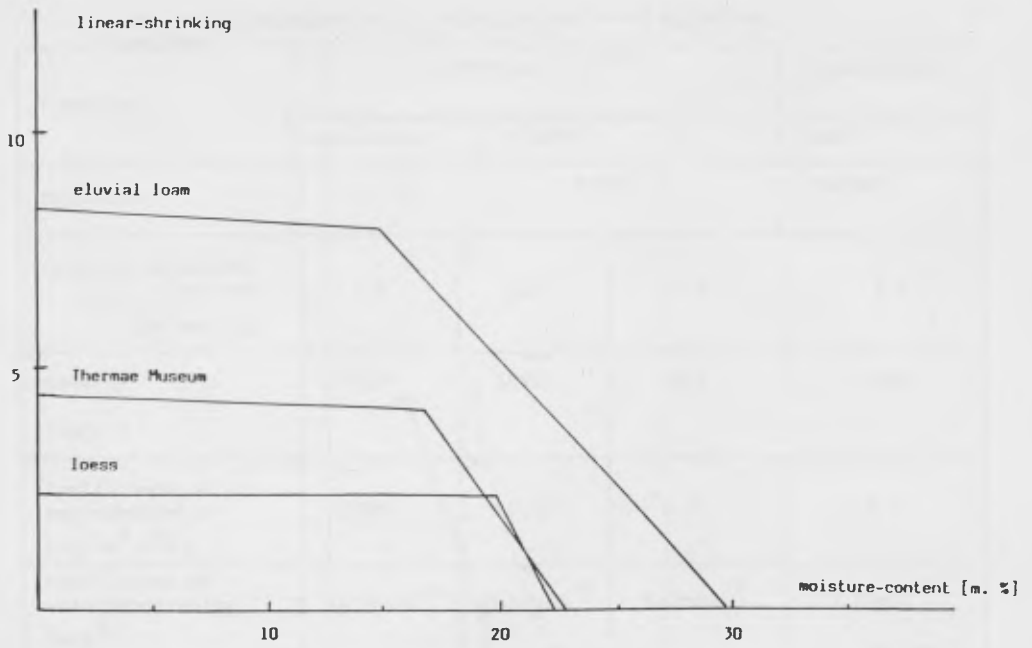


Figure 7. Shrinking curve.

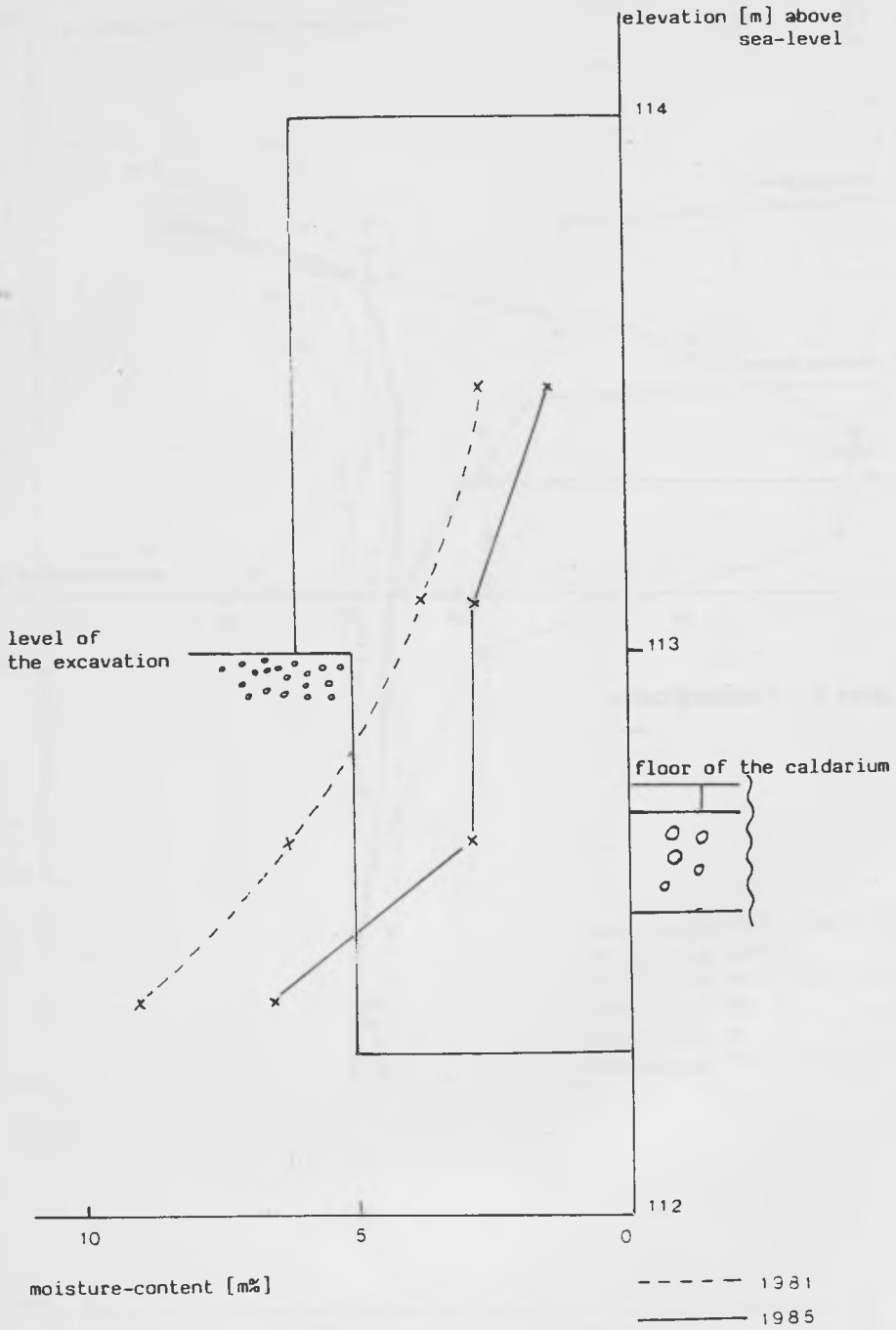


Figure 8. Moisture content of the brickwork.

Figure 9. Some properties of materials.

| Location | caldarium | | sudatorium | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| | round-wall | floor | wall | |
| Material | brick | | mortar | |
| Critical moisture-content [by mass %] | 5,1 | 6,2 | 7,3 | 5,2 |
| Density [kg/m ³] | 2015 | 1895 | 1817 | 1891 |
| Coefficient of waterabsorption [kg/(m ² ·s ^{1/2})] | 0,095 | 0,20 | 0,15 | 0,12 |
| Coefficient of waterpenetration [m/s ^{1/2}] | 0,54×10 ⁻³ | 0,87×10 ⁻³ | 0,62×10 ⁻³ | 0,74×10 ⁻³ |
| Porosity [vol. %] | 25,6 | 29,8 | 32,2 | 27,9 |



Figure 10. View of the caldarium (east side).

PROTECTION OF ARCHAEOLOGICAL SITES:
THE BRUGES SITUATION AND THE EXAMPLE OF THE CHURCH OF OUR LADY

H. De Witte*

SUMMARY

This paper discusses the difficulties we meet concerning archaeological site protection in Bruges, mainly caused by the lack of any archaeological legislation as well as by a shortage of money and sufficient staff.

Two cases where major protective measures have been taken are the chapel of the medieval Saint John's hospital and the Church of Our Lady. These are explained in more detail.

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Protection of archaeological sites - before, during and after excavation - is a very difficult task in a city like Bruges. The main reason for this is the total lack of archaeological legislation in Flanders.

The only means of protecting an archaeological site is to classify it on the list of monuments and sites. This classification is a very time-consuming and cumbersome task. In this system one would be obliged to classify the whole medieval town of Bruges, because it is in fact one large archaeological site. No city council, provincial council or government would ever accept that.

The obligation to do excavations on every building site would require a very elaborate archaeological infrastructure and a very large staff. No city council would be able to afford that.

In this situation we depend totally on the good will of the principals (city council, government, building contractors, private persons), the architects and the building firms.

When we do have the opportunity to do an excavation on a building site in Bruges, it is almost always impossible to do protective work during excavation. Most of the time the duration of the excavation is very limited, and in cases where new buildings are to be erected, any archaeological structures (walls, foundations...) have to disappear for new cellars, underground car parks and so on. In order to be able to carry on the excavation work in all types of weather, and when the duration of the excavation permits, we use protective roofs, constructed from scaffolding tubes and especially strengthened colourless plastic.

Apart from a few minor interventions to protect and recover fragments of medieval floors, for instance, only two major excavations have led to major protective measures. In both cases an excavation inside a building was involved: the first in the Sanctuary of the Church of Our Lady, the second in the Chapel of the medieval St. John's Hospital.

The most impressive measures, during and after excavation, were taken in the Church of Our Lady in 1979-1980. We will discuss these at the end of this paper.

In winter 1983-84 we carried out a three-month long excavation in the Chapel of the medieval St. John's Hospital in consequence of work being done to instal a new heating system under the floor. On that occasion several 13th, 14th and 15th century painted tombs were found.

There were no means to conserve these tombs in situ as we had done in the Church of Our Lady, and that was for several reasons:

- the function for which the hospital chapel was destined after the works, namely as the Memling museum;
- the very poor condition of the paintings, which were seriously damaged by the very high water table. Some graves were almost completely filled with water.

Lifting up the painted tombs in one piece, as had been done for three tombs in the Church of Our Lady, was impossible as well. The main reason for that was the shortage of time and especially money. Therefore we decided to saw out the wall fragments with the best preserved paintings, to be treated and exhibited later.

The treatment of circa 9 m² of painted walls was done by the Institut Royal du Patrimoine Artistique. The sawing in pieces of the painted walls and the lifting and transport of the wall fragments (up to 1000 kg) was carried out by the staff of the

town archaeology department. Therefore, supporting and protecting plates were constructed of steel laths (underside), L-shaped bars in steel, plywood and foam rubber.

Due to the poor condition of the brick and cement, in a few cases the back side of the wall had to be consolidated with a layer of cement, in one case even with a layer of reinforced concrete. The sawing of the walls was done with a handsaw to avoid vibration. The lifting was carried out by means of scaffolding and tackle.

Church of Our Lady

In 1979-1980, prior to the shifting of the mausolea of Mary of Burgundy and Charles the Bold from the Lanchhals Chapel back to the sanctuary of Our Lady's Church, their original site, thorough archaeological research was carried out on the spot by the town archaeology department.

In the first place the investigations threw new light on the early history of the present church, as the foundations of the eastern wall of the Romanesque church were discovered, together with some graves belonging to it, or even to an earlier church or chapel, possibly erected in the 9th century.

A great number of brick constructions from later periods were also found, among which were the foundations of the mausolea of Mary and Charles and those of the mausolea of the famous Louis of Gruuthuse. Moreover, the archaeological team was able to localize 17 brick burial vaults of which 12 were thoroughly examined.

Tomb I, of which the inside was decorated with cross motifs, proved to be the very burial vault of Mary of Burgundy. It contained, indeed, the skeleton of the duchess, as well as the heart urn of her son, Philip the Handsome. It dates from 1482.

The other tombs appear to belong to the period between the second half of the 13th century and the first half of the 17th century.

The inner walls of nine of them (among which seven belong to the period between the second half of the 13th century and the first half of the 15th century) were decorated with frescoes. The principal motifs used in the decoration are: Calvary, the enthroned Madonna, thurifer angels, saints (especially patron saints of the deceased) and twice a representation of the deceased. The space between these main subjects is generally decorated with crosses and floral motifs.

Inscribed leaden tablets found in two of the tombs led to their identification and exact dating. Thus we know that tomb II is the burial vault of Peter Calf, tenth provost of Our Lady's Church, who died in 1295. Up to now this would be the oldest painted vault that can be dated with certainty. Tomb V is that of Nicholas Van der Steene, twelfth provost of the same church. He died in 1339.

Two other painted tombs date back to the 17th century and were identified and dated on the basis of inscriptions, coats of arms and other data painted on the walls.

Tomb XVI is the burial place of Gaspar de la Torre, 33rd provost of the church. He died in 1631, but his tomb was built some years before, i.e. in 1618.

In tomb XII, Peter Tristram, 34th provost of the church, was buried. He died in 1639.

As mentioned above, these 17th century tombs are decorated with coats of arms, devices, death's heads, crosses and other motifs.

During and after the excavation, treatment of the tomb paintings was necessary to fix the flaking stucco and paint. The flaking was mainly caused by salts produced by the groundwater. The object of the first intervention was to insulate the brick walls of the tombs from the groundwater by means of schist. The treatment of the painted surfaces was essentially restricted to cleaning, fixing and filling up the lacunae.

On account of the high archaeological and aesthetic value of the finds, it was decided that Mary's burial vault as well as three other painted tombs would be kept in situ, which could only be achieved by building an appropriate new vault around them (figs.1-3). To make this construction possible, however, three other painted tombs had to be lifted and transferred to another place.

Needless to say, the building of a moisture-free vault around the existing constructions was not an easy undertaking. Underneath the tombs a second floor was built, viz. cast, whereafter their own floor was strengthened with polyurethane injections. During the operations the tombs were carefully screened and aired in order to prevent fungal growth.

At floor level, the tombs were covered with solid glass, and mirrors were installed within them so that today interested visitors can have a complete view of all the paintings.

After identification, the skeleton of Mary of Burgundy was given a new leaden coffin, entirely reconstructed according to available written information and drawings, and laid to rest in the original burial vault.

Special care was taken for lighting the finds. To prevent damage, use was made of special tiny spot-lamps, of which the temperature, chromatic index and U.V. rays had to meet definite standards. The light intensity had to be lowered to 50 lux and the lighting time strictly limited.

Air conditioning of the vault was also a must. Indeed, excessive fluctuations of temperature as well as insufficient humidity of the air would damage the frescoes. Therefore a ventilator was installed in the vault to ensure permanent air circulation and, in front of it, an air mixing device with an electric heating unit. All these devices together should contribute to maintaining a relative humidity level of about 55% to 60% and keeping the temperature some 2°C higher than that in the church, so as to prevent condensation in the tombs and on the covering glass sheet. A control board in the vestry allows checking of their normal functioning at any moment.

To enable the contractor to build the new vault, three of the tombs had to be lifted and taken away (fig.4). To that end it was also necessary to cast a layer of concrete under them and to provide it with the required draw hooks. During this operation the painted walls were carefully protected and reinforced by means of supporting frames. Coating the entire walls with concrete was thought to be less advisable, since the porous brick would absorb a good quantity of water, which would most likely cause the plastering on the inner walls to come off.

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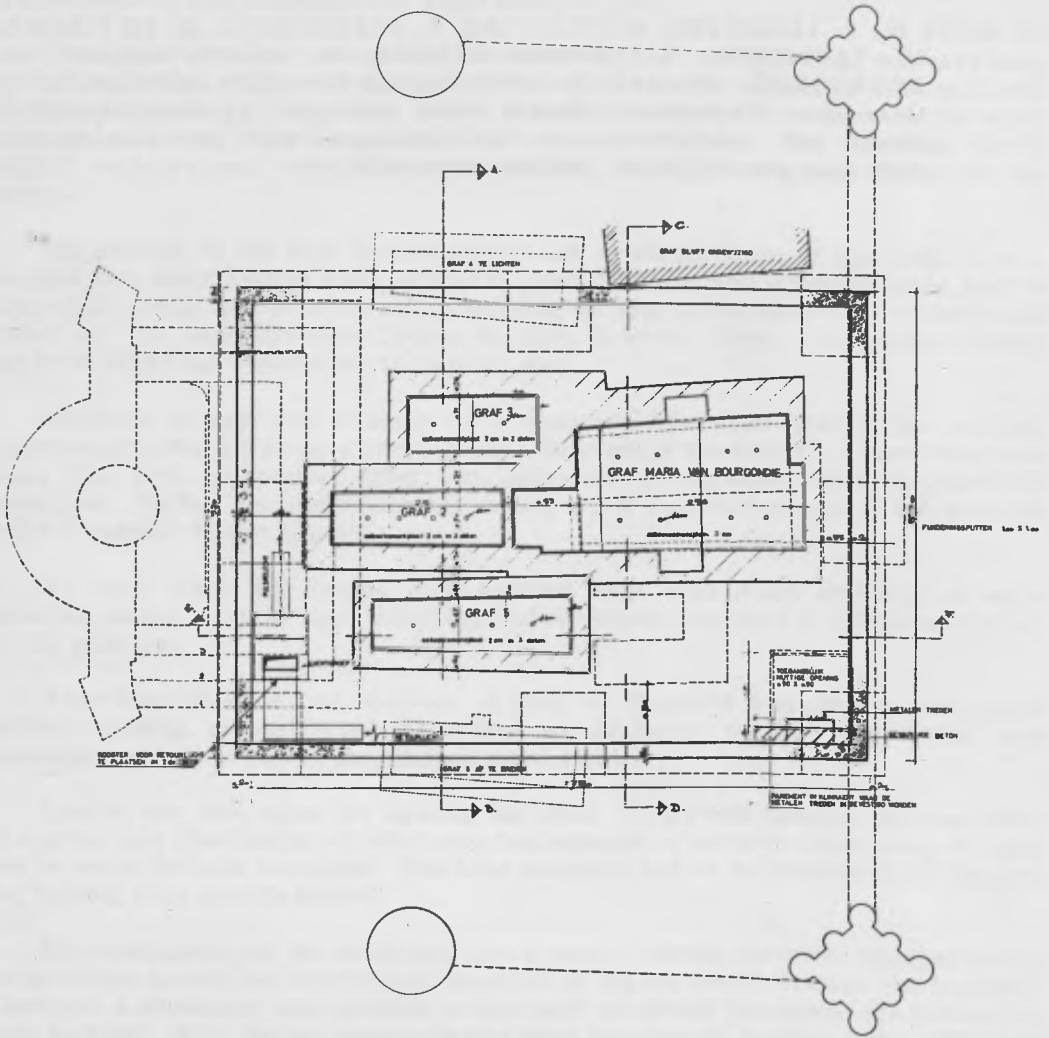
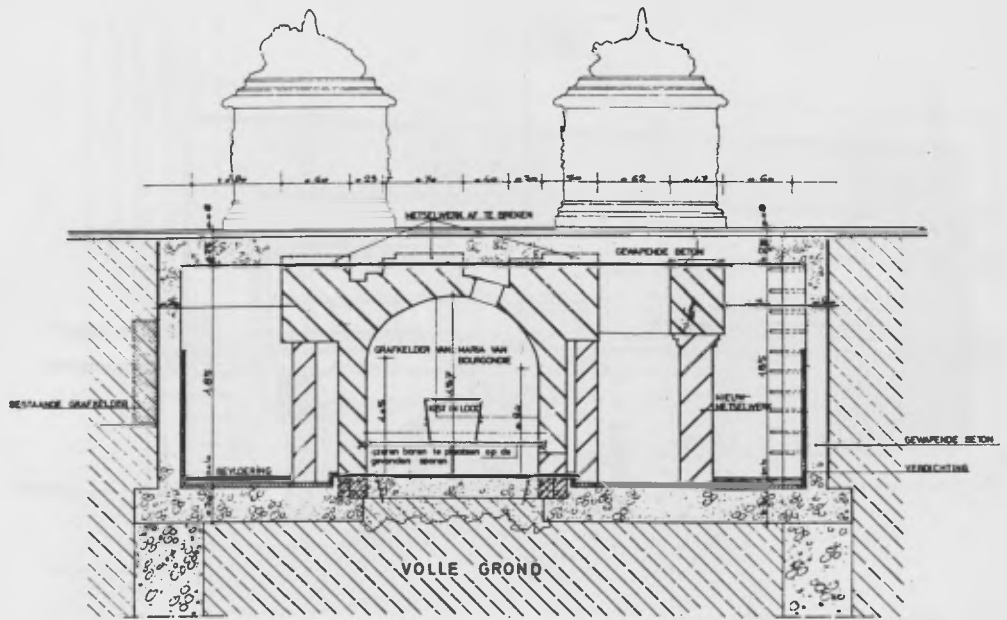
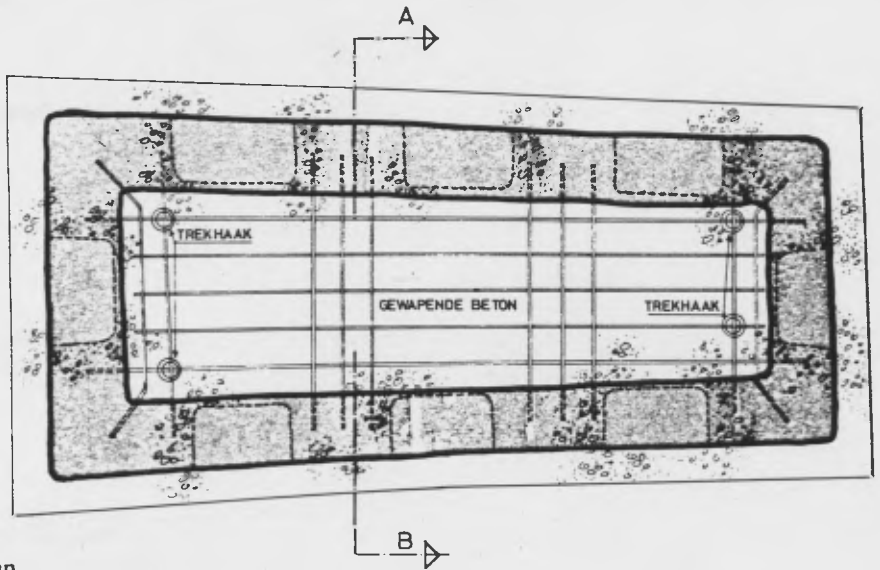


Figure 1. Localization of concrete vault.

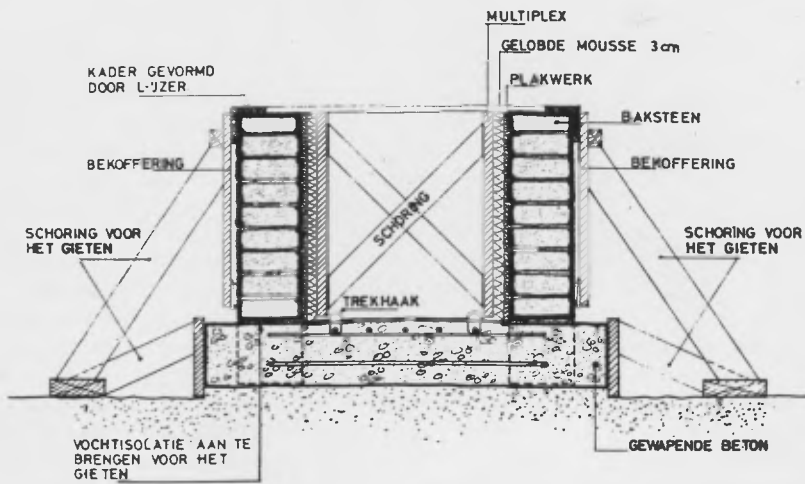


Doorsnede CD

Figure 2. Cross-section of vault.



Grondplan



Doorsnede AB

Figure 4. Way of lifting painted tombs.

THE SITE OF THE CATHEDRAL AT ATRI: A CASE STUDY OF IN SITU CONSERVATION OF ARCHAEOLOGICAL REMAINS

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Since 1980, in Atri (province of Teramo, on the Adriatic coast of Italy) a joint research project has been developed by the Archaeological Superintendency for the Abruzzo Region and the Institute for Ancient Topography of Rome University.¹

Along with a clear understanding of urban development since Roman Republican times and of its diachronic and synchronic modifications, a series of individual archaeological remains has been located. Among these, in the square of the 13th century cathedral -- by far the very heart of the city with its most important monument -- a miraculously preserved sequence of architectural remains witness (on an area of less than 100 m²) to over four centuries of Roman use of the site since Republican times.²

After study and documentation of the finds, a choice had to be made regarding the possibility of leaving the excavated Roman structures permanently visible in situ rather than backfilling the area and re-establishing the modern pavement in the square. Here the relatively superficial position of the Roman levels (from about -1.20 to -1.70 m below the present grade) made impossible, if ever desirable, a sharp separation of *past* and *present* phases, while the monumental and social relevance of the site in the modern city called for a very careful treatment. On the other hand, though by no means "monumental" by current standards, this continuum of archaeological data not found elsewhere seemed to deserve permanent display; therefore, after a complex debate with the local authorities and with the community, the archaeological Superintendency developed a project for the conservation and the presentation in situ of the remains.³

The basic idea was in fact that of not simply protecting the structures by adequate means from severe environmental changes, but also of stressing the intention of permanently presenting those remains as "museumified evidence". Taking into account what was needed for the conservation of the excavated structures as well as the social needs related to the use of the square, the archaeological area selected for permanent display was first of all surrounded by a continuous wall in reinforced concrete. By following disturbed areas as well as gaps in the ancient stratification, this wall was brought, with its supporting "foot", to a maximum depth of -2.40 m so as to improve the control of any underground water that might infiltrate from adjoining areas. While the total length of the wall is 43 m, its thickness ranges from 0.25 to 0.35 m: the working-load varies accordingly from 400 kg/m² to 8400 kg/m², this last being the load value chosen towards the centre of the square where the most intense use is to be expected.

While all the exposed surfaces of this concrete wall have been coated against humidity⁴, the drainage of the surrounding areas was optimized by an adequate design of the wall's outer face as well as by an extensive filling of river pebbles of various sizes. Within the area defined and protected by the wall, water drainage was more simply obtained through a series of collecting basins and pipes connected to the urban drainage system. The above-mentioned continuous "foot", 1.05 to 1.75 m wide and 0.35 m thick, supports both the reinforced concrete wall and a thinner brick wall (0.15 m thick) which runs parallel to the former at a distance of 0.20 m from its inner face; the resulting uniform air space (discussed below) plays an essential role in the protection of the archaeological remains.

The project is in fact based on the idea of building, *on and around* the excavated remains to be permanently displayed, four oversized "showcases" offering a strictly controlled environment. These showcases are tied to the level of the modern square through a long, gentle slope and a short flight of steps designed and placed in such a way as to bring the visitors as close as possible to the most "legible" of the ancient remains. The orientation of both slope and stairs is in accordance with

the main axes of the square; this is meant to allow an approach to the ancient levels without altering the visual perception of the cathedral. Throughout the area a natural stone (pietra serena) with an adequate anti-slip texture and a proper, unitary design, has been used for paving.

Above the level of the square a glass parapet defines the archaeological area with a minimal visual impact on the later monumental context. This type of glass has been specially produced by the same industry that also developed the more complex type of glass to be used for the protection of the ancient structures in their "showcases".⁵ Here, in fact, laminated tamper-proof glass panes are used with a sealed inner chamber where a thermostatically controlled system can heat the glass electrically to prevent condensation. The individual panes (3 cm thick) are assembled in fixed or movable metal frames designed in such a way as to provide all the needed structural strength as well as a proper flow of rainwater. Gaskets are provided of adequate plasticity to ensure a good seal all year round, while plastic coating protects the supporting frame from corrosion.

Though the showcases could offer adequate protection from climatic factors and from all causes of decay possibly induced by human frequentation, special provisions had to be developed to prevent the growth of microflora and spontaneous vegetation of all sorts within the protected environment. To that aim, in the cavity existing within the peripheral "double wall", a sealed circuit of PVC pipes has been created to connect all four showcases in one continuous system. An intake fan brings fresh air into the system, forcing it through a specially developed combination of mechanical filters to prevent contamination of the inner environment with insects, dust, spores, etc.; moreover, fungicides and sporicides are independently introduced into the system according to a seasonal program. While an ozonizer has been included in the circuit to occasionally help inhibit the growth of vegetation, a disposable inlet can be used, whenever necessary, to introduce any suitable chemicals needed for controlling the inner environment.⁶

Four remote-control outlet valves can maintain the predetermined atmosphere within the showcases or, whenever needed, can blow it off into the peripheral cavity. Filters on all the outlets prevent any accidental pollution of the inner environment through the discharge circuit. All the electrical functions are connected to a central control system which, through specifically programmed timers, operates the anti-condensation circuits in the glass panes, the input and output of air within the showcases as well as the lighting system. Here low-voltage fluorescent lamps have been used, in high-efficiency projectors designed to adequately light the remains while balancing the environmental light in the square.

After accurate mechanical cleaning of all remains by micro-sandblasting, preventive application of specific herbicides followed. These were prepared to control the vegetal species previously recorded as potentially present in the area. After that, the closed system of the four showcases ensures an adequate level of protection, with human intervention mostly confined to recording and control of data.

A short segment of a 1st century A.D. brick wall, most of which is protected within two of the showcases, was intentionally left exposed to the outer environment. It will allow the visitor to come into physical contact with the ancient structure, while giving us all a chance to realize how much more hospitable is the "protective environment" created for the context as a whole. In a project based on the idea of expanding museum technology beyond the museum's walls, this "provocative detail" is intended to remind everyone of the difficulties inherent in the task of preserving all ancient materials today.

NOTES

1. The project is jointly coordinated by Prof. Paolo Sommella, of Rome University, and by the author of this note. The archaeological fieldwork is directed by Dr Adele Campanelli of the Superintendency, assisted by Drs Giovanni Azzena, Paola Germoni and Emanuela Tascio of Rome University. A preliminary exhibition of finds and results has been on view in Atri since August 1982. While a preliminary report is due to appear in the Fall of 1984, the preparation of the final report is still in progress.
2. The recorded archaeological sequence in this area begins with
 - a) walls and levels belonging to private houses not later than the early 2nd century B.C., followed and modified by
 - b) the substructures for a building of Augustan times. The area was then remodeled by the
 - c) creation of a small workshop (fullonica?) early in the 2nd century A.D. More superficial structures, overgrowing the site in late-antique times and in the early Middle Ages, have left scanty traces scarcely surviving the later, radical remodelling of the site, mostly in connection with the construction of the cathedral.
3. The excavations in the square lasted four months, ending in June 1982, when the area was temporarily backfilled. The conservation project was developed from September 1982 to October 1983, when construction started on the site; all works were due for completion by August 1984.

The architectural team of the Superintendency is responsible for the project. It is led by Ada Cardelicchio and Walter Pellegrini, with Mario Apolloni; the author of this note coordinated the project with special reference to problems of environmental control and preventive conservation. Consultants for special problems were Dr Gianluigi Della Pozza of Bologna University, and Dr Luigi Capasso of the Superintendency, for the study of spontaneous vegetation and preventive control of the microflora; Dr Silvano Agostini of the Superintendency contributed with a geological survey of the site and with a study of the effects of ozone on the conservation of ancient mortars.
4. As a permanent waterproofing agent, DUROGLASS-F.U. was used, a high-resistance synthetic coating patented by M.P.M. of Milan.
5. The "Società Italiana Vetro" (S.I.V.), in close cooperation with the architectural team, has developed, produced and generously donated all the glass panes used for this project as well as their supporting metal frames. The "showcases" in Atri are in fact also a testing laboratory for glass technology as applied in the protection of archaeological and architectural contexts; the data collected thereby will be monitored by architects, conservators and glass engineers as well. An extensive publication of all the scientific, technological and technical aspects of this project is being prepared by all the experts involved.
6. All the relevant data (hygro-thermal fluctuations, preventive chemical treatments, special treatments, etc.) recorded during the first year of activity (Summer 1984 to Summer 1985) are being computer-processed to develop a management program to be used in the future.



Figure 1. Atri, in situ conservation of Roman remains: general view.

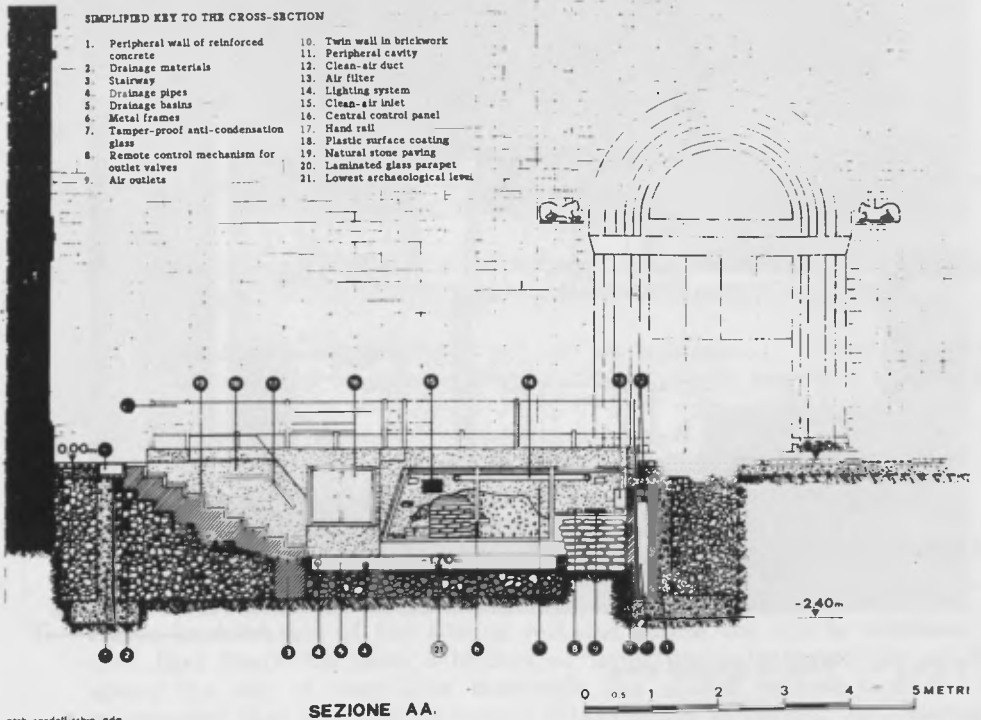


Figure 2. Section of display area.

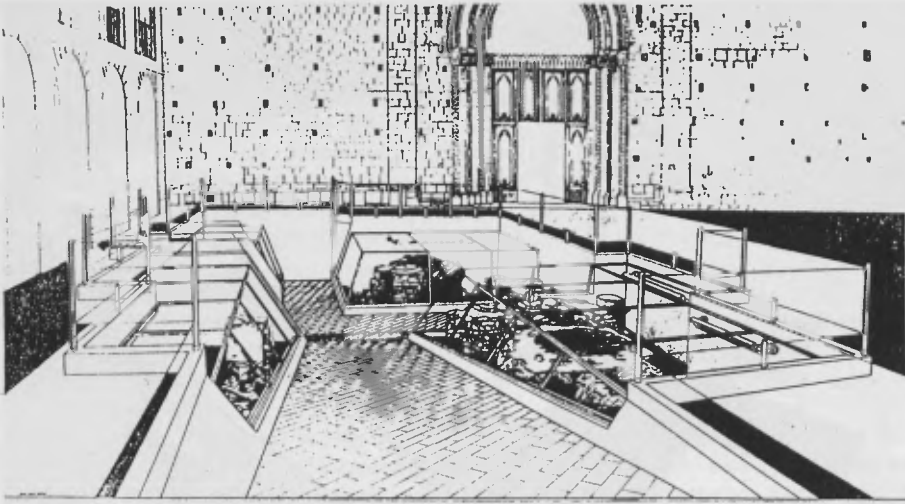


Figure 3. Relationship of display area to the Cathedral.



Figure 4. Plan of display area.

RECOMMENDATION ABOUT CONSERVATION ON ARCHAEOLOGICAL SITES
MADE BY A WORKING GROUP OF ARCHAEOLOGISTS
AND CONSERVATORS AT THE GHENT CONFERENCE

(a) *General Principles*

1. We would encourage the mapping of archaeological sites, which would then lead to a correct strategy for archaeological intervention.
2. Archaeologists and conservators have a duty to slow down the destruction of monuments and sites by influencing planners, helping to interpret current legislation properly, and forming priorities in archaeological and conservation matters.

(b) *The planning of excavations*

3. Archaeologists must recognize the needs of conservators and build sufficient amounts for conservation into excavation budgets.
4. Conservators must be involved in the planning of each excavation.
5. Conservation should be one of the criteria by which applications to national or local authority for permission to excavate are judged.
6. Project directors should make sure that the appropriate level of conservation skills is provided on or near the excavation site.

(c) *Preventive measures on site*

7. Project directors should provide adequate circumstances for the capture of all possible archaeological information, in at least the following ways:
 - (i) maximizing archaeological access to the strata by the development of applications of civil engineering to archaeological sites;
 - (ii) stabilizing the environment of excavations in order to retain information, by means of roof shelters, pumps, and other machines;
 - (iii) developing means of extracting all levels of information from the site -- buildings, artefacts (organic and inorganic), ecological and biological information;
 - (iv) recording the processes of degradation of the structures uncovered, including the effects of recent exposures.
8. Where preservation of the site or remains within the site is intended, we note that there has been a history of unfortunate interventions on sites where the use of unsuitable materials has caused serious damage. We recommend that the least necessary intervention be carried out, bearing in mind the necessity for future maintenance.
9. Further, we would encourage the wider use of traditional building materials and methods in conservation as well as more recently developed materials.

10. We recommend that greater effort be put into control of damage by visitors to archaeological sites during excavations.

(d) *After an excavation: a principle for conservation of structures and monuments*

11. When a structure or monument is to be conserved after excavation, we recommend the following principle:

To return a structure to its original state is not always the only correct policy. The changes experienced by a structure through time reflect human use of it over the centuries. We therefore urge archaeologists, conservators and those in charge of monuments to consider the possibility of conserving illustrative portions of all the main periods of a structure's life and decay. The use of the structure in later periods should be investigated, planned, and sampled in the same way as its period of initial use. It is our duty to record all stages in a monument's history. The remains of the later periods of its life should therefore also be conserved if at all possible. They do have historic merit and should rank in value with the original construction.

(e) *General*

12. We recommend the compilation of an illustrated glossary of terms used in conservation of archaeological sites, in several languages, so that fruitful dialogue may continue between archaeologists and conservators around the world.

RECOMMANDATIONS RELATIVES A LA CONSERVATION DES SITES
ARCHEOLOGIQUES FAITES PAR UN GROUPE DE TRAVAIL COMPOSE
D'ARCHEOLOGUES ET CONSERVATEURS A LA CONFERENCE DE GAND

(a) *Principes généraux*

1. Nous encourageons la création d'une cartographie des sites archéologiques qui pourrait ensuite mener à une stratégie correcte d'intervention archéologique.
2. Les archéologues et les conservateurs ont le devoir de freiner la destruction des monuments et sites en influençant les planificateurs, en aidant à interpréter la législation actuelle et en définissant des priorités en matière d'archéologie et de conservation.

(b) *Programmation des fouilles*

3. Les archéologues doivent reconnaître les nécessités des conservateurs et envisager des financements suffisants destinés à la conservation dans l'élaboration des budgets pour les fouilles.
4. Les conservateurs doivent participer à la programmation de chaque fouille.
5. La conservation devrait être l'un des critères sur lesquels juger les demandes d'autorisation à effectuer des fouilles aux autorités nationales ou locales.
6. Les directeurs de projet devraient s'assurer de la présence d'un niveau adéquat de spécialisation en conservation sur les lieux des fouilles ou proche de celles-ci.

(c) *Mesures préventives sur les sites*

7. Les directeurs de projet devraient assurer les meilleures conditions pour la récolte de toutes les informations archéologiques possibles au moins d'une des manières suivantes:
 - (i) maximiser l'accès archéologique aux différentes couches grâce au développement des techniques d'ingénierie civile appliquée aux sites archéologiques;
 - (ii) stabiliser l'environnement des fouilles afin de conserver les informations, au moyen d'abris, de pompes et autres machines;
 - (iii) développer des moyens d'extraire tous les niveaux d'informations du site - édifices, objets d'art (organiques ou inorganiques), informations écologiques et biologiques;
 - (iv) enregistrer les processus de dégradation des structures à ciel ouvert, en incluant les effets aux expositions récentes.
8. En ce qui concerne la préservation des sites ou des ruines sur le site, nous remarquons qu'il existe une longue histoire d'interventions malheureuses sur les sites où l'utilisation de matériaux non adaptés a causé de graves dégâts. Nous recommandons une intervention réduite en tenant compte de la nécessité d'un entretien futur.

9. En outre, nous encourageons une utilisation plus répandue aussi bien de méthodes de conservation et matériaux traditionnels que de matériaux de production plus récente.
 10. Nous recommandons qu'un plus gros effort soit fait pour contrôler les dégâts causés par les visiteurs aux sites archéologiques pendant les fouilles.
- (d) *A l'achèvement des fouilles: un principe pour la conservation des structures et des monuments*
11. Lorsqu'une structure ou un monument doit être conservé après l'achèvement des fouilles, nous recommandons le principe suivant:

Restituer une structure à son état original n'est pas toujours la meilleure solution. Les changements subis dans le temps par une structure reflètent son utilisation par l'homme à travers les siècles. Nous sollicitons donc les archéologues, conservateurs et responsables des monuments d'envisager la possibilité de conserver des exemples illustratifs des principales périodes de la vie et de la détérioration d'une structure. L'usage d'une structure dans sa période la plus récente devrait être étudiée, analysée, programmée et échantillonnée de la même manière que pour sa période initiale d'utilisation. Il est de notre devoir d'enregistrer toutes les phases historiques d'un monument. Les ruines des périodes plus récentes de sa vie devraient donc, si possible, être conservées. Elles possèdent une valeur historique et devraient occuper le même rang que la construction originale.

(e) *Généralités*

12. Nous recommandons la compilation d'un glossaire illustré en plusieurs langues, des termes utilisés en conservation des sites archéologiques afin qu'un dialogue fructueux puisse se poursuivre entre les archéologues et les conservateurs à travers le monde.

Il primo punto è che...

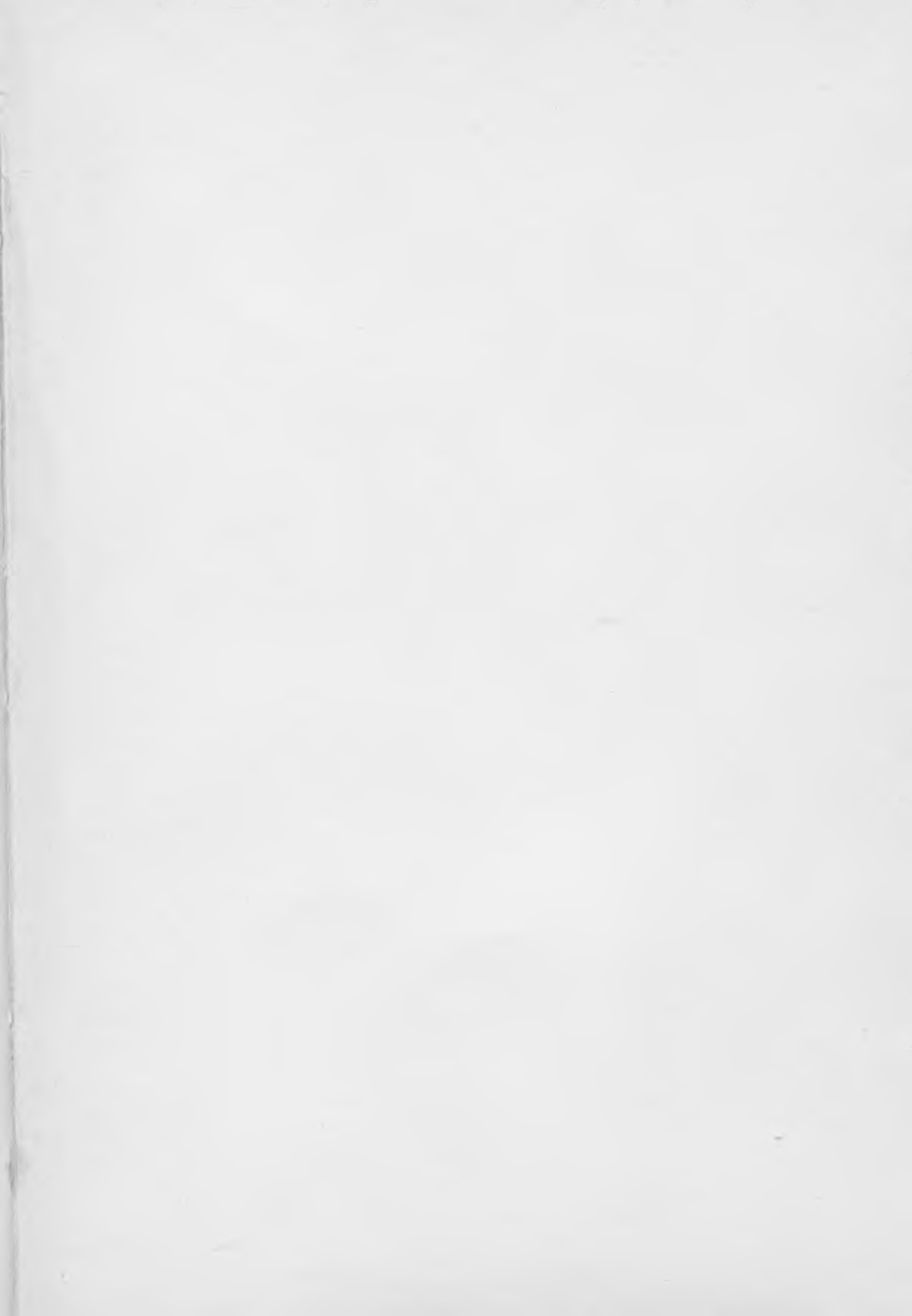
La seconda parte...

Il terzo punto...

La quarta parte...

Il quinto punto...

La sesta parte...



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