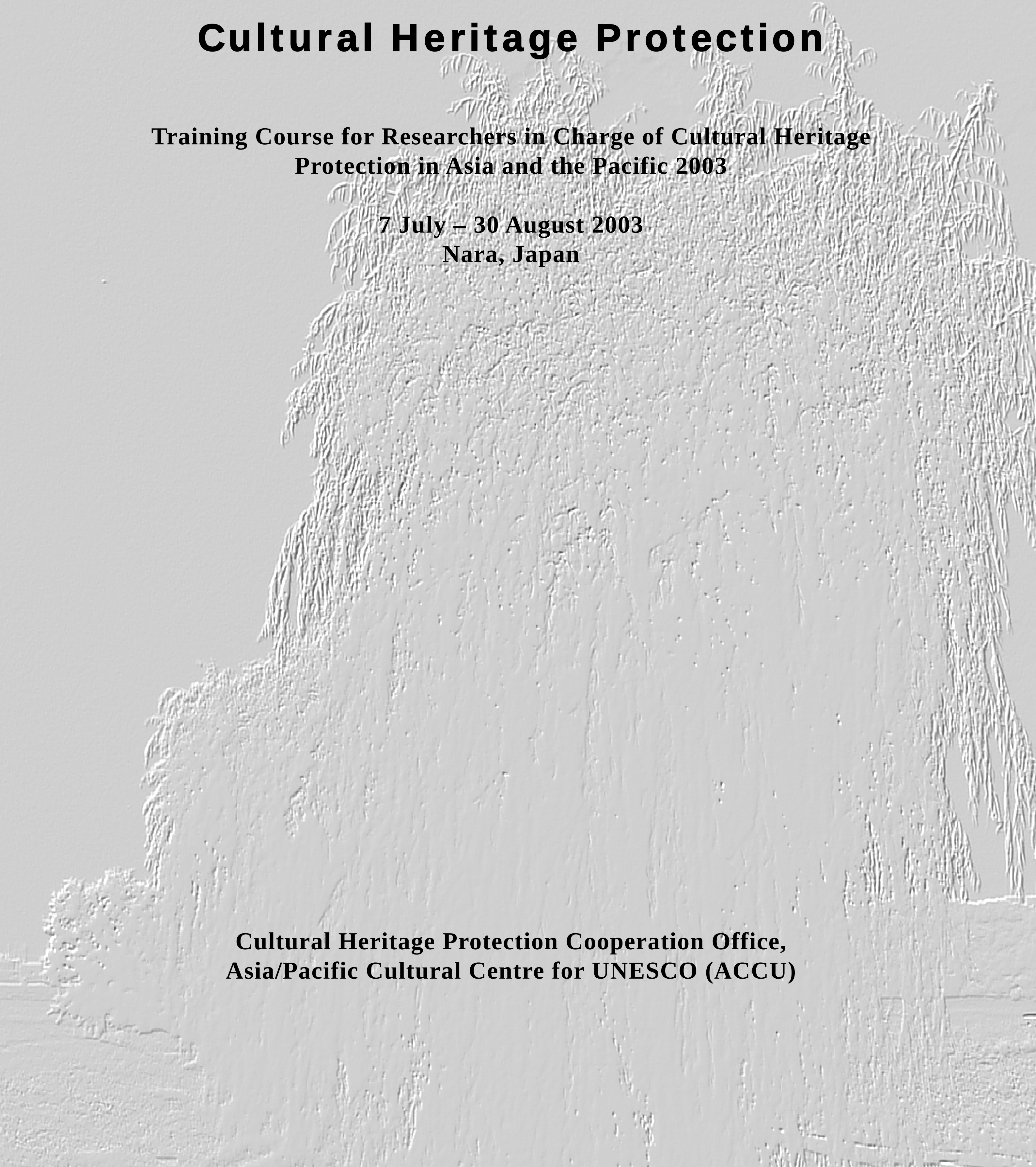
Training Report
on
Cultural Heritage Protection

Training Course for Researchers in Charge of Cultural Heritage Protection in Asia and the Pacific 2003

7 July – 30 August 2003
Nara, Japan



Cultural Heritage Protection Cooperation Office,
Asia/Pacific Cultural Centre for UNESCO (ACCU)

Preface

In many countries in the Asian and Pacific Region, cultural heritage is at risk of damage and destruction for various reasons, including: a shortage of human resources for the protection of cultural heritage, inadequate legal system and a shortage of financial sources. Under these circumstances, the Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Centre for UNESCO (ACCU Nara Office) has initiated various projects to contribute to the protection of cultural heritage in the region. Our projects include organizing training courses, international conferences and symposiums as well as gathering and distributing information.

This time, we provided a Training Course for Researchers in Charge of Cultural Heritage Protection in Asia and the Pacific 2003, and invited Dr. Nguyen Kim Dung who belongs to the Viet Nam Institute of Archaeology of the National Center for Social Sciences and Humanities of Viet Nam in the Socialist Republic of Viet Nam. Viet Nam previously experienced the calamity of war, and consequently both research institutes and universities lack human resources with up-to-date sophisticated expertise in the field of cultural heritage protection.

In response to this problem, the ACCU Nara Office provided this Training Course as a part of the projects to develop human resources for the purpose of ensuring a higher quality of academic research and educational activities in the near future in Viet Nam. We provide trainees with the opportunity to acquire specialized knowledge of conservation sciences and scientific methodology required in archaeological study.

Dr. Nguyen Kim Dung has already received her doctorate and is well known as a researcher of the Neolithic Period in Southeast Asia. Though she is neither a junior nor an inexpert researcher, Dr. Nguyen Kim Dung had a longcherished desire to participate in our training courses because she believed that the specialized training provided would be necessary for setting up the conservation science laboratory which the Viet Nam Institute of Archaeology is presently planning. We have therefore decided to invite her to Japan this year.

During the training course, her enthusiasm and serious efforts to study were highly appreciated by the lecturers of each organization. With the hope that results of the training might be transferred, disseminated and actually utilized in Viet Nam as quickly as possible, a veteran like her is expected to benefit the programme more in a short period than a younger professional.

We believe that this case suggests that if we consider not only young trainees but also experienced researchers to participate in the training programmes of the ACCU Nara Office, results of the training might be visible more quickly.

This Training Course was co-organized with various independent administrative institutions, in particular, the National Research Institute for Cultural Properties, Nara, which gave us much support during this training programme. Many organizations and experts, including the Archaeological Institute of Kashihara, Nara University and Gangoji Institute for Research of Cultural Property as well as Dr. Mariko Yamagata of Rikkyo University also supported us. We greatly appreciate their help.

October 2003

USHIKAWA Yoshiyuki
Director
Cultural Heritage Protection Cooperation Office,
Asia/Pacific Cultural Centre for UNESCO (ACCU Nara Office)

Contents

1. Introduction

Introduction

1. About The ACCU Nara Office

In many Asia/Pacific countries, numerous cultural properties are threatened by such risks as deterioration, weathering, and quick and shoddy repair or incomplete restoration urged on by the promotion of tourism. In addition, in many of these countries, the number of specialists committed to the protection of cultural properties as well as the number of experts capable of preserving and restoring these sites are far from sufficient. To respond to requests for cooperation from these countries, the Cultural Heritage Protection Office, Asia/Pacific Cultural Centre for UNESCO (ACCU) was established in August of 1999, as a centre for promoting cooperation in cultural heritage protection.

The office is located in Nara, Japan's ancient capital, where many cultural properties have been preserved. With cooperation of UNESCO and the International Centre for the Study of Preservation and Restoration of Cultural Property in Rome (ICCROM), the ACCU Nara Office organizes training courses for experts in the Asia/Pacific region, holds international conferences gathering experts and specialists, and collects cultural heritage information through overseas site survey. The center is also actively involved in disseminating information that it gathers through its researches.

2. Providing Technical Support and Specialist Training

We organize various training programs to provide participants with expertise and advanced technology in the surveying of archaeological remains, preservation and restoration of wood and stone structures. We are also involved in teaching conservation science and other related areas.

The training course for researchers in charge of Cultural Heritage Protection in the Asia-Pacific region is one of the programs in which the ACCU Nara Office undertakes every year. Each year two or three experts from Asia-Pacific region are invited to Japan for training at appropriate institutions/organizations under the coordination of the ACCU Nara Office.

3. Vietnamese Expert

The ACCU Nara Office accepted one Vietnamese expert for the first time as a participant to the training program for Researchers in Charge of Cultural Heritage Protection. The specialized training for this year's visiting scientist included advanced Conservation Science and Archaeological Survey Method. The duration for this program was from July 7th to August 30th 2003 and included the participation of Dr. Nguyen Kim Dung who belongs to the Vietnam Institute of Archaeology, National Center for Social Sciences and Humanities of Viet Nam.

4. Training Program

The training program for her had been organized under the cooperation of the Independent Administrative Institution and affiliated National Research Institute for Cultural Properties in Nara. Also, several organizations including the Archaeological Institute of Kashihara, Nara University and Gangoji Institute for Research of Cultural Properties provided an opportunity not only to give lectures, but also gave open access to use their facilities for a field workshop. The main survey field workshop was planned at the Nara Palace Site program. Several changes to the schedule had to be accommodated because of ground surface conditions at the site caused by inclement weather. Nonetheless, conservation method and excavation procedure schedules were rearranged and some of this training was provided for within the laboratory.

2. Training Programme Report

2-1. Participant’s Report

2-2. Activity Record

The Current Situation of Conservation Science and Archaeological Surveying in Viet Nam

Nguyen Kim Dung
Institute of Archaeology
National Center for Social Sciences and Humanities of Vietnam

In Viet Nam, as in other countries of the world, conservation of the cultural heritage and archaeological research are two important responsibilities for the future. The purpose of conserving and restoring the cultural heritage, including archaeological ruins and objects, is to maintain them and hand them down to future generations.

In recent years, especially after Viet Nam's Law for Cultural Heritage Protection was launched in 2001, conservation science and archaeological surveying have increasingly developed, and are receiving more attention. The Vietnamese government has expressed greater concern for cultural conservation, and given it higher priority, so that in today's society more and more conservation activities are proceeding under the law. According to this law, archaeological excavation is required prior to any construction work. At the same time, with the current trend for regional integration and globalization, Viet Nam has more favorable opportunities for exchanging ideas and experience regarding conservation work. Under these circumstances, Viet Nam will certainly receive more help and aid, in terms of both financial support and scientific training, from developed countries such as Japan, Italy, Sweden, France, as well as from international organizations.

1. The Current Situation of Conservation Science in Viet Nam

Because conservation and preservation aims at maintaining the full cultural significance of monuments and sites, there are two aspects to cultural heritage conservation and preservation work: one involving archaeological sites, historic monuments, and examples of architecture in situ, and the other including all cultural objects and artifacts kept in central and provincial museums.

1-1. There are many cultural sites and monuments needing conservation work in Viet Nam every year. The processes of modernization and the industrialization of the economy have exerted a severe negative impact on the cultural heritage, including archaeological sites. Construction of new roads and new multi-storied buildings is destroying ancient and historic monuments. Faced with this problem, site protection and conservation work play a crucial role in the preservation of traditional values. Annually, about 100-200 sites urgently call for conservation projects.

Although conservation work is conducted according to the needs of particular sites, it also shares common steps. In general, these steps are as follows.

Step 1: Classification of a site based on such criteria as features, situation, function, value, etc. This specifically includes:

- Examination of each site, including surveying, mapping, photographing, and note-taking, followed by the compilation of documents to certify the site's features and value, and its need for protection.

Step 2: Discussion and assessment of the site's current situation, including careful and detailed analysis to define the degree of conservation required. This degree may vary as follows.

- Partial conservation, in which conservation work is applied only to certain parts of the site, as for example the roof, surrounding wall, pedestal, or doorstep, or the redecoration of wooden as well as stone monuments. In such work, priority should be given to traditional techniques and materials, which are combined with conservation experience from developed countries such as Japan and Italy.
- Large-scale restoration, to be conducted only when the government permits a call to be made for the participation of specialists from many nations, as well as experts from international organizations in the conservation field.

Such assessments of the degree of conservation required are made for every part of the site, and ranked in the order of condition and urgency. Next, financial estimates are made for the conservation work. The best conservation often involves the least work and can be inexpensive.

Step 3: Determining reasonable methodologies and solutions for conservation work.

Step 4: Making scientific reports to be submitted to responsible agencies.

1-2. With regard to cultural objects needing conservation and preservation, there are more than 300 museums in Viet Nam where important cultural objects are housed, and these objects need to be maintained continually in good condition, using modern techniques of preservation.

In actuality, however, only the collections kept in the national museums in Ha Noi and Ho Chi Minh City are preserved in good condition. By contrast, provincial museums are not sufficiently equipped with modern techniques of preservation or human resources. Generally speaking, conservation work on archaeological, cultural, and architectural materials in Viet Nam still faces a number difficulties, such as the following.

- There are many sites badly in need of conservation and restoration, as many pagodas, temples and monuments are currently in poor condition.
- Due to the advancements of archaeological excavation, many sites are being discovered which require thorough conservation and restoration.
- Knowledge of conservation science (techniques, procedures, materials) is still inadequate. Viet Nam must rely on scientific and technical work done by specialists from other countries, in addition to improving its traditional methods of conservation and protection.
- Funding for conservation work remains limited. Almost all provinces lack sufficient financial resources to spend on conservation work.

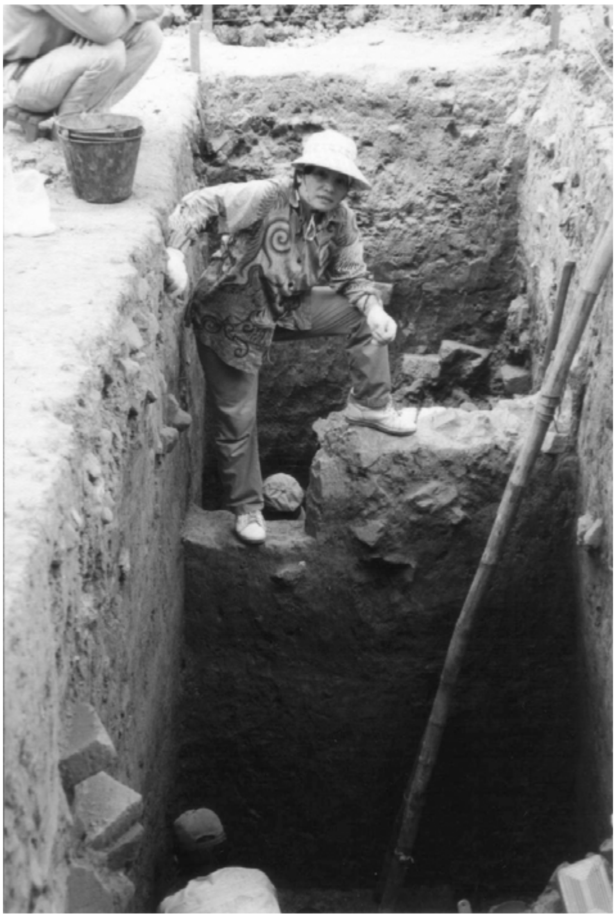
2. The Current Situation of Archaeological Surveying in Viet Nam

As already noted, archaeological surveying in Viet Nam is now being carried out in many provinces, on every kind of place of cultural significance, from pre-historical to historical sites. In recent years, surveying is mainly conducted when industrial or other construction is planned. Almost all archaeological surveys rely mainly on the experience of experts, due to technological inadequacies. During these surveys, archaeologists often use photography and manual measurements, instead of modern techniques and surveying equipment.

Archaeological sites are distributed everywhere, in both the lowlands and the highlands, in mountainous as well as in coastal regions. More open-air sites are discovered and excavated than underground or underwater ones. Ever year, the Annual National Archaeological Conference is held in the capital Ha Noi, in which hundreds of newly discovered sites are included in archaeological reports made to scientists from across the nation. After the Conference, schedules for future surveys and studies are submitted to the Government for permission and funding.

Currently in Viet Nam there are about eight large archaeological projects being conducted by the Institute of Archaeology, including the following: excavation at My Son Temple, a World Cultural Heritage recognized by UNESCO in 2000; large-scale excavation in the area of the National Assembly House; surveys and post-excavation work in the highlands where a hydroelectric station will soon be built. In addition, the Institute is simultaneously conducting archaeological surveys in Hue, Thanh Hoa, and the Mekong River Delta.

As scientists directly involved in these surveys, we realize that under current conditions improvements in the techniques employed in our surveys and excavations, and in our conservation and restoration work, are urgently required for the conservation and protection of Viet Nam's national heritage.



Excavation at Tra Kieu site,
Quang Nam Province,
Viet Nam

Activity Record

Training for the Expert in Charge of Cultural Heritage Protection in Asia and the Pacific
July 7 to 30 August 2003

Nguyen Kim Dung
Institute of Archaeology
National Center for Social Sciences and Humanities of Viet Nam

July 7th 2003

- Arrival at Kansai International airport. Met Mr. Nishimura from ACCU Nara Office.
- Visit ACCU Nara Office. Introduction to the members of ACCU.
- Visit National Research Institute for Cultural Properties (Nabunken) and Nara University – formal introductions. Talked with Mr. Koezuka of Nabunken about Tektite which is found in impact rock, a raw material for producing stone ornament in the Bronze Age.
- Professor Nishiyama of Nara University presented a provisional schedule of the training program, and discussed methods for observing air pollution on cultural heritage.

July 8th

- Visited the Archaeological Institute of Kashihara (Kashikoken) for formal introductions. Met vice-director Mr. Nakamura, conservation scientist Mr. Imazu, archaeologist Mr Hashimoto and Mr Kawakami.
- Visited Asuka-Fujiwara Excavation Department and Asuka Historical Museum of NABUNKEN for greetings.

＜NABUNKEN＞

July 9th

- Started training programme at the Nabunken after meeting with Director Mr. Tanabe of the Centre for Archaeological Operations, and Head of International Archaeological Site Investigation Section Mr. Tatsumi.
- Introduction to the equipments used at the conservation laboratory. Tour of the separate archaeological artifact treatment sections for roof tile, wooden artifact and pottery.

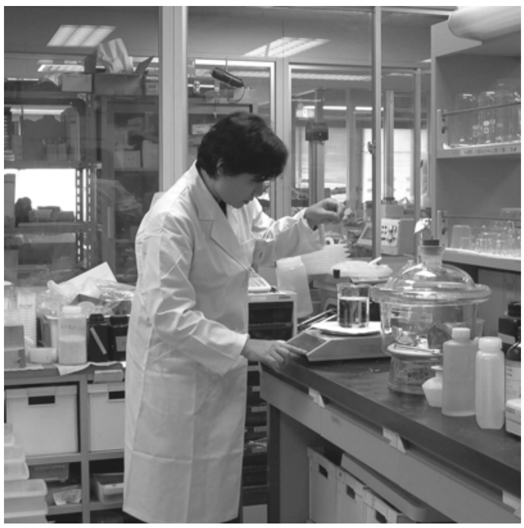
July 10th

- Lecture by Mr. Kozuma on methods of examining the material structure of wooden artifacts and metal objects.
- Introduction to the practice of wooden artifact examination by using X-Ray Radiography.

July 11th (Workshops)

- Water content percentage measurement of water-logged wood by using electric balance meter.
- Temporary storage method of water-logged wood by sealing in plastic bag.
- Computed Radiography (CR) method measurement by using digital imaging plate on glass, bronze and textile

Water content percentage measurement



Film removal method for soil layers

July 14th (Workshops)

- Film removal method for soil layers by applying synthetic resin at the excavation site of Daigokuden-in, Nara palace site. Practice of fragile object removal method from excavation sites by using liquid nitrogen and the polyurethane foam method.

July 15th (Workshops)

- X-Ray Fluorescence measurement method for inorganic materials and its application to bronze and glass artifacts.

July 16th (Workshops)

- Video Microscope Camera observation, Fourie Transform Infra-Red (FTIR) analyses and portable X-Ray Fluorescence measurement methods. Examined the eyes of an image of the Buddha Vairocana （盧遮那仏）at Toshodaiji Temple using such techniques.

July 17th (Workshops)

- Used the Infra-Red Reflect Graphy measurement method on a fragment of wall painting to detect invisible description and drawings.
- Lecture by Prof. Sato Masanori on applying the FTIR analyses method to textile and Urushi artifact.
- Traveled from Nara to Tokyo.

July 18th

- Visited the National Research Institute for Cultural Properties, Tokyo.. Met Dr. Saito Hidetoshi (Director of Japan Center for International Cooperation), Dr. Nishiura Tadateru (Director of Conservation Department), Dr. Ishizaki Takeshi (section head), Dr. Aoki Shigeo (Director, Department of Restoration Techniques).
- Introduced to an equipment which can obtain X-Ray Radiography (CR) images using digital technology in place of conventional film method for large objects and restoration work on lacquer artifacts.
- Visited Kyushu National Museum (Provisional) located in Tokyo National Museum and met curators Dr. Kawano Kazutaka and Dr. Kobayashi Koji. Discussed about ancient technologies of producting food and glass ornaments in Viet Nam, China and Korea.

July 19th

- Attended a seminar in Kokugakuin University and gave a lecture by the theme of “The evidence of agricultural activities in Phung Nguyen Culture (4500-3500BP)”.
- Met Prof. Yoshida Eiji and an old friend Prof. Tang Chung （鄧聡）of the Chinese University of Hong Kong （香港中文大学）.

July 20th

- Visited Edo-Tokyo Museum with Dr. Yamagata and Mr. Nishimura.

July 21st

- Returned from Tokyo to Nara with Mr. Nishimura of ACCU Nara Office.

July 22nd (Workshops)

- Water content measurement of wooden artifacts.
- Recorded the current condition of iron artifacts using a digital camera for documentation before applying conservation science treatment. Organized these document records by a card system.

July 23rd

X-Ray image observation

- Measured the interior structure of an iron artifact by stereo X-Ray Radiography. This is a part of the procedure for recording the condition of an artifact before conservation science treatments are applied.
- X-Ray Diffraction Analysis used to examine the nature of iron rust by observing the micro-structure of iron patina. There are two types of rust: malignant, which causes serious internal damage and benign, which covers the surface of objects and acts as a protecting layer against patina (Inhabitor).
- Practice of measuring and drawing iron artifacts by hand as a part of documentation prior to conservation treatment.

July 24th (Workshops)
- X-Ray Radiography taken from separate X-Ray source locations for creating 3-D images. It is a method for recording the status of patina production on iron artifacts.
- Patina production recording method by hand drawing, using information from the X-Ray Radiography images.

July 25th
- Lecture on Environmental Archaeology by Mr. Matsui Akira and Dr. Miyaji Atsuko.
- Lecture on Dendrochronology by Dr. Mitsutani Takumi.

July 28th (Workshops)
- Surface observation of iron artifact using a stereomicroscope. Based on the observation result, the iron artifact was cleaned by applying the Brasive Method, whereby alumina powder was blown onto the artifact, or by using a grinder.

July 29th (Workshops)
- Practice of iron artifact cleaning by the Brasive Method.
- Estimated the amount of PEG impregnated in a wooden artifact by measuring its weight.

July 30th
- Met Mr. Takahashi Katsuhisa. Discussion on pottery making techniques and materials for the restoration of pottery in the Section 2 Room of the Nara-Palace Site Excavation Department, NABUNKEN.

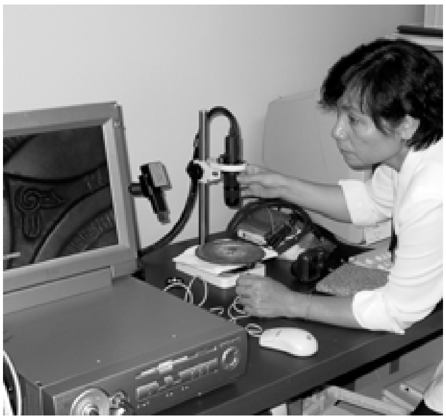
July 31st (Workshops)
- Desalination (salt removal) of iron artifact in a high-temperature and high-pressure environment using water blended with borax (decahydrate).
- Removed wooden artifacts from the PEG impregnation tank and washed out remaining PEG residues on their surfaces by warm water.

August 1st (Workshops)
- Resin impregnation into iron artifact.
- Final examination of wooden artifacts by observing distortion unbalance. Organised the data and information obtained at the NABUNKEN.

＜KASHIKOKEN＞

August 4th
- Met conservation scientist Mr. Imazu Setsuo, archaeologists Mr. Hashimoto, Mr. Kawakami, Mr. Matsuda and deputy general of the institute Mr. Nakamura .
- Introduction to Conservation Sciences, bronze mirror surface observation by

Bronze mirror surface observation



- digital-microscope, X-Ray Fluorescence measurement method and obtaining images by the 3-D Laser Scanning method.
- Introduction to Sugar-Alcohol (Lactiol) impregnation method and its application on wooden artifact.

August 5th (Workshops)

- Practised applying the Sugar Alcohol Impregnation method on wooden artifacts.
- Removal of fragile remains from excavation sites by applying the synthetic resin casting method.
- Observation of methods for the storage and display of artifacts after conservation treatment in the institute museum

August 6th (Workshops)

- Practice of Sugar Alcohol impregnation method on wooden artifacts.
- Visit to excavation sites with Dr. Nishiura from National Research Institute for Cultural Properties of Tokyo, and researchers from Thailand and Cambodia.

August 7th

- Visited Karako excavation site with Mr. Hashimoto and Mr. Kawakami. Met Mr. Fujita and Mr. Mametani who explained about excavation and hosted a tour of the exhibition room and artifact treatment room.
- Met Mr. Kanekata at the Mizuma Jomon excavation site where small pits and depression presumed to be associated human habitation were discovered. A measuring instrument which apply laser beam was introduced.
- Methods displaying plastic copied Haniwa (earthenware artifacts found on mounded tombs) were observed at Sanryobo Mounded Tomb. The planting of small trees to indicate the original location of the Haniwa artifacts was a good example of site preservation and information presentation.
- Met Mr. Aoyagi from Kashikoken who is engaged in the excavation at the Wadanakadori site, where a 5th A.D. settlement consisting of three pit-dwellings have been discovered. Although the site is in poor condition, both gray and brown color pottery artifacts have been found. They are of interest for gaining an understanding of a set of pottery configuration at that time.
- The Ohnoyasumaro tomb area is well preserved by landscaping which encloses the site from the surrounding tea-cultivation field. An inscription plate was found to accompany this 8th A.D. burial tomb .

August 8th

- Visited various archaeological sites, including:
  - mounded tombs that were excavated and preserved by the KASHIKOKEN
  - The ArchaeologicalCenter of Local Authority and Museum, where a study into the conservation and restoration of remains was conducted.
  - Sakurai city Archaeological Center.
  - Hashihaka tumulus, Hokenoyama tumulus, Nomugi tumulus, Kurotsuka tumulus and their associated exhibitions.
  - Senzuka tumuli Museum.

＜NARA UNIVERSITY＞

August 11th

- Introduction to the effect of Air Pollution on Cultural Heritage by Prof. Nishiyama.
- Methods of observing air pollution. Examples of the effect of pollution on cultural heritage in the Nara city area were also shown.
- Preparation of filter paper for air pollution observation. Triethanolamine 30 percent

aqueous solution liquid were used and 25 cylindrical paper filter were made in this practice session.

Replacement of filter paper

August 12th

- Visited various air pollution observation points within the Nara city area to collecting and replace filter papers that were placed one month ago. Sites visited include:
    1. Shosoin Nara Office of the Imperial Household Agency; met
    1. Mr. Naruse Masakazu and replaced filters in two locations in the vicinity of the original Shosoin treasure house.
    2. Hannyaji Temple; replacement of filter paper in two locations. Replacement of monthly temperature and humidity recording paper. The collected data were utilized for calibrating air pollution measurements by assessing responses to ambient temperature changes.
    3. Jyuurinin Temple, where a stone Buddha Image is kept indoors. Filter papers set up beside stone image and outside the building were replaced. Digital data of the temperature and humidity outside the building were transferred into a computer. Digital recording device can update and store such data at 5 minutes intervals for three months.
    4. Todaiji Temple Treasure House. Replaced filter papers at three key locations: both inside and outside the Azekura Treasure House and inside a wooden box kept within the building. Metal plate samples such as silver, copper, tin, lead and iron were also placed in these three locations in an experiment to compare patina breeding under various conditions of exposure.
    5. Todaiji Temple. Filter paper and monthly temperature-humidity recording paper were replaced at the north-west corner of the main hall and at the north east corner of the exterior corridor.

Kasuga Shrine. Met the curator Mr. Akita. Replaced filter papers inside the Treasure Hall (Museum), the eastern side of the shrine corridor (natural forest), and behind the Treasure Hall adjacent to the parking area.

August 13th

- Collected filter samples from the Nara city area, including:

1. the Nara University Library, where filters inside display cases, the reading room and those in the air pollution observation instrument shelter were replaced;
2. the Instrument shelter in Nara Palace Site area;
3. the Instrument shelter in Yakushiji Temple;
4. inside and outside the Treasure House (Museum) in Kofukuji Temple and the parking area;
5. the Ichijyo High School campus area along Route 24.

- Preparation for analysis by extracting samples from the filter paper collected.

August 14th

- Extraction of samples from the filter papers in preparation for analysis.
- Set up samples in the Ion-Chromatograhy analyzing instrument.

August 15th

- Analysis of extracted samples using an Ion-Chromatograhy instrument and interpretation of analyzed data.

August 18th

- Lecture by Mr. Nishimura on Cultural Heritage Protection in Japan (conducted by the Agency of Cultural Affaias) and investigation methods in archaeology.

August 19th

- Lecture by Mr. Nishimura on survey methods in Archaeology including Photogrammetry and the 3-D Laser Scanning Method.

August 20th

- Lecture by Mr. Nishimura on Archaeological Prospection methods.

August 21st

- Visited Oka Bokkodo (Japanese paper and scroll restoration workshop) in the Kyoto National Museum, where various analytical and restoration methods were introduced, including:
    - Identification of the raw materials for traditional paper making (Mulberry, *Mitumata)* by dyeing samples with a homemade dyeing solution and observing under a microscope. The special paper with gold imprint brought to Japan at c.16th century A.D. from Viet Nam was one of the trading items of the Portuguese Eastern Indian Company.
    - Paper damaged by insects are restored by patching with similar paper. This is done by using machines or by hand, which requires a high level of skill. Glue used for patching is made of flour and must be at least ten years old, as the use of strong adhesive will cause shrinkage and distortion of the original artifact.
- Visited Kyoto National Museum and met curator Mr. Ono Yoshihiro. Important masterpieces of South-East Asian origin are kept here.

August 22nd

- Visited Gangoji Institute for the Research of Cultural Property.
- Visited the Conservation Science Laboratory in Ikoma city and met Ms.Ueda Naomi. As part of the conservation process, wooden artifacts are kept in water prior to treatment. They are then washed and sealed in polyester bags.
- According to the wood species, condition and size of a wooden artifact, an appropriate treatment method is selected. Possible treatment methods include PEG, Freeze-Drying, Sugar-Alcohol (Lactiol) impregnation, Alchol-xylan and the Fatty-Acid Ester methods.
- Reapplication of preservation treatment to an iron armour. This artifact had been treated around twenty years ago but it has begun to deteriorate again. The armour was carefully dismantled and the bonding materials used in the previous restoration (plaster and synthetic resin) were carefully removed. New treatment was then applied. It was a very delicate process.
- Visited the Harimichi site located on the mountain slope in the Sakurai city area. Undertook 3-D laser scanning survey on a historic stone wall.
- Visited the Nomugi tumulus dated to the 4th century A.D.. A wide moat surrounding the tumulus containing a large number of pottery fragments had been discovered here.

3-D Laser scanner survey

August 25th

- Visited Shoso-in and met Mr. Naruse. An introduction to the conservation equipments and methods employed here were introduced after an inspection of the Shoso-in building and its natural environment. Methods for the restoration of textile and paper also introduced.

- Visited Nabunken conservation laboratory and discussed about the variety of instruments available to the Archaeological Institute in Viet Nam. Instruments for conservation science can be divided into 3 categories corresponding to the stage in which they are used and the budget allocated. These categories are: 1) Basic facility 2) Analytical instruments 3) Instruments for Conservation Science.

Special paper box

August 26th

- Visited the Nara National Museum and met Mr. Inokuchi. Exhibits are housed in special display cases which are resistant to earthquake forces. Museum exhibition rooms and storage are maintained at a constant temperature and humidity (22° and 60 percent respectively) for the preservation of artifacts. This is monitored 24 hours by staff in the central air condition control room.
- Tri-layer paper boxes are a recent invention – their strength and insulative properties make them ideal for material transportation and storage. In the past, wooden container boxes were used, these are evidence of the long history of material storage traditions in the museum.

Iron artifact keeping

August 27th

- Visited the Kawarau roof tile production factory. The factory produces not only normal roof tiles but also ornamental tiles which are used on the edges of a roof.
- Visited Zuto, which is located on axis to the south of the Todaiji Temple main hall. An earthen pagoda partly covered by roof tile in 8th century A.D. is one of the rare example of its type in Japan.

August 28th

- Introduction to the production of publications on research report including printing techniques by Mr. Nisimura. Photograph and drawing quality in reproduced in publications rely very much on printing techniques.

August 29th

- Receipt of training course certification from general director Mr. Ushikawa at ACCU Nara Office.

August 30th

- Departure from Kansai international airport.

Japanese Institutions cited:

Nabunken	Independent Administrative Institution National Research Institute for Cultural Properties, Nara
Tobunken	Independent Administrative Institution National Research Institute for Cultural Properties, Tokyo
Kashikoken	Archaeological Institute of Kashihara, Nara Prefecture
Nara Univ.	Nara University
Gangoji	Institute for Research of Cultural Property, Gangoji

3. Reference Papers

An Introduction to the Conservation Science of Archaeological Relics

KOEZUKA Takayasu
Center for Archaeological Operations,
National Research Institute for Cultural Properties, Nara
Independent Administrative Institution

1. Introduction

The field of using the natural scientific method to investigate, study, preserve and restore precious cultural properties is called preservation science. There are two types of cultural property, tangible and intangible. For example, the physical results of applications of technology are tangible, and the experiential effects of the performing arts are intangible. Preservation science deals with tangible cultural properties, including archaeological materials, works of art, handicrafts, ancient documents, classical books, and old buildings. As such, objects for preservation science encompass a wide variety of materials.

This area of science is naturally therefore closely involved with cultural and social sciences, such as archaeology, art history, the history of handicrafts, architectural history, and ethnology. By approaching cultural properties from the viewpoint of material science, preservation science makes it possible to provide important information both to cultural science and to social science. In addition, preservation science is intrinsically associated with almost all fields of natural science, and is growing as a field of study for inter-disciplinary research.

When we consider cultural properties according to the types of materials that they are made of, we can classify them broadly into three categories. There are organic cultural properties, which have their origin in the animal and plant kingdoms. There are the inorganic cultural properties, made of metal or stone. Then there are those made of both organic and inorganic materials such as metal with wood. Most cultural properties are made from a number of materials, rather than from one single material.

Excavated archaeological materials are often unearthed in good conditions, although they had been buried under the ground for a long time. This is probably because the conditions under ground, where they had rested for so long, were rather stable. However, although many objects are found in quite good condition, usually they suffer, at least, some deterioration over the long period of time in the earth. Then, triggered by changes in their environment through by excavation, the deterioration of unearthed cultural properties is often hastened. This can result in their sometimes retaining nothing of the original form that was revealed when they were unearthed. In particular, this holds true of excavated wooden and iron artifacts. All materials, including archaeological materials, have a life span. That is to say, all material things are faced with a process of deterioration. Cultural properties reveal a lot of information about the past, and often have great artistic value. It is important to extend the life of cultural properties and preserve them as long as possible, without impairing the information and value they contain. Nowadays, there are many land development projects being carried out throughout Japan and the number of academic excavations is also growing. Accordingly, the volume of unearthed relics has become enormous, to a level beyond our current capacity to treat for preservation.

Here, in this lecture, I will outline the nature of excavated archaeological materials and the application of the science that is intended to preserve them for future generations.

For your reference, I will review typical research organizations of this field.

UNESCO (United Nations Educational, Scientific, and Cultural Organization) has established the International Council of Museums (ICOM) and the International Council of Monuments and Sites (ICOMOS), non-governmental organizations that promote the preservation and restoration of cultural properties. There are also governmental organizations, such as the International Center for the Study of the Conservation and Restoration of Cultural Properties (ICCROM, also called the Rome Center). There is also an international academic society called the International Institute for the Conservation of Museum Objects (IIC). In Japan, there are two academic societies: the Japanese Cultural Properties Society and the Japanese Society for the Preservation and Restoration of Cultural Properties.

2. Study and Research Methods

2-1 Examining materials

In preservation science, the study of cultural properties starts with examining the materials. It is preferable to examine the materials without collecting samples so as to save them from damage or destruction. Needless to say, only a small amount of material should be collected, in instances when collecting samples is the only option.

Fig.1 X-ray fluorescent spectrometer

Non-destructive methods for studying inorganic relics include fluorescent X-ray analysis, PIXE analysis and radio-activation analysis. Fluorescent X-ray analysis is carried out in the following manner. The sample is irradiated by primary excitation X-rays. Consequently, the sample generates characteristic X-rays peculiar to the elements it contains. The elements contained in the sample are identified from their place in the X-ray spectrum and their energy. Furthermore, a quantitative analysis can be made, by measuring the intensity of the X-rays. The devices used for this research are usually modifications of standard devices, which vary widely in size and shape. Fluorescent X-ray analysis is the most widely used investigative technique at present (fig.1). However, radio-activation analysis and X-ray microanalysis, which make it possible to carry out qualitative and quantitative analyses on a quite small sample, are also often used. In addition, where the collection of a sample is permitted, atomic absorption spectroscopic analysis and plasma luminescent spectroscopic analysis are widely used to examine cultural properties. The X-ray diffraction method is used to identify the mineral composition of oxidized material and earthenware, the deposits on stone statues, and the compounds making up pigments (i.e., their crystalline components)(fig.2). In Fourier transform infrared spectroscopic analysis and fluorescent spectroscopic analysis, the gas chromatographic mass spectrometer, and the ultraviolet absorption spectrum method are used to identify organic remnants such as lacquer, textile, dye, and resin. You cannot carry out non-destructive (sampling) measurement using any of the above methods, but they do allow assessment of small sample amounts. The energy-dispersive X-ray fluorescence analysis device makes it possible to assess extremely small amounts of material.

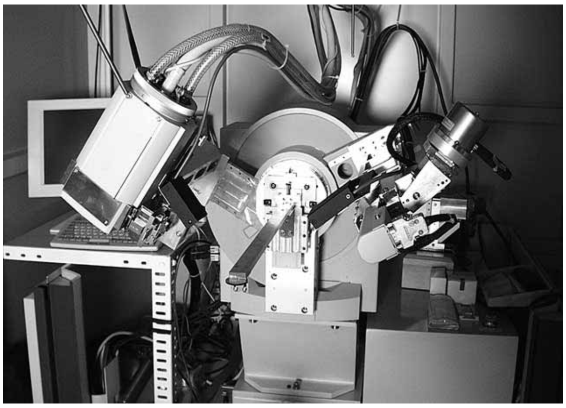


Fig.2. Non-destructive X-ray diffraction

2-2 Investigating the inner structure of relics

In order to study and preserve archaeological relics, it is necessary to know exactly what is inside them, as well as to examine the exteriors of the items. This process is indispensable for clarifying the techniques used to make the relics, but it help also to obtain the information needed to clean and restore the relics for preservation. X-ray radiography has become a popular method, in the field of cultural properties research, for investigating the insides of objects. Recently, computer image processing has also begun to be used. X-ray computed tomography (CT) which allows you to obtain a three-dimensional view of the insides of an object has been introduced to the field of cultural properties research, so it has become possible to obtain much more detailed information.

Neutron radiography has also been put to practical use to develop a method for obtaining different information from that obtained by X-ray radiography.

2-3 Preserving relics in good condition

It is necessary to examine the environment in which excavated relics were buried in order to create an ideally safe environment for preserving them in the future. For example, by examining the environment where an archaeological relic is found, you will be able to learn causes of deterioration and weathering. The results of this examination will provide important information during the investigation of the materials and construction of the relic. Furthermore, this information will also be used to determine optimal conditions (temperature, humidity, and lighting) for storing and exhibiting the cultural property and for designing the storage facility.

In these modern times, metallic and stone cultural properties that are displayed outdoors are often damaged by acid rain or automobile exhaust fumes. Furthermore, research on measures to prevent damage by mold and insects is also important to creating a good environment for relic preservation.

2-4 Preservation and restoration

Traditional techniques for preserving and restoring cultural properties have always been recognized to be important, as well as the selection of the correct materials and the best technology. Traditional materials and techniques are particularly emphasized when preserving or restoring works of art, handicrafts, and buildings. For example, when one repairs lacquered handicraft items, one should use the same type of lacquer as was used on the object originally. Ancient buildings are usually repaired and preserved by miya daiku (carpenters who specialize in building shrines and temples), who have learned the traditional techniques.

However, it is not clear how most relics unearthed during excavation were manufactured, and so there are no known traditional restoration techniques. Since the items have already been changed because of the physical and chemical processes of aging, it is necessary to use available preservation techniques that take full advantage of science.

3. The Conservation of Wet Organic Archaeological objects

Organic excavated relics include wooden artifacts, textiles and paper. Wet Wooden objects are the most abundant in Japan. Usually these wooden artifacts are in the form of building members such as poles, vessels like bowls and stemmed-cups, tools, and ornaments (fig.3). Some wooden artifacts are lacquered onto a wooden base. Excavators also find wooden tablets bearing characters written in Chinese ink. These organic relics can only survive in the ground in Japan, where the climate is very humid, if they have been in an environment where bacteria do not thrive. Most wooden artifacts excavated in Japan have lost much of their cellulose content. Cellulose is of course the chief constituent of wood. A part from cellulose, wooden artifacts contain a lot of water, which makes them quite fragile. (Some excavated wooden artifacts consist of 70 per cent or more water.)

In most cases, fresh coniferous wood has moisture content of 100 to 300 per cent as much water as its solid content, and broad-leaved tree has 300 to 1000 per cent as much water as solids. Some broad-leaved tree that has become rotten can contain up to 1500 percent as much water as solids. A rotten wood could contain 15kg of water as against 1 kg of solid weight. Wood in this state is called “waterlogged wood”, and when it is subjected to natural drying, it shrinks severely, cracks, or warps.

Excavated organic relics are examined from various aspects and treated to preserve them. One of the most popular research activities is deciphering characters written in Chinese ink on wooden tablets or lacquered paper. It is often necessary to read characters that cannot be seen with the naked eye (under visible light) by using an infrared–ray TV camera or an image enhancement device. These devices are also used for reading characters, symbols, and pictures written or drawn in Chinese ink on earthenware or metal ware, as well as on wooden artifacts or paper (fig.4). However, they may not be as effective for reading markings on the harder materials as they are for reading those on wooden materials. X-ray radiography and X-ray CT are used to examine the insides of relics, to clarify their techniques of manufacture.

Organic relics are usually less well preserved than inorganic relics, and in most cases only small pieces of them remain. However, recent advances in analytical devices for examining organic substances, such as microscopic FT-IR and GC-MASS, make it possible to analyze small

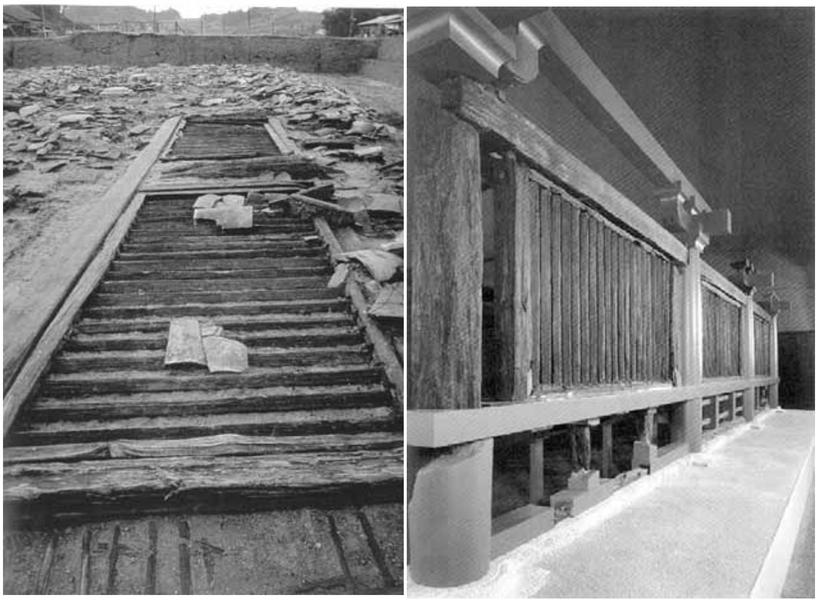


Fig.3. Left: A Japanese muntins window excavated at Yamadadera site in Sakurai, Nara prefecture, and a part of the temple left falling down was discovered with enormous quantities of building materials of wood. All the waterlogged wood from this site have been treated by PEG methods. Right:The reconstructing a part of Yamadadera temple in the museum, using the conservation-treated waterlogged wood.

samples. With such devices, methods for identifying lacquer, fibers, dye, amber, and tar have been put into practice, and the progress is being made at clarifying ancient techniques.

3-1. Brief history of wooden artifact treatment

The study of preserving wooden relics has been going on since times of old. In the 1850s, when a great number of wooden relics were found on Funen Island, in Denmark, it is said that an inquiry was directed to the Denmark National Museum about how to preserve them. At that time, the museum recommended the use of potassium alum. About 100 years later a new method, using ether, was devised by Christensen of the Denmark National Museum. In this method, the water in the wood is replaced by ether, which has a surface tension 1/4 of that of water. This prevents the relic from warping as it dries. Since then, several other methods have been developed and put to practical use, using various types of organic solvents and synthetic resin.

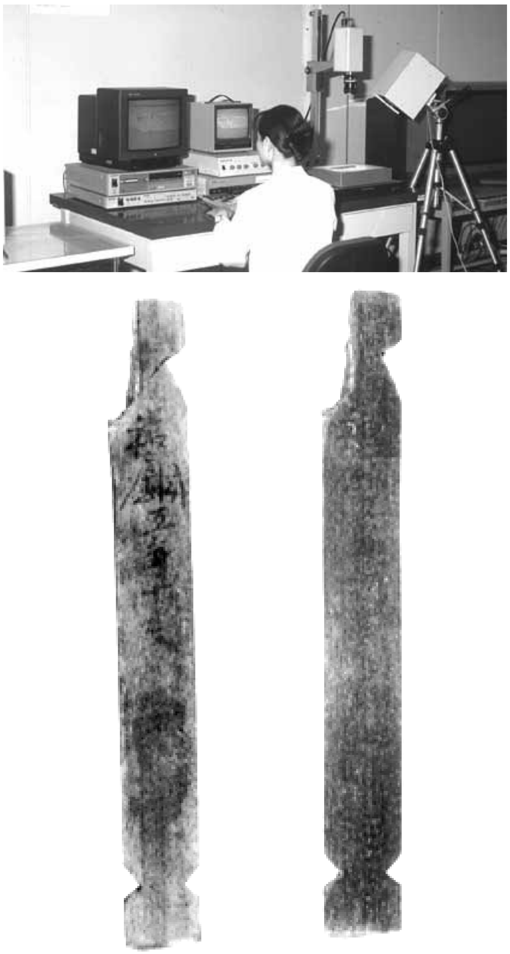


Fig. 4. Reflectgraphy of Wet Wooden-tablet Using an Infrared Vidicon Television System. (left :IR-image, right: normal)

In Japan, a great many wooden artifacts were unearthed during the excavation of the Nara Imperial Palace site, carried out by the Nara National Research Institute of Cultural Properties. This excavation triggered the study of scientific methods for preserving wooden artifacts and has continued for about 20 years. During this period, a variety of preservation methods appropriate for various kinds of relics has been developed. All of these methods rely on replacing water held in the wood with a stable substance that will prevent shrinkage or deformation of the relics while providing them with needed strength. These are called the polyethylene glycol (PEG) impregnation method, the freeze drying (FD) method, and the higher alcohol impregnation method, depending on the substances or methods to be used.

3-2. PEG Method

The PEG impregnation method is the most widely used method, at present. There are various types of PEG, differing by molecular weight (table 1). The one with an average molecular weight

Table 1 Characteristics of PEGs

Name	Mean Molecular Weight	Melting Point(°C)	Appearance
PEG200	200	—	clear, liquid
PEG300	300	—	clear, liquid
PEG400	400	—	clear, liquid
PEG600	600	—	clear, liquid
PEG1000	1000	37	like-wax, solid
PEG1500	550	40	paste
PEG1540	1450	45	like-wax, solid
PEG2000	2000	51	like-wax, solid
PEG4000S	3300	56	white, flaky solid
PEG4000N	3000	55	white, flaky solid
PEG6000S	8300	62	white, flaky solid
PEG6000P	8500	62	white, powder
PEG20000	20000	63	white, flaky solid

of 4000 is usually used to preserve archaeological waterlogged woods. This type of PEG has a melting point of 55°C and it has a water solubility of 60 (20°C) (100 g/g). This substance is solid at room temperature. In the PEG method, 5 to 10% PEG solution is put in an impregnation tank whose temperature can be maintained at about 60°C, and the wooden artifact is put in the tank for impregnation. The concentration of the PEG solution is gradually increased until the concentration of the PEG solution reaches more than 95%. When impregnation is finished, the object is taken out of the solution (fig.5) and returned to room temperature for set-up. At this point, the water in the wood has been almost completely replaced by PEG, so the object will not shrink or deform.

3-3. Freeze dry method

In the Freeze Dry method, the water contained in the waterlogged wood as liquid is frozen solid and then vaporized (sublimated) under a high vacuum. When wood is treated using this method, the water contained in the wood cannot move (diffuse internally) during drying, and the wood solids cannot collapse. Thus, there can be no shrinkage or deformation. Therefore, the shape of the object is safely maintained.

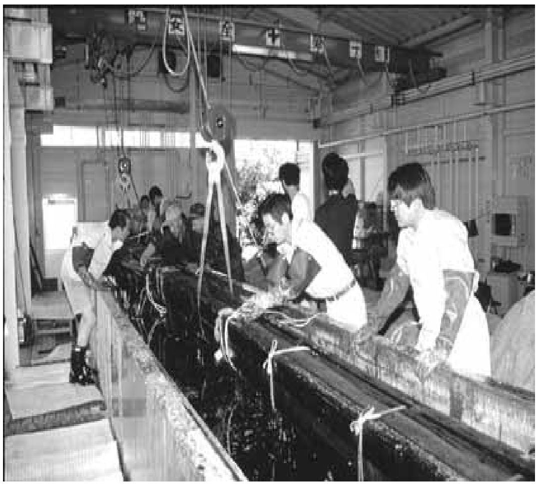


Fig.5 A large P.E.G. impregnation tank.

In actual practice, since there is a danger that the water will expand during freezing and so damage the relics, the water is first replaced with tertiary butyl alcohol. Then, to reinforce the weakened wood, the relic is impregnated with PEG at a concentration of about 40 to 50% before freeze drying. The texture of the wood is preserved when this method is used, and so this is widely used to treat wooden tablets bearing Chinese ink characters. In recent years, a process consisting of a combination of PEG impregnation and freeze drying has been developed to treat large excavated relics (fig.6).

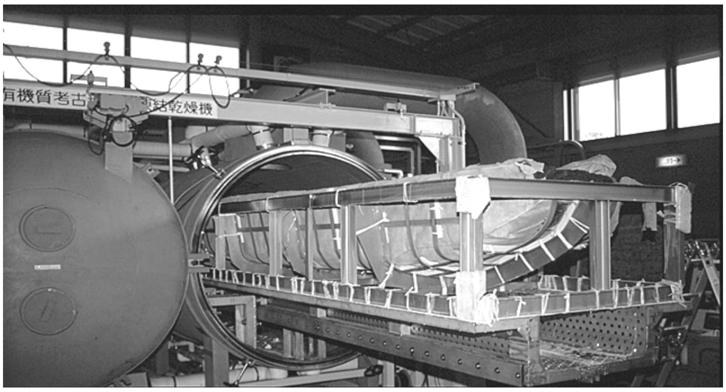


Fig.6. The large freeze-drying unit. (Conservation of log-boat, 5m long)

Recent excavations carried out in low marshy places yielded a large number of wooden relics. Since they had already been excavated and were therefore vulnerable to destruction, it was necessary to preserve them swiftly. It takes a long time to complete impregnation using the conventional PEG (quasi-polymer) method. Recently, various studies have been carried out with the aim of shortening the time required to complete impregnation by using especially permeating low-molecular-weight materials to reinforce waterlogged wood. The result has been successful in the impregnation of archaeological relics using higher alcohol or sugar alcohol. In the higher alcohol method relics are impregnated with cetyl or stearyl alcohol. Their molecular weights are so small to PEG that the impregnation time is substantially shortened. In addition, unlike PEG, they are not hygroscopic, and so the post-treatment storage of relics is made easier. It has also become possible to treat relics made of composite materials such, as a combination of wood and metal.

4. Inorganic Archaeological Objects (Metals)

Inorganic relics include earthenware, roof tiles, stone artifacts, glass, pottery and metallic artifacts. These are made of a wide variety of materials. Metallic artifacts pose a great problem due to their being subjected to corrosion, especially if they have been buried under ground, and they are also difficult to protect against oxidation while in storage.

Ancient metallic artifacts are made of many materials. Some are made of a single metal, such as iron, copper, silver, tin, or lead. Some are made of bronze (copper alloy). There are also composite relics made of several metals. For example, some relics are copper, plated onto an iron base. However, almost all metals (except gold) corrode while they rest underground. Corrosion is caused by the interaction of oxygen, water, and various ions. Chloride ions play a major role in the advance of corrosion (fig.7,8). Excavated metallic relics are usually scientifically examined as to their structure and materials, and treated for preservation before being displayed for exhibition or stored in a storehouse according to: "An Outline of the Conservation and Restoration of Stone Buildings".

In the study of and research into cultural properties, the shapes and surface of the relics are very important, and therefore you must not alter their shapes for the sake of research. In general, when examining relics, non-destructive tests or microanalysis must be used.

Fig.7. Iron rust has increased rapidly because the Iron cannon ball recovered from sea was naturally dried.

4-1. Examination before treatment

The study of metallic relics usually includes examining the techniques used to make them and the extent to which they have corroded. X-ray radiography has long been used for these purposes. This method was first used in Japan in 1935, to examine a glass pillow made of glass beads, when the relic was excavated from the Abuyama-Tumulus in Osaka Prefecture. Later, in 1978, a sword was excavated from the Inariyama-Tumulus in Saitama Prefecture. This method was used with great success to decipher a 115-character inscription written in gold inlay on that sword. Since that time, the use of X-ray radiography has spread rapidly in the study of buried cultural properties.

Fig.8. The bronze disease is formed with the chemical reaction of copper and the chloride ion.

More recently, X-ray CT is also used to study relics. This has made it possible to observe the items in more detail by obtaining sectional images of an arbitrary part or by constructing 3-D images.

In addition, with the development of new analytical instruments and advances in computer technology, methods for examining the materials used to make inorganic relics have also progressed rapidly. At present, the most popular method is fluorescent X-ray analysis, which allows non-destructive assessment. In this method, relics are irradiated by X-rays and the types and quantities of secondary X-rays generated by excitation are measured. With this method, it is possible to identify several elements simultaneously in a short period. The use of the PIXE method for examining cultural materials has also been attempted.

However, most metallic relics corrode while they are under ground and their surfaces change so much that their original composition can no longer be seen. This makes it difficult to interpret the results of non-destructive analyses correctly. Recently, a fluorescent X-ray analysis device has been developed that can be used to study micro-areas (100 μm dia.). After an extremely small area of a relic is polished, the freshly exposed surface can be analyzed using this device, to study the original material.

This method is used not only on metal but also on glass and pottery, to study the history of the material and the area from which the material was produced.

4-2. Corrosion

Generally, excavated metallic relics are covered with various type of oxidation. In some cases, oxidation may be suppressed by a coating of oxidized material, while in other cases oxidation may progress to complete destruction of the original material. To keep the corrosion of relics from progressing after excavation, it is usually important to identify the causes of corrosion and remove them, one by one. Generally, the causes of metal oxidation can be divided into two categories: external and internal. The external causes include oxygen and water in the environment. The internal cause is soluble salts contained in secondary products (such as oxidized materials) adhering to the relics. You can learn about the history of relics and whether the corrosion of a relic will progress further or not, by analyzing these secondary substances.

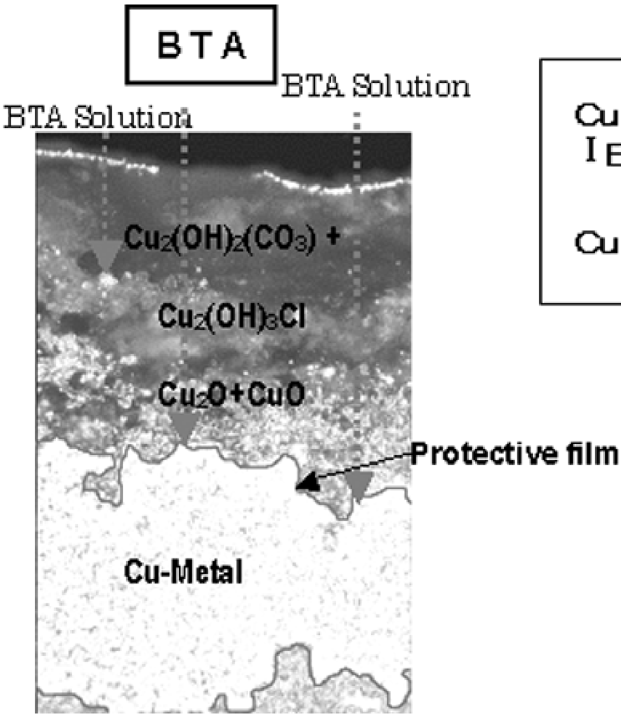
Iron relics are usually covered with oxi-iron hydroxide. The oxi-iron hydroxide found on excavated objects are of three types: α, β, γ-FeOOH. β-FeOOH is generated in the presence of chloride ions and poses a particular problem for preservation. This corrosion product was first discovered by Matsuo Nambu, inside an iron meteorite, about 30 years ago. After that, it was reported that β-FeOOH is present in excavated iron relics (fig.9) and that it is caused by chloride ions (Makoto Shima and Hideo Yabuki, 1979). At present, before preservation, the oxidation on iron relics is identified by X-ray diffraction. In addition, to determine the treatment method, the presence of chloride ions and anions such as sulfide ions, fluorine ions, and nitrate ions are analyzed quantitatively. Chloride ions are a major cause of the advance of corrosion on relics (especially in Japan, where the relative humidity is so high), and so they should be removed (i.e., the object should be desalted) to the best extent possible. There are two methods for desalinating iron relics: the dry and the solution (or washing) methods. The solution method is popular in Japan. The alkaline solution method is one that is widely used. The use of a high-temperature and high-pressure device (autoclave)(fig.10) has also been investigated as a means of extracting chloride ions and sulfide ions. Iron relics that have been chemically desalted using one of these methods are then impregnated with acrylic resin as a means of reinforcement and to block air from reaching the relic, to prevent oxidation.

Fig.9. β-FeOOH, "AKAGANEIT" This corrosion products was found from inside of sword.

4-3. Bronze disease

Copper and bronze relics, as well as iron relics, corrode and degrade in the presence of chloride ions. For example, bronze mirrors that seemed stable when excavated, often corrode within a period of some few dozen odd years, and end up with degradation of the entire object. This phenomenon, when it occurs to bronze relics, is called “bronze disease”. Copper chloride or basic copper chloride is detected in the corrosion that develops on bronze relics. The non-destructive X-ray diffraction device with parallel beams can be used to obtain diffraction data about corrosion without damaging a precious cultural property, contributing to the early detection of bronze disease.

Fig.10.
The High-temperature and high-pressure device. Chloride removal for iron.



$$Cu_2O + BTA \rightarrow Cu\,\mathrm{I}\,BTA \rightarrow Cu\,\mathrm{I}\,BTA + Cu\,\mathrm{II}\,BTA$$

$$CuO + BTA \rightarrow \rightarrow \rightarrow Cu\,\mathrm{II}\,BTA$$

Fig.11. BTA treatment:
BTA makes a stable thin protective film around the inside of the copper-metal as the chemical reacts with copper-metal and copper-oxide. This film protects the metal from chloride. This method has been used all over the world since 1968.

4-4. Iron corrosion

Bronze disease can be prevented by removing the causative substance, the chloride ions. However, the removal of chloride ions from bronze relics is difficult in most cases, because there is often a risk of causing changes to the color of the relic or damaging it in other ways. Therefore, bronze relics are usually protected from chloride ion attack by giving them a protective film over fresh metal to prevent the progress of corrosion. This is called the benzotriazole method (fig.11), a type of chemical protection. It is generally used for treating excavated copper and bronze relics.

5. Preservation of archaeological remains

Excavated remains are often reburied to preserve the site and its contents. If there are archaeological structures that would be difficult to rebury in the state they were before excavation, they are removed from the site and treated to preserve them.

However, it is ideal if the entire archaeological find can be preserved in-situ without either reburying it or removing it from the site.

5-1. Preservation of archaeological feature

If the soil is dry, houses and kilns can be reinforced and stabilized by impregnating them with synthetic resin or other materials. However, considering the vulnerability to weathering of synthetic resin, and the layout of archaeological features, it is not easy to preserve them if they are exposed. Generally, archaeological features are exhibited or preserved under a protective facility, such as an overhead structure, in addition to being impregnated with synthetic resin. Kilns often have deteriorating ceilings. If this is the case, the ceiling may be partially restored to help reinforce and support the kiln wall. The ceiling is usually restored using lightweight, somewhat flexible polyurethane foam. By partially restoring the ceiling, the structure of the kiln can be specifically revealed. This method therefore enhances exhibition and preservation at the same time.

5-2. Environmental control

Ancient sites may become degraded or even encroached by robbers, so methods for preserving or restoring them will vary according to situational demands. The Takamatsuzuka remains (in Nara Prefecture) are an example of a situation where complete preservation measures were taken. This site attracted attention among the Japanese people because there were still pictures remaining on the walls. It was considered important to restore the stone chambers based on the environment they had been in before excavation. For this reason, a total control system was installed so that the temperature and humidity inside the chambers could be maintained as they had been before the excavation. To preserve the remains, due consideration had to be taken of the structural dynamics of the stone chambers, and care had to be taken to prevent the growth of bacteria and mold, stimulated by the high humidity inside the stone chambers. Of course, since conditions vary at different sites, appropriate measures must be taken, suitable to the particular situation.

5-3. Reduced pressure impregnation

Large- sculptures carved in rock outcroppings, such as stone Buddhist images carved in cliffs, are important artifacts. Rocks are exposed to earth and weathering. They can suffer damage due to physical and chemical actions caused by temperature changes and the effects of water. With weathering, rocks can develop many gaps and absorb a lot of water, as well. They will therefore be physically damaged by the actions of the freezing and melting water. For this reason, an impregnation-reinforcing material is injected into stone outcrop Buddhist images, to protect them. The impregnated material lowers the water permeability of the rocks. Dipping, continuous spraying, pressure reduction, or pressurization is used to force the preservative material into rocks. Reduced pressure- impregnation can be used no matter what the shape or size of the object, and is widely used to preserve irregular shaped archaeological pieces, including stone Buddhist images carved into cliffs.

6. Moving materials as a means of preserving them

6-1. The removal of fragile archaeological remains from the excavation site

Archaeological relics found during excavation are usually oxidized or decayed and so, if they are removed from the site as they are, their integrity might be destroyed. On the other hand, there are times when you cannot preserve them on site. In other circumstances too, it may be necessary to dig away the part of the soil layer or the shell layer that contains the relic and take it to the laboratory for detailed examination. Archaeological relics and structures removed from the site in these circumstances are often exhibited at museums or other educational institutions.

To remove archaeological relics and other artifacts (fig.12,13), they are usually packed in rigid polyurethane foam system for internal and external support and taken from the site. There are presently several types of expanded polyurethane resin available. Two inactive liquids are mixed and stirred, activating them to foam and harden, producing an expanded styrol-like material. This material expands and completely fills the small and irregular spaces around the object. Using this material, you can completely package complicated and oddly shaped archaeological relics at the excavation site. Even after it sets up, this material can be cut easily with a knife.

Fig.12. As for a Wet Organic objects, liquid nitrogen is applied.

6-2. Collecting samples of thin-films of the stratum at archaeological sites

Fig.13. The wall, covered with Japanese paper or aluminium foil and in the cardboard box, are embedded in polyurethane form

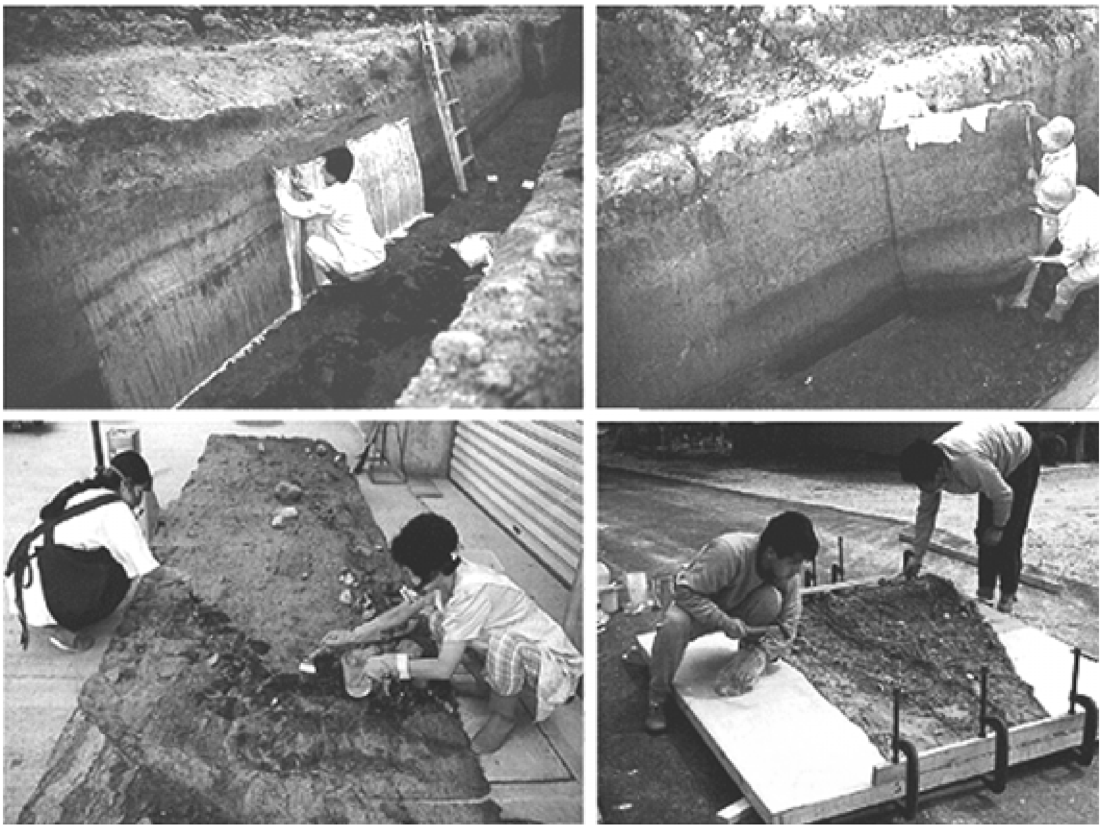
It is important to the sciences of geology, prehistory, archaeology, and soil science to record the stratigraphy. In Europe, various methods for collecting thin sections of the sedimentary layer have long been studied with a view to preserving a profile of the stratum. E.Voigt, in 1932 –33, developed a new type of resin to be used for collecting thin-film samples, from cellulose nitrate dissolved in acetone (Firma Gustav Tuth Z4/924). This resin formed a film quickly, and was flexible and strong. Later, in 1963, D.E. Dumond developed a method of using polyvinyl acetate [Elmer’s Glue-All] to collect thin-film samples of strata. In 1964, a method for using polybutyl methacrylate resin and toluene (1:10) was developed by P.H.T. Shore. Then in 1967, a method was developed by Tokuyama for using 2-acetyl cellulose and the copolymer of polyvinyl chloride and vinyl acetate, that was used for collecting outcroppings by the lack film method in order to examine the microstructure of strata and sediment.

6-3. Film removal method for soil layers

In a report of an experiment using this method, he stated that it was possible to use it to collect thin-film samples of volcanic deposits and unset-up sediment like that of quaternary deposits. He added that this method can also be used for tertiary deposits or Mesozoic or Paleozoic deposits, if they are porous like sandstone, even if the stratum has hardened to some degree. (Dai-cell LAC-7 and Denka lack #21, and Denka vinyl #1000 were used). In 1977, rubber latex was used as a backing in Britain, and it proved that it was possible to collect a thin-film sample of the stratum easily in a humid environment.

At the Nara National Cultural Properties Research Institute, we developed new types of epoxy and polyurethane resin for collecting thin-film strata samples. These new types of resin made it possible to collect thin-film samples in a very hard soil and humid environment. These materials were further improved and commercialized as Tomak NR-51 (epoxy resin) and NS-10 (polyurethane resin). In addition, isocyanate resin and acrylic resin have been used as surface treatment agents. The resin is applied to the surface you want to transfer, a backing material is attached, and then another layer of resin is applied. After the resin has set up completely, the film is peeled off the stratum. The film is washed with water and surface-treated, and then affixed to a panel for exhibition or storage (fig.14).

Fig. 14. After the stratum is made smooth, the resin is spread. Backing is done by using gauze. After consolidation, the stratum is peeled off.



Finishing stage of preparing the film surface by spraying resin

Film removal result displayed in a museum.
Even heavy materials like potsherds can be fixed onto film

Characteristics of Waterlogged Woods

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1. Introduction

Almost every organic material is a link in a food chain, and will normally be decomposed by fungus or bacteria and eventually disappear. Yet numerous wooden artifacts and pieces of natural wood that are found from archaeological sites have retained their shapes despite having been in the ground for centuries. Wooden objects unearthed from archaeological sites are generally referred to as excavated wood. The reason why excavated wood has survived over the centuries to the present day is not that it has been in a situation where it was removed from the food chain, but rather that while it was still in the food chain it was in a special environment where the deterioration process advanced quite slowly. The site environments where wooden relics are discovered fall into these general categories:

1) Bogs (especially peat bogs)
2) Soil where oxygen is cut off by underground water
3) Bottoms of rivers, lakes or seas
4) Glaciers or permafrost
5) Deserts

It seems that in these environments, excavated wood retains its form very well over the centuries because the activity of the decomposers that actively decay wood is largely suppressed. Nevertheless, since deterioration–albeit very slow–has definitely occurred in almost all of the wooden remains excavated from archaeological sites except those in deserts, some kind of conservation treatment must be carried out.

Conservation treatments for excavated wood can be traced back to the first use of potassium alum in Denmark in the mid-nineteenth century. However, after some 80 years had passed, objects treated with this method were found to have developed serious problems, and potassium alum has therefore not been used since the middle of the twentieth century. Thereafter, the defects of the

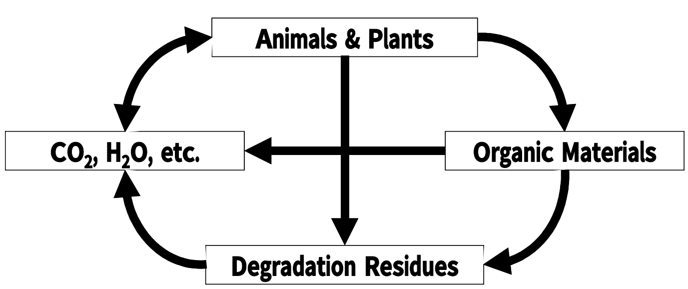


Figure 1. A food chain

potassium alum treatment were overcome as various alternative treatments for excavated wood have come into use.

This paper outlines what is known at this time about some properties of archaeological waterlogged wood, and then introduces the conservation treatment methods that are now carried out on excavated wood and other organic materials, including the latest information.

2. Characteristics of Archaeological Waterlogged Wood

2.1 Changes through Deterioration in the Constituent Components of Cell Walls

The cell walls of wood are composed mainly of cellulose, hemicelluloses and lignins. In addition to those three main components, several percent of ash and extractives are included. Among those components, cellulose and hemicelluloses are polysaccharides, which are easily decomposed and metabolized by wood-rot fungi. In the constituent analysis of wood, when lignin is selectively removed, what is obtained is holocellulose. Holocellulose can be thought of as the total of cellulose and all hemicelluloses.

Table 1 shows the main constituents of the cell walls of archaeological waterlogged wood. For simplified comparison purposes, the components have been reduced to holocellulose and lignin.

In recent wood, holocellulose content is about 70% and lignin content is about 30%. In excavated wood, the holocellulose content drops to about 20% while lignin increases relatively to about 80%. Holocellulose is the polysaccharide fraction that is easily decomposed by wood-rot fungi. While the wood is buried under the ground, the holocellulose is considerably decomposed and tends to disappear. In contrast to the polysaccharides, the quantitative decomposition and disappearance of lignin is substantially less, and as a result its content increases relatively. Although the quantitative decrease is

Table 1. Chemical composition of waterlogged woods

Wood Species	Content, %		
	Cellulose	Hemicelluloses	Lignin
Chemacyparis Obtusa (S. and Z.) Endl.	47.7	21.3	31.0
Pinus densiflora S. and Z. or P. *Thunbergii* Parl.	11.2	16.0	72.8
Cryptomeria japnica D. Don	40.8	17.8	41.4
Quercus glauca Thunb.	9.8	13.6	76.6
Quercus sessilifolia Blume	10.4	12.2	77.4
Quercus myrsinaefolia Blume	9.5	11.8	78.7
Quercus gilva Blume	10.3	13.0	76.7
Castanopsis cuspidate Schottky var. *sieboldii* Nakai	11.0	11.9	77.1
Neolitsea sericea (Blume) Koidz.	12.1	11.9	76.0
Vaccinium bracteatum Thunb.	18.3	12.3	69.4

small, it is clear that lignin actually decomposes and decreases under the ground. Archaeological waterlogged wood is regarded as wood, but it is actually in a completely different state than recent wood.

2.2 Increase in Maximum Moisture Content and Reduction in Basic specific gravity

When the structure of waterlogged wood is observed under a microscope, it can be seen to be surprisingly well preserved. As noted above, regardless of the substantial decomposition and disappearance of constituents of the cell walls, the structural characteristics are well enough preserved that the type of wood can be identified. This reflects the fact that components of the cell wall have decomposed and lost without changing the size of the cell wall itself. New voids have formed in the parts of the cell wall where components have disappeared. Disregarding pieces found in deserts, glaciers or permafrost, archaeological wood is usually discovered in humid soil. It may therefore be assumed that the reason that the size of the cell walls does not change is that the new voids opened up by the decomposition and disappearance of constituent of the cell walls are immediately filled by water.

Maximum moisture content is often used as an indicator of the scale of deterioration of archaeological waterlogged wood. The maximum moisture content is the ratio of the weight of water included in the wood to the wood weight when completely dry (weight of wood substance), expressed as a percentage.

$$u = \frac{m_w - m_0}{m_0} \times 100$$

u: maximum moisture content, m_w: water saturated weight, m_0: weight of wood substance

As noted above, the constituents of the cell wall decrease along with the deterioration of the wood, and since water increases by that amount, naturally the maximum moisture content increases. Therefore, by determining the maximum moisture content of archaeological waterlogged wood, the degree of deterioration of the wood can be estimated. To put it simply, the higher the maximum moisture content, the greater the deterioration. However, since the maximum moisture content generally differs by species or specimen even for recent wood, in order to gauge the level of deterioration with some degree of accuracy, it is desirable at the least to compare the figure with the average value for recent wood of the same species.

Basic specific gravity is the weight of wood substance per cubic centimeter in the state of maximum swelling.

$$D = \frac{m_0}{V}$$

D: basic specific gravity, V: volume of maximum swelling

For archaeological waterlogged wood, since the wood substance is reduced even though the outward size is unchanged, its basic specific gravity may decrease along with the progress of deterioration (Figure 2).

As basic specific gravity also varies according to the wood species or the specimen, as with maximum moisture content, it is desirable at the least to compare the figure with the average value for recent wood of the same species.

Maximum moisture content and basic specific gravity vary according to the decrease of constituents, and hence there is a very close relationship between these two characteristics that is approximately expressed by the following equation (Figure 3).

$$D = \frac{R\delta}{\delta + 0.01u}$$

R: density of cell wall,   : density of water

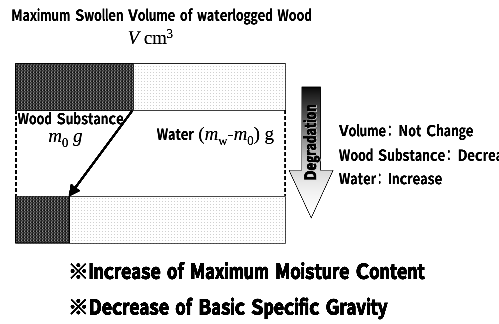


Figure 2. Degradation of buried woods

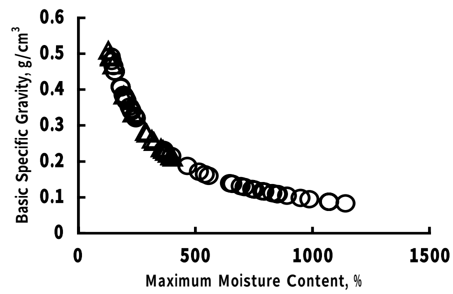


Figure 3.
A relationship between maximum moisture content and basic specific gravity

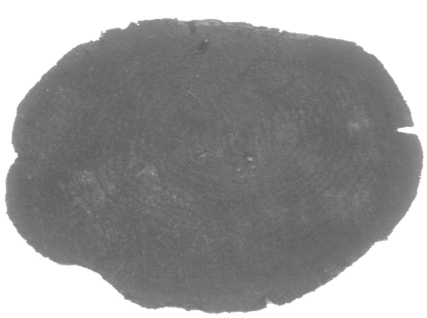
2.3 Shrinkage through Drying

Trees grow in thickness as they grow in length, and there is often some degree of difference in the physical properties of a piece of wood according to the direction of measurement. In wood science, three basic directions are defined. Such a difference in properties according to direction is called anisotropy, and the shrinkage of wood through drying is a physical property that shows striking anisotropy.

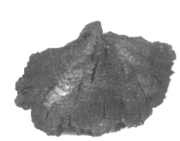
Drying archaeological waterlogged wood often leads to drastic shrinkage and deformation (Figure 4). Once such shrinkage and deformation has occurred it is difficult to return the wood to its previous size and shape even by reimmersion in water. With recent wood, thorough drying does not result in such extensive shrinkage, and reimmersion in water will restore it to almost the original size.

The degree of shrinking in wood is expressed as the shrinkage. When a wet wood is shrank by

Figure 4. Deformation of an archeological waterlogged wood



Before drying



After drying

drying, the shrinkage of the wood is the ratio of the dimensional change to the original dimensions, expressed as a percentage. The shrinkage when wood is dried completely from a state of maximum swelling is called the maximum shrinkage.

$$S = \frac{L_{\mathrm{w}} - L_0}{L_w} \times 100$$

S: maximum shrinkage, L_{w}: maximum length, L_0: oven-drying length

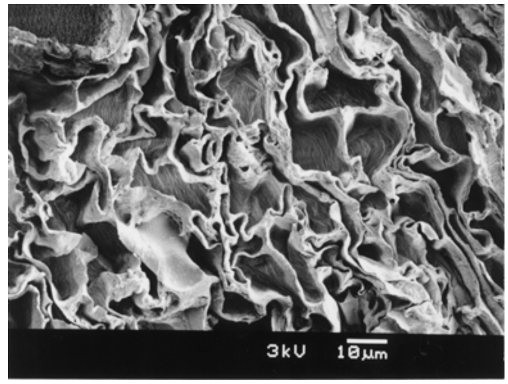


Figure 5. Deformation of cell walls

The anisotropy of wood shrinking tends to follow the approximate ratio of 1 for longitudinal shrinkage to 5 for radial shrinkage to 10 for tangential shrinkage. Since water soaks into archaeological waterlogged wood in an amount equal to the disappearance of constituent components of the cell walls, archaeological waterlogged wood shrinks drastically with drying. While tangential shrinkage amounts to 7~8% in recent wood, in archaeological waterlogged wood it often exceeds 60%. In other words, a 10 cm object shrinks to about 4 cm. The more deteriorated the object, the greater the shrinkage. Shrinkage anisotropy in archaeological waterlogged wood is most pronounced in the tangential, then in the radial, then in the longitudinal direction. In recent wood the order is the same, but the ratios are not necessarily the same.

For wood in general, shrinkage occurs in the range of moisture content below 30%, which is the fiber saturation point. When archaeological waterlogged wood is dried, shrinking and deformation begin to occur over a much higher range of moisture content. That shrinking and deformation does not result from water escaping from the cell walls, but rather from the evaporation of water from lumina and other macro-spaces. Water is a liquid with very high surface tension. When a liquid with such high surface tension starts to evaporate via one of the extremely small pits that connect one cell to another, the interior of the cell is decompressed and a strong attractive force is generated. This tends to attract an influx of outside air to the interior of the cell, but that influx is blocked by the surface tension of the water that is in the pit, causing the cell to buckle and deform along with the reduction in water (Figure 5). This phenomenon is known as collapse. Hence in archaeological waterlogged wood, the fact that shrinking and deformation occurs in a range of moisture content that is much higher than the fiber saturation point may be regarded as being

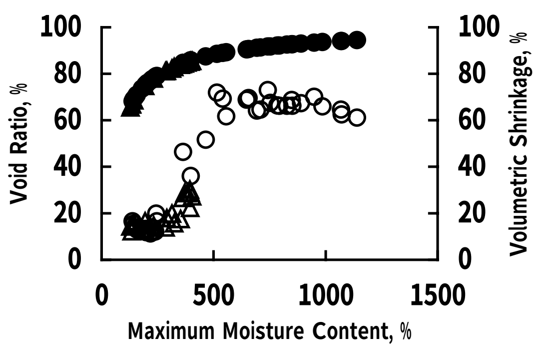


Figure 6. Changes of void ratio and volumetric shrinkage of buried woods

caused by the cell wall having lost the strength to bear the surface tension generated by the evaporation of water.

The fragility of the cell walls results from decomposition and leaching of components of the cell wall structure, and also depends on the increase in the voids inside the wood. Consequently the shrinkage due to drying of a piece of excavated wood may be expected to escalate suddenly at the point where the amount of air space inside the wood increases to a certain level. In Figure 6, the overall porosity and the maximum volumetric shrinkage are plotted against the maximum moisture content or a wood sample. This shows that the overall void ratio increases sharply in the range of the maximum moisture content. Meanwhile, assuming that the fiber saturation point is unaffected by the degree of deterioration and remains virtually unchanged at 0.3, the temporary void ratio will gradually decrease.

That indicates that as recovery occurs through moisture absorption and the amount of temporary void decreases, collapse will be caused and the amount of permanent void will rapidly increase. The rise of the maximum moisture content to the 200% level indicates a maximum bulk shrinkage that follows the line of the temporary void ratio. In this range, rather than being associated with the collapse of permanent void, the shrinkage from drying appears to depend rather closely on the blockage of temporary void due to desorption of moisture. If similar correlations can be derived for many kinds of wood, the data may well be useful in the selection of appropriate methods of conservation treatment.

3. Methods of Conservation Treatment

This section describes the treatment methods that are in current use, in keeping with the principles outlined in the previous section for the preservative treatment of organic materials.

3.1 Polyethylene Glycol Impregnation

The highly reliable PEG method is one of the best treatment methods using water-soluble impregnation agents. The PEG method was pioneered in the late 1960s and early 1970s by Broson and Christensen of the National Museum of Denmark with the Skuldelev Viking ships, and by Barkman with the Wasa warship in Sweden. For small objects an impregnation tank is used to perform the treatment, while for the huge ships which could not feasibly be placed in tanks, a PEG solution was sprayed onto the wood. In Japan PEG was first used to treat tablets discovered at the *Gokuraku-bo* of the *Gango-ji* temple in Nara, and the first treatment with the currently used heatable stainless-steel impregnation tanks, in 1972, was for dam parts excavated from the Kodera site in Matsuyama.

PEG is a polymer with the following formula:

$$HO(CH_2CH_2O)nH$$

where *n* is the number of repetitions inside the parentheses, i.e. the degree of polymerization

The properties vary with the molecular weight. PEG 4000S, with a mean molecular weight of about 3300, is used for conservation treatment of wet organic archaeological materials. A solid at ordinary temperature, PEG 4000S is easily soluble in water and an aqueous solution of about 50% can be produced at room temperature. It melts when heated to 60°C and becomes entirely liquid.

The PEG impregnation treatment begins by immersing the artifact in a low-concentration 20% solution. Then the concentration is gradually stepped up along a predetermined gradient. During the treatment, the PEG concentration and the condition of the artifact must be monitored. With some objects and some kinds of wood, drastic shrinking and warping may begin as soon as a certain concentration is reached. This results from too high a concentration gradient inside and outside the wood, and is actually due not to PEG diffusion into the wood, but rather to dehydration of the wood occurring on a priority basis, similar to the phenomenon of natural drying. To preserve the shape when this happens, the PEG concentration must be temporarily lowered and then raised very slowly, and in some cases it is better to switch to the freeze-drying method described below. Care must also be taken with respect to acidity, as PEG will break down in acidic conditions even though it is a stable polymer. Organic objects are penetrated by a variety of elements while they are buried underground, and many of them are acidic when excavated. As heating accelerates PEG decomposition, the pH level of the solution must be monitored during the treatment.

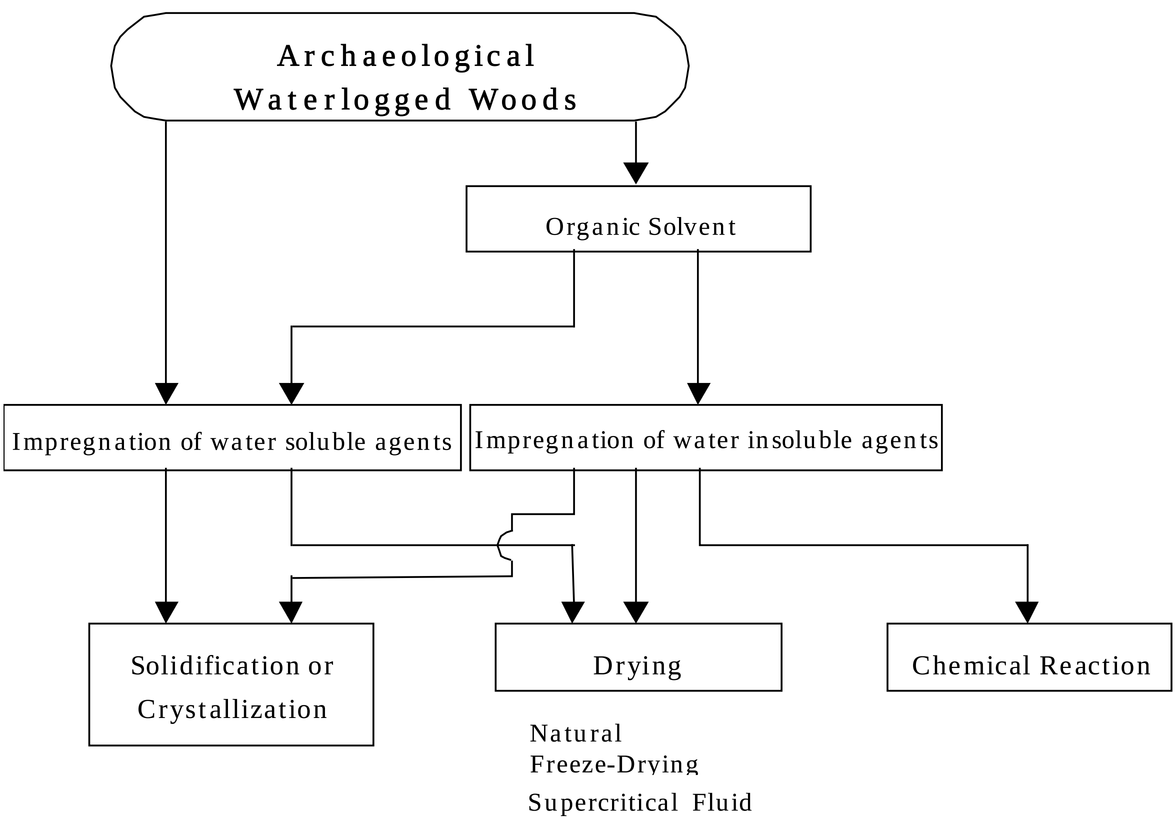


Fig.7 Schematic diagram of conservation treatments of archaeological waterlogged woods

Impregnation is usually performed up to nearly 100% PEG concentration. But with coniferous wood that is in a good state of preservation, it is sometimes advisable to remove the object from the tank when 80% concentration is reached and allow it to dry naturally.

The ease of performance and the safety and stability of the chemical make PEG impregnation a highly reliable treatment method. Yet there are some problematic aspects: the treated object takes on a darker "wet" coloring, and penetration or diffusion may be difficult due to the high average molecular weight (3300) and large molecular size of PEG. Cleaning away PEG on the surface, using alcohol that has been warmed in a hot-water bath, can substantially brighten the darkened surface. Objects for which penetration is difficult have been successfully treated with a two-stage impregnation method using PEG with different molecular weights, and by adding a surfactant to the aqueous PEG solution. The two-stage treatment consists of impregnation first with a solution of PEG 400, which has a low molecular weight and will penetrate spaces the heavier chemical cannot enter, and then with a solution of PEG 4000S. There is a risk of PEG elution from the treated artifact if it is placed in an environment where the relative humidity exceeds 85%, because PEG itself has high affinity with water. Hence it is best to store treated artifacts in a stable, low-humidity environment.

3.2 Sugar Alcohol Impregnation

To overcome problems in the conservation treatment of wooden artifacts using PEG and sucrose, and to identify an alternative material for treatment, Morgos of the Hungarian National Museum and Imazu of the Kashihara Archaeological Institute have conducted experiments with sugar alcohol impregnation since the late 1980s. Imazu *et al* found that lactitol was an outstanding candidate due to its effectiveness in conserving organic artifacts and its low molecular weight, resistance to rotting, stability under heat, high solubility, low hygroscopicity, limited discoloring effect and reasonable cost. After experimental treatments, lactitol was put into use for conservation.

The impregnation process for lactitol is almost the same as that for PEG. The difference is that whereas PEG melts at 60°C and thus can be added to a solution that is kept at that temperature, powdered lactitol can be added to a vessel heated to 60~80° only up to a concentration of about 70%, after which the concentration can be increased to a maximum of about 90% by means of gradual evaporation of water from the solution.

It is in the drying and hardening phases that lactitol treatment differs significantly from PEG treatment. After removing a PEG-treated artifact from the treatment solution and washing the surface with water, it is cooled in order to harden the PEG inside it, but cooling alone is not sufficient to harden the lactitol solution inside an artifact. To promote crystallization of lactitol, the surface of the object must be covered with lactitol powder which will serve as crystal nuclei. Also, because there are four kinds of lactitol crystals which have different coordinate numbers for water of hydration, monohydrates must be produced in sufficient quantity to ensure good crystal formation. For this purpose, after covering the surface with lactitol monohydrate, the object is dried by keeping it at a temperature of at least 50°C.

The lactitol impregnation method has many advantages as noted above, and the treatment has been applied in a growing number of cases. Yet problems remain: sometimes the impregnation density is low, and cracking may be caused by the formation of trihydrates due to non-uniform crystallization during the drying process. Further development work is needed.

3.3 Higher Alcohol Treatment

The greatest concern in the conservation treatment of excavated wood is the long time period required for chemical impregnation. One way to shorten the time required for penetration of the chemical into the excavated wood is to lower the molecular weight, i.e. the molecular size, of the chemical. Among water-soluble impregnation agents, as noted above, sucrose and sugar alcohol are the leading treatment agents. On the other hand, non-water-soluble solvents and resins may also be used, and a treatment method using higher alcohol, which has a low molecular weight, is under development.

Higher alcohol is the term used for any alcohol with more than six carbon atoms. Higher alcohols that are used for conservation treatment of archaeological waterlogged wooden artifacts include stearyl alcohol (molecular weight of about 242) and cetyl alcohol (molecular weight of about 270). In contrast to methyl alcohol and ethyl alcohol that mix well with water, stearyl alcohol and cetyl alcohol are insoluble in water. They will melt to liquid form when heated to about 60°C.

The procedure for treatment with higher alcohol is to first substitute methyl alcohol for the water in the wooden artifact, then immerse it in a methyl alcohol solution containing 20% higher alcohol, and gradually raise the concentration of higher alcohol.

One advantage of this method is the short amount of time required for dehydration and substitution with methyl alcohol followed by impregnation with higher alcohol. Another is that since the higher alcohol itself is not hygroscopic, there is no need to worry about elution of the chemical after treatment even if the object is placed in a humid environment.

Fatty acid ester is another non-water-soluble agent with which treatments are being performed on an experimental basis.

3.4 Freeze Drying

Freeze drying methods are another means of drying and stabilizing the treatment chemical. In the freeze drying treatment, after the sublimated vapor is removed, further sublimation is brought about by one of two techniques, vacuum freeze drying or freeze drying at normal pressure.

To enhance the efficiency of the freeze-drying treatment, a pretreatment is performed which temporarily replaces the water contained in the wooden object with *tert*-butyl alcohol. When the pretreatment is added, there is a definite brightening in the color of the freeze-dried wooden object. For that reason this technique is often used for the conservation treatment of wooden tablets (narrow tablets used for official records in seventh and eighth-century Japan).

For coniferous wood in a relatively good state of preservation, PEG impregnation is not continued to the normal 100% concentration but is halted at a level between 60 and 80%, after which freeze drying is performed.

Experiments are under way in the application of high-vacuum freeze drying to very large wooden artifacts. There are three kinds of wood that are especially difficult to treat: camphor, chestnut, and oak. Large artifacts made from these kinds of wood tend to twist and crack in the course of a normal PEG treatment. As it is impractical to prepare a heatable treatment tank that can accommodate a very large wooden artifact, the impregnation treatment for such an object must be performed at room temperature. It has been found that such large artifacts hold their shapes remarkably well when pretreated at room temperature with a mixture of *tert*-butyl alcohol, water and PEG, and then dried in a large facility using the high-vacuum freeze-drying method.

4. Conclusion

Conservation treatment of wet organic archaeological objects has been performed with the main goal of drying them without shrinkage or deformation so they are suitable for display and can withstand storage. Yet the purpose of conserving cultural assets is not limited to shape retention. It is vital to keep in mind that in addition to information that can be grasped visually, there are other kinds of information hidden within a cultural asset.

This paper has surveyed the conservation treatment methods that are currently used for organic artifacts, and for archaeological waterlogged wood in particular. Further study and development is required in the field of conservation treatment of organic artifacts, which includes the preliminary examination of artifacts to determine their levels of deterioration.

Recording Methods on Ruins and Relics

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1. Subject - All the things to be recognized as cultural properties

1-1. Archaeological sites, features and remains

1-2. Buildings on the ground made of wood, stone, etc.

2. Purposes of record - Record in the form of numerical data and drawings

2-1. Keep the records

2-2. Communicate the information to a third party as objective data

2-3. Utilize them as research materials (data)

3. Methods of record

3-1. Types of method to communicate to a third party

3-2. Measurement

3-3. Photograph

3-4. Description

4. Basis of measurement
- Determine the position based on the specific criteria

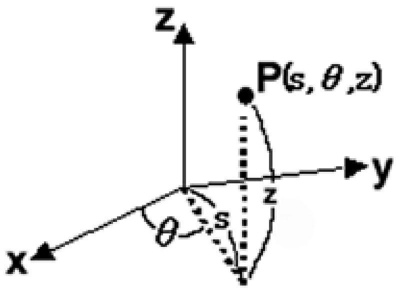
4-1. Three basic elements: distance, direction, height (x, y, z=h)

4-2. Determine the position

4-2-1. Relative position (position determined locally)

4-2-2. Absolute position (position on the earth)

Three Elements



5. Methods to record the position

- The datum point for making records and methods

5-1. Plane position

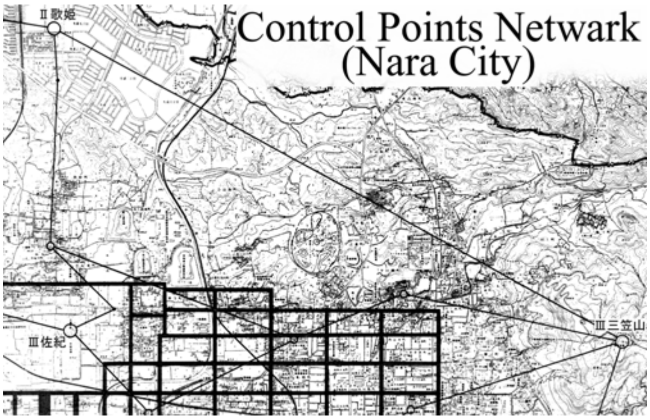
5-1-1. Record by latitude and longitude

5-1-2. Record by Rectangular Plane Coordinate System

5-2. Height

5-2-1. Make sea level the standard

6. Data of datum point



6-1. Distribution map of control points

6-2. Description of control point

6-3. Results

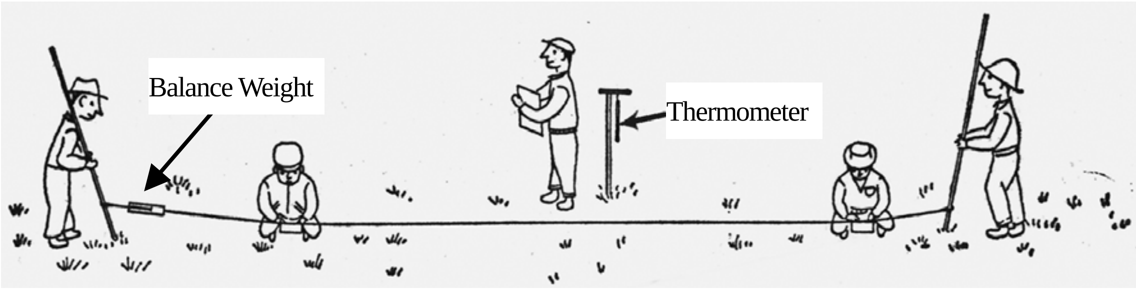
7. Practice of measurement

7-1. Distance survey

7-1-1. Direct survey of distance

a) Foot pace　　b) Tape measure (plastic, steel)

c) Invar measure　　d) Electric Distance Meter (EDM)



7-1-2. Indirect survey of distance

a) Optical rangefinder　　b) Stadia surveying

c) Triangular surveying　　d) Trilatelation

(Law of Sine-Cosine and Formula of Heron)

7-2. Angle survey

7-2-1. Equipments

a) Transit, Theodolite, Total station

7-2-2. Methods of survey

a) Set of angle measurement

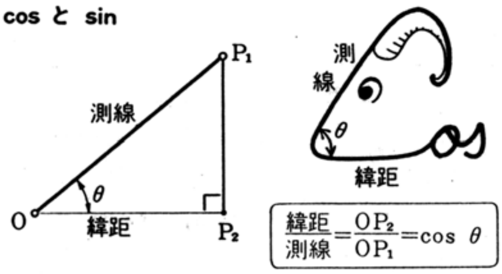
b) Repetition Angle Method

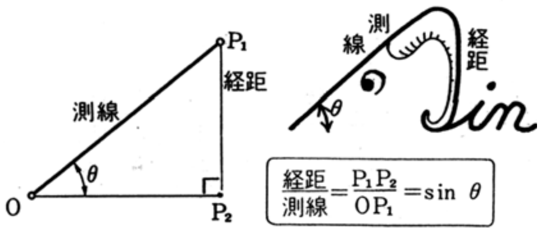
7-3. Traversing - Determine the position by combining the surveys of angle and distance

7-3-1. Connected Traverse

7-3-2. Closed Traverse

7-3-3. Calculation of latitude and longitude distance





7-4. Height survey (Leveling)

7-4-1. Equipments

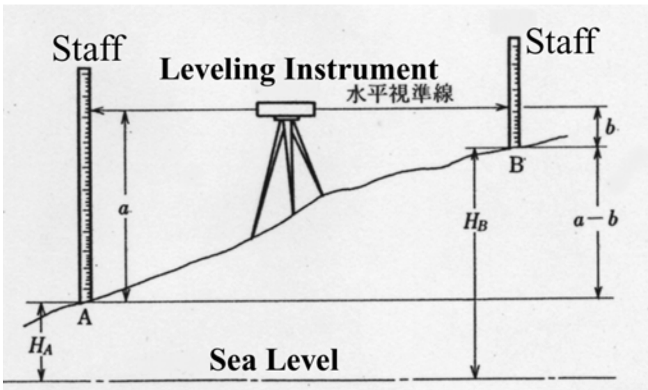
a) Tilting level b) Self-compensating level, automatic level

c) Extensible staff (rod) d) Foot plate

7-4-2. Method of survey - Center leveling is required.

a) Connected

b) Closed



7-5. Survey of details

7-5-1. Plane Table survey

7-5-2. Actual survey

(manual survey)

7-5-3. Laser scanning survey

8. Photogrammetry

Survey based on the recording media, photographs. It includes the technique of the Photo-Interpretation. Photographs are instantaneous records at the moment taken.

8-1. Principle

a) Use a pair of photographs.

b) A target should be included in the photograph to restore the original situation when it was taken.

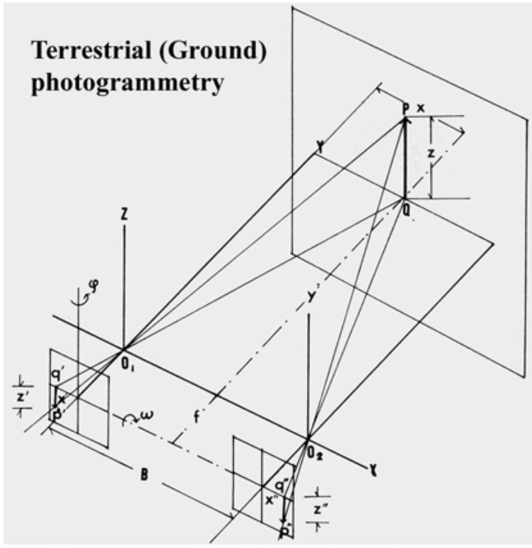
c) Draw a plan by a plotter

d) Analog plotter and analytic plotter

e) Scale of plans and scale of photographs

Photographs in a larger scale are required for drawing plans in a larger scale.

When an analytic plotter is used, the plot scale becomes variable.



8-2. Photography

a) Aerial (vertical) photography

b) Terrestrial (Ground) photography

9. Global Positioning System (GPS)

- Method to determine the position by receiving radio waves from the satellite

9-1. Principle

24 artificial satellites

9-2. Method of survey

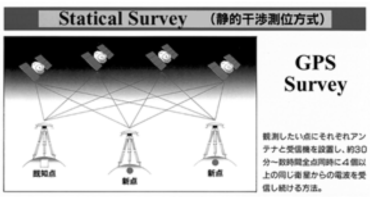
a) Independent survey

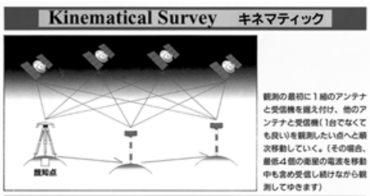
b) GPS survey

9-3. Possibilities of application

a) Datum point survey

b) Survey of details





10. 3-D Laser scanning survey

- Utilize a laser beam

10-1. Device

Receive the reflection of a laser beam as three dimensional data

a) Three types for short to long distance

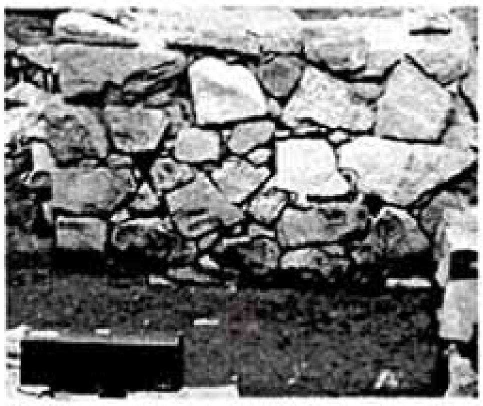
Leica Cyrax2500

Leagle LMS-Z210

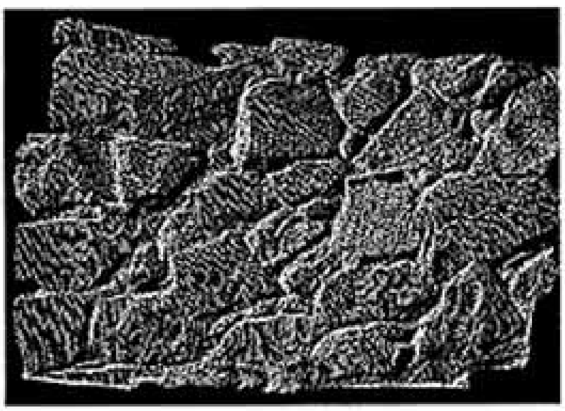
Can be applied for survey of archaeological remains like potteries, buildings and drawing of maps for general use.

10-2. Calculate and draw the plans by using computers

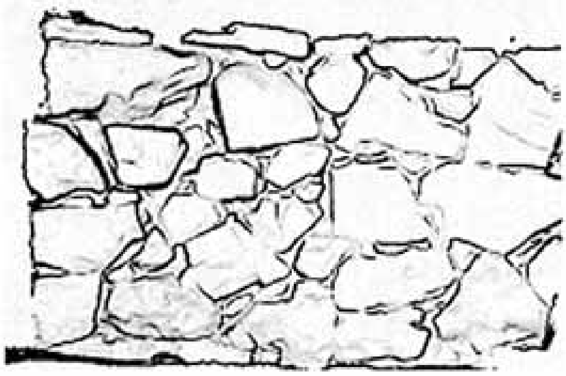
Measuring survey by Short Range 3-D Laser Scanner



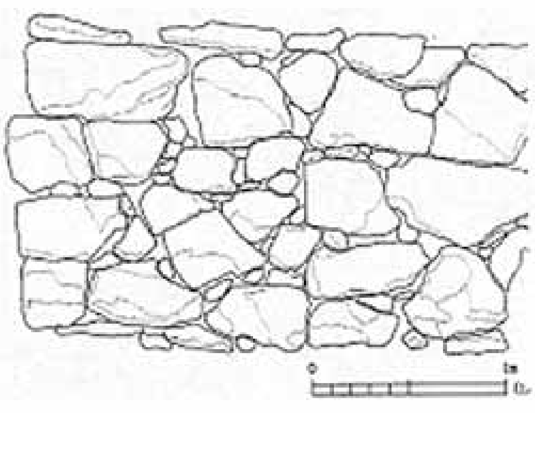
Stone Wall Measurement by Laser Scanner



Result: Dot Image (3-D)



Draft Drawing (2-D)



Final Drawing

Archaeological Prospection

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1. Introduction

The nondestructive methods of searching from above the ground for artifacts and features buried below, without making any changes to the ground surface itself. Recently, however, this field is coming to be thought of more broadly as 'cultural properties prospection', including not only the study of subsurface features, but also the diagnosis of the internal structure of above-ground wood or stone edifices. Additionally, the method of analyzing soil, in order to learn the nature of a feature after it has been uncovered through excavation, might be called 'chemical prospection' . If a pit has been detected, for example, but its nature is not well understood, the method of identifying whether it is a rubbish pit, a mortuary feature, or a simple depression in the soil through chemical analysis could also be called a form of prospection, according to the perspective currently being advanced.

2. General principles

Archaeological prospection assumes that subterranean conditions, namely differences in the soil and the presence of foreign objects, may be elicited through differences in some kind of physical property. The ground surface might, for example, be pounded with a hammer; as an acoustic pulse travels faster through hard strata, but more slowly through soft ones, it may be possible to distinguish between subsurface strata by its speed of transmission alone. Or when an electric current is applied to the ground, it does not conduct well in dry soil. In other words, the electrical resistivity is high. But in damp soil the current conducts well and the resistivity is low. Such phenomena make it possible to differentiate between soil strata and to detect foreign objects in the soil, based on differences in electrical resistivity.

In this manner, with regards to subterranean features alone, it is possible to differentiate between soils, and to detect objects of an alien nature, based on a variety of their physical properties. Archaeological prospection is a nondestructive means of probing for artifacts and features from above ground, by searching out the sizes, shapes, and extents of differences detectable to the physical sciences.

Generally speaking, when trying to infer the existence of foreign objects or differences in the soil, efforts are made to emphasize the data so that anomalies, thought to show artifacts and features, are rendered more readily understandable. This process simultaneously amplifies noise, however, requiring care in the actual treatment of the data.

Also, in investigations of limited geographical extent, it becomes impossible to distinguish between those portions of the data representing the average ground conditions for the location, and those that are anomalous. For this reason, it is desirable to measure the widest area possible.

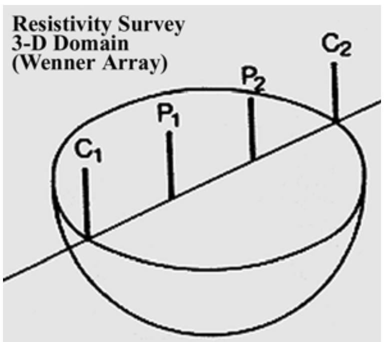
It goes without saying that archaeological geophysical prospection differs from general prospection for ground water or mineral resources. One aspect of this difference is that prospection for underground resources normally involves the probing of considerable depths (many tens of metres). If such methods of measurement and analysis are applied directly to the shallower depths of interest in archaeological prospection (often less than one or two metres), the results will be insufficient. From the perspective of these deeper geological investigations, the regions of archaeological interest fall within the range of noise associated with the Earth's crust.

Of great importance for understanding the results of prospection, since it is being conducted for archaeological sites and artifacts, is the need to refer to the results of previous investigations of the site in question and the immediate environs. It is necessary to consult sufficiently with the archaeologists investigating the site in question. When a geophysical anomaly is detected, if previous archaeological findings for that site and those of the surrounding area are taken into consideration, this should enhance understanding of what is causing the anomaly.

If the site and surrounding are totally unknown archaeologically, and moreover there is no general information about the site, it may be possible nevertheless to distinguish between different soils on the basis of some inherent property, and to determine the extent of such differences. But in such an area it is not possible to link the results of prospection with particular types of artifacts or features. If prospection is conducted at a location where not even a distribution survey has been undertaken, and where no record exists of the recovery of artifacts, the prospection results will be of little validity.

3. Earth resistance surveys

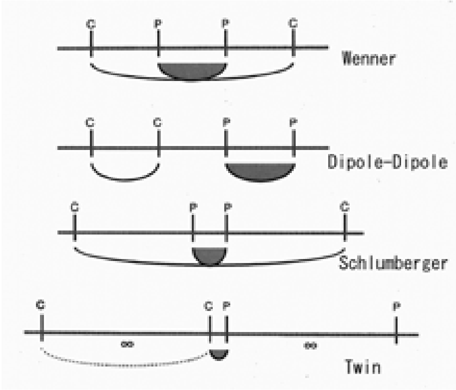
3-D Domain for measurement



This method consists of passing an electric current through the ground, and then inferring the presence of artifacts and features from differences in electric resistivity produced by different soils or by foreign objects. There are many methods, using different configurations of electrodes, for measuring resistance to an electric current flowing through the ground. These include the Wenner, Double Dipole, Schlumberger, twin electrode configurations, and so forth (1). The basis of measurement for these configurations is the use of four electrodes, two for the current ('C') and two for measuring the potential difference ('P').

The difference between the various electrode configurations is one of measurement sensitivity. Double Dipole is the most sensitive, followed by Schlumberger, Wenner, and then twin electrode[(2)]. Of these, the Double Dipole and Schlumberger configurations are seldom used for archaeology. This is because variations in the contact resistance, between the electrodes and the soil in which they are inserted, greatly affect the resulting measurements[(3)]. When using these configurations on poorly conducting ground, salt water is often poured at the points of contact in order to obtain sufficient conductivity between the electrodes and the soil. Another reason why these configurations are not used archaeologically may be because they are greatly affected by differences in surface topography[(4)], making the results difficult to interpret.

Probe Array Configuration



In archaeological prospection, use of the Wenner and twin electrode configurations is common. This appears to be because, unlike geological prospection which aims at producing a *pseudo-section* (i.e., a vertical cross-section), and takes measurements with a large number of fixed electrodes, in order to obtain information showing the sizes and shapes of features extending over a horizontal area, archaeological prospection uses a method in which the electrodes have to be moved between each measurement. Even though the contact resistance changes slightly with each measurement as the electrodes are moved, since the modern instrument impedance is high the effect on the measurement is not great[(3)]. Another reason why these configurations are commonly used is the commercial availability of such equipment adapted for these methods.

3-1. Survey equipment

Multipurpose Resistivity Meter and RM15 Resistance Meter

Equipment employed in archaeological prospection includes all-purpose instruments used for generalized surveying, and those developed especially for archaeological applications. Generally speaking, all-purpose instruments must be capable of greatly increasing the electric current, when prospecting in deep strata, for which the electrodes must be spread widely apart. These instruments therefore have the benefit of being able to increase the signal/noise ratio by elevating the current. Since they are capable of high-voltage electric output (currents of 20 mA or greater), caution must be exercised to prevent harmful effects to the operator, and careless contact with the electrodes should be avoided. Because it is not possible to use these instrument in a portable fashion, the power unit location is fixed, and wires are run to the electrodes. In geological prospection, the electrodes are not moved for each measurement once they have been initially set. Accordingly, this method is used mainly in archaeological prospection when the objective is to produce a vertical “pseudo-section”.

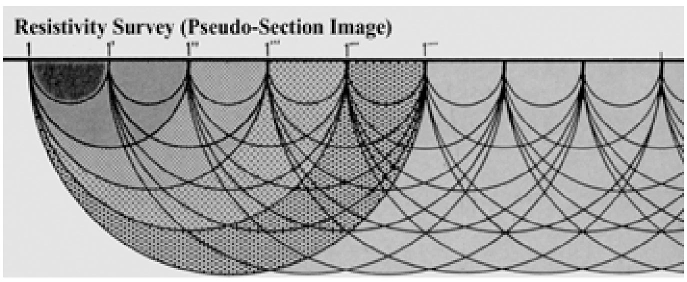
The RM15 Resistance Meter (Geoscan Research, England), is an example of equipment widely used in archaeological prospection. Designed for use mainly with the twin electrode configuration, the instrument is mounted on a portable rectangular frame, with the two mobile probes (C_1, P_1) fixed to the bottom of the frame. The remote probes (C_2, P_2), set at a position sufficiently removed so that the flow between the current probes (C_1, C_2) is radial, are connected to the instrument by wires. When the electrodes are pushed into the ground at each measurement position, data are automatically recorded and saved on a mobile data-logger. The system is one permitting very speedy measurement - typically ~0.7 hectares per day with experienced operators in suitable locations.

The mobile probes on the frame sold with the RM4, a prototype of this model, were fixed at an interval of 0.5 m, but with the RM15 the probe interval can be selected from 0.5, 0.75, 1.0, 1.25, and 1.5 m. Also, using several of these intervals, it is possible to take measurements for a *pseudo-section*.

3-2. Survey methods

Survey methods can be divided into two types. One aims to produce a *pseudo-section* as a vertical profile, the other seeks to find the horizontal distribution of electrical resistance variations. If the mobile probe interval is widened in earth resistance prospection, it is possible to obtain information from deeper strata in the soil. In three-dimensional terms, each measurement roughly represents the average electrical resistivity of a hemispherical volume in the soil. If the probe interval is widened, proportionately greater volumes of soil are averaged, but small objects become difficult to detect. From experience, the greater portion of the information is obtained from a depth up to half the probe interval; if the latter is 1 m, for example, the readings typically reflect conditions down to 0.5 m in depth.

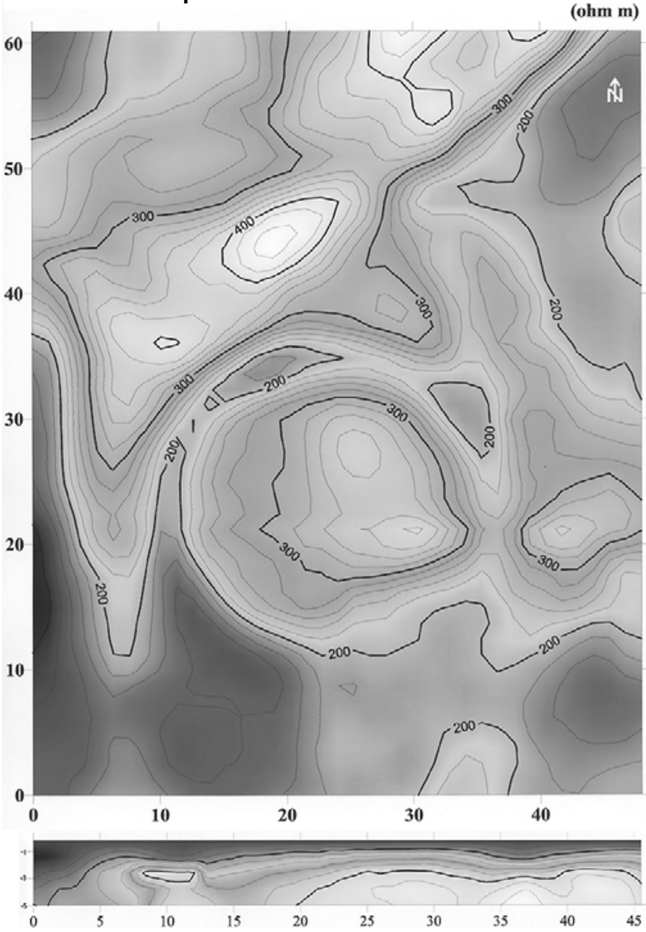
3-3. Vertical profiling



By traversing a single line several times, and increasing the electrode interval on each traverse, followed by displaying the results as a series of rows laid next to each other (with the smaller intervals toward the top), the result has the appearance of a vertical profile cut through the soil. This is referred to as an *apparent* or *pseudo-section* [5]. While research on analytical techniques for converting this approximate section into a true section has been underway for some time[6], it is still a matter of trial and error, and an appropriate method has yet to be developed. It is particularly difficult to analyze the soils lying underneath a stratum of high electrical resistivity near the surface.

3-4 Horizontal surveying

Horizontal Map: A burial mound



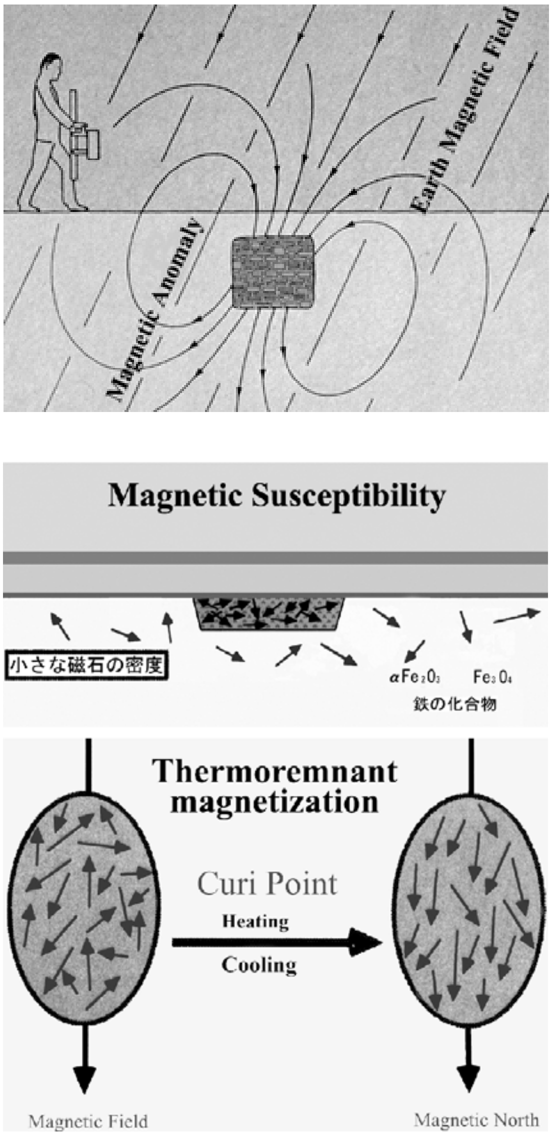
Surveys made over a horizontal area are more common in archaeological prospection than those made to obtain vertical profiles. This is because the purpose of prospection is more often to determine the location of artifacts and features, by observing the distribution of electrical resistance, and attempting to infer the nature of anomalies from their shapes, sizes, positions, and relative strengths.

In this type of survey, measurements are often displayed as maps showing the horizontal distribution of earth resistance, with collected data often averaged by dedicated software over a number of adjacent measurement points. In other words, the value for any point is replaced with the average of its own measured value plus those of the four nearest measurement points. Since this is the smallest area for which averaged values can be calculated, the use of this method is common. This is because there may be anomalies in the process of taking any individual measurement, or discrepancies in the actual measurement interval; making the averaged area small is intended to minimize the resulting disparities.

If vertical profiling as described above is conducted over a large number of parallel lines, it is possible to obtain results similar to those from a horizontal survey[7]. These data may first be processed to approximate a series of true vertical sections, and then it is possible to compile a horizontal plan for specific depths. This is similar to the *time slice technique* used with ground-penetrating radar data. Further, it becomes possible to produce three-dimensional renderings which approximate the particular object under study, using only resistivity data[8]. Research aimed at developing this type of three-dimensional resistivity representation is likely to advance in the near future.

4. Magnetometer surveys

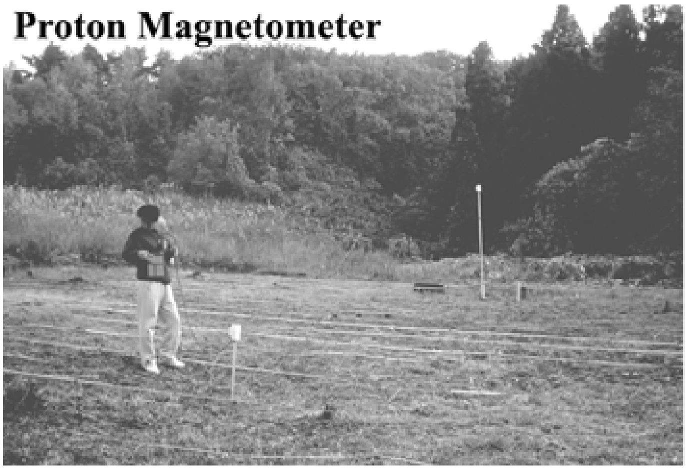
Image of Magnetic Survey

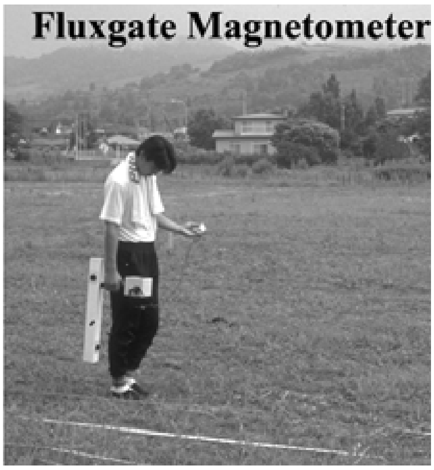


This method infers the presence of subterranean artifacts and features by measuring magnetic fields. If there is a difference in magnetism between a feature and the surrounding soil, there will also be a slight difference in their effect on the Earth's magnetic field, which can be detected by magnetometer surveys(9). Iron-oxides (Fe_2O_3, Fe_3O_4) are the most widely-distributed strongly magnetic substance on the Earth's surface.

Apart from searching for features which may be detected by slight differences in magnetism, magnetometer surveys have the unique characteristic of being a very powerful method for the prospection of kilns and hearths which display thermoremanent magnetism. Even though a hearth may have turned visibly red as a result of being heated, as the soils making the hearth and those around it are essentially the same, it is very difficult to detect a difference in electrical resistivity. Because of the physical phenomenon of thermoremanence, in which the magnetic domains within the feature are re-aligned by heating, the hearth produces a large anomaly by greatly distorting the Earth's magnetic field, which is possible to detect with magnetometers(10).

In contrast to other, more active, survey methods, magnetometer surveys consists of a passive measurement of the Earth's magnetic field, which is a drawback in conducting the survey. When railroads, motor vehicles, houses, or other objects containing masses of iron which produce magnetic anomalies greater than those of archaeological features, are near the survey site, the small variations caused by the features are masked by these larger disturbances, and are impossible to detect. Moving objects such as trains and motor vehicles are especially disruptive for magnetic survey work. In addition to these human influences, variations in the magnetic field surrounding the Earth also produce disturbances. These include diurnal changes in the Earth's magnetic field, as well as those which take place over the space of hours, and others occurring in a matter of minutes(11). All these disturbances are labelled 'noise'.



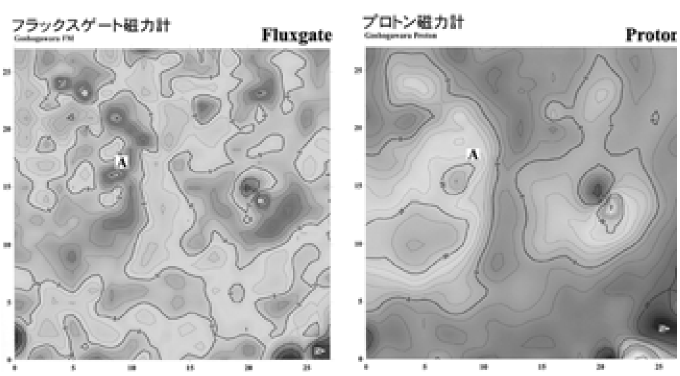


4-1 Survey methods and equipment

At present, there are two methods utilized in archaeological magnetic prospection. One measures the total intensity of the magnetic field, while the other measures its component on the vertical axis. For measuring total intensity, *proton magnetometers* are most popular, but recently *cesium magnetometers* have also become available. For vertical axis measurement, the *fluxgate gradiometer*, developed especially for archaeological applications, has become universal. Because these instruments measure different components of the Earth's magnetic field, it is necessary to exercise caution regarding the results they display.

In a proton magnetometer, it is necessary to excite the protons in heavy water or kerosene enclosed within the sensor, during which time the device must be fixed in place. This interval is short, only about one second, but this still means that more time is required for measurement than with fluxgate gradiometers or cesium magnetometers, which provide constant excitation and make continuous measurements possible.

When making a survey, measures are taken to reduce the effects of noise. For example, in total intensity surveying with a proton magnetometer, measurements can be made simultaneously using two sensors attached to the upper and lower portions of a pole (gradiometer), or using some other arrangement of two measuring devices, one of which serves as a reference station while the other is moved from point to point over the target area. In either case, assuming that both devices are subject to the same background noise, then by taking the difference between the two values, only the effects due to artifacts and features are obtained. The same method is followed when using the newer cesium



Survey results (Goshogawara kiln site)
Fuluxgate magnetometer (Left), Proton Magnetometer

magnetometers. As noted above, the fluxgate gradiometer was devised specifically for archaeological prospection. The FM18 and FM36 are two models developed by Geoscan Research, which have two sensors stacked vertically 50 cm apart, and record the differences between their readings.

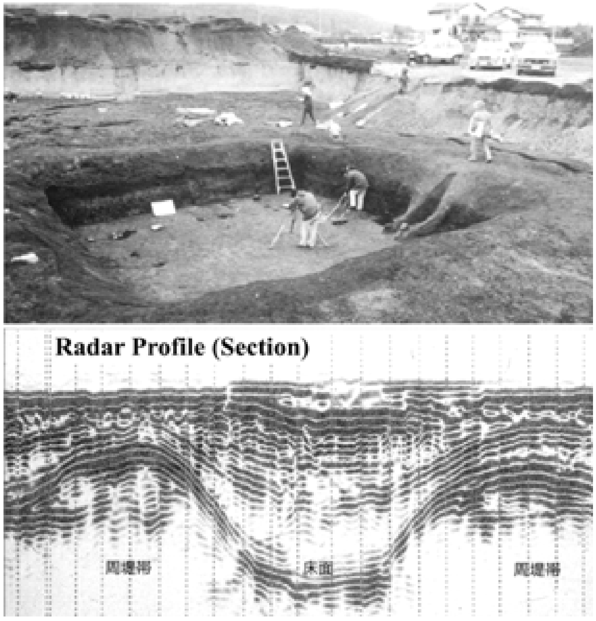
For both proton magnetometers and fluxgate gradiometers using sensors positioned 50 cm apart vertically, the effective depth of reading is about 1.5 m. Any attempt to increase the sensitivity and collect data from greater depth would require setting the sensors farther apart. Since these are placed vertically on the same pole, it becomes difficult to maintain a vertical orientation while moving, making the arrangement impractical. A tri-axial fluxgate gradiometer, which measures independently each of the three directional components of the magnetic field, has been developed(12), but it cannot be said to have been used widely yet. Analytical methods utilizing the three components independently may be a future development in this field.

5. Ground-penetrating radar (GPR)

This type of prospection applies the system and methods utilized in general survey work, such as investigations of buried pipes and underground cavities, and accordingly there is no equipment developed specifically for archaeological research. As applied research in this area is rapidly advancing, there is much information which should be given consideration for archaeological prospection. GPR in archaeology is necessarily connected with this research(13).

5-1 Principles

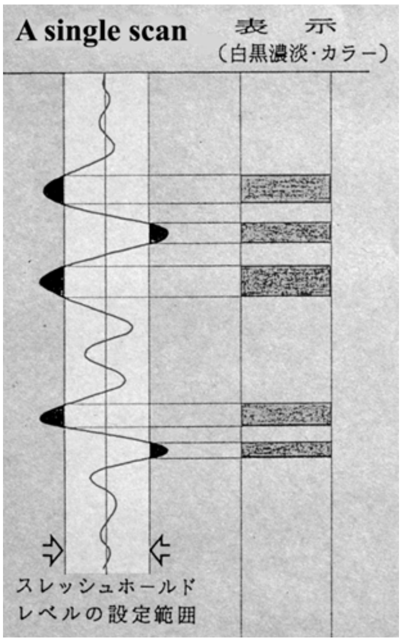
If an electromagnetic wave is propagated towards the ground, about 40% of the energy is reflected at the ground surface, but the remainder penetrates into the ground, with a portion subsequently bouncing back to the surface from any buried interface. If the returning signal is displayed in temporal sequence, in different colours or shades on a grey scale according to its strength, an image looking very much like a section of the strata in the ground may be obtained. Making inferences about subterranean conditions, namely the presence of artifacts and features, by observing these images is the basis of this method.



The electromagnetic waves utilized fall within the band known as microwaves, and the antennae used in archaeology are nearly all within the range of several tens to several hundreds of Megahertz (MHz). As this band overlaps the VHF and UHF ranges used for ordinary television broadcasts, lifting the antenna unduly when surveying in the vicinity of houses may produce noise in their reception. Electromagnetic waves also tend to leak out from the gap between the antenna and the ground surface. It is accordingly necessary to take precautions while surveying, such as maintaining a sufficient distance from dwellings.

The waves travel freely through a medium of uniform density, but if there is a difference between soils, for example, they will reflect or refract at the soil interface, where different media come together. If radical density differences, such as those offered by metals, rock, or cavities, are encountered, these will cause strong reflections. Even in cases such as postholes, where the difference between the soil within the feature and that comprising it is not great, nonetheless there will be reflections according to the degree of difference, which may allow detection of the feature.

As the waves reflect most strongly where media of very different densities come together, the largest reflection in GPR is produced between the antenna and the ground, or where the waves encounter an air and soil boundary. This is especially pronounced in pulsed radar. For this reason, any variation produced by shallow soil differences or the presence of artifacts can be obliterated by the saturated condition of the signal from the region immediately below the ground surface. It is advisable to think that this condition will apply to the first 30 cm or so from the surface, a point of caution associated with this method of prospection.



Threshold level

5-2 Instrumental considerations

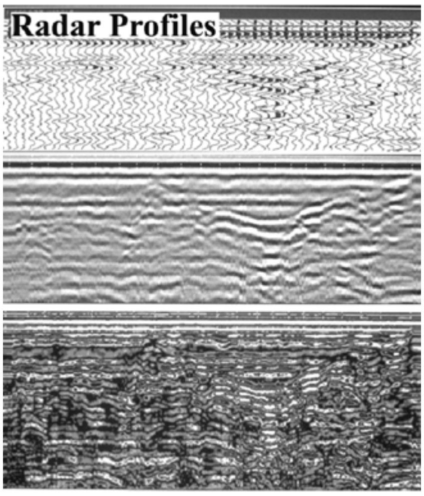
At present, the most widely-used method compresses the electromagnetic waves into pulses for transmission and reception. As the compressed wave strikes an object and is reflected by it, resonances are produced, which cause a succession of similar reflections to show below the object as a characteristic of this method. At a particular soil interface, for example, because of the reflection occurring there, a pattern of horizontal stripes continues from that point on. The occurrence of this phenomenon can be misinterpreted as a series of thin soil layers. In extremely large reflections caused by metals or subterranean cavities, these repetitive reflections continue downward for a considerable extent. In such cases, the distinctive pattern of reflection enables the inference of the object as being of metal or a similar material.

A single wave or scan can be displayed in the manner shown in Figure. In displaying images made from such data as a vertical section, portions of the scan falling within specific ranges are assigned different colours or grey scale intensities. The lowermost values of these ranges are called the threshold levels.

During actual survey work, these scans are lined up across the display image, and as the number of scans taken per second varies from several tens to more than a hundred, if the antenna is moved at a pace of about 8 – 10 sec/m, the number of scans representing the data for 1m ranges from 100 to more than 1,000. Because of this, one characteristic of GPR is that large amounts of data are obtained in comparison with other prospection methods. In most other surveys it is normal to take only one measurement over a 50 cm or 1 m interval, hence GPR is noteworthy as a prospection method which may enable studying subterranean conditions in great detail[13].

5-3 Antennae

There are two types of antennae for sending and receiving the pulses. In the *combined* or *unitary antenna* arrangement, the same antenna is used for transmission and reception, while the *split* or *dual arrangement* uses separate antennae for sending and receiving signals. With the split arrangement it is possible to combine the two antennae into a single bundle. Where a gap separates the two in a split arrangement, an angle is produced in the signal path which may be better suited to detecting certain objects, but the vertical path travelled by the signal going upwards and downwards in the unitary arrangement provides more potential for detecting an object in detail. Perhaps because only one antenna is used for sending and receiving, frequencies are generally lower in the unitary arrangement. In fact, it is difficult to distinguish between the results of the two arrangements in actual use.



Different display from same data

Methods for moving the antenna over the survey area include pulling a unit fitted with wheels, dragging one mounted on a sled, and carrying one by hand. The use of a sled keeps the unit in contact with the ground, minimizing energy loss of the pulse. The method of carrying an antenna suspended from the shoulders by ropes is used with low frequency antennae of 70 or even 40 MHz. In low-frequency surveying, the disturbance arising from the interval between the antenna and the ground surface does not greatly affect the data.

With the dual arrangement, in which the antennae can be separated by fixing the transmitter and moving the receiving antenna, it is possible to measure the velocity of the signal to a particular stratum(14). The initial and final receiving times for a wave reflecting from the top of the stratum can be read from an image recorded over a specific period of time, and therefore the wave velocity calculated from the distance travelled by the receiving antenna. The only requirements in this case is information about the distance travelled by the antenna and the travel times of the waves. In this manner, by having the transmitter and receiver in separate locations, it is possible to calculate the actual depth of subterranean features.

5-4 Angle of transmission

The wave radiating from the transmitting antenna is generally taken to be wider than 90°, although it depends on the frequency. With this wide an angle of transmission, even before the antenna arrives directly over an object, its presence may be detected from (albeit weak) reflections, travelling diagonally and being displayed on the resulting image. For this reason, objects such as pipes or even isolated stones may be displayed on the screen before the antenna reaches their actual position, and their images may appear larger than reality. These images typically describe a parabolic form below the object in the radar image(15). In a separate phenomenon, a V-shaped ditch may be displayed with an inverted V-shaped form extending downward from its bottom. Also, the edges of ditches or post holes are sometimes seen to assume sharp angles, with reflections centring upon the edge. This phenomenon, known as the *edge effect,* is seen not only in GPR, but also in magnetometer surveys and other methods. For all of the above phenomena, the reflection is not an expression of the actual condition of the soil or features.

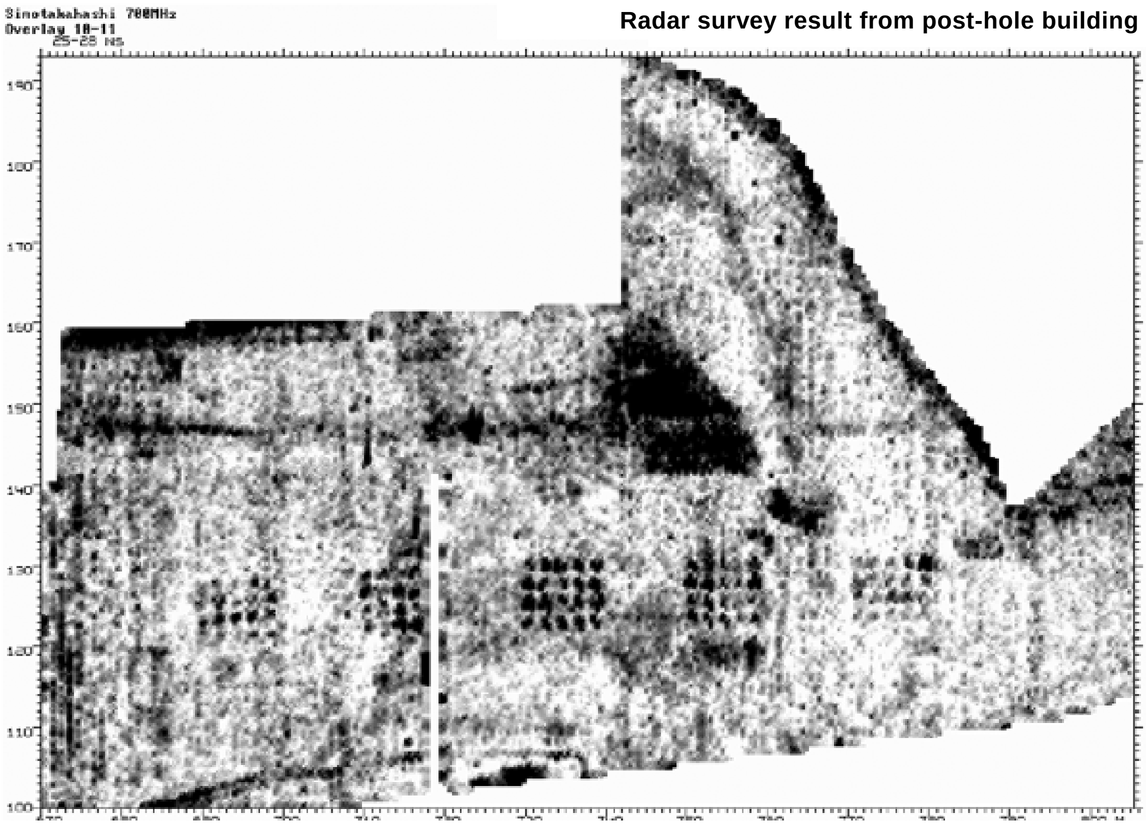
5-5 Wave frequency and resolution

The wavelength of the emitted pulse is related to antenna size and frequency. A large antenna with a low frequency emits a pulse with a long wavelength, whereas that from a high-frequency antenna is short. Furthermore, the ability of the antenna to discriminate objects, or its power of resolution, is related to the wavelength, with longer wavelengths lacking the ability to detect smaller objects. Generally speaking, antennae used in archaeological prospection with frequencies around 500 to 900 MHz are called high frequency, and those of 300 MHz or less called low. This difference in frequency is also related to the penetrating power of the wave. High frequency antennae are able to survey only shallow strata, while lower frequencies may work at deeper levels(16). With high frequency antennae of 500 to 700 MHz, it is difficult to survey depths of 1 m in wet paddy soils as seen in Southeast Asia, but it is possible to obtain data for nearly 2 m with antennae of 200 to 400 MHz. However, for dry soils such as sand or volcanic ash, it is not difficult to obtain data up to 4 m below the surface with antennae of around 300 MHz. The electric resistivity of the soil is of some value as a criterion for judging the penetration of the wave. If the overall resistivity is low, radar prospection at deep levels is not hopeful. Conversely, if the resistivity is high, then prospects for deeper radar prospection are good. Generally speaking, if the relative dielectric constant of the soil is around 27, prospection to a depth of about 2 m should be possible with a 300 MHz antenna.

5-6 Surveying

GPR equipment consists of an antenna (or antennae) for transmitting and receiving signals, a control unit which sends the signals to the transmitter, and a device to record data picked up by the receiver. It is common for the control unit and data recorder to be combined into a single device. Electric generators and batteries are used as the power source; batteries range from large items made for automobiles, to specially-designed smaller ones.

The antenna or antennae are connected to the control unit by cables, but caution must be exercised with these in operation. Since the cables themselves are capable of acting as antennae, they should be kept as far from the receiving antenna as possible. If such measures are not taken during the survey, the cables may produce noise, making it impossible to obtain good data. Similarly, when surveying with long wavelength antennae



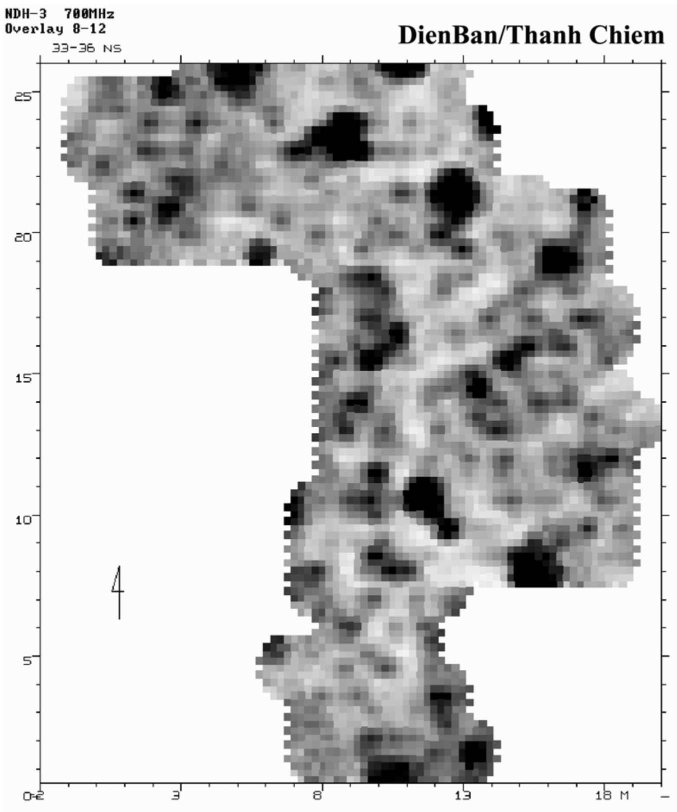
Radar survey result from post-hole building

(300 or 400 MHz), there is danger of noise from nearby dwellings or other structures. At these frequencies, the antenna's reception will be greatly affected when close to structures containing steel piping spaced less than 1 m apart, for example. Also, in large-scale surveys, if an automobile serves as the power source, or the control unit is mounted on an automobile which follows the antenna, it is conceivable that reflections will be received from the metallic body of the automobile itself.

Ordinarily, the receiving antenna is scanned over the survey area along lines separated by a set interval. This interval is determined by the size of the object being sought. If the object is small (e.g., of the order of 50 cm), the space between scan lines must be smaller than this. But no matter how narrow the interval, if the wavelength is too long for the object being sought it cannot be detected. Moreover, as discussed above with regard to resolution, since higher frequency antennae are unable to survey deeper strata, deeply-lying small items cannot be found. This is true regardless of the method of prospection employed.

Even though the signal radiates over a wide angle, if the object being sought is shallow, depending upon the scan interval used, it may fall between scan lines, and only a small portion of it may be detected. Accordingly, there are instances when it is necessary to make the interval very close. Also, depending on the characteristics of the particular antenna used, the angle of transmission may be rather narrow, making it possible that even deep lying objects will not be picked up in detail with wider scan intervals.

Another vital practical aspect of surveying is to run the scans in zigzag fashion, with each line being measured in the opposite direction from the previous one. If a feature such as a ditch presents a symmetric V-shaped or U-shaped section the direction of the scan will not matter, but if one side has a different angle from the other, it is likely that the reflection of the signal will vary between the two sides. If this feature is surveyed from both directions, each directional set will obtain a different type of data, and by comparing both sets it may be possible to learn more accurately the actual shape. With scans taken from a single direction only, there is a risk of losing important data. On the other hand, some linear features may be detected accurately when the antenna



Radar survey result from Dien Ban/Thang Chiem, Viet Nam

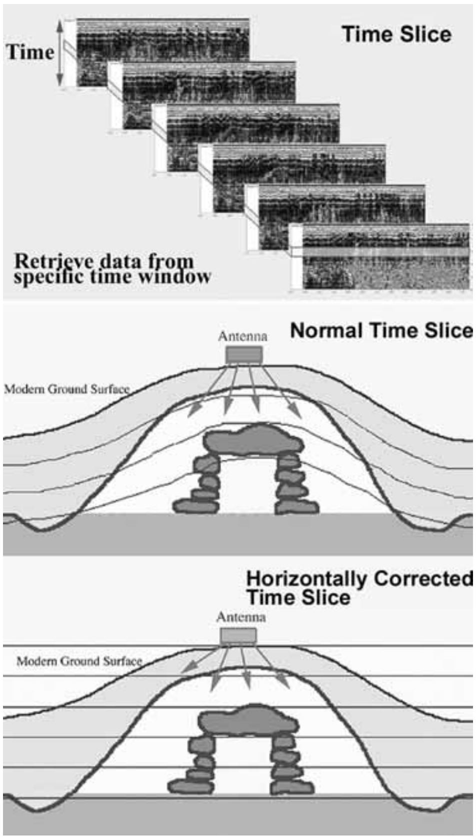
Bulletin of the Research Center for Silk Roadology
SILK ROADOLOGY 15, colour page 4, 2003

makes a traverse perpendicular to the feature, whereas the reflection obtained when the scan direction is parallel to the object is insufficient. Accordingly, it is ideally preferable to cover the survey area twice, with one set of scans run at right angles to the other. From limitations of time, however, this method often cannot be followed. As the next best measure, it is best to make scans at as fine an interval as possible.

5-7 Displaying the results

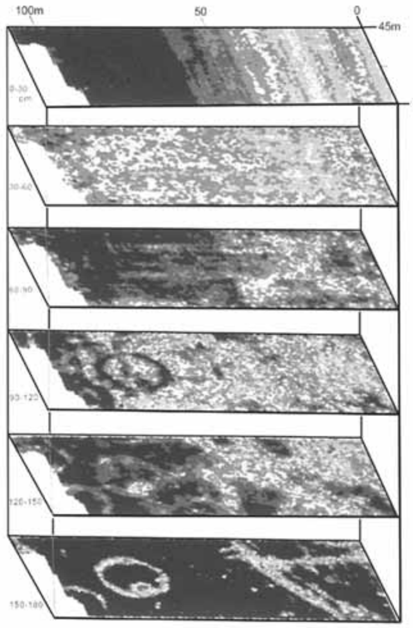
As stated above, displaying GPR results in a manner resembling a vertical section is the basis of this surveying method. A variety of techniques are used for this, such as displaying in different colours or grey scale values, or showing the outline of the wave trace itself. In examining such displays, caution must be paid to special patterns of reflection such as ringing or the edge effects described above. Also, as a characteristic of wave transmission, the velocity will be slower for wet soils, and faster in dry ones. Accordingly, should there be a feature presenting a straight line in actuality, if the soil above varies locally from drier to wetter, the object will be displayed as a curved line because the time of travel to and from the object varies with the overlying soil conditions[17]. Generally speaking, no matter what the topography of the ground surface surveyed, the results will be displayed with the surface shown as a horizontal line. Accordingly, the topography must be kept in mind when interpreting the results. Also, when scans are taken with the antenna run up or down a slope, the waves are transmitted and received at angles perpendicular to the slope, and it must be borne in mind that the results will differ in nature from those taken along a level surface.

5-8 Compiling a horizontal plan



The technique of making horizontal plans using data taken from apparent profiles, previously mentioned for resistivity, is widely gaining popularity in GPR. Data from profiles taken at a set interval are entered into a computer, and data for a particular period of travel time are extracted from each profile and arranged horizontally. This produces a horizontal plan of the distribution of the reflection, refraction, and attenuation in wave strength for a particular time period, and is called a ‘time slice’ [18]. When transposing the results of the wave behaviour onto a horizontal plan, the data must be converted to numeric values; as large differences between the greatest and smallest values make computation difficult, measures are ordinarily taken to reduce the order of magnitude of this difference.

The reason for producing these horizontal plans is because the shape and size of an anomaly thus



observed becomes the basis for making inferences about the nature of artifacts and features of interest to archaeology. If supplemental information about the physical properties of the anomaly in question is available, the inference may draw closer to the actual condition. If GPR shows a feature extending in a straight line, for example, and from the archaeology of the surrounding region this is thought to be perhaps a ditch or a moat, a road, a rampart, a roofed earthen wall, etc., then it becomes easier to infer the nature of the feature if the physical properties of the object can be brought into consideration, such as very low readings in a resistivity survey, or high signal attenuation in the radar survey. Low resistivity would suggest a feature associated with wetter soils, such as a ditch or moat; high resistivity would indicate a different sort of feature, such as a stone wall or earthen rampart. However, should a ditch with low resistivity, or a road with high resistivity be encountered in a GPR survey, if the soil above such a feature is different, this may cause a strong radar reflection. Accordingly, the reflection provides no way to determine the nature of the feature. But by utilizing the results of a resistivity survey over the same area, it is possible to specify certain physical properties of a particular locus, and it becomes possible to infer the nature of the feature.

By making a horizontal plan, at times it becomes possible not only to infer the existence of features, but also to observe historical changes in the strata they occupy. As shown in Figure for example, in a survey in search of subterranean chamber graves, from the stratigraphic positions of graves where the chamber still survives, differences may be inferred in the direction of cultivation and in the boundaries of cultivation. These differences are thought to be associated with changes over time in land ownership.

In the time slice method, when the intent is to differentiate and display separately features in overlying layers from different periods, it may not be possible to depict the desired features adequately unless the proper time slice is selected. At times it is necessary to proceed in trial-and-error fashion. Also, although data are taken continuously along the lines surveyed, as the interval between lines is ordinarily 50 cm or 1 m, it is necessary to interpolate for these regions to display the same amount of data along both the vertical and horizontal axes of the plan. Accordingly, when averaging the data in the interpolations, some definition is lost for the finer details of features, such as the corners of a square feature being displayed as rounded. Some method of preventing this effect will be needed in the future.

5-9 Topographically-modified time slices

As stated above, in GPR profiles the ground surface is normally displayed as a flat horizon.

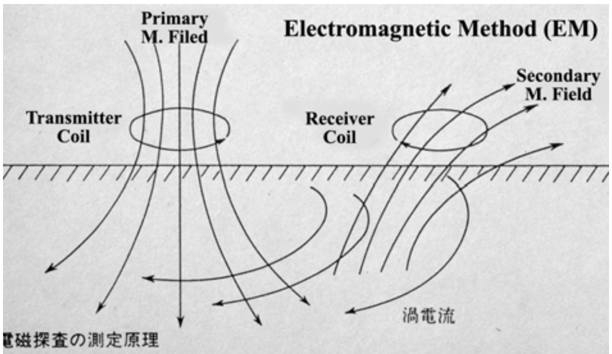
In actual survey work, such as a mound of earth covering a stone burial chamber, the ground surface rises and falls, yet the structure underneath was built with a level surface as its base. If the normal time slice procedure is followed, the slices will be made parallel to the ground surface, and the structure will not be accurately represented. For such cases some means of modifying the profile is required, so that they conform with the actual topography prior to making the slices. It is also possible to use topographically-modified time slice techniques not just where the surface level varies, but also when the ground surface itself may be flat, but the buried features are on an incline. In this case, the slices need to be taken parallel to a reflective layer in the profile images.

In comparison with other prospection methods, GPR is characterized by an abundance of data. As a tool for archaeological prospection, it is still in need of further research. It should also be borne in mind that, under certain topographic conditions, it may not be possible to use an antenna effectively, and that there is also a limit on the depth that can be surveyed.

6. Other prospection methods

While the three methods described above are those most widely used in archaeological prospection, other techniques are also employed, including electromagnetic (EM) and seismic methods, and occasionally the microgravity. The following account introduces EM.

6-1 Electromagnetic prospection (EM)



If an electric current is passed through a coil this sets up a primary magnetic field, and when this passes over substances such as soil or metals with high conductivity, a secondary magnetic field is generated(19). The EM method of prospection is performed by observing the strength of the latter, and the size of the secondary field is often expressed in units of conductance (mho or Siemens), the inverse of the ohm used for earth resistance measurements. This type of survey can therefore be used to the same effect as an earth resistance survey, and is thus classed as a non-contact type of resistivity prospection. As the characteristic of this method is the generation of a magnetic field during measurement, it has the drawback that accurate readings cannot be taken if more powerful magnetic fields or other types of noise interfere. But as there is no need to set up electrodes, it has the advantage of being easy to perform.

In addition to being utilized for the same purpose as resistivity surveying, EM is often employed in the detection of metals. Using it in parallel with magnetometer surveys for this purpose increases the effectiveness[20]. By surveying the same area with both methods, should any location show an anomaly in both surveys, this means there is some form of iron object present. But should an anomaly be detected by EM but not be picked up by the magnetometer, it is likely that some non-ferrous metal is buried at that location.

6-2 Equipment

It is generally agreed that the greater the spacing between the transmitting and receiving coils, the deeper the penetration of the survey[3]. Among equipment utilized archaeologically there are models designed for detecting shallow-lying metals with a spacing of 1 m, and those intended for searching out large deep structures such as ditches and moats, with a coil spacing of 3.6 m. The EM38 produced by the Canadian firm Geonics is an example of an instrument with a 1 m spacing, where the measuring coil can be used in two modes, one with the coil vertical to the ground surface and the other with it horizontal. The depth of information detectable in the two modes is 1.5 m for the vertical, and 0.75 for the horizontal position. Also, by taking data in both modes, it can be used for analyzing the conditions of buried strata.

7. Summary: essential points of geophysical prospection

In archaeological geophysical prospection, since the purpose is to detect the presence of subterranean features and artifacts, collecting information on previous site investigations, and historic information on the surrounding region, and making use of these in interpreting the survey are essential elements of the process. In addition, it is necessary to utilize different types of survey on the same target area, and to compare the results. The various geophysical prospection methods reviewed here such as earth resistance, magnetometer, GPR surveys, and so forth, all detect different physical characteristics of the soil. If any of these detect an anomaly, it is highly possible that an artifact or archaeological feature of some kind lies buried at that spot. Experience over the past 50 years has shown that these techniques, alone or (preferably) in combination, can provide rapid and reliable information on the location, depth and nature of buried features without the need for excavation. Not only does this reduce expense in archaeological research but it offers a uniquely powerful tool in the broader area of cultural heritage management.

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Temperature and Relative Humidity Environment of the North Section of Shoso-in Repository

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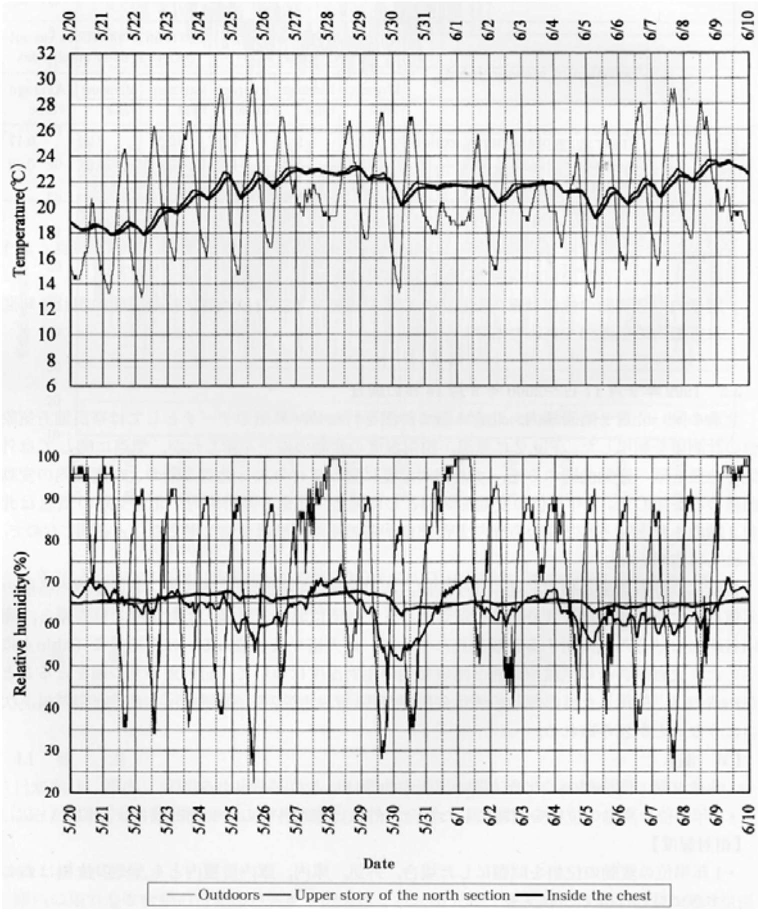
Temperature and relative humidity environment in the Shoso-in repository has drawn the attention of various researchers interested in the conservation of cultural properties since the Edo period. Investigations with a self-recording thermo-hygrometer (using a bimetal strip and a bundle of human hair) were made between 1949 and 1959 by the Osaka District Meteorological Observatory. In the last few years we have used data loggers to record temperature and relative humidity in the north section of the repository and in a storage chest inside that section. This paper presents the results of measurement over a six-week and a one-year period in 1999 and 2000.

At the daily amplitudes of variations, the average ratio of the temperature variations in the upper story of north section to the outdoors was 14/100 and that in the chest to the outdoors was 13/100, while the average ratios of variations in relative humidity to the outdoors were 20/100 and 3/100, respectively. At the annual amplitudes of variations, the ratio of the temperature variation in the upper story of north section to outdoors was 77/100 and that in the chest to the outdoors was 76/100, while the ratios of variations in relative humidity to outdoors were 60/100 and 25/100, respectively. The limited humidity variation inside the chest is due to the buffering properties of wood used.



Temperature and relative humidity variation from May 20 to June 9, 2000

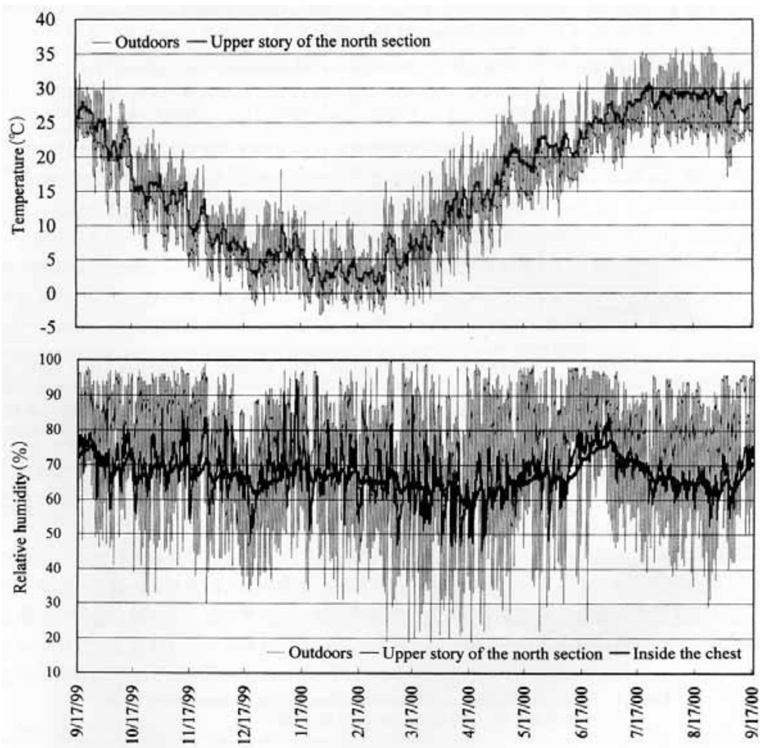


Fig. 2 Temperature and relative humidity variations, September 17, 1999 to September 16, 2000

Temperature and relative humidity variations from September 17, 1999 to September 16, 2000

The temperature variations curves for the lower story and inside the chest are not shown because they are nearly identical to that for the upper story. The relative humidity variation curve for the lower story is not shown because it is nearly identical to that for the upper story.

4. Final Report

Training course on cultural heritage protection in Asia and the pacific

Report

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The training programme for Cultural Heritage and Archaeological Conservation Science was organised by the Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Centre for UNESCO in Nara, Japan (ACCU), from 2003, July 7th to August 30th. I am a Vietnamese archaeologist and have fortunately been accepted as a participant of the programme titled: "Training course for Researchers in charge of Cultural Heritage Protection in Asia and the Pacific".

The training course was very well organised by ACCU, Nara. It focused on two important subjects:

Subject A**:** Cultural Heritage Conservation Science.

Subject B**:** Archaeological science: Archaeological research and survey methods.

The training course took place at various venues, including the Conservation Science Laboratory of Nara, the National Research Institute for Cultural Properties *(Nabunken*), the Institute of Archaeology in Kashihara (*Koshikoken)*, Nara University, and the ACCU, Nara Office.

During the training course, field trips to various museums, temples, shrines, archaeological sites, as well as conservation laboratories were taken. These field trips provided a valuable opportunity for the participants to network with experts within this field; this has promoted mutual understanding and cooperation in our work. Looking back to what I have learnt and what I have seen, I could hardly believe that I was able to achieve so much practical experiences and professional liaisons in just two months. These will be very useful for my work and I wish to share my new-gained knowledge and skills with my colleagues. The subjects covered in this training program were broad and detailed; this report could only serve as a summary of some of the main topics and what I have learnt in this training course.

I. Cultural Heritage Conservation Science

1. Conservation science for archaeological objects:

Archaeological objects are classified into many categories according to their materials and production techniques. Unearthed archaeological objects could also be scientifically classified by the degree to which their inorganic and organic components have deteriorated. Artefacts within these classifications still differ in their type and sources. Conservation science involves the study of excavated objects and their treatment methods so that they may be preserved for various purposes such as exhibition and research.

Conservation Science as a formal discipline was established in Japan in the early 1970's; it has been developed to a high standard in response to the necessity of protecting the cultural heritage in Japan.

Conservation Science is sub-divided into various branches of study:

1. XR (X-Ray Radiography) analysis for metal and wooden archaeological objects.
2. CR (Computed-Radiography) analysis for glass objects.
3. XRF (X – Ray Fluorescence spectroscopy) analysis for metal and glass objects.
4. XRD (X-Ray diffraction) analysis for metal and glass objects.
5. FT-IR (Fourier Transform Infrared spectroscopy) analysis for textile (organic) objects. This method is developed with the use of a Computed Scanner equipment.
6. PEG (Polyethylene Glycol), FD (Freeze drying), Higher alcohol, Lactitol and Trehalose mixture methods used for the treatment of waterlogged wood.
7. Environment and Zoo archaeology analysis.
8. Dendrochronology.
9. Pottery reconstruction and treatment.
10. Air pollution and its effects on cultural heritage.
11. Conservation treatment used in excavation.

Workshops in which the above conservation methods were demonstrated were held by conservation scientists of the Nabunken, Kashikoken and Nara University. I was able to learn about various methodologies and conduct practical experiments. Although there was an opportunity to learn about a wide range of techniques, due to time constraints in the two-month training course, I wasn't able to follow through the experiments daily and observe their outcomes. Conservation science activities undertaken in other Japanese institutions such as museums, temples and other conservation laboratories such as the Gangoji Institute, Laboratory of Cultural Properties in Sosho-in and Todaiji Temple gave me further insight. I observed that high technological instruments were used for conducting conservation work in many of these institutions and was impressed by the advance development of conservation science in Japan.

1-1. Conservation of Inorganic archaeological objects

(Inorganic objects include bronze, iron, gold, clay, pottery, roof tiles, stone and glass etc.)

Within this subject, I learnt about two key stages in the conservation process:

1. Analysis of excavated articles before conservation treatment. The examination of archaeological objects before applying conservation treatment is considered a high priority.
2. Selection and application of appropriate conservation treatments in consideration of the characteristics of the artifact. The production technique used and the current condition of an object are also important considerations in determining the appropriate treatment to apply.

1-2. Analysis of iron objects before conservation treatment

X-ray Radiography is commonly used to analyse objects in the first stage. I practised the various steps of analysing an iron object before the conservation treatment stage. Being an Archaeologist, I understand the importance of the analysis process and in this case I was very interested in learning how to apply scientific technologies usefully. The analytical procedures usually takes a long time since it is important to gain a thorough understanding of the nature of an artefact before an appropriate conservation treatment can be determined. In particular, we need to choose a suitable resin solution to use for treatment.

The procedures of analysing iron objects is described below:

1. Take digital photographs to record the original condition of an artefact before conservation treatment.
2. Use X-ray Radiography to understand an object. In the case of iron objects, short wavelength hard X-rays are used.
3. Use stereo X-ray Radiography to study the inner structure of objects.
4. Use X-ray Diffraction to understand their degree of damage and locate cracks, corrosion etc.. This method is also used to identify the mineral composition of oxidized iron.
5. Use X-ray computed tomography (X-CT) on the object to obtain a three dimensional view (3D image). From this, we can analyse the distribution and extent of cracks and corrosion on the surface of objects.
6. Hand-drawings are made as records which are placed on object-cards. In the process of drawing and recording, the condition of an object can be better understood.

7. Observation using a stereomicroscope to determine the cleaning and conservation methods to be applied.
8. Initial cleaning of the object by a hard steel tool. More thorough cleaning is achieved by applying the Brasive method (blowing alumina powder onto the object) or by using a grinder to clean its surface.
9. Desalination of iron objects , ie. extracting chloride ion from the object by using deoxidized water with an inhibitor under high temperature and pressure .

Within X-ray Radiography, I was introduced to various advanced equipment, including the X-ray fluorescence analyser and the X- ray diffract meter. These are essential instruments for the analysis of inorganic objects.

The analysis process may involve a combination of different techniques. For example, a bronze mirror was analysed by using a digital microscope, X-ray Fluorescence Analyser as well as a Computed 3-D laser Scanner. The analysis results were remarkable.

Examination of materials by X-ray is preferable as it causes no damage. The chemical constituents of an artefact can be identified using an X-ray fluorescence analyser. X-ray is fired into a sample and the energy emitted is measured. This provides an accurate quantitative analysis of the material.

X-ray Radiograph of iron artefacts are examined using a stereomicroscope. The microstructure of cracks and corrosion on the surface of objects can be observed. In our case study, the artefact under examination also contained damage caused by chloride compounds (salt damage). These were drawn and recorded in detail based on examining the X-ray photographs. Desalination is commonly achieved by using mechanical methods; a precision grinder or hard steel tool is used to remove corrosion.

1-3. Iron object conservation treatment

After desalination, the iron objects were impregnated by acrylic resin and immersed in a solution (1000ml H_2O + 0,2% Natri Boras BTA + 0,1% Benzotriazole) under high temperature and high pressure. Benzotriazole treatment is applied for iron objects that contain chlorides and extensive corrosion. Acrylic resin Paraloid B-72 is effective for the consolidation and protection of objects.

2. Conservation of organic archaeological objects

(Organic objects include wooden objects, wooden container, wooden tablets, waterlogged wooden objects, textile, lacquer etc.)

2-1. Before conservation treatment

In the case of organic objects, non destructive analytical tools commonly used include fluorescent X-ray analysis, X-ray diffraction, and high technology equipment FT-IR. Soft X-ray).

Advance techniques such as the application of stereo X-ray Radiography for wooden objects were also taught.

X-ray Fluorescence Spectroscope (Three dimensional emission of fluorescent rays) and Scanning electron microscope or microscopic FT-IR spectroscope is used on textile materials to understand the infrared spectra of silk fibres. The gas chromatographic mass spectrometer and the ultraviolet absorption spectrum method are also used to identify organic objects. However, samples of ancient textile materials are usually rare, especially those featuring *urushi* (Japanese lacquer), dye or resin. To solve this problem, according to Prof. Masanori Sato, the FT-IR spectroscope used together with a scanning electron microscope can provide useful information even from small fibres.

2-2. Conservation Methods for waterlogged wood

This topic was covered at the Nabunken and Kashikoken. I was engaged in experimental work at both institutions and have found the various conservation methods applied for waterlogged wood very interesting. As an archaeologist, I have often excavated sites where wooden objects were found, yet I have had very little experience in treating wood. I can therefore appreciate the importance of training in these techniques. I hope that I can further my knowledge after reading the numerous reports and publications which were so generously given to me.

Similar to other conservation procedures, the analytical stage for the conservation of wooden object is of high importance. In particular, the characteristics of waterlogged wooden object must be identified.

Wood is composed mainly of cellulose, hemicelluloses and lignin. In the case of excavated wood, the content of holocellulose and lignin is 20% and 80% respectively according to Dr. Koezuka. Compared to recent timber, old wood that has been buried underground has a high content of lignin. Other constituents have deteriorated while the percentage of water have increased. With this in consideration, excavated wooden objects must be kept soaked in water.

The following are key considerations when analysing samples of wooden artefacts:

1. Observation of waterlogged wood sample with a microscope.
2. Measuring changes in moisture content.
3. Shrinkage from drying is measured by taking radial and longitudinal measurements. This helps in understanding the direction in which shrinkage occurs.
4. Choice of conservation technique is dependent on the size, weight, fragmentation and physical strength of the wooden object.

2-3. PEG treatment method:

PEG is a type of polymer with the chemical formula HO(CH2CH2O)n H. ‘n’ signifies the degree of polymerization.

The PEG 4000S method is often used for treating wet organic materials.

At ordinary temperature, a solid sample of PEG 4000S is soluble in water. At room temperature, 50% solution of PEG is widely used. However, a low concentration of 20% solution is used at the beginning of the impregnation process. The concentration is then monitored and increased slowly.

When the concentration of the PEG solution has reached 80%, the wooden object is considered to be well treated for preservation. It is then washed with warm water and left to dry naturally.

After applying conservation treatment, the wooden object should be kept in low humidity conditions.

2-4. Lactitol Conservation method:

Lactitol is a sugar alcohol composed of galactose and glucose units. Trehalose is also a sugar alcohol. Lactitol with Trehalose can be mixed at a ratio of 9:1. Wood is often immersed in a 1% solution of EDTA-2Na for 24 hours to help preserve its natural colour.

Summary of experiment:

1. Lactitol (50% lactitol+50%water); Trehalose (50% trehalose+50% water) were used in this experiment.
2. Immerse wood object in tap water for 2 to 3 days.
3. Sugar concentration of the impregnation solution may be increased at room temperature.
4. At the beginning, 30 % lactitol-trehalose solution is used. 0.02% Kathon CG is then added to the solution. The melting temperature of lactitol-trehalose is 60^{o}C. The sugar concentration of the solution is gradually increased to up to 65% sugar concentration at room temperature during the impregnation process.
5. When the impregnation process has been completed, the drying process can occur at room temperature, or in an oven at 50°C.
6. The wood is then in water and absorbent paper is used to pat its surface dry. Sometimes, the drying process is repeated at a temperature of 50°C.
7. The treated wooden object is then kept at room temperature.

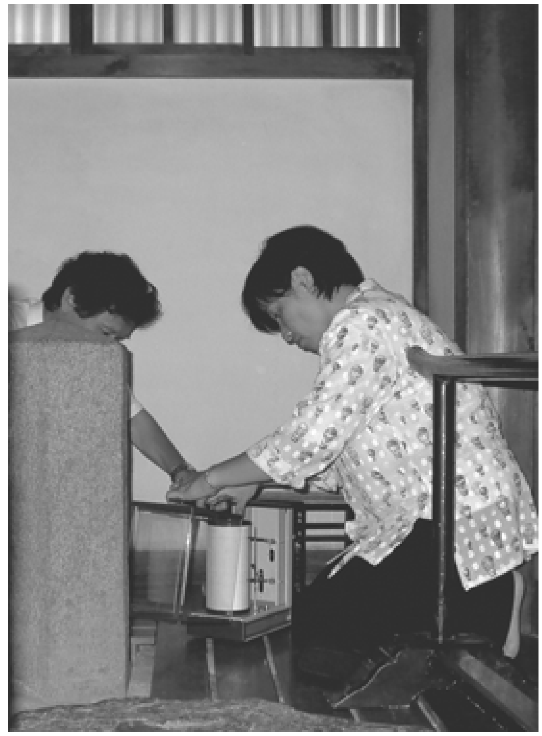
Other methods also used in the experiment include freeze drying and treatment using higher alcohol content solution.

<u>3. Practices observed at excavation sites</u>:

It was particularly interesting to observe the practice of making imprints of the section of an excavation site (its cultural layer). This was done by applying epoxy and polyurethane resin onto the surface of the soil section. A backing material such as thin cotton fibre is then attached, and more resin is applied onto its surface. When the resin has consolidated, a soil imprint of the section of an excavation site is achieved. Such imprints of the cultural layer of an excavation site are important as a record of the result of an excavation, or for exhibition purposes.

Various methods used to extract objects from an excavation site were also observed. Liquid nitrogen mixed with polyurethane foam was used to remove organic object from wet soil. Fragile artefacts are removed by using the synthetic resin casting method.

4. Air pollution and its effect on archaeological objects and cultural heritage



An interesting research *Air Pollution and its effect on Cultural Properties* presented in this training programme highlighted that there has been much focus to increase scientific research in the area of cultural heritage protection. Our cultural heritage is being adversely affected by environmental conditions, such as the changes in humidity and temperature, acid rain and other pollution. Further damage is being caused by mould and insects. For example, numerous stone carvings and tablets have been damaged by environmental factors. Bronze objects are often damaged by acid rain. Archaeological objects and historical monuments have deteriorated due to corrosion, discoloration, the presence of iron sulphate and calcium carbonate etc.

At Nara University, I learnt about the methods for monitoring air pollution. We prepared 25 filters with 30% Triethanolamine solution for our experimental work.

Filters were replaced at various sites. Old filters that were collected were analysed by transferring the digital recording data into a computer. From these results, I observed changes in humidity and temperature, and the effect of air pollution on plates of metal samples from the site. Analyses of these samples were carried out using an Ion Chromatography equipment. Results were interpreted using a computer and scanner, which automatically classified the causes of changes on the metal sample. From these information, scientists can determine the appropriate actions for cultural property protection at specific sites.

II. Archaeological science: Archaeological research and survey methods

1. Archaeological method and Archaeological survey science

Archaeological research in Japan is highly developed and incorporates the latest technologies. Advanced survey and excavation equipments, as well as various scientific instruments are used for investigation and analytical work. They are very useful tools for conducting archaeological research.

Archaeological excavation procedures in Japan are summarised in the following:

1. Preliminary research to identify the site: Site investigation by photographing and mapping to record the features and topography of the site; collect soil samples for dating; research the history of the site from old drawings and archives.

2. Making an excavation plan: Taking detailed site surveys using geophysical survey methods; taking original topographical recordings; setting up small test pits to collect and analyse soil samples; setting up control points for the measuring survey; preparing large-scale maps.
3. Excavation: Firstly, grids are set up on the site. Further measuring surveys are taken by hand drafting, photogrammetry, 3D laser scanning and photographing. Excavation pits are then dug taking into account the site layers and features identified. Soil samples are taken for pollen analysis. After excavation, conservation science is applied for the preservation of soft remains, important soil layers or at times the entire site (such as a burial site) is preserved. The public is informed about the findings and the historical significance of the site.
4. Post excavation work. Mapping of the archaeological features; Analyses and classification of unearthed objects, records are taken of artefacts by hand-drawing or photographing. Reports are published and artefacts are preserved and prepared for exhibition.
5. Preservation of the excavated site if necessary. This may include landscaping work or the addition of public facilities.

The following is a detailed description of some of the above archaeological procedures:

2. Preliminary Site Identification

Information from maps, photos and other local documents are collected for an archaeological site and field trips are taken. The surface of the site is examined to obtain further information to determine the nature of the site (ie. Whether it's a settlement site, burial site or architectural site.) Often aerial photographs are taken.

Collected samples are analysed for further information such as the historical period to which the site belongs. Further historical research is undertaken by studying old drawings, ancient archives or by interviewing local residents.

Site distribution maps are printed to educate the public about the location of archaeological sites and the role of archaeological research. This is done so that the historic importance of a site can be understood before the site is used for other purposes. I consider this a very important part of the preliminary research stage.

2-1. Test pit

Test pits are dug before excavation in order to understand the stratigraph (the cultural layers) of the site and hence the nature of the artefacts to be found. This information is used to plan large scale excavations. Traditionally several small pits around $1m^3$ are dug around the site. The core boring tube method is used in some cases. However more advanced techniques have been used recently, such as the Geophysical Survey method. This method will be described in detail later.

2-2. Excavation.

$1m^2$ or larger pits are set up in grids. The size of the pits may vary depending on site characteristics.

Advanced survey methods are now commonly used in Japan. Besides the traditional techniques, Japanese archaeologists use advanced scientific instruments such as EDM (Electromagnetic Distance Meter), Photogrammetry and 3D laser scanning.

2-3. Post excavation work.

In Japan, reports are produced after archaeological excavations. The technology available for creating photos, drawings, maps, and other documents is very important in this stage. Such archaeological reports are produced as records, which could be used for future reference, information sharing, and as research data. The records take various forms and are produced by various means to suit a range of uses

3. Survey methods:

I undertook a lesson on basic survey methods to determine the location of a site. There are 3 components: distance, direction and height. Absolute position is determined by giving the longitudinal and latitudinal location of the site on earth. Relative position is determined by giving the xy-coordinates of the site - this describes the location of the site by its distance (in meters) and direction from a local datum; this is known as the Rectangular Plane Coordinate System. The height of the site is measured relative to sea level.

Various measuring techniques and survey equipments were introduced during the course. I also learnt how to calculate the latitudinal and longitudinal distance of a site, as well as how to take a levelling survey. Archaeologists often use database from topographical research, and usually have hands-on experience with survey instruments. However, I have very limited knowledge in taking surveys and this training course has given me a valuable insight on the techniques involved.

Photogrammetry, GPS and 3-D Laser scanning are commonly used in Japan for archaeological surveys. I was given basic training in the techniques of Photo-interpretation and its principles, Aerial photography as well as Terrestrial photogrammetry. From this training, I can appreciate the importance of scientific technology and its application in Archaeology.

4. Archaeological Prospection

Archaeological Prospection was a very interesting subject taught. Using various techniques, archaeological features and objects buried underground may be detected prior to excavation. The lectures introduced the principles of archaeological prospection and some of the techniques used:

- *Earth resistance survey:* this technology is applied in archaeological vertical cross-section surveying as well as horizontal surveying. Mr. NISHIMURA Yasushi pointed out that in archaeological survey, the Wenner and Twin electrode configurations method is popularly used.
- *Magnetometer surveys*. Buried archaeological artefacts or features are detected by measuring earth magnetic fields.
- *Ground-Penetrating Radar (GPR).* This method is useful for taking general surveys, for example, to investigate buried pipes and underground cavities. I was introduced to the instruments used for this technique and the ways in which results were presented, such as using a 'wave trace'. I also learnt how to compile a horizontal plan (Time Slice) from GPR profile survey. The lecture also covered Topographically-modified time slices.

5. Conclusion

On completion of this training program, a comparison between various conservation and archaeological methods was possible. I was able to understand the importance of selecting the appropriate method in conservation and archaeological practice. As an archaeologist, such knowledge and practical experience is essential.

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5. Appendix

5-1. Programme Schedule

5-2. List of Instructors

Nguyen Kim Dung
(Viet Nam)

Training Schedule

July 7th (Mon)	Arrival in Japan	
8 (Tue)	Introduction to ACCU and Greeting (Nabunken, Kashikoken, Nara Univ., Gangoji)	
9 (Wed)	**<Conservation Science for Archaeological Remains> (Nabunken)** Introduction to Conservation Sciences and Facilities	
10 (Thur)	Removal of Fragile Objects from Archaeological Site	
11 (Fri)	Removal of Fragile Objects from Archaeological Site	
12 (Sat)		
13 (Sun)		
14 (Mon)	First Aid for Finds	
15 (Tue)	First Aid for Finds	
16 (Wed)	Lacquer Film Method for Soil Layer Removal	
17 (Thur)	Lacquer Film Method for Soil Layer Removal	
18 (Fri)	Restoration and Preservation of Finds, Keeping and Display (Tobunken, Tokyo National Museum)	
19 (Sat)	Seminar of Viet Nam Archaeology (Kokugakuin Univ.)	
20 (Sun)		
21 (Mon)	**National Holiday**	
22 (Tue)	Conservation Science for Metal Objects	
23 (Wed)	Conservation Science for Metal Objects	
24 (Thur)	Conservation Science for Metal Objects	
25 (Fri)	Environmental Archaeology	Wood and Dendrochronology
26 (Sat)		
27 (Sun)		
28 (Mon)	Conservation Science for Water-logged Wood	
29 (Tue)	Conservation Science for Water-logged Wood	
30 (Wed)	Conservation Science for Water-logged Wood	
31 (Thur)	Planning of Conservation Science Training Course	
August 1st (Fri)	Details of Conservation Science Training Course and Study of Training Facilities	
2 (Sat)		

3 (Sun)	
4 (Mon)	**<Conservation Science of the Restoration and Preservation of Archaeological Remains>（Kashikoken）** Introduction to Conservation Sciences and Facilities
5 (Tue)	Conservation Science of Excavation Site
6 (Wed)	Conservation Science of Burials and Artifacts
7 (Thur)	Restoration and Preservation of Finds
8 (Fri)	Restoration Methods and Materials for Bronze Artifacts
9 (Sat)	
10 (Sun)	
11 (Mon)	**<Air Pollution and Cultural Heritage>（Nara University）** Introduction to Environmental Science Study
12 (Tue)	Introduction to Environmental Science Study
13 (Wed)	Air Pollution and Cultural Heritage Protection
14 (Thur)	On Site Observation Method of Air Pollution
15 (Fri)	On Site Observation Method of Air Pollution
16 (Sat)	
17 (Sun)	
18 (Mon)	**<Archaeological Survey and Conservation Science>（ＡＣＣＵ）** General Introduction of Archaeological Survey Methods
19 (Tue)	Measuring Survey Method
20 (Wed)	Archaeological Prospection Method
21 (Thur)	Restoration of Japanese Fine Arts (Kyoto Nat. Museum)
22 (Fri)	Conservation Science, Treatment Method（Gangoji）
23 (Sat)	
24 (Sun)	
25 (Mon)	Conservation Science of Heirloom Treasures（Shosoin）
26 (Tue)	Restoration of Japanese Lacquer Fine Arts (Nara National Museum)
27 (Wed)	Traditional Handcraft in Nara and Restration
28 (Thur)	Draw out of Report to ACCU
29 (Fri)	Submission of Report to ACCU
30 (Sat)	Departure for Viet Nam

Schedule had been slightly modified due to weather and excavation site procedure.

Lectures

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