X-rays for Archaeology

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Cover shows an image of the tomb of Amenhotep III in Egypt.
Photo courtesy of Masayuki Uda.

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Foreword

The First International Symposium on X-ray Archaeometry took place in the conference hall of Waseda University, Tokyo, Japan, on 18–20 July 2002. The participants of the symposium were from Belgium, China, France, Greece, Hungary, Israel, Italy, Japan, Korea, Mexico, Romania, Slovenia, Sri Lanka, Taipei, UK, and USA.

One of the most important aims of the symposium was to combine two scientific fields, i.e. archaeology or art and X-ray science. Finding archaeological sites, dating, analyzing of archaeological objects, and so on needs the help of natural scientists and technicians. Natural scientists have a taste for solving mysteries hidden in archaeology. However, previously, using x-ray techniques was only a small part of the archaeological fieldwork and the x-ray field was largely disinterested in the analysis of archaeological objects. Until this symposium, no attempt has been made on having an international meeting on a worldwide scale to discuss archaeological subjects under equal partnership between the two fields mentioned above.

The symposium provided a broad forum for discussing experimental results of X-ray-based analysis. Of particular interest for the participants of the symposium was the non-destructive analysis of archaeological monuments using several kinds of X-ray techniques, especially under *in situ* and contact-free conditions, as well as the introduction of experimental results using advanced technologies such as ion beam and synchrotron radiation techniques.

This book, named "X-rays for Archaeology", consists of papers selected from presentations in the First International Symposium on X-ray Archaeometry.

Finally, it is an especially great pleasure for me to warmly recommend this book to every reader interested in knowing more about X-ray archaeometry and understanding the importance of joining both scientists in the fields of archaeology or art and X-ray analysis.

Tokyo, Japan

Professor M. Uda
Chairman
Organizing Committee of the First International
Symposium on X-ray Archaeometry

Figure IV-3-5. Paint cross-section of 'The flight of Lot and his family from Sodom', magnification100X.

Figure IV-3-6. Back-scattered electron image of the paint cross-section of 'The flight of Lot and his family from Sodom'.

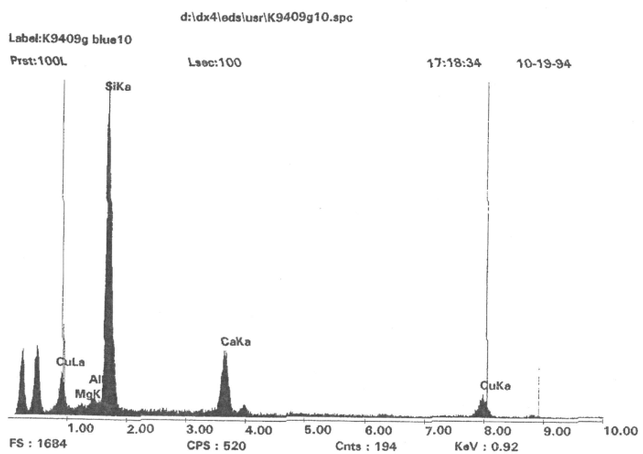

Figure IV-3-7. Energy-dispersive spectrum of the paint cross-section. The spectrum was acquired using a scanning electron microscope.

Chapter IV-4

Radiographic Findings in Ancient Egyptian Mummies

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Preservation of human bodies after death is usually designated by two expressions, namely, embalming and mummification. The word "mummification" is derived from the Latin word "mumia" which was mentioned by Dioscorides (first century A.D.) as a black bitumen found oozing from the earth in certain places. This word was applied later to the embalmed bodies in ancient Egypt. Mummification is undoubtedly the most distinctive technique or art, which developed in ancient Egypt.

In 1895, Roentgen, a German physicist, discovered the rays that were to form the basis for the X-ray method. An X-ray examination in 1932 of the mummy of Amenhotep was reported by Derry (1934). The largest series of radiographic examinations of mummies is that of Peter H. K. Gray (1967), who analyzed 133 specimens from museums in Great Britain, France, and Holland. He emphasized the importance of the archaeological aspects of the radiological findings, including the determination of the presence or absence of human bones to detect fraudulent specimens, the determination of sex and age, the correlation of radiological findings with known embalming techniques, and the demonstration of amulets. The palaeopathological aspects of his report included osteoarthritis, growth arrest lines, ante-and postmortem fractures and dislocations, several isolated cases of other bony pathology, dental disease and attrition, vascular calcification, gallstone, and ureteric calculus. Many of the radiological findings in the ancient Egyptian mummies had been described in the past (Harris and Wente, 1980). The author would like to review the several radiological findings in Egyptian mummies.

Radiographic evidence indicates intact nasal septa in Thutmose I, Thutmose III, Thutmose IV, Ramesses VI and Ramesses IX or XI. The septa are missing in Semekhare, Merenptah, Siptha, Ramesses III, and Ramesses V. Visual inspection in Ramesses IX or XI revealed penetration of ethmoid, good evidence for nasal excerebration. Since the septum was intact in this pharaoh, its status cannot be used conclusively to determine a nasal route for brain removal.

M. Uda et al. (eds.), X-rays for Archaeology, 259–261.

X-ray film revealed the scarab and the four sons of Horus in the mummy of Queen Nodjme of the Twenty-first Dynasty. The two-part stone eyes are clearly indicated in the film of the head of Queen Nodjme. Radiograph of the head of Bakenren also shows the artificial eyes.

Frontal radiograph of the dorsal spine of Henttowy shows marked osteophyte formation along the right lateral margin of the mid and lower dorsal spine. Lateral radiograph of the upper cervical spine of Merenptah indicates the hypertrophic lipping particularly marked at the level of C3-4 and C4-5. Antero-posterior radiograph of lumber vertebrae and pelvis of Merenptah reveals moderate rarefaction (atrophic area) of the iliac fossae. The film of thorax and neck shows compressed, demineralized, and osteophytic cervical vertebrae in Merenptah. The antero-posterior film of pelvis of Merenptah shows striated margins of pubic symphysis indicative of maturational stage.

The lateral head film of Ramesses II indicates marked tooth wear and alveolar resorption. Antero-posterior radiograph of lumber vertebrae of the X-ray film of Seti II shows absence of lipping and presence of sharp contours of the centra. The X-ray film of knees shows that the epiphyses at the distal ends of the femurs and at the proximal ends of the tibiae are not united with their respective shafts in the mummy of Thutmose I. The distal epiphyses of the tibiae and fibulae of Thutmose I are also not yet united to their shafts. This radiological finding suggests an age of 18-22 years.

Growth arrest lines (Harris's lines) can be recognized radiographically in the diaphysis of the long bones. It is generally regarded as evidence of previous arrest of growth due to malnutrition and several diseases during childhood. The prevalence of growth arrest lines has been regarded as a valuable indicator available for assessing the state of health and nutrition in the past human populations. Gray (1967) detected a rather high incidence of growth arrest lines in his study of 133 mummies.

Lateral radiograph of skull of Seqenenre Tao reveals multiple skull fractures and multiple fractures of facial bones. Frontal X-ray of the chest of Merenptah shows the absence of the medial head of the right clavicle, comminuted fracture of the right forearm, and an arcuate defect in the border of tenth right rib postero-laterally. Frontal radiograph of the skull of Merenptah shows the cranial defect and a defect in the nasal septum, presumably incident to the transnasal route of evacuation of the cranial contents at the time of embalmment.

The X-ray cephalogram of the head of Ramesses II indicates severe periodontal loss, pulp exposure, and periapical abscess. The X-ray cephalogram of Merenptah reveals severe periodontal destruction around the remaining teeth and the apparent cause of the loss of most of his posterior teeth. The X-ray examination of Ramesses V of the Twentieth Dynasty, who died young of small pox (thirty years age), illustrates a healthy dentition with minimal wear and periodontal disease.

Dense fluid level in the posterior skull represents hardened resin, which layered horizontally in the lateral radiograph of the skull of MIA II. Irregular density in the posterior cranial fossa consists of resin-soaked linen. The presence of radiopaque mass in the cranium may indicate a desiccated, shrunken or cranial packing. Lateral radiographs of naturally desiccated skulls of Nubian mummies show the typical radiopaque appearance of the brain in its undisturbed position. Although rapid

putrefaction and liquefaction of the brain might be expected, dehydration may produce a consolidation of about one-fourth the brain volume, which adheres to the posterior cranial base. Smith (1902) has described natural preservation of the brain. Density and outline are important in differentiating brain remnants from cranial packing. Desiccated brain tends to be mottled in appearance, with an undulating border. The radiograph cannot indicate cranial packing unless it contains radiopaque material such as resin.

Magnified CT scan of Lady Tashat (25^{th} Dynasty) reveals the funerary mask supported against the inner surface of the cartonnage face by linen packing. The oblong structure lying obliquely immediately anterior to a thoracic vertebral body represents the collapsed heart which dips into a mass of hardened resin in CT scan film at the level of the mid-thorax. Antero-posterior radiograph reveals the second skull placed between Lady Tashat's legs. Lateral radiograph of the second skull shows much of the basiocipital region, maxilla and mandible. Lady Tashat's fingers extended in front of the proximal femurs and flanking the skull. Magnified CT scan of the second skull reveals the eyes are shriveled in their sockets. The hole in the paranasal sinuses, between the orbits, indicates the defect through which the brain was extracted. It can be seen the Many layers of linen wrapping can be seen on this CT scan taken at the level of Lady Tashat's left hip. Denser layers indicate extra coats of resin. Unfused epiphyseal plates are visible Antero-posterior radiograph of Lady Tashat's knees. CT scan of the skull shows a crack in the nasal septum created to remove the brain.

Mummification greatly affected the habits and customs of the ancient Egyptians and, through it, much knowledge was gained in anatomy, medicine, chemistry, and many arts and industries. The radiological interpretation of the X-rays under somewhat restricted circumstances on the mummies in ancient Egypt has indicated findings of both historical and medical interest.

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