Indian and African Elephant Ivory

Elephas maximus and *Loxodonta Africana*

A 1987 summary of work in progress to distinguish different types of ivory

By

W.A.B. Brown* and K.I.M. Kelly

Gerry Martin

My meeting with Gerry Martin was fortuitous. He had never heard of me and I knew nothing about him. I had decided as I was approaching retirement age, as the Reader in Dental at Kings College, University of London, I should prepare myself for what I was going to do after I had retired. I had always had an interest in archaeology and because of my detailed knowledge, especially of teeth and skulls, I thought I could make a modest contribution to the archaeo-biological scene.

In July 1982, I discovered they were seeking volunteers for a "dig' in Châtres so I went to have a look at what was going on before I signed on. A hundred yards to the southeast of the magnificent Gothic Cathedral a large site had been cleared and over a half had already been excavated to ten or more metres deep. A youngish woman appeared to be in charge and I watched and listened as, speaking English with a soft Irish accent, she guided twenty or so very young helpers. I liked her style and volunteered. Valorie Shortland de Hoog was the archaeologist in charge. She said they were planning to dig through the 17th and 18th century layers fairly quickly so they could concentrate on the underlying Gallo-Romano occupation layers. I was assigned to a square metre plot and set to very slowly with my trowel to scrape away at the surface and soon uncovered some bony fragments and small pieces of green glazed pottery. During the following days I worked steadily on my own, carefully observing what my fellow diggers were doing and what they were finding on other parts of the site. I quickly realised that very few of them could identify the bones and the teeth that were routinely being uncovered. Everything they found was conscientiously packed into a plastic bag and labelled with the date and the exact location where it was found. The contents of the bags were subsequently washed and then stored on metres and metres of shelving in the archaeology headquarters. I wasn't sure when anybody would find the time to analyse them.

As I scraped away the surface, saving anything of interest and removing the debris, I slowly descended towards the Gallo-Romano layers. Every so many centimetres it was necessary to take a reading of the levels with a theodolite. It was a two-person job and it was Louise Martin who was working on the adjacent one square metre to me who helped me to take the readings. She was a recent school leaver. I found her precociously informed about archaeology and she had worked at Châtres before. As well as taking the levels, we measured and charted the pit profiles. She taught me a lot. She told me she had

a place to study archaeology at the University of London and when I left the "dig", I wished her well and told her to keep in touch, never, of course, expecting to see her again.

After I returned to King's from my summer archaeological vacation I searched in vain for simple manuals for the non-specialist to identify teeth and assess the age of animals. There was a real need to gather basic information about teeth and bones of the animals that are likely to be uncovered in an archaeological excavation, because so much information can be derived from them. Working at the University of Illinois in Chicago in 1959, I had worked, for my Master's degree, on the Chronology of Tooth Development in Cattle, (Brown *et al* 1960), and later I had worked on the effects of malnutrition on the teeth and jaws of pigs, (McCance *et al* 1961). I began collecting skulls from abattoirs and local gamekeepers and dissected the teeth out of the jaws. It was a big enterprise. One lunchtime, I was in Trafalgar Square and to my surprise saw Louise Martin who had started her archaeology course at University College, London. I told her what I was doing and she said she had some spare time and would happily help taking photographs. Later, Louise was to do her selected BA project on sheep dentition under my guidance.

At the time Gerry Martin, Louise's father was interested in the ivory sundials of Nuremberg. He had his own collection and was sponsoring an exhibition at the Whipple Museum in Cambridge, of these rare and beautifully designed instruments, masterminded by Penelope Gouk, (1988). It had occurred to Gerry that no one knew whether the ivory with which they were made came from African or Indian elephants.

I met Gerry and I told him I had no idea what the difference might be between the ivory of the two species, but I'd be very interested to find out. So, with Gerry's enthusiastic support and a substantial financial contribution towards technical assistance, I embarked on the project. Unfortunately, the microscopical techniques with which I was familiar and were available failed to recognise any differences, but my attempt to find them gave me a wide range of new insights.

During the course of my investigations with the help of Katriona Kelly, a dental graduate who had started her dental studies at King's College, I used to send frequent reviews to Gerry of our progress. We began by considering the general use of ivory by Man over the centuries from the earliest Paleolithic findings to today, determining who used it, for what and from where the ivory came.

This manuscript was never written for publication but is now offered as a grateful tribute to Gerry Martin (1930-2004). He was a gifted man who had wide-range of in-depth interests. Macfarlane*, 2004, writes that he shaped a generation of work in the fields where history of science and technology and society overlap. He did so with very generous support.

***Note: Google: Gerry Martin an Invisible Life by Alan Macfarlane**

Introduction

This review is the background information we obtained while studying ivory. The notes are from a variety of sources. The following aspects have been considered:

1. Definition and types of ivory
2. Sources of ivory
3. History of use
4. Economics of ivory
5. Research into identifying the structure of ivory
6. Research into distinguishing Indian and African elephant ivory
7. Biological development
8. Morphology
9. Histological Structure
10. Bibliography
11. Current research
12. Summary

Definition

Ivory is derived most commonly from the tusks of male and female African elephants *Loxodonta Africans* and from the male Indian elephant *Elephas maximus.* The female Indian elephant has no tusks or only very small ones. Tusks are teeth, continuously growing upper incisor teeth. Approximately a third of a tusk, which grows throughout life, is within the bony socket of the skull.

The teeth of the hippopotamus, walrus, narwhal, sperm whale and some types of wild boar and wart hog are also defined as ivory.

Types of ivory (Encyclopaedia Britannica 1970)

1. Hard ivory tusk from Western half of Africa. It is darker in colour, more slender and straighter than a soft ivory tusk.
2. Soft ivory tusk from Eastern Africa. It is white, has a blunt point and is more twisted in its growth pattern.
3. Baby elephant deciduous tusk, shelley scrivello.
4. Solid scrivello

5. Wide or hollow grown tusk from male elephant
6. Close or solid grown tusk probably from female
7. Wide or hollow grown tusk of male elephant.

Sources of ivory

Most ivory comes from African elephants India augments its supply of ivory from Africa. Trade in ivory has been found in Mincing Lane in the City of London since the middle of the nineteenth century. Nathaniel Bowers & Son were among the earliest manufacturers who started in business as ivory comb makers in 1685 and whose descendants were still in trade in the 1960s.The U.S.S.R. has been a source of mammoth tusks collected from the glaciers and rivers of Siberia.

Vegetable ivory

The fruit of the of the ivory nut palm or tagus (Phytelephas) growing in damp localities in South America is described as ivory.

History of use (Encyclopaedia Britannica 1970)

Tusks from Africa and later from Asia have been used in Europe as the main source of ivory. In the Middle Ages walrus tusks were much used in northern countries. Hippopotamus teeth were fairly widely used in the 18th and 19th centuries in France and England.

THE NEAR EAST AND WEST

1. In Ancient History
    a. Paleolithic Period: Carvings of are usually of nude female figures and are thought of scant aesthetic value.
    b. Egyptian Predynastic and Dynastic Period: many combs, hairpins and other utensils have been found. J.E Quibell at Hierakonpolis found many ivory figures of men and women. Two masterpieces were found at Abydos, one of a king belonging to the 1st Dynasty (British Museum) and the other of the 4th Dynasty King Cheops (2,600 BC).
    c. Phoenician: Syrian and African craftsmen specialised in using ivory for inlays.
    d. Babylonians and Assyrians crafted an unrivalled series of ivory objects found at Nimrud and now in British Museum. They show Egyptian influences
    e. Aegean, Etruscan, Grecian and Roman. Among the earliest finds are the ivory acrobats from Knossos (16th century BC). There are many works of superior workmanship from 14th to11th centuries BC from Cyprus (Enkomi) now in the British Museum. Carved ivory has been found at Ephesus in the Temple of Artemis, Rhodes, Sparta and in Italy and Spain. The earliest ivory carvings found in Etruscan tombs date from 700-600 BC and are likely to have been imported from Cyprus. No ivories have survived from the early classical Greek period.

2. Middle Ages
    a. Late antique and early Christian ivories: Old and New Testament scenes were found on the 4th century Brescia casket echoing 4th century sarcophagus styles. One of the most beautiful of all late ivory carvings is the Nichomachi-Symachi diptych (Musée de Cluny, Paris and Victoria and Albert Museum), which was probably executed in Rome. Centres of ivory carving existed at Milan, Rome, Constantinople and Alexandria.
    b. Byzantine: No Byzantine ivory of the 7th to 8th centuries appears to have survived and it is assumed that the iconoclastic controversy is responsible for this. In the 10th century the ivory carvers produced some of the finest achievements of Byzantine art. There is a unique statuette of the Virgin and Child (Theotokos Hodegetrial) in the Victoria and Albert Museum. The 11th and 12th century have a carved St. John the Baptist and four saints.
    c. Islamic: Ivory was used extensively in the decoration of furniture with geometrical and arabesque patterns found in Spain and Sicily in the 13th century, which are sometimes supplemented with figures of animals and birds.
    d. Carolingians: Essentially related to the acceptance of Mediterranean heritage by the Northern ruler Charlemagne, (768-814). Among the earliest ivory carvings in the court styles are the panels, which once formed the covers to the psalters and ivory book covers (Bodleian Library, Vatican and Victoria and Albert Museum).
    e. Ottonian: Otto I (936-973) created the Holy Roman Empire. There is a superb situlae (holy-water bucket) in the Victoria and Albert Museum with scenes from the passion and resurrection of Christ.
    f. Anglo-Saxon: After the monastic reforms of the 10th century, the Canterbury and Winchester centres produced a distinctive style. There is an ivory Christ on a gold and enamel cross in the Victoria and Albert Museum.
    g. Romanesque: In the 11th and 12th centuries a variety of styles of carving were practiced. In Cologne, Germany, were some altar panels now in the V & A and two reliquaries one of which is in the V & A. In England at the V & A are a whalebone relief and the superb head of a pastoral staff and, as well, chess pieces which reflect the style. The ivory carvers of Spain depicted faces with distinguishing heavy noses, protruding eyes, thick lips and oval contours. Examples of Italian craftsmen are depicted by a last Judgement panel from the 12th or early 13th centuries (V & A).
    h. Gothic: the cathedral schools and the universities became the source of intellectual and creative inspiration. However, at the School of Paris in the Ile-d-Paris and with the emphasis towards building new cathedrals decorated with statues and stained glass windows, ivory ceased to be a major art form. The workshops began to serve private needs. The Soissons diptych in the V & A reflects the consummate elegance of

style and craftsmanship. England, Germany and Italy all contributed to the works produced.

i. Renaissance to Modern: Ivory was really used except for inlay and domestic purposes during this period. A large array of furniture was made in the 17th century in Germany and Flanders, devotional ivory carvings in Spain and Portugal and 17th century portraits painted on ivory in several countries in Europe. The Turks in the eastern Mediterranean developed their own distinctive style with arabesque of foliage and flowers and the use of cursive script.

THE ORIENT

A. China

a. Early Chinese: Ivory carving is one of the oldest of the arts. The Shang Dynasty carvings are so handsomely designed and executed, they suggest a tradition stretching back prehistoric times. In Shang times elephants roamed the forests of the yellow River region. The last Shang king is supposed to have invented ivory chopsticks. The Chou Dynasty (c. 1122-256 BC) are said to have had chariots of ivory. It became fashionable for princes and high officials to carry ivory tablets. In the Han Dynasty these tablets were considered marks of rank. In later dynasties these tablets became more than a foot long tapering to conform to the arc of the tusk.
b. Peking work: Peking was the centre for the finest work.
c. Canton work: The second great centre for ivory carving in the last 300 years. Their work was popular with visiting sailors.
d. Hong Kong: began as a carving centre in 1930.
e. Artists: The names of the greatest carvers have been preserved in history.

B. Japan

The Japanese learned the art of carving ivory on the Tokuwaga period (1603-1867). Kyoto was the original centre turning out products for the Imperial court. Ivory was originally used for making the plectrum for plucking the strings of the samisen. It was used for the ends of the rollers for traditional scroll painting. Later a kind of toggle called a netsuke was made from ivory. The ivory was obtained from elephants, whales and narwhal. By 1900 endless repetition of existing designs and the use of machine tools for mass production had destroyed the remaining elements of the art.

C. India

Ivory has always been plentiful and ivory carving has been practiced for 4,000 years, but only a few ornaments and pieces for playing games have been discovered from 3rd and 2nd millennium BC. It was exported to the Mediterranean during the Roman Empire and to the West and China up to modern times.

The most important group of early ivories, which reveal a mastery of carving the human body date from the 2nd and 3rd century AD. They were found at Begram, Afghanistan. Several fine pieces are known from Kashmir made in the 8th – 10th centuries. Ivory carvings have been found in a number of other locations. There are several styles identified with the 18th and 19th centuries, which appeared to have been developed for the European traders and military around the time of Clive of India.

D. North America.

a. Eskimo (Inuit) ivory carving: Walrus and narwhal were only found in the arctic and subarctic and it is only in these regions that the art of carving has developed. The earliest examples are from the Bering Sea region, but are of uncertain date, though thought to be at least 1,000 years old. Mammoth ivory was available. Russian exploration of the Chukchi peninsula in the late 17th century introduced iron tools, which brought a striking development in ivory carving. Little realistic engraving appeared before the Eskimos had contact with Europeans.
b. Scrimshaws: Scrimshawing is a nautical term. It is a general term that may be applied to the art of making useful ornamental articles at sea using shells, whales' teeth, walrus tusks and other hard-mineralised materials. Some specimens date from the late 18th century, but most were made between 1830-1850.

General Observations

a. Ivory from earliest times has been considered a luxury material.
b. Carved ivory was often dedicated to the highest religious and secular purposes.
c. Emperors and patriarchs honoured each other with gifts in ivory.
d. The display of precious materials was an integral part of sublime ceremonies. The onlooker was expected to be overawed by these tangible riches and see in them a forecast of heavenly splendour.
e. Under the Carolignian and Ottonian dynasties the display of works of gold, ivory and precious stones was one of the principal means by which the Western emperors showed to the world the plentitude of their power and their devotion to God.
f. Ivory carvings served as ambassadors of style and iconography. A consular diptych of the 6th century might be copied in stone by a Visigothic sculptor of Spain. Early Christian ivory carvings from Rome, Constantinople and elsewhere became models for the court artists of Charlemagne. The extension of the Gothic style throughout Europe from its centre in the Ile-de-France may be in part due to the ivory statuettes and poly diptychs issued from the school of Paris.
g. By the late Middle Ages ivory had lost its highly religious and political significance. In the 16th, 17th and 18th centuries ivory carving became essentially objets de vertu.

h. In the 19th century ivory came into prominence again for the making of forgeries.

Sandford, Elizabeth C. (1973): Observations

In her thesis, the Identification and Working of Ivory, 1973, Sandford, Elizabeth makes some relevant observation:

a. The ivories from Hierakonopolis are part of the Flinders Petrie collection.
b. Scrivelloes are tusks weighing seven ponds or less and are used for making billiard balls.
c. Bangle tusks are large and thick and suitable for making bangles.
d. "Green" or "live" ivory is from recently killed animals. It is warm (wabb?) in colour, but dries to a much lighter shade.
e. Mammoth Elephas primigenius flourished during the upper paleolithic periods 50,000 years ago. Mammoth ivory has been so abundant in the Siberian deposits it has been exported to Asia and Europe.
f. Odontolite is ivory stained blue by cupric salts and has been used in the manufacture of jewellery.
g. Hippopotamus ivory is extremely hard and dense and contains proportionally more inorganic and less organic constituents than elephant ivory. WABB query. Could this be related to slow growth rate of hippopotamus teeth?
h. The tusks of Loxodonta Africans and Elephas maximus have an outer covering of cementum while they are in the jaw, but this becomes worn away once the tooth has erupted.
i. WABB is of the opinion that Sandford's thesis may have misunderstandings of the histology of teeth.

Thornton, J. (1981); Observations

WABB is of the opinion that there are misunderstandings in the section on human tooth formation and structure, which has been used as a model for ivory. Nevertheless photographs of the slides are invaluable.

WABB and KK Studies

A selection of small ivory specimens from a variety of sources was generously made available to us by Don Clogher of the Natural History Museum

A miscellany of ivory fragments was obtained from Harare.

Macroscopic appearance of ivory

Elephant ivory is derived from the animals' tusks, which are modified paired incisors, which develop and grow within the bone of the maxilla, the upper jaw. There are no incisors in the lower jaw.

When the incisors first erupt they are composed an outer cap of enamel, which it is assumed is covered by an outer layer of cementum, which quickly becomes worn away. The enamel, which also becomes worn away, overlies dentine, which is what is known as ivory. Forming the main bulk of the tusk. The dentine surrounds a central pulp chamber of cellular tissue with their blood supply and nerves. Encircling the pulp chamber is a continuous layer of odontoblasts, the dentine forming cells.

The dentine which is not capped by enamel is covered by a thin layer of cementum which, with its associated fibre mesh attached the tusk to the surrounding bone of the socket serving to attach the task to the bone but, and most importantly functioning as well, to enable the tusk to erupt.

Throughout the life of the tusk, as it continuously erupts its length is extended at its base or apical end by the formation of dentine and cementum. At the same time the dentine forming cells that line the pulp chamber are laying down daily increments of dentine, which will eventually fill the whole of the space occupied by the pulpal tissues thus explaining the solid nature of the first formed tusk in older animals.

Tusk observed in living animals

The size of the tusk will depend on the species, age and sex of the animal. The tusks of very young animals are tipped with enamel, which is quickly worn away to expose the underlying dentine or ivory. After the enamel has been worn away, no new enamel is formed and the tusk that subsequently erupts does so with a thin layer of coarse looking cementum covering the dentine, which is essential for the attachment of the tusk to the bone and its eruption. This thin layer of cementum is progressively worn away and towards the tip of the tusk of older animals there will be none to be seen.

The only way to assess the size of the central pulp chamber in a living animal would be by taking a radiograph.

Tusk removed from a dead animal

A tusk may be likened to a slightly curved and rotated cone. The part of tusk that was within the tooth socket is covered by cementum, which is rough to the feel and is grooved and ridged along its longitudinal axis. At intervals there maybe seen, at irregular intervals, a raised ridge of dentine and cementum, which most likely reflects varying seasonal growth. At the base of the forming end there will be thin layers of cementum and dentine surrounding a large mass of pulpal tissue.

Understanding the structure of ivory

a. Histology

Examination of fractured tusks or polished transverse and longitudinal sections help to reveal how the tusk is formed. To understand the histological structure of tusks, it is essential to know how they are formed by groups of co-ordinating cells. Cells, the odontoblasts form dentine is the first mineralised tissue. The odontoblasts synthesise and secrete proteins to form collagen fibres and a cementing substance, the matrix. This is mineralised by very small hydroxyapatite crystals. Immediately after the mineralization of the first dentine, enamel is laid down by ameloblasts, cells that synthesise and secrete protein, which, in turn, is mineralised by large crystals of calcium hydroxyapatite. Cementoblasts synthesise proteins and cementing substance, which is mineralised by hydroxyapatite crystals to form a layer of cementum over dentine and maybe over enamel.

While the odontoblasts are laying down a layer of dentine they retreat centripetally leaving behind a protoplasmic process which is continuously being added to at the junction of the process with the cell body of the odontoblast. The collagen fibres are arranged as an interweaving network at right angles to the odontoblast processes. It is

this mineralised intermeshing network, which gives ivory its elasticity and why it can be so easily carved in all its planes.

b. Macroscopic appearance

1. A fractured tusk can reveal how the dentine is laid down incrementally in a woven pattern.
2. A cross-section through a tusk will show an outer layer of cementum if it has not already been worn off and in the dentine the following patterns may be observed:

a. Overlapping arcs, which give a "milled" appearance. The arcs have a long radius towards the outer surface of the tusk with the radii of the arcs becoming smaller towards the centre. The greater the width of a tusk the larger is the arc. It is the size of the arcs, which gives an indication of how large and from which part of a tusk a particular cross-sectional cut piece of ivory has come.
b. Annular bands of contrasting light and dark ivory. The bands vary in width from a millimetre to several millimetres wide. It is assumed that these may be related to seasonal variation, environmental or dietary factors.
c. Annular lines of contrasting light and dark ivory. These lines of 500 microns or less are evenly spaced and most likely reflect the regular rhythmic nature of odontoblast dentine deposition. The contrast of the dark and light lines is attributable to the varying level of mineralization.
d. Faint radial lines are distinguishable, but it is not known what causes them.

3. A longitudinal section reveals:

a. Alternating broad light and dark bands. Because of the curved nature of the tusk these lines will only be seen for short distances.
b. Parallel lines of contrasting light and dark dentine, which will coincide with similar lines in a cross section.
c. Black speckled zones are visible where the section has cut through the pulpal surface of the dentine. On magnification the black speckles can be seen to be cuts across the tubules in which the odontoblast processes would be found in a living elephant.

C. Microscopic appearance

Using a light microscope to examine a ground or thin demineralised section enables the odontoblast tubules in which the odontoblast processes are seen and around which the dentine has formed. The following features may be identified.

a. Groups of tubules follow a wavy or undulating course, which causes the cross-sectional surface to appear "milled".
b. Tubule branchings may be seen.
c. The tubules are more widely spaced towards the periphery of the tusk and become increasingly close together towards the centre of the tusk. This reflects the diminished surface area at the centre compared with that at the periphery of the tusk.

The properties of ivory, which make it an ideal material for carving.

a. It is a biological material, which is composed of a dense, highly organised, complex weave of collagen fibres, which have been minerlised by minute, tightly

bound together, calcium hydroxyapatite crystals. It is this composition, which makes it resistant to fracture.

b. Though it is a biological material of collagen and in life has a living organic component, the mineralization of the dentine prevents it from decaying.
c. Dentine is moderately soft and easy to carve and because of the intermesh of collagen fibres can be carved equally well in all three dimensions.
d. Ivory is hard enough to cut and define very small features.
e. Ivory is porous and so is readily stained by dyes.
f. Because of the nanometre size of the hydroxyapatite crystals, ivory can be highly polished. The density of the crystals resists easy contamination by air pollutants.

Techniques for studying ivory

a. Chemical analysis (Clocher)
b. Back scatter (Clocher)
c. Scanning electron microscopy
d. Energy dispersive analysis of x-rays.
e. Lowenstein's radioimunassay analysis

Miscellaneous uses of ivory

a. Watercolour painting.
b. Production of ivory black.
c. Mountings for compasses
d. Piano keys
e. A miscellany of a hundred and one uses.

Miscellaneous information

a. Age of elephants: There is no authenticated record of *Elephas maximus* or *Loxodonta Africana* reaching the age of 70 years. (Flower, 1947).
b. Elephant numbers. The number of elephants in Uttar Pradesh increased from 380 to 507 between 1966-1967. There were 180 females in 1967 and they should produce at least 30 calves per year. A survival percentage of not more than 60% is assumed (Singh, 1978).
c. Rate of tusk growth: Humphreys (1926) reported 16cm. of growth per year for tusks of *Elephas maximus* and 17cm.

Conclusion

With the resources and techniques available to us we were not able to distinguish the ivory derived from *Elephas maximus* from that of *Loxodonta Africana*.

Bibliography

Brown, W. A. B., Christofferson, P. V., Massler, M. & Weiss, M. B. (1960). Postnatal tooth development in cattle. *Am. J. Vet. Res*. **21:** 7-34.

Encyclopaedia Britannica. (1970). William Benton, Chicago

Flower, S. S. (1947). Further notes on the duration of life in mammals. *Proceedings of the Zoological Society, London.* **117**: 680-688.

Gouk, P. (1988). The Ivory Sundials of Nuremberg, 1500-1700. *Whipple Museum of the History of Science, Cambridge.*

Humphrey, H. F. (1926). Particulars relating to the broken t of a wild Indian elephant. *British Dental Journal.* **47:** 1400-1407.

Lowenstein, J. M. (1981). Immunological reactions from fossil material. *Philosophical Transactions of the Royal Society, London.* **B 292:** 143-149

McCance, R. A., Ford, E. H. R. & Brown, W. A. B. (1961).Severe undernutrition in growing and adult animals. 7. Development of the skull, jaws and teeth in pigs. *Brit. J. Nutr.***15:** 213-224.

Singh, V.B. (1978). The elephant in U.P. (India) – A resurvey of its status after 10 years. *Journal Bombay natural History Society.* **75:** 71-82.

Thornton, J. (1981). The structure of ivory and ivory substitutes. *The American Institution for Conservation of Historic and Artistic Works.* (Paper presented at 9th Annual meeting.173-181.