Studies on elephant tusks and hippopotamus teeth collected from the early 17th century Portuguese shipwreck off Goa, west coast of India: Evidence of maritime trade between Goa, Portugal and African countries

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Shipwreck findings are indicators of the provenance of artefacts and trade routes. Many shipwrecks datable from the Bronze Age to the modern period have been excavated to yield numerous varieties of artefacts, including cargo, personal belongings of the crew, arms and ammunition, treasure, royal belongings, etc. Similarly, exploration of a Portuguese shipwreck in Goa waters has led to the recovery of a variety of artefacts, including elephant tusks, hippopotamus teeth, the barrel of a handgun, Chinese ceramics, stoneware (Martaban pottery), iron guns, an iron anchor, bases of glass bottles, pieces of lead sheets, copper vessel and strap, stone and clay bricks and dressed granite blocks. A comparative study of the findings and the thermoluminescence date of excavated stoneware dated the wreck to the early 17th century AD. The ^{14}C date of ivory is 740 ± 130 yrs; with a calibrated age range of 740 to 560 yrs BP. The elephant tusks are highly degraded, discoloured and soft to the touch, whereas the hippopotamus teeth are still very hard. Maritime trade records suggest that these tusks are likely to have been brought from African countries to India to make different types of finished artefacts before being sent back to Portugal and her colonies. This article highlights the state and analysis of elephant tusks and hippopotamus teeth recovered from the wreck site with the provenance determined primarily on the basis of maritime trade records that report the importation of these materials from African countries to India.

Keywords: Elephant tusks, Fourier transform infrared analysis, hippopotamus teeth, maritime trade, Portuguese shipwreck.

PRIOR to the expedition of Vasco da Gama (1460–1524) to India, a series of Portuguese navigators had vainly attempted to sail to the East. Their voyages terminated in and around the African coast. On 8 July 1497, with instructions from Lisbon, Vasco da Gama left for the East with the flagship *Sao Gabriel* and the *Sao Raphael* and the caravel *Berrio*. After making landfalls at St. Helena Bay, Mossel Bay, Mozambique, Mombasa and Malindi, he eventually reached Calicut with assistance from an Indian pilot Ahmad Ibn Majid, who guided him across the Arabian Sea to India.

Subsequently, agreements were signed between the local rulers of India and the Portuguese for trade and commerce and trading stations were established. The Portuguese monopoly over maritime trade continued for more than a century and their ships plied the high seas along the shores of the Indian Ocean region without competition until the arrival of the British, Danish, Dutch and French, who then also established their trade centres in India.

The basic pattern of trade of the European countries was to bring soldiers, trade goods, administrators, furniture, war material, building material, etc. to the region and on return carry spices, porcelain, cloth, silk, rice, timber and finished manufactured products. In the course of time, vessels from many European countries have been wrecked in the Indian waters with a greater proportion of Portuguese ships wrecked in the Goa waters. As these ships carried valuable cargo and or artefacts, attempts were often made to salvage shipwrecks, sometimes successfully. Over the years Portuguese shipwrecks have been explored and excavated off African, Indian and Portuguese coasts. Most of the cargo has left no tangible traces of the spices, tea, cloth, silk, rice and other organic substances that they would have carried; those are most likely to have completely degraded or to have been washed away. Other cargo such as guns (cannons), anchors, ceramic and stoneware sherds as well as building material still lie on the seabed, as these are of little commercial value to the salvagers and treasure hunters.

Portuguese ships wrecked in Indian waters soon after the arrival of Vasco da Gama at Calicut on 17 May 1498. Archival documents reveal that several Portuguese ships wrecked in Indian waters between the 15th and 18th centuries

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Figure 1. Location of Sunchi Reef shipwreck site.

AD, majority of them due to unskilled navigation, warfare, hidden rocky reefs, woodborers, and natural calamities.

The National Institute of Oceanography (NIO), Goa has undertaken the exploration of the Portuguese shipwreck at Sunchi Reef off Goa. Sunchi Reef is located between Marmagao and Cabo headlands (Figure 1). The Reef consists of laterite shoals more than 5 m in height and extends in a north-south direction, separating Marmagao Bay from the Arabian Sea. These shoals have extended to the shore zone making navigation extremely hazardous in this area. The reef near the wreck is uneven and the water depth ranges from 3 to 7 m. The currents, along with wave action in the reef region, helped deposit a thin layer of silt on the remains of the wreck. The maximum speed of ebb currents is about 3 knots, whereas during the spring tide it is about 1.8 knots. As the region is shallow, the strong current action in the working area severely hampered survey work. The seabed in this region is covered with shelly sand, lithified sediment and a rocky bed thinly covered by sediment[1].

Extensive and thorough search in and around Sunchi Reef led to the recovery of sherds of storage jars, the barrel of a handgun, Chinese ceramics, elephant tusks, hippopotamus teeth, guns (cannons), an iron anchor, gun shot, bases of glass bottles, pieces of lead pipe and sheets, copper vessel and strap, stone and clay bricks and a number of dressed granite blocks. These artefacts were either found in the laterite crevices or covered with a thin layer of silt or buried in the sediment. The guns and iron anchor, however were lying on the laterite with prolific growths of marine organisms on their surface[2,3].

Ivory trade between Goa and Portugal

Commodities like ivory, gold and some precious metals were brought to Goa in Portuguese ships in exchange for Indian spices, cloth and foodgrains[4]. The main items of export by the Portuguese were pepper, ginger and other spices from Malabar and Karnataka, cotton and silk from Bijapur, Bengal, Cambay and Golconda, cinnamon from Ceylon, and mace, nutmeg and clove from the Maluccas and Banda Islands. Similarly, ivory, gold, slaves, precious metals, stones, corals and other articles of trade

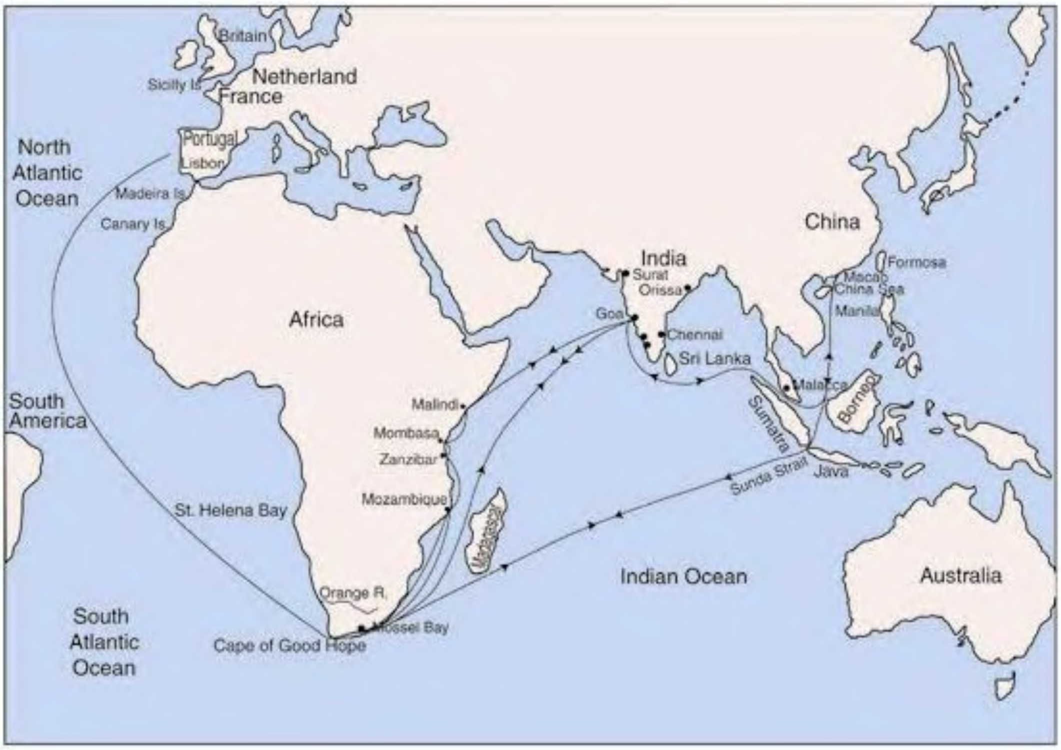

Figure 2. Portuguese trade centres in African countries, India and Macao and routes followed by Portuguese ships.

were brought to Goa from Mozambique, Mombasa, Sofala, Angola and other places in Africa (Figure 2). The Portuguese generated huge revenue and wealth by trading with these centres, with ivory being one of their most profitable commodities. Ivory brought to Goa was dispatched to Cambay, Surat and other places in Gujarat because artisans concentrated in this region were more skilled than those in other regions. They enjoyed a *de facto* monopoly on producing ivory goods and no one could compete with them. The ivory was stored at the house of Manuel Moraes, a merchant contractor, of Goa and subsequently sent to Cambay or Surat according to the particular contract. Even ivory imported by private merchants was carried under the Portuguese banner. The *nau* (a type of a Portuguese ship) *Sao Miguel*, for example, sailed from Mozambique to Goa carrying 600 quintals of copper and eighty pieces of ivory[5]. Sometimes *naus* carrying ivory sailed directly from Mozambique either to Cambay, Diu or Surat since ivory was in great demand. Further, Portuguese records mention that a *nau* called *Nazare* belonging to the king of Portugal sank at the bar of Goa in AD 1523, and some of the cargo such as ivory and copper was recovered by divers[5].

Textiles purchased from Cambay and Surat were sent to Malindi through the Hindu merchants. Ships loaded with beads, rice, textiles from Gujarat and materials for warfare set sail from Goa and other Portuguese ports in India to African countries every January, returning between March and May loaded with African goods such as gold, ivory, slaves, amber, tortoise shells and ebony wood[6].

After the death of King D. Jose in AD 1777, there was disarray in the Portuguese maritime trade until D. Francisco de Souza came to the rescue. He considered that each Portuguese ship could fetch 400,00 *cruzados* per year by selling the cargo at Mozambique and then sailing for Goa with the remaining goods and other merchandise purchased at Mozambique such as gold, ivory, hippopotamus teeth, tortoise shells and slaves. After selling goods at Goa the ships could then sail for Daman, Surat and Diu from where they would collect all consumable goods and sail for Portugal[7].

Portuguese records which indicate the volume of ivory imported to Goa between AD 1613 and 1661 are summarized in Table 1. It is evident from the table that more than 50% of ivory was imported from Mozambique, but the quantity of ivory imported from other countries is not clearly known[8]. It is generally believed that ivory from the African elephant is much better in quality than the Asian elephant because of its superior hardness, pale blonde transparency and ability to be more finely polished. African elephant tusks can measure up to 2 m in length with diameters of 9 to 11 cm and weights up to 90 kg, while tusks of Asian elephants are smaller and lighter.

Ivory and hippopotamus teeth were used for making sculptures, statues, bangles, various types of handles, seals, cones, pyramids, buttons, cylinders and toy animals in a wide variety of shapes and sizes. Besides ivory statues, inlay ivory figures were incorporated in chairs, tables, wardrobes, chests, sofas and boxes for keeping gold and

Table 1. Import of ivory to India

Year	Volume (in kg)	Amount invested in Xerafins	Imported from
1613	26691	79332	Mozambique
1614	23282	69246	Mozambique
1619	11641	17695	Mozambique
1620	2308	3476	Mozambique
1621	2622	3985	Mozambique
1625	1232	1870	Mozambique
1626	1311	1993	Mozambique
1644	944	1432	Mozambique–Lisbon
1646	44834	72996	Mozambique–Diu
1650	1229	1846	Mombasa
1661	55884?	84944?	Mozambique
1661	34642	52655	Mozambique

Source: Ahmed Afzal[8].

jewellery. Indian artists were exposed to non-Christian art prior to the arrival of the Portuguese. Influenced by the Portuguese they started making sculptures and statues of non-religious, secular as well as profane artefacts of the Christian art made out of stone, wood and ivory in Goa and elsewhere.

Hippopotamus are large aquatic mammals that live in the wetlands of southern, western and Central Africa. They were once found throughout Africa, but now they are extinct in northern Africa. Over the centuries people have hunted hippopotamus for meat and teeth. The enormous mouth contains large canine teeth which may be over 1.5 m long. The hippopotamus is also known as 'river horse'. The teeth of the Hippopotamus are hard, retain their whiteness for a long time and do not change colour when cut and polished. Hippopotamus have enormous jaws that hold long, curving teeth which consist primarily of enamel.

Composition, structure and properties of elephant ivory

Ivory is dentine, a non-cellular substance present in all teeth, including those of the walrus, hippopotamus and sperm whale. Each type of ivory has its own characteristics and distinctive processes by which dentine is formed. African ivory is of the highest quality, hardest and most brilliant. It also tends to retain its yellowish-white colour better as it ages. The best African ivory comes from Gaboon, Mozambique and Zanzibar, and, as stated earlier, was much in demand by Indian craftsmen for making sculptures, bangles, inlay work and other artefacts.

A transverse section of a piece of un-degraded African ivory shows its typical pale blonde transparency and the clear, sharp, engine-turned, decussating appearance characteristic of elephant ivory. These markings are clearly evident in the transverse section of a piece of degraded ivory recovered from the Sunchi Reef wreck (Figure 3).

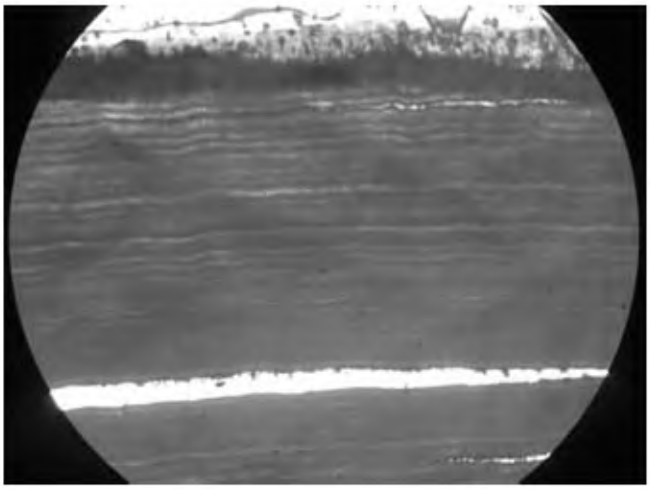

Figure 3. Transverse section of an elephant tusk from Sunchi Reef (25X).

As described by Penniman, 'the longitudinal section shows straight continuous lines, and usually long thin parallel clouds which are whiter and more opaque than the material between them'[9]. Indian ivory, on the other hand, is whiter, softer and more opaque, with a tendency to discolour and takes less fine polish than African ivory. When exposed to light it tends to become dull in appearance, whereas African ivory often takes on a porcellanous sheen. The appearance of a cut section is creamy with a mellow sheen and the engine-turned decussating appearance on the transverse section is less distinct in the Indian ivory. As with African ivory the longitudinal section of Indian ivory also had the characteristic straight lines and long, thin parallel milky clouds.

Fresh ivory contains two main components, a complex protein that permeates the structure and a mixture of minerals that provide strength. The ratio of inorganic to organic matter is about 65 : 35 in African elephant ivory[10]. The principal organic component is type I collagen, a protein with a triple-helical structure that contains a high proportion of the amino acids, glycine, proline and hydroxyproline. The major mineral component is a non-stoichiometric, carbonate-containing apatite, similar to hydroxyapatite. Evidence from X-ray diffraction and infrared studies[11,12] indicates that this mineral is best represented by the formula $Ca_{10}(PO_4)_6(CO_3)H_2O$. Small amounts of calcium carbonate and calcium fluoride comprise the bulk of the remainder.

Chemistry and deterioration of ivory

The physical, chemical and biological characteristics of the burial environment and the period of interment largely determine the condition of recovered ivory artefacts, with microbiological activity critical in the early stages of deterioration[13]. The breakdown of collagen leads to the formation of more soluble peptides and amino acids, which are subsequently leached from bone[14]. This breakdown may be attributed to either microbiological attack or chemical hydrolysis. The latter mode of collagen deterioration is expected to be predominant in environments which inhibit demineralization of the inorganic matrix[15]. Porosity of ivory enhances both exchange and deposition of minerals within the inorganic matrix. The breakdown of collagen increases the exposure of the hydroxyapatite crystallites and thereby promotes crystallographic change[16,17]. Hydroxyapatites are also known to undergo alterations such as anionic exchange with fluorine, cationic exchange with strontium, radium and lead, and substitution of the phosphate moiety with carbonate[18].

State of elephant tusks and hippopotamus teeth

Explorations off Sunchi Reef, Goa, yielded eight elephant tusks of different sizes ranging from 65 to 32 cm in length and 15 to 22 cm circumference. These tusks were buried in the coarse sand and covered with dead shells with only small portions visible above the seabed. Of the eight tusks, two are inscribed, one with three English letters 'ICM', with 'CM' visible clearly, while the first letter 'I' has been abraded (Figure 4). These inscriptions could be the trader's mark. The other inscribed tusk has some geometrical designs on its surface. No engraved marks were found on the other tusks. All tusks are cut pieces except the longest one which measures 65 cm and has the distal end intact. The original length of the tusks could not be determined. The long period of immersion has produced degraded ivory that is soft, brittle and flaky.

Similarly, nine different sizes (53.5, 47, 43, 39, 28, 27, 20.5, 16 and 12.5 cm in length) of hippopotamus teeth, partly buried in the seabed to the east and northeast side of the guns were recorded and subsequently recovered (Figure 5). All these teeth are curved, indicating that they are canines. No straight incisor teeth were found on the wreck site. On each tooth a straight cut-like depression is present, due to continuous rubbing (abrasion) between the lower and the upper jaw. The teeth of hippopotamus are the hardest of all teeth that are used as ivory. They retain their whiteness for a long time and do not change colour when cut and polished. Hippopotamus teeth are composed of enamel, the outer 'glazed' surface, and dentine the hard inner substance. These white teeth have turned brownish in colour due to prolonged exposure to the marine environment. Presence of marine organisms on their surface also supports this view. The largest of the teeth has separated into two parts but all others are intact.

After excavation, the elephant tusks and hippopotamus teeth were kept in marine water for some days. Subsequently, 5, 10, 15, 20% of freshwater was added to them by removing the same quantity of marine water. Salt analyses were used to estimate the quantity of salt in the water, with desalination continuing until all detectable salt had been removed from the tusks and teeth. On completion of desalination, the tusks and teeth were placed in freshwater, with the solution changed every two months. Each of the tusks had been bound with twine to retain the flaking and splitting fragments.

The ivory, which appeared to be highly degraded, was soft to the touch and discoloured. This discolouration was not uniform, indicating that the ivory was differentially degraded. Previous work on bone and ivory had indicated that Fourier transform infrared (FTIR) spectroscopic analysis was capable of providing information about the inorganic and organic components that make up these material types[19].

Experimental techniques

FTIR spectra were collected using a microscope diamond cell accessory on a Biorad Excalibur FTS 3000MX FTIR

Figure 4. Elephant tusks recovered from the shipwreck off Sunchi Reef.

Figure 5. Hippopotamus teeth collected from the shipwreck off Sunchi Reef.

spectrometer. Duplicate spectra were collected for each sample. Samples were taken from areas in which different colouration indicated that there may be differential degradation of ivory. FTIR spectra were collected for samples that were identified as being 'black', 'inner', 'pink', 'rusty' and 'general'. Heights for the peaks centred at approximately 1650–1620, 1420 and 1035 cm^{-1} were determined using the Galactic Industries Corporation GRAMS/386 software and a baseline of 1800–800 cm^{-1}. The amide I peak (1650–1620 cm^{-1}) and the phosphate peak (PO_4^{-3}), centred at approximately 1035 cm^{-1}, were used as the respective reference absorptions for the organic and mineral components of ivory, while the peak centred at 1420 cm^{-1} was used as the carbonate (CO_3^{2-}) reference peak. The intensity ratios I_{1640}/I_{1035} and I_{1420}/I_{1035} were calculated for all duplicate samples to quantify the relative retention of organic material and the incorporation of carbonate, relative to phosphate, in the inorganic matrix respectively.

Results

Data pertaining to the FTIR spectra are given in Table 2 as are FTIR spectra for modern, un-degraded African elephant ivory and for a typical piece of degraded Goa ivory (Figure 6). All the spectra of the archaeological samples differ from those of un-degraded ivory and provide information on the impact of immersion and diagenetic change. Characteristics of the FTIR spectra include the loss of substantial amounts of collagen, retention of the hydroxyapatite inorganic framework and incorporation of carbonate into the structure. The IR spectra of modern ivory (un-degraded) and Goa ivory (degraded) retrieved from Sunchi Reef, Goa were compared. Absence of peaks between 1540 and 1660 cm^{-1} in the latter is due to degradation of collagen, while the stronger peaks at 870, 960, 1420 and 1450 cm^{-1} in the Goa sample may be attributed to its richer carbonate content due to incorporation from carbonate-rich sea water. The IR spectrum of the hippopotamus teeth also resembles that of the Goa ivory since they also have little collagen, but higher levels of carbonate.

Evidence for the depletion of collagen from the archaeological samples is provided by absorptions in the 1700–1500 cm^{-1} region. For each sample the intensity of absorptions in the amide I region, centred at approximately 1640 cm^{-1}, is markedly diminished in relation to the characteristic phosphate absorption centred at approximately 1035 cm^{-1}. It is interesting that slightly more collagen appears to have been retained in the 'rusty' samples. Although no analyses were carried out to determine if in fact iron is present in these areas, the typical rust colour indicates that this is likely. If this is the case, it would provide further evidence for the preservative effects of iron corrosion products on immersed collagen. In a recent study[19], greater amounts of collagen were found in the outer, iron-rich regions of a tusk fragment than in the iron-depleted, inner regions. This tusk has been recovered after 350 years of immersion in a marine environment.

Table 2. FTIR spectral data

Sample	I_{1640}/I_{1035}	I_{1420}/I_{1035}
Black	0.12	0.56
Inner	0.17	0.64
Pink	0.20	0.63
Rusty	0.42	0.70
General 1	0.16	0.66
General 2	0.14	0.56
Modern ivory*	0.62	0.16

*Godfrey *et al.*[19].

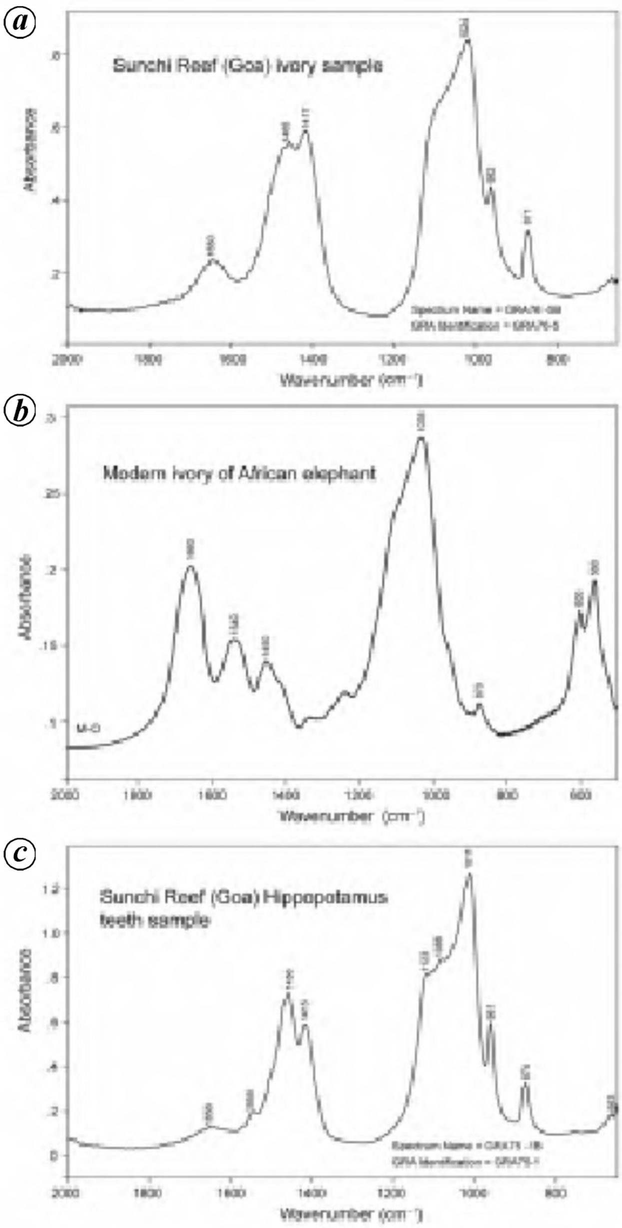

Figure 6. FTIR spectrum of elephant tusk off Sunchi Reef and sample of modern ivory of African elephant and hippopotamus teeth off Sunchi Reef.

Absorptions at approximately 1035 and 960 cm^{-1}, typical of phosphate and at 1460, 1420 and 873 cm^{-1}, typical of carbonate in un-degraded biological apatites[20], indicate that the carbonate-containing hydroxyapatite structure has been substantially retained in these materials. Interestingly, high carbonate/phosphate ratios (I_{1420}/I_{1035}) for all samples indicate that carbonate substitution for phosphate has been a significant part of the overall diagenesis of the ivory found off Goa. This finding, although contrary to the Western Australian tusk fragment described previously[19], is consistent with the proposal that an increase in the amount of secondary carbonate in the matrix may be related to the loss of organic matter[17]. ^{14}C dating of ivory gave an age of 740 ± 130 yrs with a calibrated age range of 740 to 560 yrs BP.

Discussion and conclusion

Elephant tusks and hippopotamus teeth have been traded for thousands of years. Excavations of the *Uluburun* wreck off the southeast coast of Kas, Turkey[21], for example, yielded several artefacts, including elephant tusks and more than a dozen hippopotamus teeth, dated to 1400 BC. Portuguese maritime explorers turned towards India primarily in search of spices which were in great demand in Europe. Being emboldened by the discovery of the sea route to India, the aim of the Portuguese was to obstruct as much trade as they could between India and the Red Sea and between India and the Persian Gulf, and to channel the trade of the East with Europe as well as Portugal. To achieve these goals they strove to make Goa a main entry point for all kinds of activities. The Portuguese mainly dealt with high demand goods which could fetch large profits, with ivory being one of the most profitable among these.

After discovering the new sea route to the East at the end of the 15th century, the Portuguese understood the importance of and high demand for ivory in India, importing it from African countries to meet this demand. The ivory tradition was not known to the Portuguese prior to this and it was a surprise for them to see the extent of developed ivory art in India. Although Indian ivory has been used for making miniature sculptures and artefacts since the beginning of the Bronze Age in India, it was unsuitable for making big sculptures because of its brittle texture, softness, opaqueness and tendency to discolour. Excavations at Harappa, Mohenjodaro and Chanhudaro, for example, have yielded ivory and other artefacts. The ivory comb shows the characteristic layered breakages and other artefacts have turned brownish to pale dark[9]. Artefacts made out of Indian ivory were smaller in size hence the Portuguese brought longer ivory from African countries for making bigger sculptures. With the passage of time the export of Indian textiles to the African countries increased concurrently with increased volumes of ivory heading back to India.

Many ivory sculptures and statues are found in museums and private collections in India, Portugal, Mozambique, Brazil, Great Britain, France, Holland and their former colonies, which had exported finished products from India through the port of Goa. The ivory from the wooded and humid regions of Africa was considered better for carving sculptures, statues, bangles and other objects of religious and secular art. Thus, despite the difficulties of using morphological features to unambiguously assigning a provenance to ivory artefacts, these regions of Africa are the most likely source of the ivory used in such artefacts.

The engine-turned decussating appearance usually found on the transverse section of elephant tusks was not detected in the Sunchi Reef because these tusks are highly deteriorated and degraded. Likewise the usual features such as colour, hardness and opaqueness which can sometimes be used to differentiate between African and Indian ivory could not be used for these deteriorated samples because of the changes in the properties that occurred during prolonged immersion.

It was not only the Portuguese ships that were involved in the ivory trade. In the mid-19th century, the wooden hulled British ship *Child Harold*[22] sailing from Bombay to London and carrying 1336 pieces of ivory, cotton, deer horns, pearl shells and cardamom wrecked off Dassen Island, South Africa, in February 1850. The Dutch East Indiaman *Vergulde Draeck* struck a reef close to the Southland about 120 km north of Perth, Australia in AD 1656. The underwater explorations brought to light iron guns, cannon balls, ballast bricks, resin, slate, wooden and bone handles, comb, shoes, timer, pitch and 13 elephant tusks. It was presumed that these elephant tusks were exported from the Netherlands[23]. Similarly, the Danish–Norwegian ship *Fredensborg* involved in triangular trade (Europe, Africa and West Indies) wrecked off the Island of Arendal in Norway in 1768 carrying slaves, 927 kg of elephant tusks, hippopotamus teeth, cinnamon, tobacco and cotton. These elephant tusks and hippopotamus teeth were from Africa[24]. Two hippopotamus teeth have also been recovered from the wreck of the *Santo Antonio de Tanna*. Unfortunately, no elephant tusks were found in this case. Excavations of the VOC *fluit Risdam* (1727) near Mersing on the east coast of Malaysia has yielded tin ingots, lead ingots, 90 elephant tusks, Dutch bricks and storage jars. It appears that these tusks may have been of Southeast Asian origin[25].

As hippopotamus are now confined to only African countries, it is this region that is the original source of the hippopotamus teeth which were recovered from Sunchi Reef wreck site. The co-location of hippopotamus teeth of definite African origin with elephant tusk material indicates that latter material is also likely to have been sourced from Africa. Further, as the largest quantities of ivory were imported from Mozambique, it is likely that this country was the source of the tusk material and hippopotamus teeth found on Sunchi Reef wreck site. The historical record and the co-location of hippopotamus teeth with the tusks therefore provide the most compelling evidence for Sunchi Reef tusks having an African origin. Although further investigations may shed new light on the origin of the teeth and the tusks, conclusive determination of their provenance will not be an easy task. DNA analysis, for instance, which could differentiate between Indian and African ivory is problematic, due to the deterioration of organic compounds caused by prolonged immersion in the marine environment.

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