The following is a request for permission to access and sample archaeological ivory material in the University of Pretoria Museum collection for the post-doctoral project *Mapping the flow of ivory in eastern and southern Africa using a bioarchaeological approach* (project summary attached) carried out by Dr. Ashley Coutu, Department of Archaeology, University of Cape Town. The aim of the project is to catalogue and sample ivory artefacts and ivory working debris from sites across pre-colonial southern Africa to better understand the ivory trade during the Iron Age.

In June 2014, with permission from Chief Curator Sian Tiley-Nel, I visited the collections to examine the ivory materials excavated from the Iron Age site of K2. I would like to ask for permission to return to the collection, this time with the specific purpose of sampling some of the ivory pieces, as outlined below. Some of the objects are not suitable for sampling due to the intact nature of the armbands, cultural modifications, and the delicacy of the objects. However, during my visit, I noted that the samples listed in the table following would be suitable for minimal sampling due to the fact that pieces are already flaking off these objects, as broken fragments have been stored in vials with the original specimen. Therefore, it is possible to sample only from the loose material that has already detached from the specimen.

Because all of the material has been identified to species, there is no need to determine the species of the ivory. Thus, I have noted in the table following which pieces I would like to ask for permission to do minimal destructive sampling (~100mg) for multi-isotope analysis ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) to map the possible source regions of this ivory. This data will be compared to the isotope results I have already obtained from sampling ivory artefacts from two other Iron Age sites (KwaGandaGanda and Ndondondwane) held at the Natal Museum in KwaZulu-Natal. The isotope data from these two sites provided evidence that the ivory material was coming from distinctive catchment areas. I also plan to sample more ivory material from K2 held at the University of Witswatersrand collection. Thus, it is critically important to analyse the material in the University of Pretoria collection in order to add to the complete understanding of ivory found in different phases of excavations at the site of K2.

UP #		Description
UP 1	IV 12	Large piece of an elephant ivory tusk with many smaller broken fragments in vials
UP 3	IV 14	Large piece of hippo tusk with smaller broken fragments in vials
UP 4	IV 05	Fragment of elephant ivory armband – could sample from broken end
UP 5	IV 03	Fragment of elephant ivory armband – could sample from broken end
UP 6	IV 04	Large piece of elephant tusk and smaller fragments of tusk
UP 8	IV 09	3 larger armband fragments and one small fragment flaked off
UP 11	IV 02	Large armband and one small fragment flaked off
UP 13	IV 11	7 individual armband fragments and two small fragments flaked off

Examples of material listed above, including unworked tusk fragments and ivory bangle waste fragments. The black circle in the first photograph is an example a fragment that weighs approximately 100 mg, which would be the amount necessary for sampling.

Mapping the flow of ivory in eastern and southern Africa using a bioarchaeological approach

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Aims: The primary aim is to use bioarchaeological techniques (isotope analysis and ZooMS) as well as mapping tools (ArcGIS) to better understand the types, source regions and trade of ivory during the Iron Age by identifying and sourcing ivory artefacts from archaeological sites in eastern and southern Africa. The isotopic composition (especially $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) of animal tissues, including ivory, reflects the soils, vegetation and climate of the region where the animal lived. The patterning of these isotopes can be mapped across the landscape, and used to trace the origin of non-local materials, including trade goods. This study will enhance archaeologists' understanding of trade and connectivity across Africa from the first millennium AD onwards. It will also add substantially to the database of isotope values for modern and historic elephants in these regions. This can be used to fingerprint ivory to specific regions, which has application in modern wildlife conservation.

Background: For my PhD research, I used isotope analysis as a tool to source ivory artefacts traded from East Africa to the US, UK, and Europe in the 19th and 20th centuries. This approach required the construction of an isotopic database of East African elephants. I collaborated with a number of organisations to collect tissue samples from modern elephants from known localities (National Museums Kenya, Kenya Wildlife Service, Tanzanian Wildlife Division, Tanzanian National Parks) historic provenanced elephants (Quex Museum, Smithsonian, Field Museum) and historic ivory artefacts (Deep River and Ivoryton History Museums, Hawley Collection Sheffield). I then employed a suite of isotopic analyses (the isotopes of carbon, nitrogen, oxygen, hydrogen, strontium) to create a database of East African elephant isotope values. This enabled me to provenance a range of ivory artefacts deriving from locations within primary elephant hunting grounds of the 19th and 20th centuries. By mapping traded ivory in this way, it has been possible to explore how archaeological trade routes corresponded with elephant extraction zones and how these shifted over time with increasing exploitation of ivory.

Programme: I will use this same approach for understanding the pre-colonial flow of ivory across eastern and southern Africa. Our current knowledge of the pre-colonial ivory trade in eastern and southern Africa consists of evidence from a handful of archaeological sites that have yielded ivory-working debris (e.g. Mapungubwe, Ndondondwane, KwaGandaganda in South Africa) or ivory objects (e.g. Mosu in Botswana). Small amounts of worked ivory have also been recovered from archaeological deposits at places such as Kilwa, Shanga, and Chibuene, important trading centres along the east and south-east African coast (Chittick 1974; Horton 1996; Sinclair et al. 1993). In southern Africa, sites dating from the 7-11th centuries AD such as Schroda, K2, and Ndondonwane have yielded large caches of ivory debris, suggesting that these places were centres for ivory carving/production for export (Voigt 1983; Voigt and von den Driesch 1984). Was all of the raw ivory obtained locally, or was it brought in from further afield? The primary aim of this project will be to trace the interconnectivity of the ivory trade during the pre-colonial era. A better understanding of the ivory trade will make a key contribution to the larger research goal of reconstructing wider Indian Ocean networks of trade and interaction in pre-colonial times. Another goal is to extend the existing database of analyses characterising elephants from different parks and wildlife sanctuaries across southern Africa. This will build on the work begun by van der Merwe et al. (1990). My study will increase the geographical coverage and employ a wider range of isotopic indicators, thus improving our ability to distinguish ivory from different source areas.

Objectives: My proposed research will begin with a survey of ivory production/trading sites across eastern and southern Africa, especially Chibuene in Mozambique, Mosu in Botswana, Ntusi in Uganda, and Mapungubwe, Schroda, K2, KwaGandaganda, and Ndondondwane in South Africa. In the initial stages, the project will determine how much within-site variation there is in the species of ivory present (African elephant, hippopotamus, and warthog ivory are all known to have been exploited), and how much isotopic variation exists among different pieces (both waste fragments and rarer finished artefacts). This will indicate how widely ivory at individual sites was sourced. This information alone will significantly improve our understanding of pre-colonial networks of regional interactions. Next, these measurements will be compared with maps of actual and/or modelled isotopic ranges for different parts of the southern African sub-region, in order to try to pin down the areas of origin.

Methods: The first step will be to identify the ivory to species. Apart from elephants, other species such as hippopotamus yield ivory. I will first attempt to visually identify the material to species; however, it is often difficult to identify small fragments to species level. If this is the case, it will be necessary to use the bioarchaeological method of Zooarchaeology by Mass Spectrometry (ZooMS), which is non-destructive (van Doorn et al. 2011). In the same way that we shed proteins contained in hair and skin, bone and ivory material also contain proteins that are electrostatic and have the ability to 'shed' onto materials such as a rubber (ie: eraser). Collaborators at the University of York, UK, have designed a non-destructive sampling method to collect proteins from an artefact by rubbing the outer surface of the artefact with a rubber which creates electrostatic friction that allows the protein in the bone or ivory (collagen) to bind to the rubber. After collecting the shavings, it is then possible to digest the rubber shavings in acid, extract the proteins that have adhered to the rubber, and analyse that protein (collagen) to determine the species using the ZooMS technique. ZooMS is therefore a rapid and non-destructive method to distinguish between elephant and other types of ivory when it is impossible at a micro or macroscopic level. Once the material is identified to species, the next step will be to determine the catchment area of the ivory. For this, it will be necessary to use a minimally destructive (~100mg of material) multi-isotope approach ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) to narrow the source region of the specimen. Because many of the archaeological sites under investigation have waste fragments of ivory, it will be possible to use these small scrap pieces for analysis. Any sampling of artefacts will be done in strict supervision of the curator, and with minimally invasive techniques such as using small drill bits. I have many years of experience sampling ivory artefacts in museum collections, and thus know the most appropriate techniques in how to sample in the least destructive way possible for preserving these pieces for future museum display or analysis. In terms of interpreting the results, my PhD research has already provided an isotopic database of modern and historic elephants in East Africa, and there is also a substantial amount of baseline isotope information for varying geologies and environments across southern Africa (Arnold et al. 2013; Codron et al. 2012; Codron et al. 2010; Codron et al. 2005; Copeland et al. 2011; Sillen et al. 1998; Smith et al. 2010; van der Merwe et al. 1990). Analyses of C, N and O isotopes will be carried out in the Stable Light Isotope Laboratory in the Department of Archaeology at UCT, following well-established protocols. Analysis of Sr isotopes will be done in the Department of Geological Sciences at UCT, also following standard methods utilised in my past research on elephant ivory.

Significance: The results of the proposed study will add to the database on African ivory currently available, and will map the trajectory of the trade in ivory over longer time scales and with a much higher geographical resolution than has ever been accomplished. In turn, this will provide a better understanding of ivory extraction zones and the interconnectivity of regional trade networks. This picture will be compared with information now available on other key exchange items in pre-colonial trading systems – glass beads (Wood 2012) and metals. Though this research is rooted in the past, it addresses issues relevant to contemporary society, namely by redressing the widespread ignorance of the distribution and technology of procuring and exchanging ivory within highly sophisticated pre-colonial African trade networks and through the refinement of techniques which have a direct impact on wildlife conservation.

References:

Arnold, E.R., Greenfield, H.J. and Creaser, R.A. (2013) Domestic cattle mobility in early farming villages in southern Africa: harvest profiles and strontium ($^{87}Sr/^{86}Sr$) isotope analyses from Early Iron Age sites in the lower Thukela River Valley of South Africa. Archaeological and Anthropological Sciences. DOI 10.1007/s12520-013-0121-z.

Chittick, H.N. (1974) Kilwa, an Islamic trading city on the East African coast. Nairobi: British Institute in Eastern Africa. Memoir 5.

Codron, J., Codron, D., Lee-Thorp, J.A., Sponheimer, M., Bond, W.J., de Ruiter, D. and Grant, R. (2005) Taxonomic, anatomical, and spatio-temporal variations in the stable carbon and nitrogen isotopic compositions of plants from an African savannah. Journal of Archaeological Science 32, 1757–1772.

Codron, J., Codron, D., Lee-Thorp, J.A., Sponheimer, M., Kirkman, K., Duffy, K.J. and Sealy, J. (2010) Landscape-scale feeding patterns of African elephant inferred from carbon isotope analysis of feces. *Oecologia* 165 (1), 89-99.

Codron, J., Codron, D., Sponheimer, M., Kirkman, K., Duffy, K.J., Raubenheimer, E.J., Mélice, J.L., Grant, R., Clauss, M. and Lee-Thorp, J.A. (2012) Stable isotope series from elephant ivory reveal lifetime histories of a true dietary generalist. Proccedings of the Royal Society B, 279 (1737): 2433-41.

Copeland, S.R., Sponheimer, M., de Ruiter, D.J., Lee-Thorp, J.A., Codron, D., le Roux, P.J., Grimes, V. & Richards, M.P. (2011) Strontium isotope evidence for landscape use by early hominins. Nature 474: 76-79.

Doorn, v. N.L., Hollund, H. & Collins, M. (2011) A novel and non-destructive approach for ZooMS analysis. Archaeological and Anthropological Sciences 3: 281-289.

Edwards, H.G.M., Hassan, N.F.N. and Arya, N. (2006) Evaluation of Raman spectroscopy and application of chemometric methods for the differentiation of contemporary ivory specimens I: elephant and mammalian species Journal of Raman Spectroscopy 37 (1-3), 353-360.

Horton, M. (1996) Shanga: the Archaeology of a Muslim Trading Community on the Coast of East Africa. Nairobi: British Institute in Eastern Africa. Memoir 14.

Reid, A. & Segobye, A.K. (2000) An ivory cache from Botswana. Antiqutiy 74, 326-331.

Sillen, A., Hall, G., Richardson, S. and Armstrong, R. (1998) 87Sr/86Sr ratios in modern and fossil food-webs of the Sterkfontein Valley: implications for early hominid habitat preference. Geochimica et Cosmochimica Acta 62 (14), 2463-2473.

Sinclair, P. J. J., Morais, J. M. F., Adamowicz, L., and Duarte, R. T. (1993) A perspective on archaeological research in Mozambique. In T. Shaw (ed.) The Archaeology of Africa: Food, Metals and Towns, 409-431. London: Routledge.

Smith, J., Lee-Thorp, J., Prevec, S., Hall, S. & Spä̈th, A. (2010) Pre-colonial herding strategies in the Shashe-Limpopo basin, Southern Africa, based on strontium isotope analysis of domestic fauna. Journal of African Archaeology 8 (1), 83-98.

van der Merwe, N., Lee-Thorp, J.A., Thackeray, J.F., Hall-Martin, A., Kruger, F.J., Coetzee, H., Bell, R.H.V., and Lindeque, M. (1990) Source-area determination of elephant ivory by isotopic analysis. Nature 346, 744-746.

Voigt, E.A. (1983) Mapungubwe: an archaeozoological interpretation of an Iron Age community. Pretoria: Transvaal Museum.

Voigt, E.A. and von den Driesch, A. (1984) Preliminary report on the faunal assemblage from Ndondondwane, Natal. Ann. Natal Mus. 26 (1), 95-104.

Wood, M. (2012) Interconnections. Glass beads and trade in southern and eastern Africa and the Indian Ocean – 7th to 16th centuries AD. Studies in Global Archaeology 17, Uppsala: Department of Archaeology and Ancient History.