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A decorated Late Postclassic Mixtec human skull from Teotitlán del Camino, Oaxaca, Mexico, possibly dating to c.1400–1520 CE. The type of adhesive used to affix the mosaic to the skull raised some doubts about the authenticity of the object. Photo P. Erdil. (Collection Nationaal Museum van Wereldculturen. Coll.No. RV-4007-1.)

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Radiocarbon-based investigations into the authenticity of Mesoamerican artefacts in museum contexts

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***Abstract**: In this article, radiocarbon dating has been used as a tool for investigating the authenticity of two Mesoamerican artefacts from the collection of the National Museum of World Cultures (*Museum Volkenkunde*), Leiden, the Netherlands. The first artefact is a ceremonial Aztec, possibly a* tecpatl*, knife, and it is presumed to date to 1300–1500 CE. The second object is a decorated Mixtec skull, presumed to date to 1400–1520 CE. The efficacy of radiocarbon dating was thoroughly tested in this study, especially in regard to the tiny quantities that could be sampled from the skull. However, with the newly revamped radiocarbon facility at the University of Groningen, this was an opportune moment to attempt such research. Ultimately, a credible result could not be obtained on the skull; however, the ceremonial knife was dated reliably to the Aztec period. The article also discusses the broader issue of whether radiocarbon results can be used as a definitive proof of authenticity and examines the risk-reward nature of radiocarbon testing.*

***Keywords**: Mesoamerica, pre-Columbian artefacts, radiocarbon dating, authentication, museum studies.*

1. Introduction

Authentication studies on archaeologically or historically valuable artefacts can be conducted through interdisciplinary work between scientists, archaeologists and historians (Simon & Röhrs 2018: 2). The goal is commonly achieved through a series of studies that involve the identification of components and fabrication methods, and concludes with the assignment of unknown objects to a specific culture and time period (Richardin & Gandolfo 2013: 1810). This article focuses on the use of radiocarbon (^{14}C) dating as a means for determining the authenticity of two Mesoamerican artefacts: a knife with a wooden handle, and a decorated skull, from the collections of the National Museum of World Cultures (NMVW) in Leiden, the Netherlands.

Like all other pre-Columbian pieces on display at the NMVW, the precise provenance of these two artefacts is unclear. As a result, their authenticity remains in doubt. They were acquired in the 1960s from Robert Stolper, an art dealer with galleries in New York, Amsterdam and Munich. In Latin American archaeology, the looting and commercialization of archaeological material has been a persistent problem ever since the first European incursions into the continent. Looting intensified in the 20th century, when pre-Columbian art became *en vogue*, especially in the United States among museums and private collectors. As a result, the demand for these pieces exploded and museums across the world started to acquire large numbers of pre-Columbian pieces of art. The 1950s and 1960s were an especially significant period in this regard (Coggins 1969; Boone 1993; Alva 2001; Tremain & Yates 2019). The unprecedented extent to which looting took place in these decades eventually led to the creation of international legislation that prohibited the trade in these pieces, especially the UNESCO 1970 Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property. The combination of increased demand and prohibitive legislation concerning excavation and sale led to an increase in the number of forgeries available on the market (Kelker & Bruhns 2010). Many of these forgeries ended up in museum collections, either through direct purchase or through donations made by private collectors. A recent study of one museum collection proved the extent of the

problem, when it was found that 96% of the pre-Columbian pieces failed authentication (Kinsella 2017).

^{14}C dating is one of the various empirical methods used in authentication studies. It allows one to determine the age of an object, which in turn provides an idea about its origins. Many authentication studies that utilise ^{14}C dating have been published to date (see Strydonck *et al.* 1992; Craddock *et al.* 2002; Richardin & Gandolfo 2013). This article demonstrates that there are some important limitations to ^{14}C dating, not particularly in terms of the methodology, but in terms of the interpretation of the dates obtained for evaluating the authenticity of an object.

The ceremonial knife

The ceremonial knife (inventory number RV-3928-2, https://hdl.handle.net/20.500.11840/783533) was found in a cave in the state of Guerrero in Mexico in the 1950s. No documentation of this find was provided by the art dealer. Based on stylistic grounds, it is classified as Aztec and dated to 1300–1500 CE by the museum. The archive states that the knife was used for sacrificial purposes, possibly even for human sacrifices. The wooden handle is carved to resemble a hand. A long piece of flint is attached to the handle, and it has been sharpened on both edges (see Fig.1.c). The precise provenance of the artefact is unclear.

It is highly likely that this artefact is a sacrificial knife, taking into account the aforementioned physical features. Flint knives were called *tecpatl* in Nahuatl, the Aztec language. These knives would be used in ceremonies of blood offerings. Human and animal sacrifices and bloodletting were customary gifts to the gods in Mesoamerican culture. The most sacred of offerings was the offer of a human heart. Temple priests would cut through the chests of human sacrifices using the *tecpatl* knife, remove and present their hearts as an offering (Carrasco & Sessions 1998: 190). The remaining organs would then also be removed; the skull would be preserved and the flesh of the sacrifice would be eaten in a ritual meal (Miller & Taube 1993: 54).

The Aztecs are widely known for their tradition of human sacrifice. This impression may be based on Spanish Colonial propaganda that served to legitimate conquest (de Castro *et al.* 2019). The historical records kept by Spanish friars claim that more than 80,000 war captives were used as human sacrifices at the site of Tenochtitlan, the Aztec capital; however, there is actually no archaeological evidence to support that the number of sacrifices reached even 1% of this total (Carrasco 2011: 63). Some studies on Aztec culture also suggested that people were practising cannibalism in order to obtain the necessary amount of protein in their diet (Harris 1978). However, this claim was later refuted by proving that there were enough protein sources in the local environment (de Montellano 1983). The act of cannibalism was a ritual that was not a necessity; it was practised so that the Aztecs could 'feed' their gods to renew their energy, in order that they would continue giving life to the universe (Carrasco & Sessions 1998: 190).

The decorated skull

The decorated human skull (inventory number RV-4007-1, https://hdl.handle.net/20.500.11840/784610) is a Late Postclassic Mixtec piece (1400–1520 CE). According to the art dealer who sold this piece to the NMVW, the place of origin is the city of Teotitlán del Camino (today known as Teotitlán de Flores Magón), located in the state of Oaxaca, Mexico. A mosaic of turquoise, shell and mother of pearl decorates the face of the skull (see Fig.1.a). An outline of a snake is depicted on the forehead.

The authenticity of the skull with its elaborate mask is a matter of conjecture according to a previous study by Berger (2013), which combined scientific analysis of samples taken from the object with archival study of the provenance of the piece. Around 20 similarly decorated skulls are held in collections in Europe, the Americas and Asia. There is a striking absence of archaeological information associated with these skulls, since it is not known when and by whom they were excavated, and this has fuelled discussions about their authenticity. Between 2012 and 2016, the museum had the skull thoroughly investigated using various techniques. An isotope study, based on strontium, oxygen and carbon isotopes, suggested that the individual had lived in a drier, inland, higher-altitude region of volcanic bedrock geology in the early years of life and had consumed a diet that most probably consisted largely of maize as a staple crop (Berger 2013). The isotope ranges obtained were similar to known ranges from southwestern Mexico. For example, the Valley of Oaxaca is one of the places in Mesoamerica in which a combination of these isotope values would be expected to occur. The mosaic on the skull was also found to be authentic; however, analysis of the adhesive used to affix the mosaic showed that it was shellac, a material that did not exist in Mexico in pre-Columbian times (Berger 2013). While these results indicated that the skull could well have been excavated around Teotitlán, as claimed by the dealer, a ^{14}C study was needed to understand whether the individual had indeed lived in the correct time period (i.e. *c.* 1400–1520 CE).

2. Experimental

The samples from the ceremonial knife and decorated skull were obtained with the help of museum staff on 3 December 2018. A small number of thin bone fragments were broken off using tweezers from the lower back of the skull through a hole in which a stand is placed for

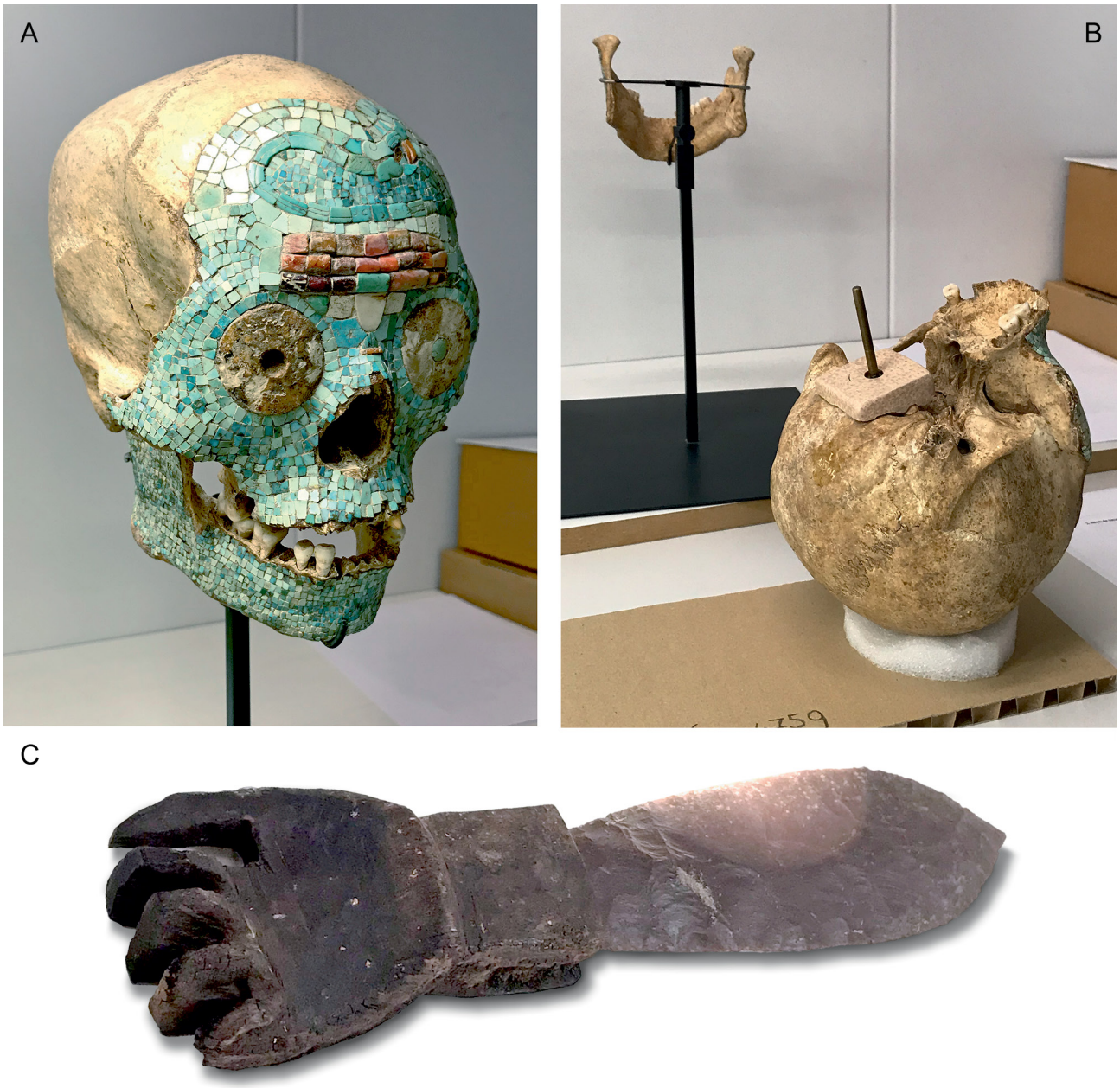

Fig. 1. a. The decorated skull ready to be sampled. b. Before sampling, the stand was removed and thin bone parts were taken from the inside of the skull. c. The ceremonial knife ready to be sampled (Collection Nationaal Museum van Wereldculturen, *Coll.Nos RV-4007-1, RV-3928-2. Photo P. Erdil).*

display purposes. Dust-like, wooden fibres were clipped out from the wooden handle of the ceremonial knife. The sample preparation protocols used in this study are covered in the following sections and more information can be found in Dee *et al.* (2020).

Sample preparation for holocellulose

The acid-base-acid (ABA) bleach protocol of the Centre for Isotope Research (CIO) was performed to extract holocellulose from the wooden handle of the knife (see Dee *et al.* 2020). The prepared sample consisted of wood fibres and wood powder and weighed 75.23 mg in total. The procedure is done as an intensified aqueous (water-based) pretreatment. The sample was first subjected to HCl (4% w/vol, 80°C, 30 min) followed by a triplicate rinse with demineralized water (DW). After each rinse, the sample was centrifuged (2000 rpm) in order to minimize sample loss. Next, NaOH (1% w/vol, 80°C, 30 min) was applied, also followed by another triplicate rinse with DW. Then, it was treated once more with HCl (4% w/vol, RT, 30 min). After a set of five rinses, an additional treatment of $NaClO_2$ (5% w/vol, RT, 30 min) was applied. Finally, the samples were again rinsed and left for air drying. The resulting pretreatment yield weighed 5.74 mg in total, 4.34 mg of which was placed in a tin capsule for ^{14}C measurement.

Sample preparation for collagen

In this protocol, the collagen extraction method of the CIO was performed on the skull sample (see Dee *et al.* 2020). The weight of the sample was 36.22 mg before the start of the pretreatment. The bone sample was placed in HCl (4% w/vol, RT, 24 hr) for decalcification, followed by a thorough rinse (×5) with DW until the pH level reached 4-5. Then, the sample was kept in NaOH (1% w/vol, RT, 30 min), followed by a further step of rinsing (×3) with DW. The test tube was centrifuged between each rinse until the solution was pH neutral. Next, an additional step of HCl (4% w/vol, RT, 5 min) was carried out. After another triplicate rinse, the sample was placed in pH3 water (80°C) and left overnight (~18 hr). This step denatured the collagen to gelatin and allowed it to be dissolved into solution. The end product was filtered through 50 μm mesh and oven-dried. Collagen was scraped off and collected from the sample tube for ^{14}C measurement. The resulting pretreatment yield weighed 0.15 mg – right at the very limit of what any ^{14}C laboratory in the world might be able to measure – so it was immediately placed inside a tin capsule. Since this amount was not enough to perform a regular graphite measurement, a gas measurement was attempted.

Radiocarbon measurements and calibration

^{14}C measurements were performed on the MICADAS accelerator mass spectrometer (AMS) of the CIO facility at Groningen. The calendar ages of the samples were then determined using the OxCal program version 4.4 (Bronk Ramsey 2009) and the calibration curve IntCal20 (Reimer *et al.* 2020).

3. Results and discussion

The ^{14}C ages and the calibrated calendar age of the samples are given in Table 1. As stated previously, the pretreatment yield from the decorated skull was too small to produce any analytical results and ultimately the object could not be dated. One possibility is that there might have been no collagen left within the bone tissue. Bone artefacts tend to degrade with time and this affects the probability that the ^{14}C dating process will be successful (Aitken 1990). Degradation of collagen is a common problem in bone analysis. Preservation of the bone depends on a combination of factors such as temperature, humidity, soil acidity and time (Schoeninger & Moore 1992). Guerrero lies in the tropics, and it could be that the collagen dissolved due to the humidity and acidity of the conditions of the ground from which it was excavated, or due to subsequent storage conditions. Another possibility is that, due to the very low amount of initial sample (75.23 mg), we might not have obtained enough collagen. A small proportion of the datable material is of course lost during the pretreatment steps. Even though the CIO has the capacity to date extremely small amounts of material via gas measurements, in this case no date could be produced.

This investigation underlines the importance of obtaining enough sample material for ^{14}C dating. In a situation like this, a clear dichotomy exists. On the one hand, ^{14}C is regarded as a destructive procedure and museum curators are understandably unwilling to damage the artefacts on exhibit. However, on the other, in order to get successful ^{14}C results, one requires about 100-1000 mg of bone material to obtain enough collagen to date (see Dee *et al.* 2020).

In an article from 2013, ^{14}C dating was performed on a similarly decorated skull held by the Musée des Arts Africains, Océaniens et Amérindiens (MAAOA) in Marseille, France. This skull was found to date to 772–900 CE (1180 ± 30 yr BP, SacA-20295) (Richardin & Gandolfo 2013). In this article, it is argued that this date indicates the mosaic skull is quite probably a forgery, since turquoise was not in widespread use in Mesoamerica during the Classic period (250–900 CE) (for details, see Richardin & Gandolfo 2013; Calligaro *et al.* 2011). Additionally, the adhesive used on the Marseille mosaic skull was found to be made of shellac (Calligaro *et al.* 2011). Shellac is known to be widely used in Asia and Europe; however, there are no known reports of its use in the Americas during pre-Columbian times. Richardin and Gandolfo (2013) concluded that further investigations were required in order to confirm the authenticity of the object. The fact that there is no archaeological context available for the Marseille skull supports the idea that it could be a counterfeit artefact.

Nevertheless, in our project the authenticity of the skull could not be verified due to the failed attempt of ^{14}C measurement. Just like the earlier publications,

Table 1. The AMS ^{14}C results of the Mesoamerican artefacts from the NMVW.

Artefact	Museum inventory number	Origin	Material	Lab code	δ^{13}C(‰)	F^{14}C (± 1σ)	^{14}C age (BP)	Calibrated age range (years CE, 95.4% probability)
Decorated skull	RV-4007-1	Oaxaca, Mexico	Bone	n/a	n/a	n/a	n/a	-
Ceremonial knife	RV-3928-2	Guerrero, Mexico	Wood	GrM-17482	-24.27	0.9141 ± 0.0016	722 ± 21	1265–1300 (94.8%) 1374–1376 (0.6%)

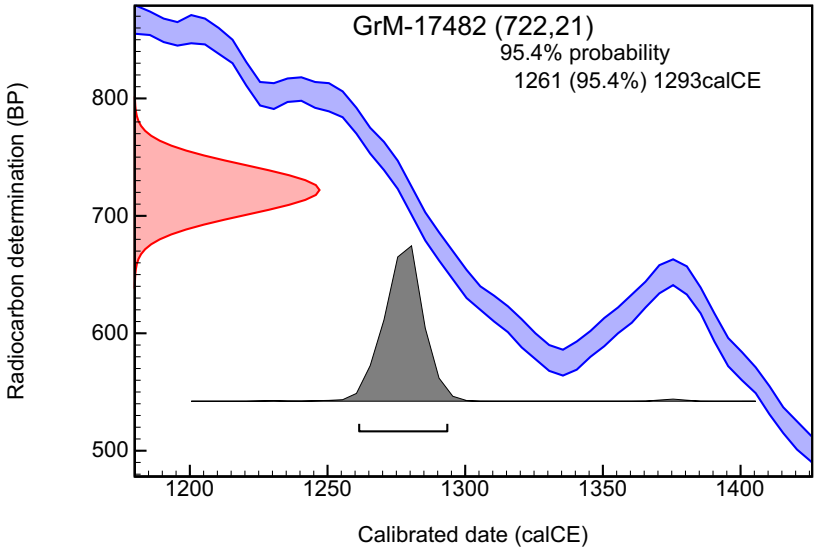

Fig. 2. OxCal calibration and probability graph for the ceremonial knife (Bronk Ramsey 2009). The probability curve (in red) represents the 14C date, which is calibrated against the atmospheric calibration values of IntCal20 (Reimer et al. 2020) (in blue), resulting in a calibrated calendar date probability (in grey).

a clear answer cannot be given and further research is required.

In Fig. 2, the ^{14}C determination (722 ± 21 BP) is calibrated against the atmospheric IntCal20 NH ^{14}C curve. After calibration, the wooden handle of the knife was dated to 1265–1300 CE at 94.8% probability and to 1374–1376 CE at 0.6% probability. For the purposes of our discussion here, we concentrate on the former range, as it encompasses almost all of the dating probability. The 1265–1300 CE range is both extremely precise, because it strikes a very favourable part of the calibration curve, and in congruence with the Aztec period (*c.* 1100–1500 CE) in this region (Smith 2011: 32), especially when one takes into consideration the inbuilt age error. In this case, inbuilt age refers to the time difference between wood formation and age of the carving of the handle. The ^{14}C date obtained (1265–1300 CE) is the time since the constituent carbon was removed from the atmosphere and incorporated into the living tree. This date may not equal to the date of the carving event, as the wood piece used might have been recycled from another object, or stored for a period of time after the felling date. Alternatively, the wood might be from the interior of the tree, which would also result in considerably older dates than the felling date. Therefore, there could be an inbuilt age error of up to 100 years or more.

Although the date of the wooden handle matches the presumed calendar dates for the Aztec period, it is impossible to claim categorically that the knife is authentic. Stylistically, there are no indications that the knife handle is a modern-day creation. Similar carved wooden knife handles are known from original contexts, most notably the knife handles encountered by Holland and Weitlaner (1960) in the Cuicatec village of San Andrés Pápalo, in the Mexican state of Oaxaca. While the probability is very low, it should be considered that the wooden handle could have been fabricated by anyone who was able to acquire wood from an Aztec archaeological site. Alternatively, the wooden handle could be authentic; however, the attached flint could be an imitation.

Suspicion over the authenticity of the object is intensified by the fact that there is no excavation information available for it. No information was also available about whether recycling or storing of this type of wood was practiced in this area during this period, since the species of the tree used is also unknown. Unfortunately, ^{14}C dating on its own cannot provide any information on whether this knife was actually used.

As has been demonstrated here, ^{14}C dating cannot prove the authenticity of ancient artefacts with absolute certainty, although it is very useful for identifying imitations. It is statistically impossible to get an ancient date for a modern object, as long as the extract dated is endogenous to the original organic material. Although any contamination may introduce additional carbon to the sample, which could alter the ^{14}C date, it is liable only to elevate the ^{14}C amount towards a modern date (a younger date rather than an older date). One common exception to this could be a large amount of ^{14}C-free glue or preservative, but the amount necessary to make an object like this appear so old would make the contaminant obvious to the naked eye (>10% of the sampled material). Furthermore, even if the ^{14}C date matches the presumed time period of an artefact, that is not proof that it is genuine. Although ^{14}C dating is very useful, there should still be interdisciplinary work between scientists, conservators, archaeologists and art historians for any concrete confirmation of authenticity. For example, for this specific ceremonial knife, there would need to be use-wear or micro-wear analysis performed on the flint surface. Any signs of repair could indicate object lifetime, which would provide supporting evidence for the object's authenticity. Provenance analysis

on the tree species from which the item was carved could also be used alongside the ^{14}C evidence.

Authenticity is a relatively recent issue for museums, since it is "a 20th century reaction to the Industrial Revolution's capacity to mass produce simulated objects" (Evans *et al.* 2002: 50). Visitors to a museum rarely question the authenticity of the objects on display, as a bond of trust exists between a museum and its visitors. Without the opinion of an expert, the general public have no means of identifying the authenticity of an artefact. Moreover, it could be said that our fascination with the ancient past stems from our interaction with archaeological artefacts, as they are the concrete evidence that remains from our predecessors. Whether authenticity affects how people experience objects is a matter of great debate in the philosophy of aesthetics, attracting a wide range of research fields, such as psychology, archaeology, museology and tourism. Some scholars argue that there is no difference in how people experience an original or a replica of an artefact; furthermore, what is considered to be authentic or fake is very open-ended and depends on personal interactions between the subject and the object (see Goodman 1978; Eco 1990; Holtorf & Schadla-Hall 1999; Jones 2010). However, research on human psychology has shown that people value the meaning and the history behind an artefact more than its physical appearance, and aesthetic judgements depend heavily on the background context given for an item (see Benjamin 1968; Kirk 2009; van Gerven *et al.* 2018).

Although the concept of authenticity is very broad and complicated, the presence of forgeries in museums has wide implications in archaeological research. If scholars are forming theorems about the past based on items that were forged in modern times, it would cause our understanding of the past to be spurious (see also Kelker & Bruhns 2010).

Apparently, it is very common for pre-Columbian antiquities to be faked. There used to be a high demand for Mesoamerican artefacts in European and North American museums, and it caused the art of forgery to be highly developed in order to meet this demand (Sease 2007: 146). The collection of pre-Columbian artefacts began in the 19th century when there was no empirical research available to investigate authenticity. Furthermore, there was not much documentation on Mesoamerican iconography until the 20th century (Walsh 2005). There are many published studies on the history of fake Mesoamerican artefacts (see Batres 1909; Hill 1982; Kelker & Bruhns 2010). Unfortunately, over the years these fakes have caused scholars to misinterpret pre-Columbian art and culture (Sease 2007; Graves-Brown 2013). It is difficult to know how common counterfeit objects are in archaeological museums but, as shown in this study, ^{14}C can play an important role in helping to determine whether objects are genuine or not.

At the NMVW, the suspicion over the authenticity of the decorated skull has been incorporated into the permanent exhibition. It is considered as a part of the history of the museum itself, and teaches visitors that forged artefacts are unfortunately common. It is definitely an interesting take on the relationship between an archaeological museum and counterfeit objects, which attracts public attention and calls for further research into the process of authentication.

4. Conclusion

In this article, it has been demonstrated that ^{14}C dating on its own cannot prove the authenticity of ancient artefacts with absolute certainty, although it is very useful in identifying imitations. In our study, either due to the low amount of sample provided or due to poor collagen preservation within the bone, we were not able to give a date to the decorated skull. ^{14}C dating, in this instance, was ultimately not useful in determining the authenticity of this particular object. The ceremonial knife was found to date to 1265–1300 CE with 94.8% probability, coinciding with its presumed Aztec origin. However, even this compelling result does not completely confirm the authenticity of the knife. Since there is no archaeological context associated with the object, there could still be suspicion over its authenticity. In order to be more certain, a ^{14}C date on an artefact should be complemented by other conclusive data, such as matching archaeological and stratigraphic contextual information or various other empirical analyses. ^{14}C dating is utilised most efficiently when there is collaboration between different fields in authenticity studies.

Finally, as has been shown, confirmation of authenticity is not always easy to accomplish. Having an object scientifically authenticated is usually quite expensive. The ^{14}C dating process is perceived to be destructive, even if the damage caused by the sampling is indistinguishable to the naked eye. Naturally, most of the artefacts in museums never get verified for these reasons. However, if the consequences include the misinterpretation of the past in archaeological research and misinforming the public, more studies should definitely be done on establishing the authenticity of artefacts displayed in museums.

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