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3D Imaging of the Parthenon Sculptures: Assessing the Archaeological Value of 19th Century Plaster Casts

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Abstract

Ambitious plaster casting campaigns were embarked upon in the 19th century. These were often led by archaeologists and intended to record in situ ancient sculptures at risk of deterioration. The surviving collections of casts are now of renewed interest, often seeming to preserve lost details from the originals. Some of the earliest such casts are those held by the British Museum of the Parthenon sculptures. This paper uses 3D imaging to determine the accuracy of the casts, whether they do preserve lost information, and if they can now be employed as surrogates for the originals.

Introduction

In recent years, plaster casts have become a hot topic. Conferences have been held, galleries rejuvenated, research projects started, and books published. Francis Haskell and Nicholas Penny's 1981 book *Taste and the Antique* gave new weight to the evaluation of historical casts and paved the way to conferences like *Plaster Casts: Making Collecting and Displaying from Classical Antiquity to the Present* held at Oxford University in 2007 (Frederiksen & Marchand 2010); the Cast Gallery at the Ashmolean was renovated and reopened in 2010, and the casts at the Edinburgh College of Art were curated by Margaret Stewart, culminating in a 2012 exhibition *Cast Contemporaries* by artist Chris Dorsett.

The trend continues with the 2018 reopening of the V&A's second Cast Court containing the famous cast of Trajan's Column acquired in 1873, and a current project between the British Museum and Google Arts and Culture to conserve, digitize, and share the 19th century casts created by Alfred Maudslay of sculpture from ancient Maya sites. Such projects involving the 3D scanning and digitization of casts are now increasingly common. Casts are often easier to access than their related original sculptures. However, digitization projects are typically based on the idea that casts are accurate surrogates of the sculptures from which they were moulded, permitting study of original objects that may now be lost or damaged. This paper seeks to unravel the under-explored relationship between cast and original. The most

important question for archaeologists using casts as surrogates for the originals is their accuracy. Are the casts reliable records of the condition of the originals at the time of moulding? Do they contain lost information from ancient sculptures? To answer these questions, this paper draws upon a group of casts and originals of the Parthenon sculptures, employing 3D imaging to examine their surfaces in detail and to quantify and characterize differences between them.

Casts as Surrogates in the 19th Century

Once dismissed as 'plaster dinosaurs', 19th century casts are now recognised as significant objects in their own right (Beard 1993, 22). As stimulated by Haskell & Penny's *Taste and the Antique*, the range of casts available, the markets to which they were sold, and the ways in which they were created, finished, treated, and displayed, have now been explored to provide a wealth of information relating to 19th century artistic taste, attitudes to sculptural reproduction, and the reception of ancient sculpture. While their role as surrogates is an important one, there is much more to casts than their ability to reproduce ancient forms. Nevertheless, this reproductive capacity was central to their creation. Through the 19th century, alongside photography, plaster casting was increasingly employed by archaeologists to record and transmit newly discovered ancient works. At the German excavations conducted at Olympia 1875-1881, Napoleone Martinelli was employed to make casts (*The Times*, 15th April 1876, p.7. Issue 28604) and when the French School at Athens started major excavations at Delphi in 1892, finds were recorded both using photography and by establishing a workshop in Athens for the making of moulds (Mulliez 2007, 151).

Museums and universities became keen to acquire high-quality casts made directly from fresh moulds taken from the originals. The creation of such casts was not just for teaching and scholarship but in many cases formed part of a strategy to record ancient sculptures that were too difficult to move but thought to be at high risk of deterioration. For instance, in 1887, Cecil Harcourt Smith, then a curator at the British Museum, marvelled at the ruins of Persepolis but bemoaned their state of neglect. He wrote to the museum to request funds to preserve a copy of the sculptures '*for all time*' and in 1891-2, Herbert Weld Blundell led an expedition to create casts at Persepolis, hiring Lorenzo Giuntini, who had previously worked for Maudslay (Reports to the Trustees 1887/88, 125, see Simpson 2000, 28-29).

One of the pioneers of this use of casts and the inspiration for casting campaigns of the later 19th century was Lord Elgin. The moulds and casts of ancient Greek sculptures that he commissioned during his campaign in Athens were later acquired by the British Museum. There they were supplemented with additional casts of newly discovered missing pieces of sculpture from the Athenian Acropolis obtained at various points through the 19th and 20th centuries. Their acquisition was inspired both from the desire to be able to show in London the Greek sculptures in their entirety and out of concern that those originals remaining onsite were rapidly deteriorating (*The Illustrated London News*, 8th March 1845, p.156; report of Edward Hawkins, Keeper of the Department of Antiquities, 15 May 1852, 446). This nurtured the beginnings of a scheme at the British Museum to use casts to record vulnerable originals.

Elgin's early 19th century casts of the West Frieze of the Parthenon are the primary subject of this paper, together with casts of the same section of frieze created later in the same century. The West Frieze is now in the Acropolis Museum but remained in situ on the temple until 1993. It is well-established that the sculpted details of the frieze appear in significantly better condition in the casts derived from Elgin's moulds than in the originals. Differences between the casts and the originals were noticed as early as the 1870s by Charles Newton, then Keeper of Greek and Roman Antiquities at the British Museum; however, the relationship between the casts of the 1800s, the 1870s, and the originals has not been thoroughly assessed.

Exploring the presence, absence, and possible distortions of fine surface details by comparing the casts and originals is an important step in the study of these sculptures. This will help to establish the reliability of the casts and the extent to which elements have truly been lost from the originals. In turn, this information may be used in future work to guide understanding of the state of preservation and history of deterioration of the originals, as well as aspects of the ancient creation of the sculptures: the tools used, the desired finish and physical characteristics of the subjects rendered.

Creating the Parthenon Casts

At the turn of the 19th century, the Athenian Acropolis was a hive of activity. Elgin had been appointed as British Ambassador to the Ottoman Empire (1799-1803) and initiated a programme to record the ancient sculptures of Athens. In order to document the monuments and their sculptures in situ, Elgin employed a private secretary, William Richard Hamilton;

two artists: Giovanni Battista Lusieri and Theodor Ivanovitch; and two architects: Vincenzo Balestra and Sebastian Ittar. Moreover, following the trend set by 18th century architects (Kockel 2010, 427-430), and paving the way for its widespread adoption by archaeologists, Elgin also appointed two casters (*formatori*) to make moulds of the sculptures. These were the Italians, Bernardino Ledus and Vincenzo Rosati (Smith 1916). In this respect, Elgin followed in the footsteps of his French counterpart, the Comte de Choiseul-Gouffier, who had commissioned casts from the antiquary Louis-François-Sébastien Fauvel during his second trip to Asia Minor in 1786 (Zambon 2014).

More controversially, Elgin also removed many original pieces of sculpture from Athens and brought them back to London where the moulds were cast in plaster by Papera in 1808. The collection was displayed in a house owned by Elgin on the corner of Park Lane and Piccadilly. By 1809, Elgin was becoming out-of-pocket and looked to sell the collection to the British government (Smith 1916, 297-313). A Select Committee of the House of Commons was convened to decide upon the offer. Elgin testified that his primary motivation for removing sculptures from the Acropolis, and for moulding those remaining, was the neglect and defacement they were suffering at the hands of the Ottomans. In 1816, Parliament finally agreed with the Committee to buy the collection and it went to the British Museum (Parliament of Great Britain: House of Commons 1816).

Many of the casts taken were from the West Frieze of the Parthenon, which was the only whole section of frieze still attached to the building at the time. Elgin removed the first two slabs of the sequence but the remaining 14 stayed in place until 1993. By 1872, Elgin's early moulds had become worn out through continued use and Newton acquired new casts of the West Frieze from Consul Merlin in Athens, made by Martinelli (Jenkins 1990, 97). However, upon arrival, Newton found that comparison of the Elgin and Merlin casts suggested significant deterioration of the West Frieze. Following this discovery, the British Museum instated a display of the earlier and later sets of casts in which they were deliberately juxtaposed (Jenkins 1990, 111-112). Further uproar regarding the deterioration of the frieze was then provoked in 1929 when *The Illustrated London News* (18th May 1929, 839-441) published photographs (taken by Walter Hege for the German Archaeological Institute in Athens in 1828) of the original frieze in situ comparing their condition with the corresponding Elgin casts.

[Table 1]

3D Imaging of Originals and Casts: Methodology

Newton's testimony and the 1929 photographs provide a very strong indication that the casts now contain valuable archaeological surface information no longer evident in the originals. These losses to the West Frieze seem to have occurred between 1802 (when the Elgin moulds were created) and 1872. Given that this part of the frieze remained in situ on the Acropolis for a further 121 years, the divergence of the originals from the casts would be expected now to be even greater. Using comparative 3D imaging it is now possible to investigate these objects in detail.

3D imaging facilitates quantitative comparisons of surface morphology between the casts and originals without the interference of external factors, such as lighting, which hinders photographic comparisons (Schwab 2004, 152). A Breuckman smart*SCAN* with X, Y resolution of up to 140 microns was used for 3D scanning and OptoCat software was used to process the files. This is a triangulation-based system using structured white light scanning. The system had a 400-millimetre field-of-view and one-metre working distance. Five slabs of Parthenon frieze were identified for comparative 3D imaging. These included sections of sculpture displaying visible differences between the cast and original of varying type and extent. The originals were scanned at the Acropolis Museum. At the British Museum, where possible, both earlier and later casts of the same section of frieze were scanned. Sections from four slabs from the West Frieze (III, VIII, XII, XVI) and one from the North Frieze (XXXVI) were imaged and stereolithography (STL) files produced. The STLs can be used for standalone visual analysis, and can be overlaid to create colour-coded deviation maps highlighting and quantifying differences between corresponding casts and originals. Different maximum deviation limits can be set, revealing different levels of information.

Comparative analysis is necessarily based on the initial assumption that the casts reproduce the originals with a significant degree of accuracy. Some loss of detail inevitably occurs during moulding and casting. However, Frischer (2014, 141-144) has demonstrated that a good first-generation cast (from a mould taken directly from the original) will reproduce most of its surface to within one millimetre. Several of the British Museum's Merlin casts are now lost, but those remaining are first-generation casts. Upon dismantling Papera's Elgin casts from exhibition at the outbreak of war in 1939, it was discovered that their condition had

seriously declined. They were moulded in gelatine and two new sets were made: one set was white and one varnished (Jenkins 1990, 112). Most survive to this day but mean that the 'Elgin casts', as they now exist, are no longer first-generation casts. Gelatine moulds do, however, facilitate extremely close copies and retain the seam lines from the original piece moulds. Therefore, based on Frischer's findings, it can be hypothesized that deviations from the original of >1 mm in the Merlin casts and >2 mm in the Elgin casts can reasonably be assumed to relate to subsequent changes to the original or deliberate adaptations by the *formatori*, rather than loss of detail from the moulding process.

In addition to quantitative comparisons, surface texture was characterized using Gaussian curvature and mean curvature. Gaussian curvature is an algorithmic calculation of curvature, which can characterise surface roughness in the 3D models. Zero Gaussian curvature indicates a perfectly smooth surface, whereas positive and negative Gaussian curvature indicate concave and convex features. This is particularly useful for analysing the finish of the sculptures. Mean curvature, the mean of the principal curvatures, can also be used to reveal differences in surface texture. As it involves the calculation of an average, mean curvature is less sensitive than Gaussian curvature. Whereas Gaussian curvature is useful for characterising very fine details, the mean curvature can more effectively illustrate larger features.

Results of 3D Imaging

The Precision of the Casts

The deviation maps reveal that the casts taken during the 19th century were in most cases even more precise than expected. Reducing the maximum permitted deviation from 5 mm to 1 mm reveals increasingly fine degrees of difference between the surfaces of the casts and of the original. Features caused by the moulding process slowly become visible (Figure 1). These include not only the seam lines, but also areas where different sections of the piece-mould are fractionally offset, rather than completely flush. However, these are very small flaws: the pieces are offset by less than 1 mm.

[Figure 1]

The table below shows the average deviation between the casts and the originals. This data excludes substantial changes of >5 mm, which are likely to have been caused by later damage rather than poor moulding practice.

[Table 2]

As expected, these results show that the Merlin casts most closely reproduce the original Parthenon sculptures. However, the Elgin casts are also very precise, replicating the originals to well within the level of deviation anticipated by Frischer's study. Moreover, these measured levels of deviation include not only differences caused by the moulding practices of the *formatori* but also those resulting from weathering and other damage to the originals that occurred after moulding took place.

The Finish of the Sculptures

Analysis of the surface using Gaussian curvature reveals areas of the original sculptures that were deliberately textured: the hair and clothes of the figures are noticeably rougher than the smooth planes of skin and background of the frieze. This surface working is more apparent in the casts than the originals, demonstrating not only that fine details of the original sculpture can be closely transmitted to the casts but also that this transfer of medium enables textural distinctions to be more effectively analysed. Specular reflection can pose a problem when imaging crystalline, translucent marble surfaces. Plaster is much less reflective and promotes higher quality 3D models (Frischer 2014, 141) (Figure 2).

[Figure 2]

Evidence of Deterioration between the Casts and Originals

The cast demonstrating the greatest average deviation from the original is the Elgin cast of West Frieze XVI. This slab was located at the end of the frieze and appears to have suffered most severely from weathering. The Elgin casts all reveal features that appear much sharper and crisper than those of either the Merlin casts or the originals. This is particularly pronounced in West Frieze VIII and XII. In the case of West Frieze VIII, the entire head of figure 15 is present in the Elgin cast but missing in both the Merlin cast and the original. Similarly, in West Frieze XII, the face of figure 23 is present in the Elgin cast but missing in the Merlin cast and the original (Figure 3). More restricted differences to the facial features

are observed in figures 5 and 6 of West Frieze III. These losses are all greater than 5 mm (Figure 1).

[Figure 3]

Characterizing the Differences between the Casts and the Originals

The loss of the head of figure 15 in West Frieze VIII presents as a sheer fracture from the stone. Such fractures can occur naturally, typically because of inclusions like alumino-silicate veins within the marble. These erode differently from the main calcitic matrix: large cracks and fractures can occur, as well as exfoliation, where layers parallel to the surface begin to separate and can sheer away. However, in this instance, the balance of probability points to a deliberate instance of vandalism. Elgin claimed (not, of course, as an objective source) that these heads were specifically targeted for petty attacks, mortar production, and removal for collectors (Parliament of Great Britain: House of Commons 1816, 41). The 3D image of the original also reveals traces of chisel marks around the edges of the missing area (Figure 4). It is similarly conceivable that at least some of the losses found in West Frieze XII were achieved with human assistance. While less pronounced than that of figure 15, the loss of the face of figure 23 is particularly sheer and the torso remains remarkably intact; however, there are no clear tool marks.

[Figure 4]

What is odd about the results of the quantitative comparisons is that there is greater difference between the Elgin and Merlin casts than between the Merlin casts and the originals. There were 70 years between the creation of the moulds for the Elgin and Merlin casts, but 143 years between the moulding of the Merlin casts and the time of 3D imaging (and 121 years between the moulding of the Merlin casts and the date that the originals were moved into the Acropolis Museum). The obvious conclusion to draw is that there was a period of particularly rapid deterioration between 1802 and 1872.

The marble of the Parthenon sculptures displays an orange-brown patina, approximately 100-150um thick. The origins of this patina, whether it is ancient or modern, natural or manmade, have been disputed. However, it is stable, uniform, and preserves the original surface details. This is distinct from the thicker, disfiguring pollution crust (200um < several mm thick) once

covering the sculptures and now mostly removed from the West Frieze by laser cleaning that shows that they were affected by air pollution (Papakonstantinou-Ziokis 2012, 61-62). Such crusts are caused by suspension of atmospheric pollutants in a gypsum crust, created by the reaction of the marble with sulphur dioxide. The crust retains the surface details of the original to a certain extent but is discoloured and highly friable.

It is noteworthy, however, that the decay of the sculptures appears to have slowed during the 20th century precisely when problems with sulphurous emissions and acid rain were most acute. It is difficult to avoid the conclusion that the apparently greater rate of deterioration found during the 19th century can be largely attributed to deliberate human attack, as suggested by Elgin, rather than the more insidious effects of the environment. The relative lack of change between the Merlin casts and originals suggests that these attacks subsided through the 19th century following Greek independence and increasing restoration efforts.

Interpretation of the comparative 3D models might, then, be straightforward: there are some very fine differences caused by moulding practices, there is a small amount of overall weathering, and there are more significant areas of loss caused by vandalism. However, interpretation of the casts, their accuracy, and their archaeological importance, is complicated by the fact that as well as these losses there are also additions. There are known instances where the casts of damaged sculptures were altered so that they would appear more complete, calling into question the reliability of the information they preserve. The two documented instances of such additions made to the Elgin casts concern figure 98 of North Frieze XXXVI and figure 30 of West Frieze XVI.

'Restoring' the Parthenon Sculptures through their Casts

In 1910, Arthur Hamilton Smith noted the abnormal appearance of figure 98 in the Elgin cast suggesting that the loss to the side of the face observed in the original had already occurred by Elgin's day and was instead made up in clay (Smith 1910, 59) (Figure 5). This was restated by Stanley Casson (1921, 111) who suggested that the heads of all three riders in this slab were entirely made up. The 3D image shows an area of the head of figure 96 that appears clay-like in texture (Figure 6). It is likely that the section was composed of original fragments (since lost) combined with clay additions. The heads of figures 96 and 97 are far finer than the crudely shaped addition to the head of figure 98, which appears incongruous. The addition to figure 30 in West Frieze XVI is a little more carefully modelled. This was spotted

by Ian Jenkins (1990, 113) and the edges of the addition are smoother and flusher with the original parts.

[Figure 5]

[Figure 6]

We may then repeat the question: to what extent do the casts truly contain lost archaeological details and to what extent have they been manipulated? The sculptures have suffered from weathering, the effects of pollution, and vandalism. However, the presence of additions in the casts indicates that some of the more significant areas of damage may in fact predate 1802 and the moulding of the Elgin casts; the additions have made the Elgin casts appear to deviate from the Merlin casts more substantially than was truly the case. This hypothesis is further substantiated when we take a closer look at the quantitative comparisons in conjunction with the individual 3D models, bringing to light more cases of possible additions.

It is highly likely that the sections of the face and forearm of figure 23 (West Frieze XII) missing in the Merlin cast but present in the Elgin cast were also added by the *formatori*. The deviation map reveals patterns of change characteristic of human intervention in the Elgin cast. These are visible around the moulding seam lines, as expected; however, there are also clear indications of intervention around the hand. The 3D model of figure 23's face also reveals a distinction in texture between those parts extant and those now lost (Figure 7). This softer texture is not observed in the model of the now-missing head of figure 15 (West Frieze VIII); however, it is harder to compare missing and extant areas in this case because the whole head is lost. The deviation map for West Frieze VIII reveals some patterns around the moulding seam lines, but nothing clearly indicative of deliberate additions. We can conclude, therefore, that this head was cast from the original, which was lost between 1802 and 1872.

[Figure 7]

Examination of the mean curvature is particularly useful for identifying clay smoothing marks in the additions. These smoothing marks can be found not only in the known additions of figures 30 and 98 but also in the faces of figures 5 and 6 (West Frieze III) (Figures 8 and 9). It is highly likely that the *formatori* modelled small pieces of clay to reduce the

appearance of weathering to the facial features. This conclusion is supported by analysis of casts of the same sections of the West Frieze at the Akademisches Kunstmuseum, Bonn, which derive from those of Fauvel (Himmelmann & Sinn 1981, 23). From 1787, Fauvel took casts from the Parthenon sculptures on behalf of the Comte de Choiseul-Gouffier (Zambon 2014, 144-145). The Fauvel and Elgin casts were first produced from moulds taken directly from the Parthenon sculptures within 15 years of each other. The Fauvel casts, being the earlier, should reflect the originals in a marginally superior state of preservation. Yet the opposite is the case. The noses of figures 5 and 6 (West Frieze III) appear more complete in the Elgin cast than in that at Bonn: these sections are precisely where analysis of the mean curvature in the 3D models of the Elgin cast reveals discrepancies. However, casts derived from those of Fauvel should not all be assumed to be more reliable than those of Elgin: those at the Petite Malmaison, Paris, are known to contain restorations (Pinatel 2005).

[Figure 8]

[Figure 9]

Conclusions

Analysis of 3D models of the British Museum's Parthenon casts shows that they are, in general, very accurate copies of the originals at the time of moulding. This is a hugely positive finding for the role of casts as an (often digitized) archaeological resource. 3D imaging provides an effective tool to measure and visualize changes that have occurred between the casts and originals. Since plaster scans more effectively than the specular marble surfaces of the originals, these accurate casts provide a particularly useful medium for analysing the sculptures, including investigation of the original finish.

Some changes between the casts and originals have occurred. Many of these were caused by deterioration of the frieze in the years following moulding. However, this research indicates that deterioration was less extensive in the 19th century than has been commonly assumed. While most of the casts are accurate reproductions, there are certain sections which have been subject to alteration, primarily to complete areas that had already been destroyed. These additions are found in the Elgin casts but not in the later Merlin casts. However, casts containing the Elgin additions circulated widely. For example, the 1906 catalogue of the New

York moulding company, Castelvecchi, includes a cast of Parthenon North Frieze XXXVI. It contains the very same addition as that found in the Elgin cast at the British Museum.

Since the Merlin casts do not appear to contain any such additions and are shown to reproduce the originals with precision, we may surmise that the likelihood of interventions made to the casts in this way declined through the 19th century. This chimes with the more restrictive attitude to restoration that also grew during this period and that the use of casts to preserve the forms of vulnerable sculptures became an increasingly well-defined aim. These findings have ramifications beyond sculpture. From the 19th century, plaster casts were also used to disseminate newly discovered fossils and casts of fossil hominid brains have been employed to investigate the evolution of man. The general accuracy of casts will therefore be reassuring. That we must, however, take a critical eye to such apparently indexical documentary objects is underlined by recent investigations indicating interventions and retouching made to the body casts of Pompeii (Lazer 2009, 254-258).

Archaeologists will certainly, therefore, find great value in 19th century casts and current attempts to document and digitize them. However, it is important to be mindful of the fact that just as originals were often subject to significant programmes of restoration (the Parthenon sculptures a notable exception), casts produced in this period were prone to comparable interventions; they are not unmediated reproductions.

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Image Captions

Figure 1. Deviation maps on the left show figures 5 (above) and 6 (below) of West Frieze III at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Images on the right show the same figures at 1 mm maximum deviation: greyscale > 1 mm; red > 0.6 mm; yellow > 0.3 mm; green < 0.3 mm. Data applied to Elgin cast.

Figure 2. 3D models of figure 23 (West Frieze XII) with indicated Gaussian curvature. Top: Elgin cast; middle: Merlin cast; bottom: original sculpture. In the casts, the textured surface of the clothing and hair is clearly revealed. In the original sculpture, surface noise caused by the reflective quality of the marble prevents effective characterization of texture.

Image key: Positive Gaussian curvature: green-blue; negative Gaussian curvature: yellow-red; zero Gaussian curvature: grey.

Figure 3. Deviation maps of figure 15 (above – West Frieze VIII) and figure 23 (below – West Frieze XII) at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Data applied to Elgin casts.

Figure 4. Chisel marks on figure 15 (West Frieze VIII). Photograph of original sculpture with detail from 3D model.

Figure 5. 3D models of figure 98 (above – North Frieze XXXVI) and figure 30 (below – West Frieze XVI). Originals on the left and Elgin casts with additions by the *formatori* on the right.

Figure 6. L-R: Figure 96 (photograph of Elgin cast); Figure 97 (photograph of Elgin cast); Figure 96 (3D model of Elgin cast). North Frieze XXXVI. Note the clay-like section in the 3D model.

Figure 7. Deviation map of figure 23 (West Frieze XII) at 1 mm maximum deviation: greyscale > 1 mm; red > 0.6 mm; yellow > 0.3 mm; green < 0.3 mm. Data applied to Elgin cast. 3D model with detail of the face to the right.

Figure 8. 3D models of Elgin casts with indicated mean curvature and arrows signifying clay smoothing lines. Left: Figure 98 (North Frieze XXXVI); Right: Figure 30 (West Frieze XVI).

Image key: Positive mean curvature: green-blue; negative mean curvature: yellow-red; zero mean curvature: grey.

Figure 9. 3D models of Elgin casts with indicated mean curvature and arrows signifying clay smoothing lines. Left: Figure 5; Right: Figure 6. West Frieze III.

Image key: (As Figure 8).

Tables

Table 1: Salient events in the history of the Parthenon and its West Frieze

BC	
447-438	Parthenon completed as part of Pericles' building programme following the defeat of the Persians.
AD	
267	Damaged by fire.
c.600	Converted to a Christian church; some iconoclasm.
1458	Converted to a mosque under the Ottoman Empire.
1687	Venetian bombardment: The Ottomans used the Parthenon as a gunpowder magazine. An explosion devastated most of the middle of the long sides of the building, especially on the southern side.
1787	Loius-François-Sébastien Fauvel started to take casts on behalf of the Comte de Choiseul-Gouffier. Many were lost/damaged en route to Paris.
1799-1803	Elgin removed many sculptures from the Acropolis, including the first 2 slabs of the West Frieze; other pieces were left in situ and moulded. The West Frieze was moulded in 1802.
1808	Elgin's moulds cast in plaster by Papera in London.
1816	The 'Elgin Collection' (moulds, casts, and original sculptures) was purchased by the British government for the British Museum.
1821	Casts derived from those of Fauvel were purchased by the Akademisches Kunstmuseum, University of Bonn.
1830	Greece recognised as an independent, sovereign state.
1842-1844	Restorations to the Parthenon led by Kyriakos Pittakis.
1872	New casts of the West Frieze acquired by Consul Merlin in Athens for the British Museum.
1873-1939	Exhibition instated at the British Museum juxtaposing the earlier (Elgin) and later (Merlin) casts.
1974	Completion of the old Acropolis Museum.
1929	New photographs of the frieze published by the *Illustrated London News*.
1895-1933	Restorations to the Parthenon led by Nicholaos Balanos.
1975	Establishment of the Committee for the Conservation of the Acropolis Monuments.
1993	Remaining fourteen slabs of the West Frieze removed to museum conditions.
2009	Public opening of the new Acropolis Museum.

Table 2: Average deviation of analysis areas between the casts and originals (excluding areas >5 mm) (mm)

	From original		Average deviation of Merlin from Elgin cast
	Elgin	Merlin	
NXXXVI	0.590	n/a	n/a
WIII	0.923	n/a	n/a

WVIII	0.741	0.292	1.009
WXII	0.897	0.413	0.824
WXVI	1.308	n/a	n/a

Figure 1. Deviation maps on the left show figures 5 (above) and 6 (below) of West Frieze III at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Images on the right show the same figures at 1 mm maximum deviation: greyscale > 1 mm; red > 0.6 mm; yellow > 0.3 mm; green < 0.3 mm. Data applied to Elgin cast.

254x190mm (96 x 96 DPI)

Figure 2. 3D models of figure 23 (West Frieze XII) with indicated Gaussian curvature. Top: Elgin cast; middle: Merlin cast; bottom: original sculpture. In the casts, the textured surface of the clothing and hair is clearly revealed. In the original sculpture, surface noise caused by the reflective quality of the marble prevents effective characterization of texture.

Image key: Positive Gaussian curvature: green-blue; negative Gaussian curvature: yellow-red; zero Gaussian curvature: grey.

254x190mm (96 x 96 DPI)

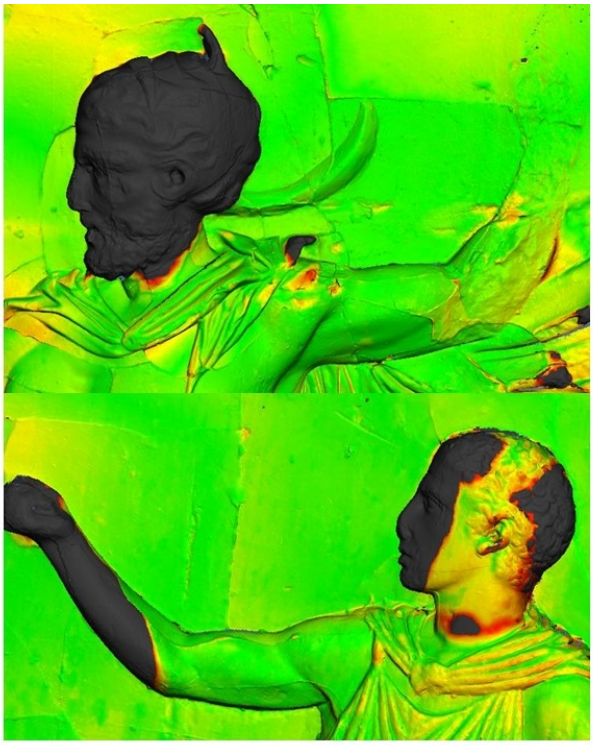

Figure 3. Deviation maps of figure 15 (above – West Frieze VIII) and figure 23 (below – West Frieze XII) at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Data applied to Elgin casts.

254x190mm (96 x 96 DPI)

Figure 4. Chisel marks on figure 15 (West Frieze VIII). Photograph of original sculpture with detail from 3D model.

254x190mm (96 x 96 DPI)

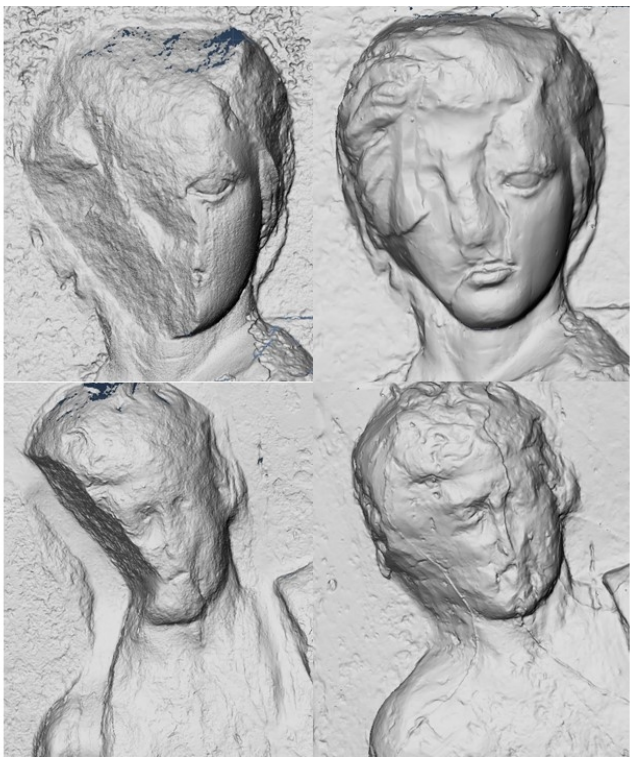

Figure 5. 3D models of figure 98 (above – North Frieze XXXVI) and figure 30 (below – West Frieze XVI). Originals on the left and Elgin casts with additions by the formatori on the right.

254x190mm (96 x 96 DPI)

Figure 6. L-R: Figure 96 (photograph of Elgin cast); Figure 97 (photograph of Elgin cast); Figure 96 (3D model of Elgin cast). North Frieze XXXVI. Note the clay-like section in the 3D model.

254x190mm (96 x 96 DPI)

Figure 7. Deviation map of figure 23 (West Frieze XII) at 1 mm maximum deviation: greyscale > 1 mm; red > 0.6 mm; yellow > 0.3 mm; green < 0.3 mm. Data applied to Elgin cast. 3D model with detail of the face to the right.

254x190mm (96 x 96 DPI)

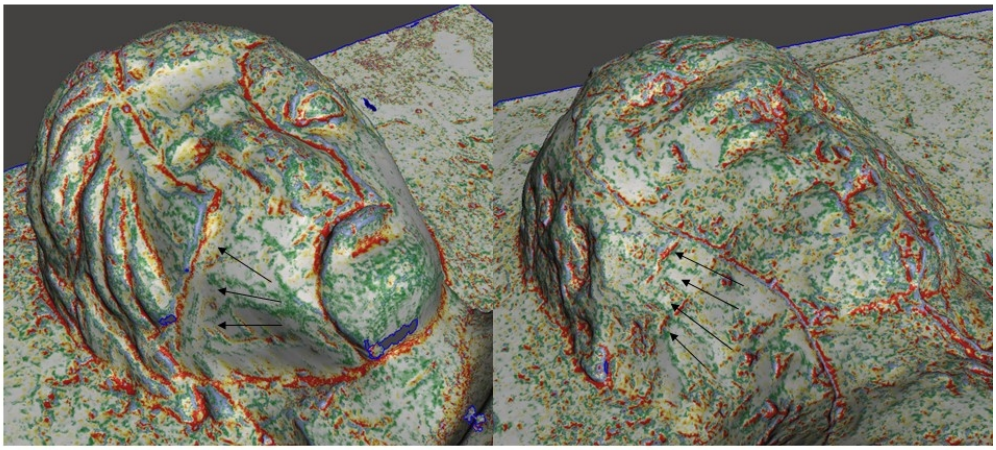

Figure 8. 3D models of Elgin casts with indicated mean curvature and arrows signifying clay smoothing lines. Left: Figure 98 (North Frieze XXXVI); Right: Figure 30 (West Frieze XVI).

Image key: Positive mean curvature: green-blue; negative mean curvature: yellow-red; zero mean curvature: grey.

254x190mm (96 x 96 DPI)

Figure 9. 3D models of Elgin casts with indicated mean curvature and arrows signifying clay smoothing lines. Left: Figure 5; Right: Figure 6. West Frieze III.

Image key: (As Figure 8).

254x190mm (96 x 96 DPI)