



King's Research Portal

DOI:

[10.15184/aqy.2019.179](https://doi.org/10.15184/aqy.2019.179)

Document Version

Peer reviewed version

[Link to publication record in King's Research Portal](#)

Citation for published version (APA):

Payne, E. M. (2019). 3D Imaging of the Parthenon Sculptures: Assessing the Archaeological Value of 19th Century Plaster Casts. *ANTIQUITY*, 93(372), 1625-1642. <https://doi.org/10.15184/aqy.2019.179>

Citing this paper

Please note that where the full-text provided on King's Research Portal is the Author Accepted Manuscript or Post-Print version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version for pagination, volume/issue, and date of publication details. And where the final published version is provided on the Research Portal, if citing you are again advised to check the publisher's website for any subsequent corrections.

General rights

Copyright and moral rights for the publications made accessible in the Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognize and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Research Portal

Take down policy

If you believe that this document breaches copyright please contact librarypure@kcl.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

ANTIQUITY
a review of world archaeology



CAMBRIDGE
UNIVERSITY PRESS

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

Journal:	<i>Antiquity</i>
Manuscript ID	AQY-RE-18-162.R2
Manuscript Type:	Research
Date Submitted by the Author:	n/a
Complete List of Authors:	Payne, Emma; King's College London, Department of Classics
Keywords:	Ancient Greece, Classical sculpture, History of archaeology, Nineteenth century plaster casts, 3D imaging
Research Region:	Mediterranean Europe

SCHOLARONE™
Manuscripts

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

Emma M. Payne
Department of Classics, King's College London
emma.payne@kcl.ac.uk

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

1
2
3 important question for archaeologists using casts as surrogates for the originals is their
4 accuracy. Are the casts reliable records of the condition of the originals at the time of
5 moulding? Do they contain lost information from ancient sculptures? To answer these
6 questions, this paper draws upon a group of casts and originals of the Parthenon sculptures,
7 employing 3D imaging to examine their surfaces in detail and to quantify and characterize
8 differences between them.
9

15 **Casts as Surrogates in the 19th Century**

16
17 Once dismissed as ‘plaster dinosaurs’, 19th century casts are now recognised as significant
18 objects in their own right (Beard 1993, 22). As stimulated by Haskell & Penny’s *Taste and*
19 *the Antique*, the range of casts available, the markets to which they were sold, and the ways
20 in which they were created, finished, treated, and displayed, have now been explored to
21 provide a wealth of information relating to 19th century artistic taste, attitudes to sculptural
22 reproduction, and the reception of ancient sculpture. While their role as surrogates is an
23 important one, there is much more to casts than their ability to reproduce ancient forms.
24 Nevertheless, this reproductive capacity was central to their creation. Through the 19th
25 century, alongside photography, plaster casting was increasingly employed by archaeologists
26 to record and transmit newly discovered ancient works. At the German excavations
27 conducted at Olympia 1875-1881, Napoleone Martinelli was employed to make casts (*The*
28 *Times*, 15th April 1876, p.7. Issue 28604) and when the French School at Athens started
29 major excavations at Delphi in 1892, finds were recorded both using photography and by
30 establishing a workshop in Athens for the making of moulds (Mulliez 2007, 151).
31
32
33
34
35
36
37
38
39
40
41
42

43 Museums and universities became keen to acquire high-quality casts made directly from
44 fresh moulds taken from the originals. The creation of such casts was not just for teaching
45 and scholarship but in many cases formed part of a strategy to record ancient sculptures that
46 were too difficult to move but thought to be at high risk of deterioration. For instance, in
47 1887, Cecil Harcourt Smith, then a curator at the British Museum, marvelled at the ruins of
48 Persepolis but bemoaned their state of neglect. He wrote to the museum to request funds to
49 preserve a copy of the sculptures ‘for all time’ and in 1891-2, Herbert Weld Blundell led an
50 expedition to create casts at Persepolis, hiring Lorenzo Giuntini, who had previously worked
51 for Maudslay (Reports to the Trustees 1887/88, 125, see Simpson 2000, 28-29).
52
53
54
55
56
57
58
59
60

1
2
3 One of the pioneers of this use of casts and the inspiration for casting campaigns of the later
4 19th century was Lord Elgin. The moulds and casts of ancient Greek sculptures that he
5 commissioned during his campaign in Athens were later acquired by the British Museum.
6
7 There they were supplemented with additional casts of newly discovered missing pieces of
8 sculpture from the Athenian Acropolis obtained at various points through the 19th and 20th
9 centuries. Their acquisition was inspired both from the desire to be able to show in London
10 the Greek sculptures in their entirety and out of concern that those originals remaining onsite
11 were rapidly deteriorating (*The Illustrated London News*, 8th March 1845, p.156; report of
12 Edward Hawkins, Keeper of the Department of Antiquities, 15 May 1852, 446). This
13 nurtured the beginnings of a scheme at the British Museum to use casts to record vulnerable
14 originals.
15
16
17
18
19
20
21
22
23

24 Elgin's early 19th century casts of the West Frieze of the Parthenon are the primary subject of
25 this paper, together with casts of the same section of frieze created later in the same century.
26 The West Frieze is now in the Acropolis Museum but remained in situ on the temple until
27 1993. It is well-established that the sculpted details of the frieze appear in significantly better
28 condition in the casts derived from Elgin's moulds than in the originals. Differences between
29 the casts and the originals were noticed as early as the 1870s by Charles Newton, then Keeper
30 of Greek and Roman Antiquities at the British Museum; however, the relationship between
31 the casts of the 1800s, the 1870s, and the originals has not been thoroughly assessed.
32
33
34
35
36
37
38
39

40 Exploring the presence, absence, and possible distortions of fine surface details by comparing
41 the casts and originals is an important step in the study of these sculptures. This will help to
42 establish the reliability of the casts and the extent to which elements have truly been lost from
43 the originals. In turn, this information may be used in future work to guide understanding of
44 the state of preservation and history of deterioration of the originals, as well as aspects of the
45 ancient creation of the sculptures: the tools used, the desired finish and physical
46 characteristics of the subjects rendered.
47
48
49
50
51
52

53 **Creating the Parthenon Casts**

54 At the turn of the 19th century, the Athenian Acropolis was a hive of activity. Elgin had been
55 appointed as British Ambassador to the Ottoman Empire (1799-1803) and initiated a
56 programme to record the ancient sculptures of Athens. In order to document the monuments
57 and their sculptures in situ, Elgin employed a private secretary, William Richard Hamilton;
58
59
60

1
2
3 two artists: Giovanni Battista Lusieri and Theodor Ivanovitch; and two architects: Vincenzo
4 Balestra and Sebastian Ittar. Moreover, following the trend set by 18th century architects
5 (Kockel 2010, 427-430), and paving the way for its widespread adoption by archaeologists,
6 Elgin also appointed two casters (*formatori*) to make moulds of the sculptures. These were
7 the Italians, Bernardino Ledus and Vincenzo Rosati (Smith 1916). In this respect, Elgin
8 followed in the footsteps of his French counterpart, the Comte de Choiseul-Gouffier, who had
9 commissioned casts from the antiquary Louis-François-Sébastien Fauvel during his second
10 trip to Asia Minor in 1786 (Zambon 2014).
11
12
13
14
15
16
17
18

19 More controversially, Elgin also removed many original pieces of sculpture from Athens and
20 brought them back to London where the moulds were cast in plaster by Papera in 1808. The
21 collection was displayed in a house owned by Elgin on the corner of Park Lane and
22 Piccadilly. By 1809, Elgin was becoming out-of-pocket and looked to sell the collection to
23 the British government (Smith 1916, 297-313). A Select Committee of the House of
24 Commons was convened to decide upon the offer. Elgin testified that his primary motivation
25 for removing sculptures from the Acropolis, and for moulding those remaining, was the
26 neglect and defacement they were suffering at the hands of the Ottomans. In 1816,
27 Parliament finally agreed with the Committee to buy the collection and it went to the British
28 Museum (Parliament of Great Britain: House of Commons 1816).
29
30
31
32
33
34
35
36
37

38 Many of the casts taken were from the West Frieze of the Parthenon, which was the only
39 whole section of frieze still attached to the building at the time. Elgin removed the first two
40 slabs of the sequence but the remaining 14 stayed in place until 1993. By 1872, Elgin's early
41 moulds had become worn out through continued use and Newton acquired new casts of the
42 West Frieze from Consul Merlin in Athens, made by Martinelli (Jenkins 1990, 97). However,
43 upon arrival, Newton found that comparison of the Elgin and Merlin casts suggested
44 significant deterioration of the West Frieze. Following this discovery, the British Museum
45 instated a display of the earlier and later sets of casts in which they were deliberately
46 juxtaposed (Jenkins 1990, 111-112). Further uproar regarding the deterioration of the frieze
47 was then provoked in 1929 when *The Illustrated London News* (18th May 1929, 839-441)
48 published photographs (taken by Walter Hege for the German Archaeological Institute in
49 Athens in 1828) of the original frieze in situ comparing their condition with the
50 corresponding Elgin casts.
51
52
53
54
55
56
57
58
59
60

[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 smartSCAN 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

1
2
3 seriously declined. They were moulded in gelatine and two new sets were made: one set was
4 white and one varnished (Jenkins 1990, 112). Most survive to this day but mean that the
5 ‘Elgin casts’, as they now exist, are no longer first-generation casts. Gelatine moulds do,
6 however, facilitate extremely close copies and retain the seam lines from the original piece
7 moulds. Therefore, based on Frischer’s findings, it can be hypothesized that deviations from
8 the original of >1 mm in the Merlin casts and >2 mm in the Elgin casts can reasonably be
9 assumed to relate to subsequent changes to the original or deliberate adaptations by the
10 *formatori*, rather than loss of detail from the moulding process.
11
12
13
14
15
16
17
18

19 In addition to quantitative comparisons, surface texture was characterized using Gaussian
20 curvature and mean curvature. Gaussian curvature is an algorithmic calculation of curvature,
21 which can characterise surface roughness in the 3D models. Zero Gaussian curvature
22 indicates a perfectly smooth surface, whereas positive and negative Gaussian curvature
23 indicate concave and convex features. This is particularly useful for analysing the finish of
24 the sculptures. Mean curvature, the mean of the principal curvatures, can also be used to
25 reveal differences in surface texture. As it involves the calculation of an average, mean
26 curvature is less sensitive than Gaussian curvature. Whereas Gaussian curvature is useful for
27 characterising very fine details, the mean curvature can more effectively illustrate larger
28 features.
29
30
31
32
33
34
35
36
37

38 **Results of 3D Imaging**

39 **The Precision of the Casts**

40 The deviation maps reveal that the casts taken during the 19th century were in most cases
41 even more precise than expected. Reducing the maximum permitted deviation from 5 mm to
42 1 mm reveals increasingly fine degrees of difference between the surfaces of the casts and of
43 the original. Features caused by the moulding process slowly become visible (Figure 1).
44 These include not only the seam lines, but also areas where different sections of the piece-
45 mould are fractionally offset, rather than completely flush. However, these are very small
46 flaws: the pieces are offset by less than 1 mm.
47
48
49
50
51
52
53
54

55 [Figure 1]
56
57
58
59
60

1
2
3 The table below shows the average deviation between the casts and the originals. This data
4 excludes substantial changes of >5 mm, which are likely to have been caused by later damage
5 rather than poor moulding practice.
6
7
8
9

10 [Table 2]
11
12

13 As expected, these results show that the Merlin casts most closely reproduce the original
14 Parthenon sculptures. However, the Elgin casts are also very precise, replicating the originals
15 to well within the level of deviation anticipated by Frischer's study. Moreover, these
16 measured levels of deviation include not only differences caused by the moulding practices of
17 the *formatori* but also those resulting from weathering and other damage to the originals that
18 occurred after moulding took place.
19
20
21
22
23
24

25 **The Finish of the Sculptures**

26 Analysis of the surface using Gaussian curvature reveals areas of the original sculptures that
27 were deliberately textured: the hair and clothes of the figures are noticeably rougher than the
28 smooth planes of skin and background of the frieze. This surface working is more apparent in
29 the casts than the originals, demonstrating not only that fine details of the original sculpture
30 can be closely transmitted to the casts but also that this transfer of medium enables textural
31 distinctions to be more effectively analysed. Specular reflection can pose a problem when
32 imaging crystalline, translucent marble surfaces. Plaster is much less reflective and promotes
33 higher quality 3D models (Frischer 2014, 141) (Figure 2).
34
35
36
37
38
39
40
41
42

43 [Figure 2]
44
45

46 **Evidence of Deterioration between the Casts and Originals**

47 The cast demonstrating the greatest average deviation from the original is the Elgin cast of
48 West Frieze XVI. This slab was located at the end of the frieze and appears to have suffered
49 most severely from weathering. The Elgin casts all reveal features that appear much sharper
50 and crisper than those of either the Merlin casts or the originals. This is particularly
51 pronounced in West Frieze VIII and XII. In the case of West Frieze VIII, the entire head of
52 figure 15 is present in the Elgin cast but missing in both the Merlin cast and the original.
53 Similarly, in West Frieze XII, the face of figure 23 is present in the Elgin cast but missing in
54 the Merlin cast and the original (Figure 3). More restricted differences to the facial features
55
56
57
58
59
60

1
2
3 are observed in figures 5 and 6 of West Frieze III. These losses are all greater than 5 mm
4 (Figure 1).
5
6
7

8 [Figure 3]
9
10

11 **Characterizing the Differences between the Casts and the Originals**

12 The loss of the head of figure 15 in West Frieze VIII presents as a sheer fracture from the
13 stone. Such fractures can occur naturally, typically because of inclusions like alumino-silicate
14 veins within the marble. These erode differently from the main calcitic matrix: large cracks
15 and fractures can occur, as well as exfoliation, where layers parallel to the surface begin to
16 separate and can sheer away. However, in this instance, the balance of probability points to a
17 deliberate instance of vandalism. Elgin claimed (not, of course, as an objective source) that
18 these heads were specifically targeted for petty attacks, mortar production, and removal for
19 collectors (Parliament of Great Britain: House of Commons 1816, 41). The 3D image of the
20 original also reveals traces of chisel marks around the edges of the missing area (Figure 4). It
21 is similarly conceivable that at least some of the losses found in West Frieze XII were
22 achieved with human assistance. While less pronounced than that of figure 15, the loss of the
23 face of figure 23 is particularly sheer and the torso remains remarkably intact; however, there
24 are no clear tool marks.
25
26
27
28
29
30
31
32
33
34
35
36
37

38 [Figure 4]
39
40

41 What is odd about the results of the quantitative comparisons is that there is greater
42 difference between the Elgin and Merlin casts than between the Merlin casts and the
43 originals. There were 70 years between the creation of the moulds for the Elgin and Merlin
44 casts, but 143 years between the moulding of the Merlin casts and the time of 3D imaging
45 (and 121 years between the moulding of the Merlin casts and the date that the originals were
46 moved into the Acropolis Museum). The obvious conclusion to draw is that there was a
47 period of particularly rapid deterioration between 1802 and 1872.
48
49
50
51
52
53
54

55 The marble of the Parthenon sculptures displays an orange-brown patina, approximately 100-
56 150um thick. The origins of this patina, whether it is ancient or modern, natural or manmade,
57 have been disputed. However, it is stable, uniform, and preserves the original surface details.
58 This is distinct from the thicker, disfiguring pollution crust (200um < several mm thick) once
59
60

1
2
3 covering the sculptures and now mostly removed from the West Frieze by laser cleaning that
4 shows that they were affected by air pollution (Papakonstantinou-Ziokis 2012, 61-62). Such
5 crusts are caused by suspension of atmospheric pollutants in a gypsum crust, created by the
6 reaction of the marble with sulphur dioxide. The crust retains the surface details of the
7 original to a certain extent but is discoloured and highly friable.
8
9

10
11
12
13 It is noteworthy, however, that the decay of the sculptures appears to have slowed during the
14 20th century precisely when problems with sulphurous emissions and acid rain were most
15 acute. It is difficult to avoid the conclusion that the apparently greater rate of deterioration
16 found during the 19th century can be largely attributed to deliberate human attack, as
17 suggested by Elgin, rather than the more insidious effects of the environment. The relative
18 lack of change between the Merlin casts and originals suggests that these attacks subsided
19 through the 19th century following Greek independence and increasing restoration efforts.
20
21
22
23
24
25

26
27 Interpretation of the comparative 3D models might, then, be straightforward: there are some
28 very fine differences caused by moulding practices, there is a small amount of overall
29 weathering, and there are more significant areas of loss caused by vandalism. However,
30 interpretation of the casts, their accuracy, and their archaeological importance, is complicated
31 by the fact that as well as these losses there are also additions. There are known instances
32 where the casts of damaged sculptures were altered so that they would appear more complete,
33 calling into question the reliability of the information they preserve. The two documented
34 instances of such additions made to the Elgin casts concern figure 98 of North Frieze XXXVI
35 and figure 30 of West Frieze XVI.
36
37
38
39
40
41
42
43
44

45 **‘Restoring’ the Parthenon Sculptures through their Casts**

46 In 1910, Arthur Hamilton Smith noted the abnormal appearance of figure 98 in the Elgin cast
47 suggesting that the loss to the side of the face observed in the original had already occurred
48 by Elgin’s day and was instead made up in clay (Smith 1910, 59) (Figure 5). This was
49 restated by Stanley Casson (1921, 111) who suggested that the heads of all three riders in this
50 slab were entirely made up. The 3D image shows an area of the head of figure 96 that appears
51 clay-like in texture (Figure 6). It is likely that the section was composed of original fragments
52 (since lost) combined with clay additions. The heads of figures 96 and 97 are far finer than
53 the crudely shaped addition to the head of figure 98, which appears incongruous. The
54 addition to figure 30 in West Frieze XVI is a little more carefully modelled. This was spotted
55
56
57
58
59
60

1
2
3 by Ian Jenkins (1990, 113) and the edges of the addition are smoother and flusher with the
4 original parts.
5
6
7

8 [Figure 5]
9

10
11 [Figure 6]
12
13
14

15 We may then repeat the question: to what extent do the casts truly contain lost archaeological
16 details and to what extent have they been manipulated? The sculptures have suffered from
17 weathering, the effects of pollution, and vandalism. However, the presence of additions in the
18 casts indicates that some of the more significant areas of damage may in fact predate 1802
19 and the moulding of the Elgin casts; the additions have made the Elgin casts appear to deviate
20 from the Merlin casts more substantially than was truly the case. This hypothesis is further
21 substantiated when we take a closer look at the quantitative comparisons in conjunction with
22 the individual 3D models, bringing to light more cases of possible additions.
23
24
25
26
27
28
29

30
31 It is highly likely that the sections of the face and forearm of figure 23 (West Frieze XII)
32 missing in the Merlin cast but present in the Elgin cast were also added by the *formatori*. The
33 deviation map reveals patterns of change characteristic of human intervention in the Elgin
34 cast. These are visible around the moulding seam lines, as expected; however, there are also
35 clear indications of intervention around the hand. The 3D model of figure 23's face also
36 reveals a distinction in texture between those parts extant and those now lost (Figure 7). This
37 softer texture is not observed in the model of the now-missing head of figure 15 (West Frieze
38 VIII); however, it is harder to compare missing and extant areas in this case because the
39 whole head is lost. The deviation map for West Frieze VIII reveals some patterns around the
40 moulding seam lines, but nothing clearly indicative of deliberate additions. We can conclude,
41 therefore, that this head was cast from the original, which was lost between 1802 and 1872.
42
43
44
45
46
47
48
49
50

51 [Figure 7]
52
53
54

55 Examination of the mean curvature is particularly useful for identifying clay smoothing
56 marks in the additions. These smoothing marks can be found not only in the known additions
57 of figures 30 and 98 but also in the faces of figures 5 and 6 (West Frieze III) (Figures 8 and
58 9). It is highly likely that the *formatori* modelled small pieces of clay to reduce the
59
60

1
2
3 appearance of weathering to the facial features. This conclusion is supported by analysis of
4 casts of the same sections of the West Frieze at the Akademisches Kunstmuseum, Bonn,
5 which derive from those of Fauvel (Himmelmann & Sinn 1981, 23). From 1787, Fauvel took
6 casts from the Parthenon sculptures on behalf of the Comte de Choiseul-Gouffier (Zambon
7 2014, 144-145). The Fauvel and Elgin casts were first produced from moulds taken directly
8 from the Parthenon sculptures within 15 years of each other. The Fauvel casts, being the
9 earlier, should reflect the originals in a marginally superior state of preservation. Yet the
10 opposite is the case. The noses of figures 5 and 6 (West Frieze III) appear more complete in
11 the Elgin cast than in that at Bonn: these sections are precisely where analysis of the mean
12 curvature in the 3D models of the Elgin cast reveals discrepancies. However, casts derived
13 from those of Fauvel should not all be assumed to be more reliable than those of Elgin: those
14 at the Petite Malmaison, Paris, are known to contain restorations (Pinatel 2005).
15
16
17
18
19
20
21
22
23
24

25
26 [Figure 8]
27

28
29 [Figure 9]
30
31

32 **Conclusions**

33 Analysis of 3D models of the British Museum's Parthenon casts shows that they are, in
34 general, very accurate copies of the originals at the time of moulding. This is a hugely
35 positive finding for the role of casts as an (often digitized) archaeological resource. 3D
36 imaging provides an effective tool to measure and visualize changes that have occurred
37 between the casts and originals. Since plaster scans more effectively than the specular marble
38 surfaces of the originals, these accurate casts provide a particularly useful medium for
39 analysing the sculptures, including investigation of the original finish.
40
41
42
43
44
45
46
47

48 Some changes between the casts and originals have occurred. Many of these were caused by
49 deterioration of the frieze in the years following moulding. However, this research indicates
50 that deterioration was less extensive in the 19th century than has been commonly assumed.
51 While most of the casts are accurate reproductions, there are certain sections which have been
52 subject to alteration, primarily to complete areas that had already been destroyed. These
53 additions are found in the Elgin casts but not in the later Merlin casts. However, casts
54 containing the Elgin additions circulated widely. For example, the 1906 catalogue of the New
55
56
57
58
59
60

1
2
3 York moulding company, Castelveccchi, includes a cast of Parthenon North Frieze XXXVI. It
4 contains the very same addition as that found in the Elgin cast at the British Museum.
5
6
7

8 Since the Merlin casts do not appear to contain any such additions and are shown to
9 reproduce the originals with precision, we may surmise that the likelihood of interventions
10 made to the casts in this way declined through the 19th century. This chimes with the more
11 restrictive attitude to restoration that also grew during this period and that the use of casts to
12 preserve the forms of vulnerable sculptures became an increasingly well-defined aim. These
13 findings have ramifications beyond sculpture. From the 19th century, plaster casts were also
14 used to disseminate newly discovered fossils and casts of fossil hominid brains have been
15 employed to investigate the evolution of man. The general accuracy of casts will therefore be
16 reassuring. That we must, however, take a critical eye to such apparently indexical
17 documentary objects is underlined by recent investigations indicating interventions and
18 retouching made to the body casts of Pompeii (Lazer 2009, 254-258).
19
20
21
22
23
24
25
26
27
28

29 Archaeologists will certainly, therefore, find great value in 19th century casts and current
30 attempts to document and digitize them. However, it is important to be mindful of the fact
31 that just as originals were often subject to significant programmes of restoration (the
32 Parthenon sculptures a notable exception), casts produced in this period were prone to
33 comparable interventions; they are not unmediated reproductions.
34
35
36
37
38
39
40

41 **Acknowledgements**

42 This work was made possible by awards from the AHRC and AICON 3D Systems. I would
43 also like to thank Corinna Riva, Elizabeth Pye, Jeremy Tanner, Will Wootton, Dirk Rieke-
44 Zapp, Dirk Booms, Ian Jenkins, Andy Liddle, Costas Vasiliadis, and John Hessler. Images ©
45 Emma Payne with thanks to the British Museum and the Acropolis Museum for permitting
46 3D scanning.
47
48
49
50
51
52
53

54 **References**

55 Beard, M. (1993). Casts and cast-offs: the origins of the Museum of Classical Archaeology.
56 *Proceedings of the Cambridge Philological Society* 39 1-29.
57
58 Casson, S. (1921). *Catalogue of the Acropolis Museum, Vol. 2. Sculpture and Architectural*
59 *Fragments*. Cambridge: Cambridge University Press.
60

1
2
3
4 Castelvevchi, L. C. (1906). *Catalogue of A. Castelvevchi & Co. Plastic Reproductions of*
5 *Antique and Modern Masterpieces of Art*. New York: L. Castelvevchi.

6
7
8 Frederiksen, R. & E. Marchand eds. (2010). *Plaster Casts: Making, Collecting and*
9 *Displaying from Classical Antiquity to the Present*. Berlin and New York: De Gruyter.

10
11 Frischer, B. (2014). 3D data capture, restoration and online publication of sculpture. In F.
12 Remondino & S. Campana eds. *3D Recording and Modelling in Archaeology and Cultural*
13 *Heritage*. Oxford: Archaeopress. 137-144.

14
15
16 Himmelmann, N. & U. Sinn, eds. (1981). *Akademisches Kunstmuseum der Universität Bonn.*
17 *Verzeichnis der Abguss-Sammlung*. Berlin: Deutsches Archäologisches Institut.

18
19 Jenkins, I. (1990). Acquisition and supply of casts of the Parthenon sculptures by the British
20 Museum. *The Annual of the British School at Athens* 85 89-114.

21
22
23 Kockel, V. (2010). Plaster models and plaster casts of classical architecture and its
24 decoration. In R. Frederiksen & E. Marchand (2010) 419-434.

25
26 Lazer. E. (2009), *Resurrecting Pompeii*. New York: Routledge.

27
28 Mulliez, D. (2007). Delphi. The excavation of the Great Oracular Centre (1892). In P.
29 Valavanis ed. *Great Moments in Greek Archaeology*. Los Angeles: J. Paul Getty Museum.
30 134-157.

31
32
33 Papanstantinou-Ziotis, E. (2012). Surface conservation. In C. Bouras, M. Ioannidou & I.
34 Jenkins eds. *Acropolis Restored*. London: Trustees of the British Museum. 57-64.

35
36
37 Parliament of Great Britain: House of Commons (1816). Report from the Select Committee
38 of the House of Commons on the Earl of Elgin's Collection of Sculptured Marbles; &c.
39 London: Printed for John Murray, Albemarle Street.

40
41 Schwab, K. A. (2004). The Parthenon East Metopes, the Gigantomachy and Digital
42 Technology. In M. B. Cosmopoulos ed. *The Parthenon and its Sculptures*. Cambridge:
43 Cambridge University Press. 150-165.

44
45
46 Simpson, S. J. (2000). Rediscovering past splendours from Iran. 19th century plaster casts of
47 sculptures from Persepolis. *British Museum Magazine Spring 2000* 28-29.

48
49 Smith, A. H. (1910). *The Sculptures of the Parthenon: British Museum. Department of Greek*
50 *and Roman Antiquities*. London: printed by order of the Trustees.

51
52
53 Smith, A. H. (1916). Lord Elgin and His Collection. *The Journal of Hellenic Studies* 36 163-
54 372.

55
56 Zambon, A. (2014). *Aux origines de l'archéologie en Grèce. Fauvel et sa méthode*. Paris:
57 CTHS-INHA.

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

	<i>BC</i>	
	447-438	Parthenon completed as part of Pericles' building programme following the defeat of the Persians.
	<i>AD</i>	
	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 <i>Illustrated London News</i> .
	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

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

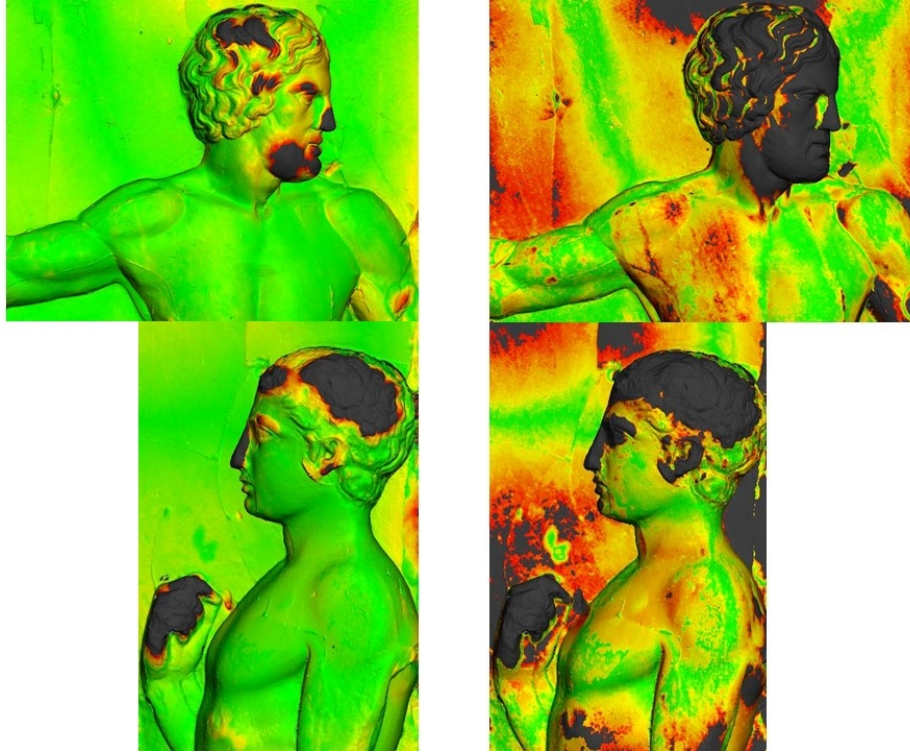


Figure 1. Deviation maps on the left show figures 5 (above) and 6 (below) of West Frieze III at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Images on the right show the same figures at 1 mm maximum deviation: greyscale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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

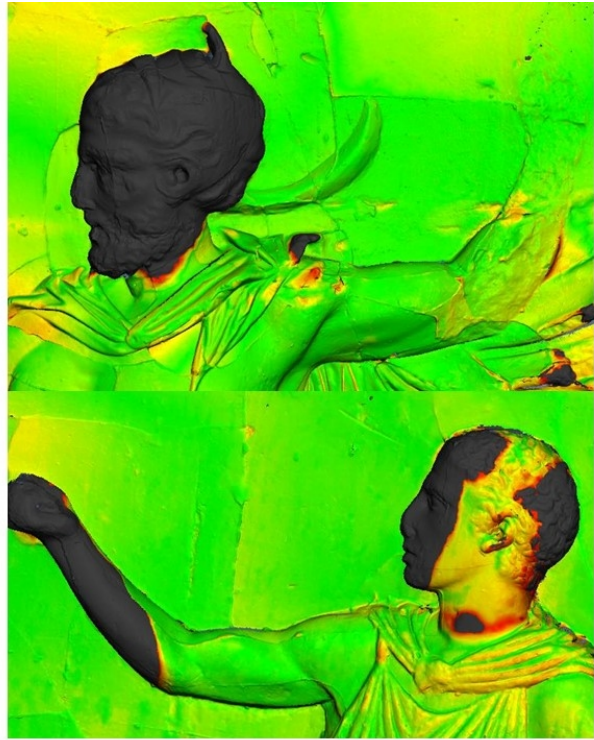


Figure 3. Deviation maps of figure 15 (above – West Frieze VIII) and figure 23 (below – West Frieze XII) at 5 mm maximum deviation: greyscale > 5 mm deviation; red > 3 mm deviation; yellow > 1.5 mm deviation; green < 1.5 mm deviation. Data applied to Elgin casts.

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)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

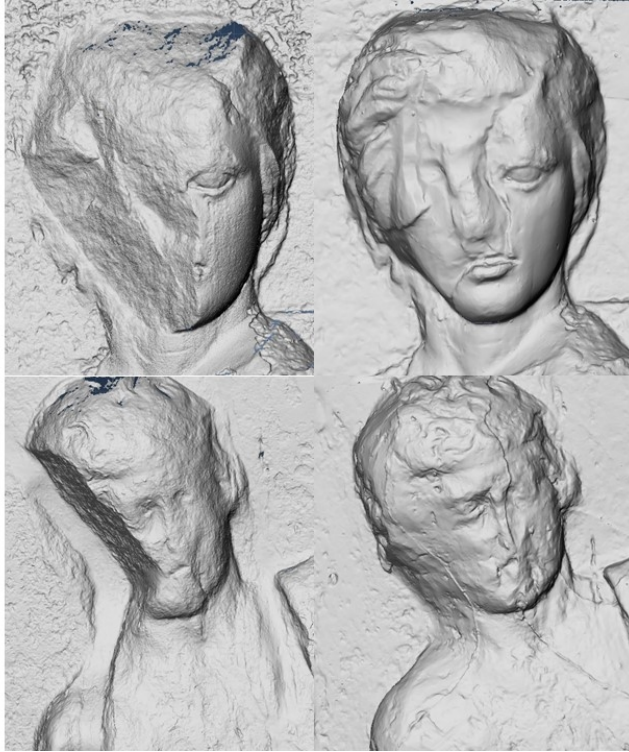


Figure 5. 3D models of figure 98 (above – North Frieze XXXVI) and figure 30 (below – West Frieze XVI). Originals on the left and Elgin casts with additions by the formatori on the right.

254x190mm (96 x 96 DPI)

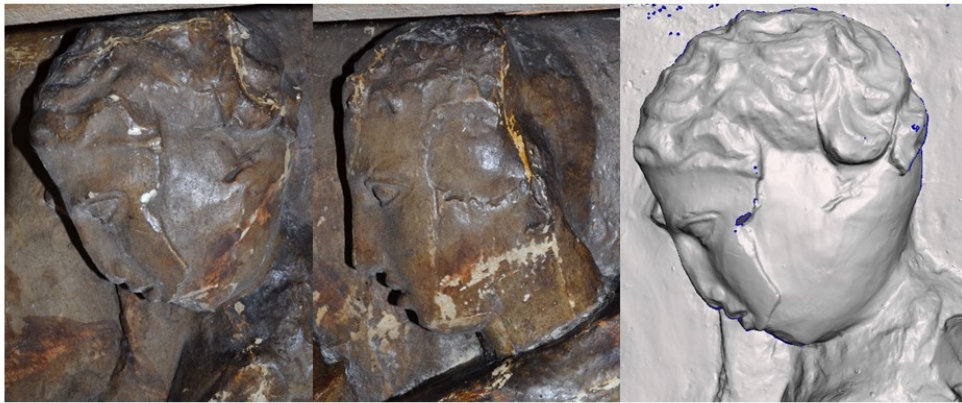


Figure 6. L-R: Figure 96 (photograph of Elgin cast); Figure 97 (photograph of Elgin cast); Figure 96 (3D model of Elgin cast). North Frieze XXXVI. Note the clay-like section in the 3D model.

254x190mm (96 x 96 DPI)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



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)

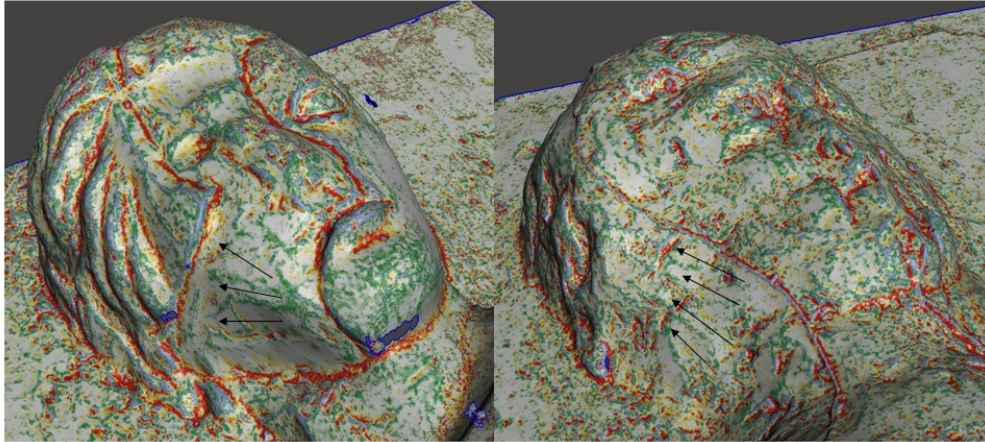


Figure 8. 3D models of Elgin casts with indicated mean curvature and arrows signifying clay smoothing lines.
Left: Figure 98 (North Frieze XXXVI); Right: Figure 30 (West Frieze XVI).

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

254x190mm (96 x 96 DPI)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



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)