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THE COMPOSITION OF PLASTER CASTS

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ABSTRACT

Over the last few years plaster casts have received increasing attention. The conservation of this material is difficult and some difficulties might be related to the composition and structure of the plaster. However, little is known about the mixtures that were used by the producers of casts. A selection of objects in the collection of the National Museum of Antiquities was studied for the bulk composition of the plaster, its structure and surface finishes. In the compositional data, two groups were distinguished which match with the Olympia casts from Berlin and a group of other casts from Berlin. The other objects did not show a correlation between the composition and origin. Also, the structure of the plaster does not correlate with chemical composition or origin, but is probably determined by other manufacturing procedures.

RÉSUMÉ

Depuis quelques années, les moulages font l'objet d'une attention croissante. La conservation de ce matériel est délicate, certaines difficultés pouvant tenir à la composition et à la structure du plâtre. Or nous savons peu de choses sur les mélanges qui ont été employés par les fabricants de ces moules. L'étude d'une sélection d'objets de la collection du Musée national des Antiquités a porté sur la composition globale du plâtre, sa structure et son fini de surface. D'après les données recueillies, deux groupes se sont dégagés, qui correspondent aux moulages de l'Olympe de Berlin et à un second groupe de moulages de Berlin. Les autres objets n'ont pas montré de corrélation entre la composition et l'origine. Par ailleurs, la structure du plâtre ne montre aucun lien avec sa composition chimique ou son origine, alors qu'elle est probablement déterminée par les autres procédés de fabrication.

INTRODUCTION

In the 19th century, in particular, many museums and art schools acquired collections of casts of important monuments and works of art. Museums enabled those who could not afford to travel to see the famous classical and Renaissance sculptures, while art school students were able to study and draw from the best works in art history. In many cases, interest for these collections declined in the 20th century. Many museums moved their plaster reproductions to their storage rooms (e.g. The Metropolitan Museum of Art in New York sold their remaining cast collection in 2006) and in many schools they were no longer considered useful for art education. Over the last few years, however, plaster casts have received increasing scholarly attention (Frederiksen and Marchand 2010), for example at symposia like the recent international conferences 'Plaster Casts, Making, Collecting and Displaying from Classical Antiquity to the Present' in 2007 in Oxford and 'Plaster and Plaster Casts: Materiality and Practice' in 2010 in London. Museums are also putting plaster casts back on display, sometimes after years of neglect which makes restoration necessary.

Conservation of these casts is challenging because plaster is a vulnerable and very porous material, sensitive to moisture and mechanical damage, dirt pick-up and changes in humidity. Methods for bonding broken pieces appear to work on some objects and not on others. This is probably caused by the different material properties of the plaster objects due to additives in the plaster and the porosity of the mixture of materials used in the cast.

The use of plaster for casting objects goes back to ancient Egypt. It was also used in ancient Greece and Rome for making death masks, stucco sculptures and copies of sculptures (Frederiksen 2010). During the Renaissance, artists like Leoni and Primaticcio copied famous works of sculpture from ancient Rome and distributed them to the courts of Europe (Cupperi 2010). In the 16th to 18th century, many plaster casts entered the collections of artists and the rich. In the 19th century, and also outside Italy, companies specializing in the production of plaster casts were established, such as Brucciani and Franchi in London and Gerber in Germany. Many major museums had their own plaster cast workshops, like those at the Royal Museums in Berlin, the Louvre or the Royal Museum in Brussels.

RESUMEN

En los últimos años, los moldes de yeso han recibido una especial atención. La conservación de este material es difícil, y algunas dificultades podrían estar relacionadas con la composición y la estructura del yeso. Sin embargo se sabe muy poco sobre las mezclas que utilizaban los productores de moldes. Se estudió una selección de objetos de la colección del Museo Nacional de Antigüedades para identificar la composición esencial del yeso, su estructura y acabados superficiales. En los datos de la composición se distinguieron dos grupos que coinciden con los moldes de Olimpia en Berlín y un grupo de otros moldes de Berlín. Los otros objetos no mostraron ninguna relación entre la composición y el origen. Además, la estructura del yeso no está relacionada con la composición química o el origen, sino que probablemente esté determinada por otros procedimientos de fabricación.

Plaster is made by heating and grinding the mineral gypsum, hydrated calcium sulphate ($CaSO_4 \cdot 2H_2O$). This mineral occurs widely on earth, in its purest form as alabaster, but usually mixed with small quantities of clay or iron oxides, which influences the colour. The well-known Plâtre de Paris contains 10 to 12% calcium carbonate. By heating the mineral to a temperature of ca. 120°C, water is lost, the first three quarters rather fast, the rest slowly after that. For casting, gypsum should be burnt until it contains ca. 7% water (fully hydrated gypsum contains 20.9 %water; Uhlenhuth 1912). When gypsum is burnt at 200 to 300°C, it is not usable for casting (Uhlenhuth 1912). The resulting anhydrite ($CaSO_4$) can be used by adding an accelerator such as alum, potassium or zinc sulphate (Ashurst 1983).

The heating temperature and particle size after grinding affect the working properties and durability of the resulting plaster. These properties can also be modified by adding various materials. Materials such as straw, hemp, saw dust or hair were added to improve the mechanical properties (e.g. Ashurst 1983).

In the late 19th century, Uhlenhuth (1912, 7th edition; 1st edition 1879) gave a list of additives and how much they accelerate or retard the setting of plaster. Nitrate and chloride salts and acids accelerate setting as well as sugar, calcium or barium carbonate. The addition of borax to the water mixed with the burnt gypsum, however, retards setting by up to 10 to 12 hours, while the standard hardening time with water is taken as 17 minutes. A small amount (3 to 5 per cent) of lime also slows down setting; the loss of mechanical strength in this case is compensated by adding glue. Glue itself also retards setting, as do stale beer and ammonia (Wager 1938, 4). The addition of glue is already mentioned by Kunckel (1689), who gives two recipes where the water used to prepare the plaster is first cooked with pieces of parchment, and a third where size water is used in the preparation of the plaster.

To change the appearance of the white casts or just to protect them from easy soiling, the casts can be treated in several ways. If they were to be painted, the casts had to be treated first with size or gelatine water or even better with milk (Uhlenhuth 1912, 68) to close the pores in the plaster. White shellac, dextrine, beeswax and linseed oil are mentioned as well (Wager 1938, 87–9). An overview of recipes in French sources is given by Chevillot (2002). After the application of a primer, the casts could be painted with normal oil paints or bronzed.

In this study, 20 plaster casts of different origin were selected from the collection at the National Museum of Antiquities in Leiden (Netherlands). The collection and its history are described by Kik (2010). The oldest object chosen, a cast of part of Trajan's column, dates from 1665 and was made in Rome. Furthermore, the selection comprises 19th century objects from the Royal Museums in Berlin, from Brucciani & Co. in London, the Louvre and the École des Beaux Arts in Paris. Some objects were made in the Netherlands and a few are of unknown origin. Samples of these objects were examined for the properties and composition of the plaster and the finishes applied to them.

EXPERIMENTAL

The plaster objects in the collection at the National Museum of Antiquities were sampled at existing fractures to obtain samples of the plaster body and the finishes were sampled near existing damage. The plaster samples were qualitatively analysed for their elemental composition by means of x-ray fluorescence spectroscopy (XRF) using an ArTax 800 instrument (Bruker AXS, Berlin, Germany) with a molybdenum tube equipped with a polycapillary lens with a spot size of ca. 90 µm (operating at 40 kV and 600 µA) and a XFLASH silicon drift detector. The crystalline phases were analyzed by X-ray Diffraction (XRD) using a Discover D8 microdiffractometer with a General Area Detection Diffraction System (GADDS) two dimensional detector (Bruker AXS, Karlsruhe, Germany). Diffractograms were acquired with CuKα radiation (40 kV, 30 mA). The GADDS software was used for integration and the Bruker AXS Eva software for phase identification using the PDF database.

The microstructure of the plaster is evaluated by scanning electron microscopy (SEM), performed with a variable pressure JSM 5910LV SEM with an energy dispersive X-ray spectrometry (EDS) system (SDD, NSS software, Thermo Fisher Scientific). The crystal shape and structure of the plaster samples were examined on pieces of gold-coated plaster. To estimate the porosity, plaster samples were embedded in polyester resin (Polypol PS230; Polyservice, Amsterdam, Netherlands) and ground dry to obtain cross sections. The percentage of pores in the cross section was calculated with the NSS software, giving an estimate of the porosity.

The finishes were characterized by embedding samples in polyester resin (Polypol PS230) and examining the ground and polished cross sections by means of optical microscopy and SEM-EDS to determine the layer structure and identify the pigments used.

RESULTS AND DISCUSSION

XRF analysis of the samples of plaster (Table 1) showed that many samples contained traces, and in some cases minor amounts, of elements like iron and zinc and sometimes trace amounts of barium, manganese, copper and lead. In a few samples, a minor amount of bromine was found, which is present in the other samples as a trace component. The elevated levels of bromine might suggest the use of the pesticide methyl bromide, which is known to leave inorganic bromide residues in food due to reaction with certain compounds (WHO Pesticide Residues Series, No. 1), but it is not known if this would have been possible in the plaster and nothing is known about the possible use of pesticides in the collection. Strontium in gypsum is present as a naturally occurring trace element in different concentrations depending on the circumstances when the gypsum was deposited. Therefore, the strontium concentration

Table 1
Results of the XRF analyses of the samples of plaster from casts from the collection of the National Museum of Antiquities. In the 'Elements' column, the elements present in the plaster besides calcium and sulphur are listed. Strontium is present in all samples and the ratio of the peak areas of strontium and calcium are given in the column Sr:Ca peak ratio, as an indication of the strontium content of the plaster

Object	Origin	Inv. nr.	Date	Elements	Sr:Ca peak ratio
Assyrian relief	*Berlin*	AB 3a	1858	(Fe) (Br)	0,031
Olympia, Sterope	*Berlin*	OA 25	1877	(Fe) (Zn) (Br)	0,053
Olympia, Apples of the Hesperides	*Berlin*	OA 13	1877	(Fe) (Zn) (Br)	0,045
Olympia, Niké Paionios	*Berlin*	OA 1	1903	Br (Fe) (Zn)	0,053
Pergamon altar	*Berlin*	OA zn 7	1883	(Fe) (Br)	0,038
Stele of king Sargon	*Berlin*	A 1892/3.9	1892	(Fe) (Br)	0,034
Elgin marbles, godesses in the east pediment of the Parthenon	*Brucciani, London*	Z 1903/11.10a	1903	Fe (Ba) (Pb)	0,119
Elgin marbles, scene in the frieze of the Parthenon	*Brucciani, London*	Z 1903/11.18c	1903	(Fe) (Mn) (Br)	0,049
Doryphoros	*Brucciani, London*	Z 1903/11.19a	1903	(Fe) (Cu) (Zn) (Br)	0,075
inscription Matribus Siberius Victor	*Leemans*	CL*10	1876	Zn (Br)	0,200
cast of an altar	*Leemans*	CL*6	1876	Br	0,069
Temple of Niké, Two Nikai with a bull	*Paris, Ecole Beaux Arts*	Z 1903/11.1	1903	Br (Fe) (Zn) (Ba)	0,094
Frieze of the House of the Knidians	*Paris, Louvre?*	Cat. 1913 III 7 A	1913	(Zn)	0,117
Trajan's column	*Rome*	St 2	1665	(Fe) (Zn) (Pb) (Br)	0,045
Temple of Aphaia, Telamon	*Rome*	AE 3/AE 14	1827	(Fe) (Ba) (Br)	0,094
Diskobolos by Myron	*Rome ?*	Cat. 1913 V 6b	1893	Br (Fe) (Ba)	0,073
cast of an altar	*Suermondt museum Aachen*	M 1929.12.1	1929	Fe (Mn) (Br)	0,058
Archelaos relief	*unknown, collection of RMA*	I 1927/4.11	1927	Fe (Br)	0,045
cast of an altar	*unknown*	e 1957 2.1	1957	Zn Fe (Mn) (Ba) (Br)	0,049
Apoxyomenos	*unknown, gift of Holwerda*	Z 1903/11.20	1903	(Cu) (Br)	0,093

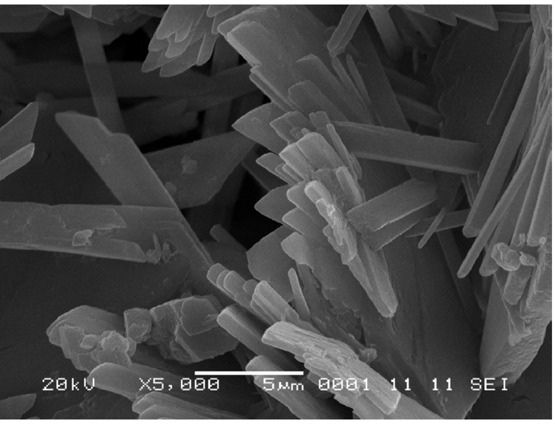

Figure 1
Secondary electron image (20 kV, magnification 5000 x) of a plaster sample showing a 3D network of crystals

can give an indication of different sources of the gypsum used to make the plaster. More information on the provenance of the material could be obtained by isotope analysis, but this technique was not available for this study.

All samples contain long and/or short tabular-shaped crystals. Most samples show flat hexagonal crystals and the swallow-tail and lamellar contact twins typical for gypsum (Table 2). Some samples display a 3D network of crystals (Figure 1). The edges of the crystals of seven samples are rounded, four of which contain relatively short rods (Figure 2). The short rounded rods indicate that the material has partly been dissolved.

The porosity of the samples varies from a dense to a more open structure. Samples with rounded crystals have a relatively dense structure.

Results of the analysis of the finishes of the casts are summarized in Table 3.

The casts from the Royal Museums of Berlin

The XRF results show that the casts of sculptures from Olympia (inv. nr. OA 13 and OA 25), made in the cast workshop of the Royal museums in Berlin in 1877, have similar iron and zinc trace contents and similar ratios of strontium to calcium. The cast of Niké Paionios

Table 2
Summary of the observations on crystal structure and porosity of the plaster samples. The crystal structure was observed by scanning electron microscopy (SEM) of gold coated fragments of plaster. The porosity was calculated as the percentage of pores in a dry ground cross-section of plaster, averaging seven measurements

Object	Origin	Inv. nr.	Date	SEM observations
Assyrian relief	*Berlin*	AB 3a	1858	Tabular short rounded crystals, swallow-tail contact twins, hexagonal plates, dense structure, mass containing Al, Si and Fe present possibly glue
Olympia, Sterope	*Berlin*	OA 25	1877	Tabular long crystals, medium open structure
Olympia, Apples of the Hesperides	*Berlin*	OA 13	1877	Tabular crystals, hexagonal plates, medium open structure, mass containing Na, Al and Cl present, possibly glue
Olympia, Niké Paionios	*Berlin*	OA 1	1903	Tabular short rounded crystals, medium open structure
Pergamon altar	*Berlin*	OA zn 7	1883	Tabular crystals, swallow-tail contact twins, hexagonal plates, 3D network of crystals, grains with Sr
Stele of king Sargon	*Berlin*	A 1892/3.9	1892	Tabular crystals, swallow-tail and lamellar contact twins, hexagonal plates, open structure, mass containing Na, Cl, Al, Si, K and Fe possibly a glue
Elgin marbles, scene in the frieze of the Parthenon	*Brucciani, London*	Z 1903/11.18c	1903	Tabular thin crystals, swallow-tail contact twins, hexagonal plates, open structure, mass containing Na, Al, Cl and K present possibly glue
Elgin marbles, godesses in the east pediment of the Parthenon	*Brucciani, London*	Z 1903/11.10a	1903	Tabular crystals, swallow-tail and lamellar contact twins, hexagonal plates, 3D network of crystals
Doryphoros	*Brucciani, London*	Z 1903/11.19a	1903	Tabular crystals, swallow-tail contact twins, open structure
inscription Matribus Siberius Victor	*Leemans*	CL*10	1876	Tabular crystals, lamellar contact twins, dense structure
cast of an altar	*Leemans*	CL*6	1876	Tabular crystals, open structure, mass containing Al present possibly glue
Temple of Niké, Two Nikai with a bull	*Paris, Ecole Beaux Arts*	Z 1903/11.1	1903	Tabular rounded crystals, swallow-tail contact twins, medium open structure, grains of calcium carbonate present
Frieze of the House of the Knidians	*Paris, Louvre?*	Cat. 1913 III 7 A	1913	Tabular short rounded crystals, swallow-tail and lamellar contact twins, hexagonal plates, 3D network of crystals, dense structure
Trajan's column	*Rome*	St 2	1665	Tabular crystals, hexagonal plates
Temple of Aphaia, Telamon	*Rome*	AE 3/AE 14	1827	Tabular crystals, swallow-tail contact twins, hexagonal plates, 3D network, dense structure
Diskobolos by Myron	*Rome ?*	Cat. 1913 V 6b	1893	Open structure, grains with Sr
cast of an altar	*Suermondt museum Aachen*	M 1929.12.1	1929	Open structure
cast of an altar	*unknown*	e 1957 2.1	1957	Tabular rounded crystals, swallow-tail and lamellar contact twins, hexagonal plates, 3D network, contains quartz grains
Archelaos relief	*unknown, collection of RMA*	I 1927/4.11	1927	Tabular rounded crystals, swallow-tail and lamellar contact twins, hexagonal plates, dense structure, mass containing Al present possibly glue
Apoxyomenos	*unknown, gift of Holwerda*	Z 1903/11.20	1903	Medium open structure

(OA 1) also has a similar composition, except for a higher concentration of bromine, which was probably not in the original plaster. The Niké Paionios was part of the casts bought in 1877, but due to its bad condition a new cast was ordered in 1903 and this is assumed to be the cast that survived in the collection (Kik 2010). In that case, the composition of the plaster used in Berlin has been quite constant during the last 25 years.

The first finish on all three casts from Olympia (inv. no. OA 1, OA 13 and OA 25) are also very similar, consisting of a white paint layer with lead white and a little barytes (barium sulphate). In the samples from OA 1 and OA 13, a varnish is present on this lead-white layer. There is no

Table 3
Summary of the finishing layers on the plaster casts. Layer 1 is the oldest layer in the sample found on the plaster

Object	Origin	Inv. nr.	Date	Finish
Assyrian relief	*Berlin*	AB 3a	1858	1: thick gray layer of chalk with ochre and black pigment 2: white layer chalk/glue(?) 3: paint layer zinc white, barium sulphate or lithopone, little black pigment
Olympia, Sterope	*Berlin*	OA 25	1877	1: paint layer lead white, little barytes 2: very thin varnish 3: very thin paint layer lead white, little zinc white 4: thin layer gypsum with little quartz
Olympia, Apples of the Hesperides	*Berlin*	OA 13	1877	1: paint layer lead white, little barytes 2: paint layer zinc white, little lead white 3: paint layer zinc white, little ochre
Olympia, Niké Paionios	*Berlin*	OA 1	1903	1: paint layer lead white, little baytes 2: varnish 3: paint layer zinc white 4: paint layer zinc white, little black pigment
Pergamon altar	*Berlin*	OA zn 7	1883	paint layer zinc white, titanium dioxide, very little ochre
Stele of king Sargon	*Berlin*	A 1892/3.9	1892	1: layer chalk or lime with red ochre 2: thin layer bone black
Elgin marbles, scene in the frieze of the Parthenon	*Brucciani, London*	Z 1903/11.18c	1903	bare plaster
Elgin marbles, godesses in the east pediment of the Parthenon	*Brucciani, London*	Z 1903/11.10a	1903	1: thin paint layer zinc white, ochre
Doryphoros	*Brucciani, London*	Z 1903/11.19a	1903	1: paint layer zinc white 2: thin paint layer zinc white, gypsum 3: paint layer brass particles and little ochre or iron oxide 4: varnish
inscription Matribus Siberius Victor	*Leemans*	CL*10	1876	1: paint layer zinc white with little ochre
cast of an altar	*Leemans*	CL*6	1876	1: paint layer zinc white with little ochre
Temple of Niké, Two Nikai with a bull	*Paris, Ecole Beaux Arts*	Z 1903/11.1	1903	bare plaster
Frieze of the House of the Knidians	*Paris, Louvre?*	Cat. 1913 III 7 A	1913	bare plaster
Trajan's column	*Rome*	St 2	1665	gypsum 1: paint layer zinc white, little ochre 2: gypsum 3: paint layer zinc white, little ochre
Temple of Aphaia, Telamon	*Rome*	AE 3/AE 14	1827	1: very light grey layer of gypsum 2: light beige paint layer with zinc white and very little ochre
Diskobolos by Myron	*Rome ?*	Cat. 1913 V 6b	1893	1: paint layer red ochre and brass particles 2: thin varnish 3: paint layer ochre, very little lead white
cast of an altar	*Suermondt museum Aachen*	M 1929.12.1	1929	1: layer gypsum 2: thin paint layer ochre, zinc white/ barium sulphate or lithopone, sand, some black pigment
cast of an altar	*unknown*	e 1957 2.1	1957	plaster with quartz (grains up to 100μ)
Archelaos relief	*unknown, collection of RMA*	I 1927/4.11	1927	bare plaster
Apoxyomenos	*unknown, gift of Holwerda*	Z 1903/11.20	1903	1: layer brass particles, 2: thin varnish 3: paint layer ochre or iron oxide pigment with brass particles

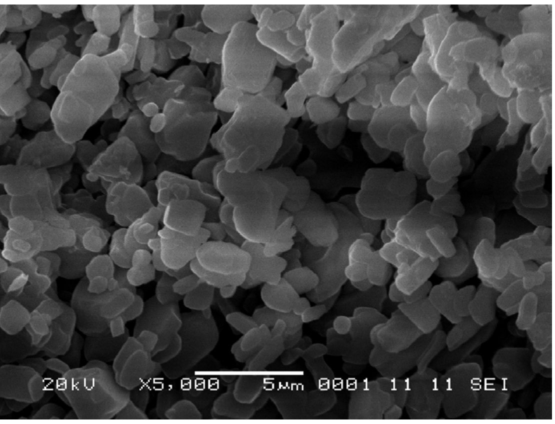

Figure 2
Secondary electron image (20 kV, magnification 5000 x) of a plaster sample with short, rounded rod-shaped crystals

sign of dirt between the paint layer and the plaster, therefore it is likely that this is an original finish. Probably the paint was applied to make the casts less vulnerable to moisture and dirt.

All three casts were later overpainted with coloured paints. The composition of these later paints is different on all three objects, suggesting that this was not done at the same time.

Three other objects from Berlin (an Assyrian relief, a fragment of the Pergamon altar and the Stele of king Sargon), dating from 1858 to 1892, are similar to each other with respect to their composition, but they differ from the group of Olympia casts; no zinc was detected and the strontium concentration is a bit lower.

The Stele of Sargon (A 1892/3.9), the fragment of the Pergamon altar (OA zn 7) and the Assyrian relief (inv. no. AB 3a) have quite distinct finishes. The relief's first finish consists of a thick layer of chalk with ochre. Later it was covered with a chalk layer as a primer for a light grey paint layer with lithopone (or a mixture of zinc white and barium sulphate) and a little black pigment. The Stele was painted with a layer of chalk and red ochre and covered with a thin, semi-transparent layer of bone black, probably to give it an appearance similar to the original. The paint layer on the cast of the Pergamon altar is not original; it contains titanium dioxide, a white pigment available after ca. 1920.

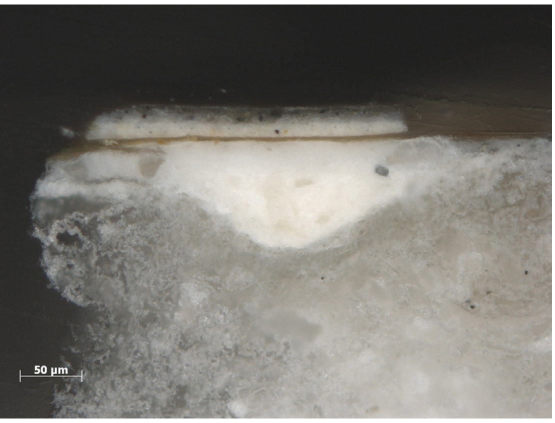

Figure 3
Photomicrograph in incident polarized light of a cross section of the finishing layers of the cast of Niké Paionios (OA 1)

SEM analysis shows that the structure of the plaster of the Olympia casts is more open when compared to that of the other three objects from Berlin. The crystals of the latter plasters also show contact twins and hexagonal plates possibly indicating a fast crystallisation. In half of the samples, a mass containing Na, Al, and Cl is present, morphologically resembling a glue.

The casts from Brucciani & Co.

The plaster samples of the casts made by Brucciani & Co. do not show similarity in composition like the objects from Berlin; the trace elements in all samples are very different and the strontium content varies widely. The trace amount of copper found in the sample of the Doryphoros has probably migrated into the plaster from the bronze imitation on the surface. SEM analysis of the Brucciani casts shows that their structure is relatively open. In the sample of a scene in the frieze of the Parthenon (inv. no. Z1903/11.18c), part of the Elgin Marbles, a mass containing Na, Al, Cl, Si, K and Fe is present, morphologically resembling a glue.

The sample of the cast of the goddesses in the east pediment of the Parthenon (inv. no. Z 1903/11.10a) shows the cast was finished with a semi-transparent layer containing zinc white and some ochre, but in the sample of the frieze of the Parthenon (inv. no. Z 1903/11.18c), no finish layer was present. The cast of the Doryphoros, the original being a Roman marble copy of a lost Greek bronze statue, is finished with a patinated bronze imitation, consisting of a layer of white paint containing zinc white, followed by a layer of paint containing zinc white and gypsum and a layer consisting of brass particles and some ochre or iron oxide pigment in linseed oil. This last layer is protected by a transparent varnish consisting of colophony and shellac (Dooijes 2005).

Two other casts with a patinated bronze imitation were investigated: a cast of the Apoxyomenos (inv. no. Z 1903/11.20) of unknown origin; and a cast of the Diskobolos of Myron (Cat. 1913 V 6b), probably made in Rome. Both objects have a similar finish, consisting of a layer of brass particles and iron oxide pigment applied directly on the plaster. This layer is covered with a thin layer of varnish. Probably in a later stage, a second finish consisting of iron oxide pigment and brass particles was applied. Apparently, the intention of these casts was to show the lost original bronze look of the Greek statues rather than the original Roman marble copies.

The casts from Rome, Paris and unknown origins

The two casts in this study that originate from Paris, the Two Nikai with a bull (Z 1903/11.1) and the Frieze of the House of the Knidians (Cat. 1913 III 7 A), both differ in the composition of the plaster. The latter was not painted, while the Nikai were finished with a thin layer containing gypsum and some ochre.

Two casts of provincial Roman objects ordered in 1876 by the museum's director Leemans have a very different plaster composition, but a similar finish, consisting of a layer of paint containing zinc white and some ochre.

The three casts from Rome that were studied were made in different centuries and therefore it is not surprising that the composition of the plaster differs. The finishes on the 17th century cast of Trajan's column (inv. no. St 2) are not original, since the first layer contains zinc white, a pigment not in use before the middle of the 19th century. The layer of paint with zinc white on the cast of the statue from the Aphaia temple made in 1827 is also not original.

CONCLUSIONS

The trace chemical composition of the plaster of selected casts in the collection of the National Museum of Antiquities varies considerably. The structure of the plaster does not correlate with the chemical composition nor with the origin of the casts. This may indicate that the manufacturing procedure plays a much more important role in the final porosity and internal structure of the casts. In the case of the objects obtained from the Royal Museums in Berlin, two groups can be distinguished based on the composition, which match the group of casts from Olympia on the one hand and the casts of Near East objects. The casts from Olympia all have a first white finish and were overpainted in a beige colour at a later time. The casts ordered from Brucciani and Co. in 1903, however, do not show similar compositions.

The three casts of Roman copies of long-lost, famous Greek statues were given a patinated bronze appearance, to make them closer in appearance to the Greek bronze statues than the Roman marble statues from which they are actually cast.

A detailed study of organic additives to plaster will be performed.

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