Karolina Michałowska

A Digital Reconstruction of Roman Terracotta Reliefs : Recreating the Ancient Technique

Światowit : rocznik poświęcony archeologii przeddziejowej i badaniom pierwotnej kultury polskiej i słowiańskiej 12 (53)/A, 39-52

2014

Artykuł został opracowany do udostępnienia w internecie przez Muzeum Historii Polski w ramach prac podejmowanych na rzecz zapewnienia otwartego, powszechnego i trwałego dostępu do polskiego dorobku naukowego i kulturalnego. Artykuł jest umieszczony w kolekcji cyfrowej bazhum.muzhp.pl, gromadzącej zawartość polskich czasopism humanistycznych i społecznych.

Tekst jest udostępniony do wykorzystania w ramach dozwolonego użytku.

MUZEUM HISTORII POLSKI

Karolina Michałowska

A Digital Reconstruction of Roman Terracotta Reliefs – Recreating the Ancient Technique

Keywords: Campana relief, digital reconstruction, polychromy, sculpture, terracotta

The main purpose of this article is to present alternative methods of digital reconstruction of the polychromy of Ancient sculpture, based upon practical experience with materials and series of experiments designed to determine physical properties of paints, grounds and binders. It focuses mainly on the Roman art of the Imperial Period and compares different properties of marble and terracotta sculpture and different applications of the same painting techniques. The reconstructions of Roman terracotta reliefs presented below were based upon analyses of objects from the collection of the National Museum in Warsaw and their existing analogies.

Materials and techniques

To picture the effects possible to achieve in polychromy of both marble and terracotta sculptures and to make any attempts toward reconstructing it, either theoretically or visually, it would be necessary to carefully analyse and understand technical aspects of Ancient ways of creating it.

The key aspect of polychromy analysis is defining the medium on which paint layers are applied. Unlike panel painting, where the wooden board is a flat, two--dimensional object, covered with an even layer of white ground, sculptural polychromy interacts with a three--dimensional surface. Its shape and properties add to the overall effect of the painting, by introducing the play of light and shadow, reflections and its surroundings.

Homogeneous, even, and naturally white marble offers a surface that is not absorbent, does not undergo discoloration, and shimmers with inner lustre. Such a surface can be covered with a thin, translucent layer of paint or tinted wax and its texture can be quite easily manipulated.[1] This is in fact the very definition of a perfect painting medium, especially for the tempera paint, which in case of any other material requires a carefully prepared ground layer.

Considering that the final painting effect depends greatly on the material used, the choice of a stone is not accidental.[2] The shade of marble influences the appearance of a sculpture, even if it was entirely covered with paint – pigments can have their full visual impact only on a pale, homogenous surface, and the warm or cold undertone of the marble affects the chromatic range of paint layers. Likewise, the transparency and the crystal structure of the stone have an influence on the luminescence of the colours. Furthermore, the porosity of the stone and its absorbing properties play an important role in the appearance of paint layers – the more fine-grained it is, the less it absorbs, and the less matte the paint appears. However, this also means that the chance of survival of paint is relatively small (hence almost no traces of paint on highly polished skin surfaces of Roman sculptures).

Some pigments with small molecules, like for example cinnabar, have an interesting feature of penetrating the crystal structure of the marble. This allows the light to play with colourful particles from the inside of the stone, without losing the lustre and transparency.[3] This property is perhaps reflected in a poetic way in one of Lucian's dialogues, where Apelles is being mentioned painting a woman's sculpture and making her skin barely tinted by blood, flushed from the inside.[4]

[1] U. Mandel, *On the Qualities of the "Colour" White in Antiquity*, (in:) V. Brinkmann, O. Primavesi, M. Hollein (eds.), *Circumlitio. The Polychromy of Antique and Mediaeval Sculpture, Proceedings of the "Johann-David-Passavant-Colloquium", 10–12 December 2008, Frankfurt am Main*, München 2010, 309.

[2] C. Blume, *The Role of the Stone in the Polychrome Treatment of Hellenistic Sculptures*, (in:) A. Gutiérrez Garcia-Moreno, P. Lapuente Mercadal, I. Rodà de Llanza (eds.), *Interdisciplinary Studies on Ancient Stone. ASMOSIA Conference (Tarragona 2009)*, Documenta 23, Tarragona 2012, 755.

[3] M. Bradley, *The Importance of Colour on Ancient Marble Sculpture*, "Art History" 32/3, 2009, 439.

[4] Lucian, *Essays in Portraiture* (or *A Portrait-Study*), 6.

The surface treatment is also an important factor that must be taken into consideration. The effort put into polishing Roman marbles, especially in skin parts, was often treated as an argument against the existence of polychromy, in the same manner as elaborated eye or hair details and fabric textures were thought to be a proof of monochromatic sculpture. And yet, all those features in fact greatly enhance sophisticated effects of carefully prepared paint layers, adding a depth of different textures and altering a hue of pigments applied.

In the case of terracotta objects the relationship between the material used to create a sculpture or a relief and a paint layer is less direct. The surface that interacts directly with a paint layer is not terracotta but a kaolin ground which covers the clay. Properties of terracotta itself are not indifferent for the polychromy, especially for the process of decomposition, but the main interaction occurs between pigments and a white ground layer.

Visual and technical importance of that preparatory layer must be clearly stated. A ground not only acted as insulation from the absorbing and rugged surface of fired clay, not only evened it out, but also created a white, light-reflecting base for the application of paint. This allowed the colour to be more easily spread and enhanced its brightness and saturation.[5]

The palette of an Ancient artist was composed of 15–20 basic pigments, with some possible variations. Most of those were naturally occurring ground and mineral pigments, with a few organic ones and two or three synthetic ones.[6] It produced a rather wide range of hues which could have been freely mixed to achieve an even richer palette. It is noticeable that polychromy of terracotta employed a rather narrower range of pigments, using simplified colour schemes in comparison with marble sculpture or panel painting. It relies mainly on Egyptian blue, yellow ochre, red and brown ochre, madder (instead of purple), white (either ground left unpainted, lime or lead white) and green earth or sporadically malachite.

The most challenging aspect of research on Ancient polychromy is determining the binder. Barely any traces of Ancient binders remained to this day and identifying those which survived poses some significant problems. To examine samples the gas chromatography-mass spectrometry (GC-MS)[7] method is used, yet with the state of preservation of those traces, the results are rarely satisfying. If there is any result at all, the only reliable piece of information merely confirms the presence of animal proteins, which gives us very little new data. Ancient literary sources are no help either – information on binding media is very scarce. Apart from epigraphic mentions about encaustic artists and a description of this particular technique by Pliny the Elder[8] we have no precise information on any of the remaining methods, like apparently very popular tempera. Therefore any attempts to find an analogy for Ancient painting techniques in subsequent periods (which might have taken over and developed them) seem to be quite justified.

All known Ancient binders were organic, which means they were very susceptible to disintegration, mainly due to being water-soluble and as a result of microorganisms digesting proteins. Decomposition of binders lead to peeling of layers of paint. However, it seems that Ancient binders were generally stronger than it is assumed. Some traces of paint on the outside of Roman buildings are still visible (for example in the Forum Romanum[9]) and many terracotta figurines bear traces or very vivid colours.

No Ancient descriptions of preparing egg tempera survive. But perhaps an early Renaissance recipe would be quite a sufficient analogy for the technique. It is probably not an ideal substitute but as the technique itself offers very little room for variations, it is the best we can use for reconstructions. Cennino Cennini[10] in his treatise dated to the 14th/15th c. writes that preparing the paint involves mixing yolk and egg white, adding a fig tree juice and stirring it. Then, watered wine is added to this mixture. This emulsion will be the binder for pigments.

Particularly interesting are his remarks on the proper usage of this kind of paint – he warns about applying layers that are too thick, because it causes the paint to crack and fall off from the surface. It is also worth noticing that incorrect proportion of yolk in the mixture can cause cracking of the paint layer too. Cennini also mentions the difference between dark yolk (from rural chickens), recommended for painting dark male complexion, and paler yolk

[5] M.L. Sargent, *Investigations into the Polychromy of Some 5th Century BCE Etruscan Architectural Terracottas*, "Tracking Colour. The Polychromy of Greek and Roman Sculpture in the Ny Carlsberg Glyptotek, Preliminary Report" 4, 2012, 30.

[6] R. Sidall, *"Not a Day without a Line Drawn": Pigments and Painting Techniques of Roman Artists*, "InFocus Magazine: Proceedings of the Royal Microscopical Society" 2, 2006, 20–31.

[7] G. Verri, T. Opper, T. Deviese, *"Treu Head": A Case Study in Roman Sculptural Polychromy*, "The British Museum Technical Research Bulletin" 4, 2010, 52.

[8] Pliny the Elder, *The Natural History of Pliny. Translated by J. Bostock, H.T. Riley*, vol. 6, London 1857, XXXV: 39, 42.

[9] P. Liverani, *New Evidence on the Polychromy of Roman Sculpture*, (in:) V. Brinkmann, O. Primavesi, M. Hollein (eds.), *Circumlitio...*, 297.

[10] G. Milanesi, C. Milanesi (eds.), *Il libro dell'arte, o Trattato della pittura di Cennino Cennini da Colle di Valdelsa*, Firenze 1859 (digital edition 2005), 44–45.

(from urban chickens) for fair female skin.[11] However this differentiation is not entirely clear, since even the orange yolk quickly loses its warm hue when exposed to light.[12]

According to Cennini, pigments were added to the binder in equal measure and then thinned with water to make it liquid, but it could vary depending on the pigments.[13] It is not, however, certain that this particular recipe would be necessary or advisable on all kinds of painting grounds, as in the early Renaissance one used a very specific, carefully prepared ground (i.e., wooden board covered with gypsum and animal glue) that varies significantly from Ancient ones.

It seems that the proportions of pigments and the solvent can be fairly easily altered in order to achieve different effects. The appearance can also be affected by thickness and number of layers, especially because tempera allows working with glazes (very thin, semitransparent layers), which is recommended due to the mentioned problem with cracking. When picking a colour, it must be acknowledged that it will turn paler and more matte once dried. In order to lessen the brittleness of the binder various plasticisers could be added – fig tree juice and/or wine, olive oil or honey.[14] Unfortunately it is impossible to discern with current analytic methods what substance was used. Perhaps more precise experiments could shed some light on subtle differences between various ingredients and their proportions.

There is a possibility that a paint layer could be covered with thin coating made of beeswax,[15] as literary sources testify to the fact that it was done with Roman frescoes,[16] but we lack any actual archaeological evidence for sculpture.

After briefly presenting the materials and their properties, a few words should be said about the painting process and its desired effects. It should be also stated that it could vary greatly, depending not only on the surface and pigments, but on the type and destination of the sculpture (i.e., meant for exterior or interior, standing on the eye level or high up on a building, etc.), the quality of the workshop and wealth of the purchaser.

Due to a fragmentary state of knowledge and scarce amount of well preserved polychromy, we lack proper comparative material. Considering that, and a fairly wide range of types of polychromy existing in Antiquity, there is no way of summarising the painting techniques briefly. However, a few known facts should be mentioned, in order to justify choices made in the following part of this article.

Thanks to research undertaken to analyse such sculptures as Caligula's portrait[17] or the so-called "Treu Head,"[18] quite a lot can be said about Roman marble polychromy. We know that no preparatory ground was used, glazed highlights were applied, and Egyptian blue was mixed with skin tone and white of the eye to achieve greater realism (as was also done in Fayum portraits). Lachrymal ducts and inner part of lips were painted with madder and additional shadows were occasionally applied under the brow bone. Hair could be painted with many elaborate layers, again including Egyptian blue in the shadows and highlights on the top of individual locks. Eyelashes were quite stylized and marked with dark pigments as an underlying layer.[19]

Sometimes, parts which were not sculptured were painted on a flat surface, as an additional piece of information (strands of hair, eyelashes, pieces of clothing, sandal parts, patterns, etc.). Some parts can be added as separate three-dimensional objects, such as jewellery, weapons, helmets,[20] etc. Parts of the sculpture (or sometimes even the whole surface) could be gilded to enhance its splendour.[21]

---

[11] G. Milanesi, C. Milanesi (eds.), *Il libro dell'arte...*, 81.

[12] The feature was observed during the experiment described later in the text.

[13] A.P. Laurie, *The Painter's Methods and Materials*, Dover 1967, 180.

[14] A.P. Laurie, *The Painter's Methods...*, 179–181.

[15] G. Richter, L.F. Hall, *Polychromy in Greek Sculpture*, "The Metropolitan Museum of Art Bulletin" New Series 2/8, 1944, 237.

[16] Vitruvius, *The Ten Books on Architecture, Translated by Morris Hickey Morgan*, Cambridge 1914, VII: 9.

[17] J. Stubbe Østergaard, *Reconstructing the Polychromy of a Roman Portrait. Caligula in the Ny Carlsberg Glyptotek, Copenhagen*, (in): C.C. Mattusch, A.A. Donohue, A. Brauer (eds.), *Common Ground: Archaeology, Art, Science, and Humanities. Proceedings of the XVIth International Congress of Classical Archaeology, Boston, August 23–26, 2003*, Oxford 2006, 512–516.

[18] G. Verri, T. Opper, T. Deviese, *"Treu Head": A Case Study...*, 39–54.

[19] G. Verri, T. Opper, T. Deviese, *"Treu Head": A Case Study...*, 44–51.

[20] G. Verri, T. Opper, L. Lazzarini, *'In picturae modum variata circumlitio'? The Reconstruction of the Polychromy of a Roman Ideal Female Head (Treu Head)*, (in): P. Liverani, U. Santamaria (eds.), *Diversamente bianco. La policromia della scultura Romana*, Roma 2014, 172.

[21] B. Bourgeois, P. Jockey, *The Polychromy of Hellenistic Marble Sculpture in Delos*, (in:) V. Brinkmann, O. Primavesi, M. Hollein (eds.), *Circumlitio...*, 230; also: M. Abbe, *Recent Research on the Painting and Gilding of Roman Marble Statuary at Aphrodisias*, ibidem, 277.

Polychromy of terracotta seems to be, in general, rather less sophisticated. Especially in the case of architectural terracottas, a narrower range of pigments was applied, perhaps for various reasons. Some were probably considered too precious for such inferior material, some probably did not work so well on such surface. As can still be observed on numerous well preserved objects, the three primary colours: blue, yellow and red were the most common combination used for mass-produced reliefs, with additions of white, madder purple and some greens. Figurines, inspired by Tanagra ones, displayed a rather wider range of somewhat pastel tones.[22]

It must be noted that while more numerous evidence presents lesser quality polychromy, it was entirely possible to do it quite masterfully, as some finer examples prove, such as, for instance, the Campana Reliefs from Palatine Hill.[23] Although they remain in a relatively narrow range of basic colours, the very fine manner of application, precise details and additions such as gilded ribbons indicate a higher level of the craft. It seems to be quite safe to assume that the choice of brighter, clearer tones and a narrower palette was a deliberate aesthetic choice, only partly connected to properties of the material itself. However, the reasoning behind that choice is not the focus of this paper and will not be further investigated.

Now, after briefly summarising the materials and methods typically employed in Roman polychromy, some of the statements concerning Ancient techniques will be verified in the experiment.

The experiment

In order to reduce the arbitrary character of a digital reconstruction as much as possible, an experiment was designed.[24] Its purpose is to analyse subsequent phases of the polychromy process, on both marble and terracotta surfaces. An empirical examination of the interaction between materials was meant to help with drawing reliable conclusions, possible to employ in visual reconstruction.

The experiment was carried on in two major parts – the first using marble slabs and the second with terracotta plaques. The egg tempera was prepared according to the recipe quoted above. Several trials were attempted in order to determine interactions of materials with different absorptive properties and various proportions of ingredients, to judge the brightness and saturation of pigments mixed with binders and to verify a possibility of working with glazing technique.

For the part with the marble surface, two kinds of white marble with varying degree of polish were used. For the terracotta one, pale ceramic clay was used, without any additions, for they would be quite irrelevant for the result. Two objects were prepared: a flat rectangular terracotta slab and a copy of the Campana Relief's fragment from the collection of the National Museum in Warsaw,[25] in full dimensions (recreated by hand without using a cast) (**Fig. 1:a**). Both of them were left to dry in room temperature and then fired in a coal stove, in the temperature reaching 900°C.

To prepare the preparatory ground, kaolin clay was mixed with water to the point of reaching the consistency of a thin suspension. It was then spread evenly on the surface of all three objects, using a soft brush. It was applied in three very thin layers, each of them fully dried before applying the next one. The ground entirely covered the colour of the clay surface, but did not exactly change its texture. It did not cover small details of the relief, either; quite on the contrary – white colour made the form more discernible.

For both marble and terracotta surfaces the same binder was prepared – an egg tempera. After separating the yolk, the egg white was filtered through a dense fabric to make it liquid. Then it was mixed with yolk in equal proportions (about 30 ml of each substance). Small amounts of water and watered white wine were added. The mixture achieved the consistency of a smooth, homogenous suspension.

The binder was distributed into a few dishes and mixed with various pigments in different proportions. Yellow and brown ochre, small amounts of hematite, kaolin white and synthetic blue (as a replacement for also synthetic but no longer available Egyptian blue) were used.

To determine the properties of the paint, the binder was first mixed with brown ochre in equal proportion and then applied on a white sheet of paper. Then, the same action was repeated with 1:2 pigment to binder ratio. The saturation of the colour in the dish did not change regardless of proportions used. The thickness of the paint did change. The samples on the paper proved significant differences in hue, saturation and transparency between both mixtures. The 1:2 ratio was much lighter and less opaque.

[22] V. Jeammet, *Sculpture "en miniature". Polychromy on Hellenistic Terracotta Statuettes in the Louvre Museum's Collection*, (in:) J. Stubbe Østergaard, A.M. Nielsen (eds.), *Transformations. Classical Sculpture in Colour*, Copenhagen 2014, 209–211.

[23] M.J. Strazzulla, *Il principato di Apollo. Mito e propaganda nelle lastre ≪Campana≫ dal tempio di Apollo Palatino*, Roma 1990.

[24] For the detailed list of materials and equipment used in the experiment see the experimental appendix at the end of the article.

[25] National Museum in Warsaw, inv. No. 199609.

The colour of yolk only very slightly affected the hue of the paint (the difference was most visible in the case of blue paint). After less than an hour the dried paint lost the yellowish shade entirely.

The terracotta and marble slabs were used as a ground for small colour samples to determine the behaviour of paint on different grounds and the interaction between colours and different materials.

Marble

The first one to examine was high polished marble from Naxos with a silvery crystal structure. As a trial, a thick layer of 1:1 ratio paint was applied. It proved to be nearly impossible to apply, due to the oily consistency of emulsion – it did not hold properly to the surface. Then, after cleaning it, a thinner, transparent layer of the same paint was applied. This time it stuck to the surface without any trouble and dried after a few seconds. It did not hide the structure of the marble. The second layer applied on top of it was even easier to apply and remained on the surface. It was still semi-transparent and the hue became deeper but the marble structure was still visible. Only after the fifth layer it was entirely covered.

The same actions were undertaken with yellow ochre, with a similar effect. However, in this case, it turned out to be not fine-grained enough, which points to the important role of proper preparation of the pigment in the final visual effect. It was also less opaque than the brown one, indicating individual differences between pigments.

The next step was examining the possibility of using glaze layers of different colours. Overlapping layers of yellow on top of brown and brown on top of yellow resulted in light brown tone, each time achieving a slightly different hue (**Fig. 2**).

An attempt to make a single colour gradient was quite successful, especially when done fast enough. With thin enough layers a transition from light, transparent tone to deep, fully-saturated one was entirely passable.

In general, working with 1:2 ratio was easier and allowed to achieve more sophisticated effects, such as gradients, glazes and highlights.

To gather more data, the same actions were then repeated on semi-polished Carrara marble with visible discoloration. The main difference was paint adherence which was slightly stronger. Dark grey streaks on the marble proved to be impossible to hide by no amount of paint. It suggests that using homogenous stone was quite necessary for the sculpture meant to be painted.

Terracotta

On the terracotta slab covered with kaolin ground three wide stripes of paint were applied – yellow ochre, brown ochre and synthetic blue. The first layer was applied as thinly as possible. On the blue one, three more identical layers were applied, each of them narrower than the former one, presenting the varying saturation of colour, depending on the thickness of the paint layer. On the brown stripe a mixture of blue and brown was applied, resulting in nearly black shade. On the yellow stripe a mixture of yellow and brown ochre was applied, resulting in light golden brown. Both actions proved the possibility of mixing colours both on the palette and by the superposition of layers.

Then, a thick layer of blue was applied over the yellow stripe, proving itself to be completely opaque. The same result was produced with kaolin white. This proved that tempera can cover underlying colours entirely (**Fig. 3**).

Moreover, changing the number and thickness of layers, proportions of pigments and adding water allowed to achieve quite a wide range of colours using a very limited number of pigments.

Relief

The final step of the experiment was producing a physical reconstruction on a full-size copy of a Roman terracotta relief. It was meant to examine the interplay of an almost three-dimensional form, employing light and shadows, with the application of tempera paint. All techniques verified above were used.

The choice of colours, the method and the order of their application was based upon the analysis of the original relief. Apart from the visual examination of visible pigment remains with a magnifying glass, the visible induced luminescence (VIL) effect was used as a method of non-invasive examination of the presence of Egyptian blue.

Visible to the naked eye were yellow remains on the chlamys and reddish brown paint on the hair and the sword handle. Observation with a magnifying glass revealed the concentration of dark blue pigment near the back of a man's head. Small traces of white ground were scattered through the whole background part. In many places the colour slips significantly outside the area it is supposed to cover.

The presence of blue pigment was a factor that motivated an additional examination with the VIL photography.[26] Photographs, taken by the author with a digital camera with the IR blocking filter removed, revealed otherwise invisible traces of Egyptian blue. They exposed some

[26] J. Gancarczyk, T. Gancarczyk, *Nieinwazyjne badania obiektów zabytkowych z wykorzystaniem fotografii w świetle widzialnym, fluorescencji UV i reflektografii IR*, "Pomiary Automatyka Kontrola" 56/3, 2010, 268–271.

traces along the line of the face, near the lower left corner, small particles scattered through the background part and enhanced the visibility of the concentration near the back of the head. These observations confirm not only the assumption that the background was painted blue, but that the paint layer is the original Ancient one and not a quite common 19th c. forgery, since Egyptian blue ceased to be used around the 9th c. AD.[27]

With the evidence of not particularly careful application of colours, the author assumed that the background was meant to cover imprecise spots. Therefore, the chlamys, the hair and the sword handle were painted first, with yellow and brown ochre, respectively. The hair was then covered with an additional layer of brown ochre mixed with hematite to achieve a slightly russet hue observed on the original relief. The shadows within the hair area were painted with a mixture of brown and blue pigments to add some depth. A very thin layer of yellow ochre was applied as a highlight. An unidentified object in the right corner was quite arbitrarily painted brown, with little evidence from the original relief. The skin tone was achieved by mixing yellow ochre, hematite, brown ochre and kaolin clay. It changed its tone to a few shades lighter after drying. Then the background was covered with three layers of blue paint and all imperfections were later carefully covered using a small brush.

At the end, using the smallest brush, face details were painted. The brow, eyelashes and iris were painted using brown ochre. The white of the eye was covered with kaolin clay. The shadows in the eye socket, the nose bridge, under the jawbone and inside the ear were painted with darker hue of skin tone. The inner part of the mouth was painted with hematite and the lips were glazed with a thin layer of hematite and yellow ochre mixture (**Fig. 1:b**).

After drying, the colours faded slightly and became more matte. Glazing was easy to achieve, and mixing colours both on a palette and by superposition of layers was equally effective. Fast drying of the paint was causing visible streaks and it forced quick application in order to avoid it. The size of relief allowed to work on small details, but it required precision and a steady hand. With enough experience in the technique it seems to be entirely possible to achieve quite realistic effects.

After completing the experiment and documenting all the steps with a digital camera, the terracotta relief and one of the marble slabs were cleaned. They were put under running water first. The top layers and the thinner ones run off the surface almost entirely, but parts of the paint layer remained intact. However, after rubbing the wet marble with a finger all remains were removed. Only minuscule amounts remained in small dents. Terracotta's polychromy proved to be more durable – only after cleaning it with a toothbrush, the paint was removed, together with the white ground. Still, lots of it remained in areas which were harder to reach. It seems to confirm what already could be observed in archaeological finds – the majority of preserved polychromy exist on terracotta surfaces.

Conclusions

- The way of preparation of the binder and the proportions of ingredients are not irrelevant to the final visual effect.
- Egg tempera with its relative thickness and sufficient adherence is well suited for both marble and terracotta surfaces.
- Manipulating the pigment to binder ratio allows radical changes in the hue and opacity of the paint, regardless of the original colour of pigment used.
- Working with glaze layers and mixing colours with the superposition of semitransparent layers is entirely possible and quite advisable.
- The ease of creating gradients suggests that shading was entirely possible to achieve.
- In case of marble surface, applying thick, opaque layers is not advisable and, at times, entirely impossible, due to immediate cracking of the drying paint.
- Terracotta ground, more absorbent in nature, allows the application of much thicker, opaque layers.
- The degree to which the surface is polished, porosity and the stone structure significantly affect the appearance of the paint layer (its transparency, saturation, lustre, and hue).
- White ground in the case of terracotta plays a slightly less crucial role in the final appearance of the object but it is important from the technical point of view.
- Egg tempera is not able to hide imperfections of the stone – all veins and discolorations can be visible under the paint layer, which explains the need to use the best quality marbles even for the entirely painted sculpture.
- Tempera that is not covered with wax is not waterproof.
- The thinner the paint layer, the quicker it disintegrates. The more complex the mixture, the quicker it disintegrates. The smoother the surface the quicker paint layers fall off.
- It is possible to achieve both deep tones with full saturation and pale, soft hues within the same colour, depending on the way of application.
- Achieving sophisticated artistic effects is entirely possible but requires some proficiency in craftsmanship.

[27] G. Verri, *Imaging of Egyptian Blue. Technical Details*, London, s.a., 1, https://www.britishmuseum.org/pdf/Imaging%20of%20Egyptian%20Blue_Technical%20details.pdf (access on 11 November 2015).

Fig. 1. A clay copy of a fragment of a Roman Campana Relief made by the author (a), colour reconstruction (b) (Reconstruction and photo K. Michałowska).

Ryc. 1. Terakotowa kopia fragmentu rzymskiego Reliefu Campana, wykonana przez autorkę (a); rekonstrukcja koloru (b).

Reconstructions

Reconstructing Ancient polychromy, either in a form of a physical copy painted with tempera, or as a purely digital creation, causes lots of methodological problems that must be addressed first.

As it was mentioned above, the relationship between the painting ground and the paint layer is crucial to the final visual effect. When creating either a physical reconstruction on a copy or a digital one, it is very important to take into account properties of the material used.

Using a gypsum copy for recreating a polychromy on a marble, as it is often the case,[28] fails to acknowledge

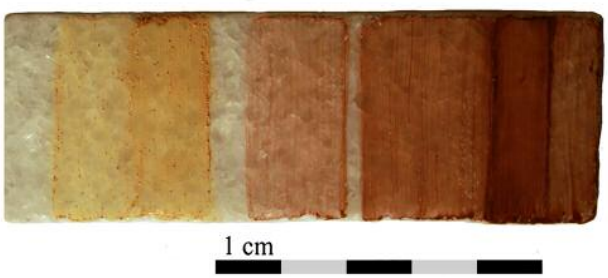

Fig. 2. Marble slab with tempera samples (Photo K. Michałowska).

Ryc. 2. Płytka marmurowa z próbkami koloru.

Fig. 3. Terracotta slab with tempera samples (Photo K. Michałowska).

Ryc. 3. Płytka terakotowa z próbkami koloru.

[28] See V. Brinkmann, A. Scholl (eds.), *Bunte Götter. Die Farbigkeit antiker Skulptur: Katalog zur Ausstellung in Berlin, Pergamonmuseum 13. Juli 2010 – 3. Oktober 2010*, München 2010.

major differences between those two types of grounds and makes the reconstruction less reliable. Using a material that is more matte, porous and absorbent gives a falsified impression of the original appearance of the sculpture.

Another issue is the interpretation of mathematically obtained data concerning the pigments. Results of sampling are only a piece of information about the chemical components of a used substance, giving us little knowledge about its actual colour.[29] It tells us almost nothing considering its appearance on the surface, the influence of the binder and the way of application, not to mention even more ephemeral factors, such as: reflections, light and shadow, the company of other colours (that can greatly influence the appearance of the nearest hue), etc.

From those, the next problem arises. Due to a lack of any certain information about binders and proportions of ingredients used, all decisions made in that area are hypothetical and quite arbitrary. It is certainly problematic because the pigment to binder ratio greatly affects the final hue of the colour picked for the surface, as it was proven above. We cannot be sure if there was, in fact, any commonly used recipe or if the mixture could be modified according to the needs or if it simply just varied form workshop to workshop.

What also needs to be taken into account when interpreting the available material, is that exterior layers tend to deteriorate faster and that mixtures of colours (such as a skin tone) are less stable than pure colours. Furthermore, it was a common practice to mix colours by superposition of thin layers. Therefore, the presence of certain pigment on the surface might not in fact indicate its original colour. In some cases blue is only an underpaint and red might be a preparatory layer for a gold leaf gilding.[30]

The last issue that needs to be addressed is simply a matter of skill. Realistic polychromy, using shading and glazes requires deep understanding of the materials, the technique, artistic skill and experience to manage to either actually apply fast drying tempera paint in the right manner, or mimic it in a digital way with a satisfactory result. It should also be noted that with a matter as subjective as colour and its perception, no two people would produce the same effect, even with the same materials and with the same assumptions. Therefore all reconstruction attempts should be considered, if admittedly scientifically justified, only as suggestions.

Digital reconstruction

Digital reconstruction becomes more popular, not only for visualising cities and buildings, as it has already been employed for a long time, but lately also for recreating the original appearance of Ancient sculpture.

In the case of reconstruction of sculpture, two approaches are possible: 3D reconstruction and photomanipulation. The choice of which one would be preferable in a specific case depends on various factors, such as the costs, availability of material and the form of publishing, just to mention only some of them.

Photomanipulation basically involves using a photograph of a sculpture, taken in a natural light, preferably at the angle showing most of the features (typically a frontal frame). Using digital tools the object can be retouched – discolorations can be removed, missing elements restored and the surface cleaned. Then the process of creating subsequent paint layers is recreated using digital tools. It can (and should) take into account restrictions imposed by traditional painting techniques. Glazing is mimicked by working on semitransparent layers of graphic software and manipulating the opacity scale of a digital brush. Colours are picked according to the visual compatibility with the effect created by a raw paint applied on a given material, in a given light source. The whole process can employ from a couple to more than a dozen layers, not unlike the real tempera painting.[31]

This method is particularly useful and efficient if the reconstruction is meant to be published in a paper form, not allowing to present an animated object. While remaining two-dimensional, it gives a reasonable impression of the object's original appearance (if only hypothetical). Furthermore, this kind of reconstruction is significantly simpler and faster to create than a 3D model. It is also cheap and can be performed with low hardware requirements.

Obviously, the achieved effect is always more or less arbitrary and is influenced by many factors, such as the light in which the original photo was taken, its white balance and other chromatic distortions and, no less importantly, the artistic skill of the person creating the

[29] H. Piening, *From Scientific Findings to Reconstruction: The Technical Background to the Scientific Reconstruction of Colours*, (in:) V. Brinkmann, O. Primavesi, M. Hollein (eds.), *Circumlitio...*, 108.

[30] M. Abbe, *Recent Research...*, 277, 281.

[31] It can be also employed in an entirely different manner, distorting and adjusting a preexisting image, as it was attempted by G. Verri, T. Opper, L. Lazzarini, '*In picturae modum...*, 171– 176.

reconstruction and their methodological assumptions. However, the main goal of this method is to give a general impression of a possible appearance of an Ancient sculpture (although based on careful examination of available evidence) rather than strictly substantive presentation of scientific data. The final effect is not, and in fact, cannot be a definitive statement about the original appearance of the object, but rather its possible, or the most probable appearance. In other words, based on scientific analysis and available data, it can be said that for all we know the object could look like on the proposed reconstruction.[32]

Based on the experiment described above and on the analysis of the Campana Reliefs from the collection of the National Museum in Warsaw and their existing analogies, three digital reconstructions were made. Each of them was treated in a slightly different manner – both due to restrictions imposed by the objects themselves and to present diverse possible approaches.

The reconstruction of the fragment of the relief with a male figure[33] was based upon traces of pigments visible to the naked eye, which were preserved on the surface and upon the VIL[34] analysis (**Fig. 4:a**). In the absence of any direct iconographic analogies, the author decided to leave it in its fragmentary state and reconstruct only the polychromy of the preserved part. Visible fracture of the terracotta was used as a way of revealing the layered structure of the painted surface.

The reconstruction of the fragment of the relief with a female figure holding a ribbon, from the collection of the National Museum in Warsaw,[35] was based upon analogical objects that were typical, recurrent motifs with a clearly symmetrical composition of a relatively unaltered type.[36] This reconstruction is more speculative, but not purely hypothetical. Thanks to numerous known analogies it was possible to make a reconstruction of the whole composition and attempt to reconstruct a possible original appearance of the whole relief plaque. Assumptions about colours were made thanks to comparisons with preserved polychromy of reliefs with the same composition and similar level of craftsmanship. This approach allows us to present a presumed original appearance of the object that survived in a very incomplete state.

The preliminary step in a digital reconstruction is preparing a surface. In the case of marble objects it can involve virtual cleaning of discoloration or missing parts. The reconstruction of terracotta objects requires recreating the white ground. Not unlike the real one, this layer will make a preparatory surface for colours.

The main challenge of that step is to create an even white layer without losing the form of the relief and keeping both light and shadow unaltered. The finished layer, like the kaolin ground, hides the clay colour completely, while keeping details and the texture discernible (**Fig 4:b**).

The following steps are significantly more mechanical and therefore less biased and less dependent on individual artistic skill of the person making the reconstruction. It allows the method to be more universally applied.

Choosing a layer setting that enables us to apply a colour with its full saturation without covering up the form and the texture of the surface[37] allows to apply an even, homogenous blot of colour on chosen areas. Such action imitates putting a single layer of a tempera paint with a high concentration of pigment within the binder. Altering the transparency of the layer (here set on 75% opacity) serves as using a paint with higher or lower ratio of binder to water. A digital brush that was used was meant to mimic a soft natural brush that does not leave its own markings. Despite the intervention in the colour of surfaces, pre-existing shadows were preserved, altering hues and saturation of colours in a natural way, contributing to a more realistic effect.

Then, semitransparent layers of matte colour were applied on an opaque layer, serving as highlights possible to create in tempera technique, deepening the three-dimensional appearance of the relief (**Fig. 4:c,d**).

The reconstruction of the relief with a female figure holding a ribbon, being a part of an adoration of *candelabrum* composition type, was carried out in the same manner, although on a differently prepared image (**Fig. 5:a**).

In this case, based on the closest analogies, a hypothetical reconstruction of the whole composition was made. Assuming that the image was symmetrical, as in all remaining cases, the preserved fragment allowed to digitally

[32] G. Verri, T. Opper, L. Lazzarini, *'In picturae modum...*, 172.

[33] For a detailed analysis of the object see the unpublished MA thesis: K. Michałowska, *Reliefy Campana w kolekcji Muzeum Narodowego w Warszawie – dokumentacja zabytków i rekonstrukcja polichromii* (Institute of Archaeology, University of Warsaw), Warszawa 2015, 36–38.

[34] G. Verri, *Imaging of Egyptian Blue...*, 1.

[35] National Museum in Warsaw, inv. No. 199607.

[36] For a detailed analysis of the object and its analogies see K. Michałowska, *Reliefy Campana...*, 35–36, 44–45.

[37] In Paint Tool SAI the layer is named "shade."

recreate the whole relief. Using a graphic software, the existing elements were copied and flipped horizontally to create a heraldic composition, while the remaining elements of the ornaments were copied and multiplied to create the whole frieze. Missing parts of the background and the *candelabrum* were filled in by hand-painting them. The whole relief was then unified in hue and cleaned out. Some choices were to some extent arbitrary due to lack of certain analogies, but the whole reconstruction remains a fairly valid (yet not unambiguous) interpretation of the available material (**Fig. 5:b**).

The main difference in the reconstruction of polychromy was made by the surface which was previously evened out. This made preparing a ground layer easier and allowed to keep the details more discernible.

Colours were applied on the same kind of layer described above and the transparency of individual layers (a separate one for each colour) varied between 95% for blue and 65% for yellow ochre (**Fig. 5:c**).

Reconstruction of polychromy in the 3D modelling technique can have a wider application if used in its full potential. It allows a detailed visual documentation of the object, a more precise examination and interactive ways of presentation. Thanks to methods of digital imagining, deteriorating traces of paint can be precisely mapped and documented in a way that allows their further exploration without any damage to the original object. A 3D model can be used as a base for processing the data, a surface for mapping samples and results of non-invasive examinations. It can also be used as a ground for recreating art techniques and exploring the interaction of surface, paint layers and their relations in space and different lighting. Only the latter approach will be further explored in this paper, mainly due to research funding limitations.

Because the whole process of this reconstruction is only a proposition and a presentation of the potential of alternative methods of working with an archaeological object, it was carried out on a clay copy of the relief. Using a full-size copy allowed a freedom of working in the space of author's private photographic studio and simplified the whole procedure for the sake of experimental research. The visual effect remained close enough to make relevant conclusions and the very same procedure can be carried out on every type of archaeological object.

Works on the reconstruction involved two main stages: creating a 3D model and the actual colour reconstruction. The first stage required making a specific photographic documentation and processing the acquired data into an interactive model, using a free application. The second stage involved creating a reconstruction using a simple graphic software.

To create a 3D model, instead of a normally used 3D laser scanner, a simplified substitute was used. An easy to use and free application Autodesk 123D Catch was employed for the task. It allows to create a fully interactive model, possible to export to other file types, using only photographs of the object.

To create a detailed and reliable model about 40 to 70 photographs must be taken. They were taken in the diffused daylight, at two different angles – 90° and 45°. They added up to the number of 43 photos, taken by slowly moving along two circular routes, with the point of view each time altered a few degrees, in the established distance from the object. One additional photograph was taken from above the object, with the lens in parallel with the surface. To simplify the processing of the data, photographs were taken on the neutral, homogenous photographic background. Furthermore, small yellow markers with numbers were placed around the object, making them points of reference for the trigonometric analysis undertaken by the application.

Photographs were then copied to the Autodesk application. All operations undertaken by this software are carried out in the so-called "cloud," which frees the computer operational memory from the time-consuming task of analysing the data. Thanks to this feature it can be used on any type of computer, personal laptops included. The whole procedure is of relatively short duration and does not require any particular skill (apart from the ability to take a properly focused digital picture) nor any previously acquired knowledge.

The model prepared thanks to this application is precise enough and preserves the information about the texture and colour of the surface. It, however, retains the lighting in which photographs were taken (**Fig. 6:a**). Only after exporting it to the different file format and opening it in a program meant specifically for 3D models (like MeshLab, which is designed for archaeological purposes or an open-source Blender) it is possible to create a fully interactive structure, pick independent light source and control all the parameters.

However, for the purposes of this article and with the resources available to the author another approach was taken. The reconstruction was made frame by frame, by taking several screenshots of the model at varying angles, and then each frame was painted with exactly the same parameters. Then all frames were put back into a kind of an animation.

While not varying from photomanipulation in practical aspects (the same settings and the same order of layers was used) (**Fig. 6:b**), this type of reconstruction enriches the presentation with an opportunity to show the relationship of colour and shape at varying angles and exposes the role of the depth of the relief and the play of light on differently shaped surfaces (**Fig. 6:c,d**). It allows us to see how the colour becomes a physical property of the object and alters its perception in space.

Fig. 4. Original fragment of the Campana Relief, the National Museum in Warsaw – inv. No. 199609 (a) (Photo K. Michałowska); the first step of reconstruction – creating a white preparatory ground (b); layers of yellow and skin tone already applied (c); complete reconstruction (d) (Reconstruction K. Michałowska).

Ryc. 4. Oryginalny fragment Reliefu Campana, Muzeum Narodowe w Warszawie – nr inw. 199609 (a); pierwszy etap rekonstrukcji – odtworzenie warstwy pobiały kaolinowej (b); warstwy koloru żółtego i cielistego (c); kompletna rekonstrukcja (d).

Fig. 5. Original fragment of the Campana Relief, the National Museum in Warsaw – inv. No. 199607 (a) (Photo K. Michałowska); recreating the whole composition of a plaque (b); finished colour reconstruction (c) (Reconstruction K. Michałowska).

Ryc. 5. Oryginalny fragment Reliefu Campana, Muzeum Narodowe w Warszawie – nr inw. 199607 (a); rekonstrukcja pierwotnej kompozycji reliefu (b); ukończona rekonstrukcja polichromii (c).

Fig. 6. 3D model of a relief's copy created by the Autodesk application (a); the first step of reconstruction – creating a white preparatory ground (b); finished colour reconstruction (c); finished 3D reconstruction, seen from various angles (d) (Model and reconstruction K. Michałowska).

Ryc. 6. Model 3D kopii reliefu wykonany za pomocą aplikacji Autodesk (a); pierwszy etap rekonstrukcji – odtworzenie pobiały kaolinowej (b); ukończona rekonstrukcja polichromii (c); polichromowany model widziany pod różnymi kątami (d).

General conclusion

The examination of the accessible objects and their existing analogies became a point of departure to create three types of reconstruction of the polychromy and a field for the analysis of possible methods of recreating the original appearance of the Ancient sculpture. Acquiring a practical knowledge via the experiment and comparing it with available literary sources and the results of non-invasive examinations undertaken by the author allowed to create a reasonably reliable reconstruction. It can possibly become a standpoint for a further discussion on the matter of restoring this very important and almost entirely lost aspect of Ancient art.

Mgr Karolina Michałowska
College of Inter-Area Individual Studies in the Humanities and Social Sciences
University of Warsaw
k.m.michalowska@interia.pl

Experimental Appendix

Materials used in the experiment:

Polished marble from Naxos
Semi-polished Carrara marble with visible gray veins
Yellow ochre from Nea Paphos
Brown and red ochre
Synthetic blue pigment
Egg
White wine
Standard ceramic clay of which three objects were made:
- Flat slab (7×7.5×1 cm)
- Small cast with a convex relief (4×3×0.7 cm)
- Copy of the fragment of the Campana Relief (13.5×16×3.7 cm)

Kaolin clay
Various brushes with both natural and synthetic bristles
Dishes and utensils, thick fabric, metal stylus
Coal stove

Tools used for documentation and digital reconstruction:

Digital camera Canon 500D with 18–55 mm lens
Digital camera Canon 550D without the IR blocking filter on the matrix
Graphic tablet Pentagram ThinType
Laptop Hewlett-Packard with Windows 7
Autodesk 123D Catch application
Paint Tool SAI graphic program

Karolina Michałowska

Cyfrowa rekonstrukcja rzymskich reliefów terakotowych – odtwarzanie technik starożytnych

Artykuł podejmuje problematykę rekonstrukcji polichromii rzeźby rzymskiej, zarówno marmurowej, jak i terakotowej. Skupia się zwłaszcza na technologicznym aspekcie polichromii i procesie jej powstawania oraz prezentuje alternatywne metody rekonstruowania jej przy użyciu prostych, łatwo dostępnych narzędzi cyfrowych.

Podstawowym problemem przy rekonstruowaniu warstw malarskich jest zrozumienie właściwości materiałów użytych do jej stworzenia oraz ich wzajemnych interakcji. Porowatość, chłonność czy odcień podłoża nie pozostają bez wpływu na efekt malarski, oddziałując nań w nie mniejszym stopniu niż indywidualne właściwości poszczególnych pigmentów, ich zdolności kryjące, sposoby mieszania czy stabilność owych mieszanek. Kluczowym problemem pozostaje identyfikacja i ocena właściwości spoiw stosowanych w antyku, jako że zachowują się one niezwykle słabo, a brak jest precyzyjnych opisów w źródłach antycznych.

W celu zweryfikowania wpływu zastosowanego spoiwa, proporcji pigmentów i interakcji farby z podłożem, zaprojektowany i przeprowadzony został kilkuetapowy eksperyment. Tempera jajeczna została przygotowana w oparciu o recepturę zaczerpniętą z wczesnorenesansowego traktatu Cennino Cenniniego. Następnie wymieszano ją z pigmentami w różnych proporcjach pigmentu do spoiwa i rozpuszczalnika, i odnotowano zaobserwowane różnice. Wykonano odrębne próby dla podłoża marmurowego (polerowany i matowy marmur) (**Ryc. 2**) oraz pokrytej glinką kaolinową, wypalonej płytki terakotowej (**Ryc. 3**). Następnie, po określeniu możliwości i ograniczeń tempery na danym podłożu, wykonana została rekonstrukcja polichromii, na wcześniej przygotowanej kopii fragmentu Reliefu Campana pochodzącego ze zbiorów Muzeum Narodowego w Warszawie (**Ryc. 1:a,b**). Ustalone zostały: właściwości kryjące farby, możliwość pracy na laserunkach i budowania gradientów, czas pracy i wysychania, interakcje farby o różnej gęstości z podłożem, możliwość mieszania kolorów na palecie oraz poprzez superpozycję warstw, a także odporność warstwy malarskiej na wodę i ścieranie.

Wnioski wyciągnięte na podstawie wyników eksperymentu zostały następnie wykorzystane w przygotowaniu rekonstrukcji komputerowych. Autorka wykonała dwie rekonstrukcje metodą fotomanipulacji oraz rekonstrukcję 3D na modelu przygotowanym na podstawie kopii reliefu wykonanej dla potrzeb doświadczenia.

Rekonstrukcje wykonane metodą fotomanipulacji prezentują dwa możliwe podejścia do odtwarzania pierwotnego wyglądu zabytku. Pierwsza stanowi rekonstrukcję kolorystyki fragmentarycznie zachowanego zabytku na podstawie widocznych na nim śladów pigmentów oraz badań nieinwazyjnych, wykonaną jedynie dla istniejącego fragmentu obiektu (**Ryc. 4:a–d**). Druga jest rekonstrukcją hipotetycznej kolorystyki fragmentarycznie zachowanego zabytku wraz z komputerowym uzupełnieniem brakujących elementów kompozycji, wykonaną wyłącznie na podstawie istniejących analogii (**Ryc. 5:a–c**). Obie stworzone zostały na podstawie zdjęć zabytków, przy wykorzystaniu prostego oprogramowania graficznego, pozwalającego na pracę na warstwach, które imitują laserunkowe nakładanie farby temperowej.

Rekonstrukcja 3D została przygotowana z wykorzystaniem darmowego oprogramowania i bez pomocy skanera 3D, w celu prezentacji alternatywnych, niskokosztowych metod pracy nad zabytkiem. Zastosowana aplikacja wymagała jedynie odpowiednio przygotowanej dokumentacji fotograficznej obiektu. Przy użyciu tego samego oprogramowania graficznego nałożone zostały warstwy malarskie, imitując efekty możliwe do osiągnięcia przy pracy temperą na podłożu terakotowym (**Ryc. 6:a–d**). Ostateczny efekt prac nad rekonstrukcją prezentuje wzajemne relacje koloru, trójwymiarowej formy reliefu, przekłamań chromatycznych wynikających z roli oświetlenia oraz interakcji tych czynników w przestrzeni.