ANCIENT SCULPTURE POLYCHROMY

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Most sculptures that we have from ancient Greece lack any sign of colors or pigments. Because of this fact, the casual observer may not even consider that this was not the intended state. However, through scientific research, analysis of the sculptures, and cross-referencing with literary material, we know that this is not the case. Practically all sculpture and architecture in ancient Greece was brightly colored. We examine some of the scientific methods that are utilized to gain insight into the original coloring of a sculpture. This is becoming very useful in cases where most of the pigments have faded away due to exposure to light.

The first evidence that ancient sculpture had coloring of any form comes from the sculptures that were covered in ash in Pompeii. The ash was able to protect the pigments from the harmful effects of sunlight. Because of this, the pigments of these sculptures were preserved significantly better than any of those on previously discovered sculptures. This makes it clear that the sunlight is a significantly harmful factor when it comes to pigment preservation.

Many of the early attempts at the inference of the colorization of sculpture and architecture was done before the discovery of many of the scientific techniques that are now used today. This means that most reconstructions were primarily based on the aesthetical preferences of the historian attempting the restoration. These reconstructions only accounted for a few bits of evidence that were available at the time. The primary evidence was if the color was clearly visible on the sculpture; if it was not, then it was up to the historian to decide what color should be placed there.

As more scientific methods of determining the colorization or the pigment of sculptures were developed, the accuracy of the reconstructions began to converge to the ground truth of how they may have been originally painted. We will go through all of the methods that are now used commonly in order to assist in the determination of the color or the pigments utilized for ancient sculpture.

Visual Analysis This is a very simplistic method of analysis for the determination of colors present on a sculpture. It simply involves visually looking at different portions of the sculpture. This can either be done by eye or by using tools for optical enhancement, such as a microscope. By looking at what remains of sculpture, and depending on how well the sculpture was preserved, it can be possible to visually identify colors.

We will describe this process of visual analysis using the example of the Peplos Kore from the Acropolis (539BCE) shown in figure 1.[1] By simply looking at this image of the sculpture, it can clearly be seen that the hair coloring is not the same as the coloring of the underlying medium. It is also evident that the hair has a

1. Art History Project, "Peplos Kore," 2019, `https://arthistoryproject.com/timeline/the-ancient-world/greece/peplos-kore/`.

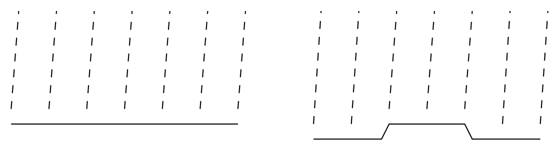
FIGURE 1. Peplos Kore, displaying the ability to use visual analysis on ancient Greek sculpture.

reddish hue. This would fairly directly indicate that the hair was originally colored red and through exposure to radiation, it has faded to where it is now.

Raking Light This is a method that involves shining light from a very sharp angle that is almost parallel to the surface of the sculpture. This method is used to pick up on the radiation resistance of different pigments and colors. Anything exposed to solar radiation will get damaged over time and some materials will get damaged faster than others. Having a paint over marble acts as a shield, protecting it from solar radiation. So instead of the marble getting damaged, the paint gets damaged. This means that there will be a raised portion where the paint was weathered away instead of the marble. This is depicted in figure 2.

This method becomes very useful in determining where different pigments were on a sculpture and to ascertain the location of the transitions between them. Since each pigment would protect the underlying medium differently, each pigment would leave a different sized "bump" on the sculpture. There is little to gain about the actual color using this method, but it does allow for knowing where the different colors start and end.

By shining a light almost perpendicular to the surface of the sculpture it is possible to see these microscopic ridges on the surface. This process is clearly depicted in figure 3. It can be seen that the parts of the sculpture that face the light source will be emphasized, and the parts of the sculpture that face away from



(a) (b)

FIGURE 2. Demonstrating the process of solar radiation wearing through the marble surface, where the center segment is protected by some pigment. Over time smooth surfaces of (a) will develop bumps like the surface of (b).

the source will be obscured in shadow. This allows the distinction between different surfaces that may be impossible to visually see without the enhancement resulting from the shadows and highlights.

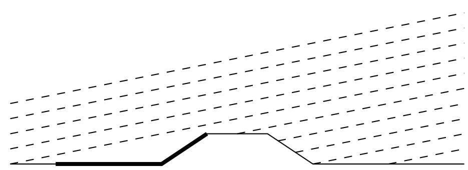


FIGURE 3. Demonstrating how using raking light will cast shadows caused by small ridges on the surface of a material. This allows for the determination of where pigments would have been present.

This method of raking light does not provide researchers will too much information about what pigments were actually present on a sculpture, but it does help in the determination of the regions of different pigments. Thus if a pigment is determined to be anywhere in the region, it is reasonable to believe that that pigment was used for the entirety of the region. Using raking light can be seen in this image of a wall shown in figure 4.[2]

FIGURE 4. Raking light on a wall, emphasizing the brush strokes in the painting process. This can be used in a similar manner on ancient sculpture.

2. Wikipedia, "Raking light across a wall," 2014, `https://en.wikipedia.org/wiki/Raking_light#/media/File:Sl%C3%A4pljus_-_Ystad-2015.jpg`.

UV Florescence This method begins utilizing the chemical composition of the pigments themselves in order to assist in determining the colors. Certain pigments will absorb light in the ultraviolet frequencies and will remit the light at a lower frequency in the visual spectrum. This method involves simply shining ultraviolet light on the sculpture, then watching for any parts of the sculpture that glow when the light is removed. What color the pigments glow also assists in determining what the original pigment could be. Using the observations of this method does not necessarily provide a direct answer to what pigment or colors were used, it certainly assists in narrowing down the options.

This method is also closely related to the more scientific method of UV vis. They both use properties of how the pigments interact with ultraviolet light. Since different pigments interact with ultraviolet light in different ways, they will also interact differently for different frequencies of ultraviolet light.

UV Visible Spectroscopy This is the final method that we will explain in detail. The basis of this process is to use how light interacts with other objects in the natural world, and how the colors of those objects are then perceived.

Light from the sun, or from light bulbs, will frequently be white, or off white. This means that all visible wavelengths of electromagnetic radiation are present in the light. Every material has specific wavelengths of light which it will absorb. The light that we observe is the wavelengths of light that a material does not absorb. For example, consider plants. Plants are green because they absorb all other wavelengths of visible light, and they reflect the green light. The wavelengths of light that a material absorbs is called the absorption spectrum.

There are wavelengths of light that are outside of what is visible to humans. These wavelengths include ultraviolet rays. The absorption spectrum is not restricted to the wavelengths of visible light, materials can absorb any wavelengths of light. This can be seen in sunscreen. Sunscreen in completely transparent to visible light, but is completely opaque to ultraviolet rays. This is how it protects one's skin from harmful light.

Every specific chemical possesses a unique absorption spectrum. Experimentally determining the absorption spectrum of an unknown material, and comparing to the set of known spectra, it is possible to determine what the unknown sample consists of, just by looking for matching absorption plots.

Because of this, it is possible to look at the absorption spectrum in the ultraviolet wavelengths of samples of unknown pigments. Since the visual absorption spectrum has been damaged by sunlight, it is important to only consider the UV wavelengths. With the determined spectrum, it is then possible to compare it to a database of known pigments and narrow the possibilities of what the sample pigment could be.

There are two methods of how UV-Vis Spectroscopy is implemented. There are the reflective spectrum and the absorption spectrum methods. For the absorption method, the material must be placed into a solution or a gas. For the purpose of analyzing ancient sculpture, this is not often feasible without incurring some damage to the sculpture by taking a sample.

For the reflective method, it is possible to not alter the original object in any way. This is perfect for our purposes. This method is done by shining a beam of light from a tungsten bulb onto the surface of the material. The material will absorb or reflect specific wavelengths of light, which is determined by the chemical structure of the pigment. The reason for using a tungsten light is it produces the most uniform spectrum of light. Most light sources only produce some wavelengths and not all of them. By using a tungsten light source, most of the necessary wavelengths of light will be present for the incident rays.

Once the light has been reflected, it is passed through a diffusing device, which uses a prism to separate the different wavelengths of light. Then sensors detect how much of each wavelength was present in the reflected light rays. Using the ultraviolet wavelengths of light allows one to determine the structure of the chemical composition of the pigments, and then by comparison to a known database, it is possible to determine the pigment that was used.

Conclusion All of the methods mentioned here are extremely useful for the determination of the polychromy of ancient sculpture. However, there is no single method that can do it alone. Each of these methods are used in conjunction to assist in furthering researchers' knowledge of a specific sculpture. Even with all of these methods and many more which were not mentioned, it is not always possible to ascertain the pigments or even the colors that were used. However, it is clear that these scientific methods play a key role in expanding our understanding of these ancient cultures and their depictions in ancient sculptures. It is important to have an understanding of the scientific research, in addition to an understanding of the historical reference frame. Only with these used together is it possible for one to gain more insight into the culture of these ancient civilizations. There is no one single method that can provide all the answers, instead one must use bits and pieces of information from a diverse collection of sources. Some of these sources are scientific, some are literary, some are artistic. The importance is that they are all considered in the overall historical analysis of a piece.

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