Expanded Spectrum Photography and Archaeological Conservation

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ABSTRACT

Archaeological conservation requires a broad spectrum of analytical tools to assist in the development of successful conservation strategies. In spite of advances in radiography, magnetic resonance imaging (MRI), and computed tomography, traditional photographic skills, adapted for digital cameras, are easy-to-use and surprisingly effective diagnostic tools for assessing the metallic state of iron objects recovered from marine environments. Expanded spectrum photography (ESP), which is an offshoot of high dynamic range (HDR) imaging, combines an extended spectral range of images to accentuate oxide dispersion and other diagnostic attributes within the matrix of a concretion. While HDR images may be artistic in nature, ESP images are designed to illuminate the distribution of metallic oxides and organic materials within an artifact. Resulting images offer unique perspectives on an artifact that are useful when developing a conservation strategy.

Introduction

In some cases of artifact imaging, variances in exposure and development techniques mask and obliterate the subtle visual cues that may be important when assessing the state of an encrusted object. Pretreatment assessment of an artifact is critical. The data gathered during such an assessment forms the basis upon which a treatment strategy is developed. If the conservator does not have sufficient data to form a conservation plan, the long-term stability and success of conservation treatment may be compromised. High dynamic range (HDR) imaging broadens the visual spectrum range of a given image by combining three or more images; the end result is a crisp, almost surrealistic final representation. By design, expanded spectrum photography (ESP) processing of digital photographic images uses the basic components of an HDR image to create pictures which may not be aesthetically pleasing, but serve to capture and convey visual data which can easily be obscured using conventional visible spectrum digital imaging.

All cameras function to capture a spectrum of light reflected by an object. This captured light is translated into an image by a digital film plane (sensor). Most photographers attempt to record perfectly balanced exposures of an artifact, assuming that these well-balanced images are always best. Depending on variables such as ISO setting (adjustable sensitivity to light), aperture setting (size of the lens opening), exposure compensation (an adjustment to increase or decrease image lightness or darkness), and shutter speed chosen, both film and digital cameras are designed to record only the visible spectrum of light. This spectrum is approximately from 400 nm (4×10^{-7} m) to 700 nm (7×10^{-7} m) in wavelength. Compared to the total spectrum of light, including ultraviolet and infrared light, the visible light spectrum is very small.

All cameras allow the photographer to take multiple exposures of a given subject. In the case of artifact photography, most archaeologists will take multiple images of a single artifact, changing aperture/ISO settings for each series of images recorded. This practice is referred to as "taking bracketed exposures." In the days when film was used exclusively, there was a time lag between the taking of photographs and the final development and printing of the film. In this situation, bracketed exposures ensured that at least one image from the set would be successfully recorded.

Digital cameras have eliminated the time-lag factor in creating photographic records of an artifact before and during the conservation process. Modern digital processing, often called the "electronic darkroom," provides new tools for creating information-rich artifact photographs. A bracketed series of photographs (a series of images taken at different exposure settings) holds a greater potential for producing good diagnostic images, because when combined or stacked together, the dynamic spectral range is greater than the spectral range of a single image. It is this expanded spectrum which encompasses more light and therefore more potential data. When these images are combined into one image, the visible spectrum of data will be greater than the visible spectrum of data available in one conventional image. In order to capture a greater dynamic spread of the visible light spectrum, the exposure settings for the bracketed images can be increased.

After determining which exposures may be effective for an HDR image, the next step is to address other critical components of the photographic system setup. Since HDR/ESP images rely on combining several images to create one super-broad spectrum image, it is critical to ensure that the artifact is framed in the viewfinder in exactly the same position for each shot in the sequence. To do this, a high-quality tripod is essential. Because budgets for archaeological projects are usually tight, many cost-conscious archaeologists eliminate things such as tripods. If the bracketed sequences are not identical in artifact placement, one cannot successfully record HDR images; in this case, the tripod will pay for itself in the form of information gained from the image during later analysis.

Remote trigger systems or extension release cables are useful tools for minimizing camera movement while taking a series of images for use in ESP imaging. Digital cameras also have a locking mirror function, which minimizes vibrations in the camera caused by the movement of the mirror when taking an image. Most single lens reflex (SLR) digital cameras have such a camera lock, so photographers should consult their camera manuals and become familiar with this invaluable tool.

Once data acquisition (image capture) is complete, tools in the digital darkroom can be used to create ESP images. A number of companies make software that assists in turning bracketed images into diagnostically important images. Two such programs are discussed here. Under the "File" directory within Adobe Photoshop (from CS2 through CS5) there is a subdirectory called "Automate." A left click on this directory will reveal a subdirectory called "Merge to HDR." After left clicking this menu heading, the program will ask for source files; after three or more images are selected, the program can start the largely automated process of creating an HDR image.

Another powerful software tool for creating HDR images is PhotoMatrix Pro. This software is simple to use and only requires a few practice images to build familiarity with the process. When the program starts, a menu entitled "Workflow Shortcuts" will be visible. Select "Generate HDR Image." Once selected, a box entitled "Open" will appear. Identify the location of the desired bracketed images and select "Open." The selected images will appear in the "Generate HDR-selecting source images" box. Simply select "OK," and the program will provide a long list of parameters which may be used to adjust the images. The best way to understand the parameter adjustments is simply to play with the settings and compare the results. Once a pleasing image is attained, set additional parameters for processing and select either "Tone Mapping" or "Tone Compressing." The program will compile the image in a short period of time.

To create ESP images, parameter settings within a program such as PhotoMatrix Pro are deliberately manipulated—not to create a hyperrealistic image—but to accentuate the diagnostic features of an artifact. The illustrations provided for this technical brief show an encrustation containing the remains of a very rusty nail. Figure 1 is a traditional digital image of this artifact. Clearly, the iron nail has seriously decayed, and much of the detailed surface of the artifact is obliterated by orange corrosion products.

A series of three images of the encrustation was taken for the purpose of creating an ESP image. These images range from being underexposed to being overexposed.

Figure 1. A traditional digital image of an encrustation showing a cross-section view of a corroded iron nail. Note that corrosion products (generally orange in color) have permeated the matrix of the surrounding concretion. As a result it is more difficult to identify potentially recoverable metal. The corroded mass is 4.25 inches across its largest dimension (Photograph by author, 2010.)

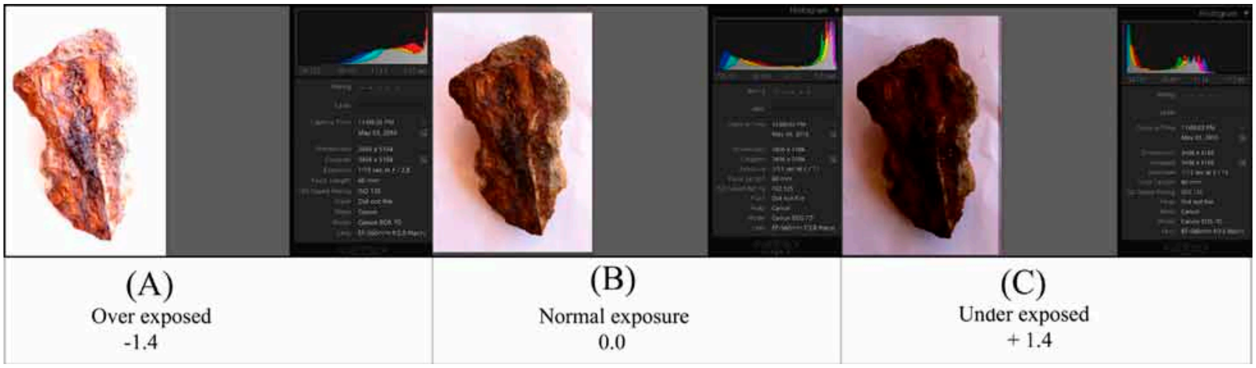

Figure 2. A series of three images was taken of the encrustation: (*A*) an overexposed image (-1.4) emphasizing the lighter spectrum; (*B*) a relatively normal exposure (0) with balanced highs and lows; and (*C*) an underexposed image (+1.4) emphasizing the darker spectrum. The graphs accompanying each image show the brightness value of all the pixels in the image. (Photograph by author, 2010.)

Notice the spectra associated with each image in Figure 2. Figure 2*A* is a greatly overexposed image and its corresponding graph indicates that the darker spectrum of data is missing. The image is excessively bright. Figure 2*B* is a relatively normal exposure. Its corresponding graph indicates that the image includes balanced highs and lows. Figure 2*C* is dark, containing more low-spectrum data and sparse high-spectrum data. The resulting ESP image (Figure 3) includes a much broader spectrum of data, resulting in an image that is less aesthetically pleasing than a traditional photograph, but which better defines the remains of recoverable iron within the concretion.

Figure 3. The resulting HDR image clearly defines the outline of the remaining iron running through the center of the concretion. The large areas of corrosion around the head of the nail are better defined in this image. Generally, iron that has been bent or hammered during the manufacturing process is more susceptible to corrosion. (Photograph by author, 2010.)

Equipment Suggested for HDR and ESP Photography

Because of the nature of HDR and ESP photography, several pieces of equipment and camera setup configurations are recommended. Under normal circumstances, small errors in exposure settings are not important. When compiling three, four, or even more images into one ESP image, it is essential to prevent camera movement. Most digital cameras offer a mirror lockup setting. This feature is essential, because under normal shooting circumstances, each exposure taken includes movement of the mirror assembly within the camera. For a single image, this may not be important. For a series of images that will be compiled, slight movements will lead to errors in the final compilation. Check the owner's manual and be familiar with the camera lockup settings.

The simplest way to prevent general movements when taking photographs is to use a high-quality tripod; for ESP imaging this is essential. Additionally, the photographer should consider investing in a remote triggering device for archaeological photography; this is the best way to ensure well-focused images. Remote trigger systems can either be tethered or radio-frequency controlled. In either case, these devices prevent excessive handling during the taking of the photograph.

It is always important to record the finest details of an artifact; this includes color. Accordingly, a grayscale card and a color registration chart should be readily available and used as part of the photographic process. Doing so will ensure that the photographer has a known set of colors by which individual images can be adjusted during later computer processing. Digital SLR cameras often include a very handy setting that allows the adjustment of the white balance. To do this, routinely take a photograph and select it as the white balance for continued shooting. Even without a color calibration chart, this will ensure the recording of images which are consistent with one another. It is essential to take a new white balance image every time a new location is selected, or when the artifacts being photographed are changed. The camera manual will have very detailed information about successfully using and adjusting white balance settings.

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