MULTISPECTRAL IMAGING OF TWO HIERATIC INSCRIPTIONS FROM QUBUR EL-WALAYDAH

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Abstract

During the 2010 excavation season, two inscriptions with Hieratic signs written in black ink were found at Qubur el-Walaydah in the coastal plain of southern Israel. Although unearthed recently, a comparison of new color photographs of the inscriptions with those taken shortly after excavation shows that their legibility has already deteriorated. We made images of the inscriptions using multispectral (MS) techniques described by (Faigenbaum, Sober *et al.* 2012). Notwithstanding the fading of the ink, the MS images significantly improved the inscriptions' legibility. In several cases, faded and unrecognizable letters became clearly visible. The new MS photographs, which were essential in deciphering the inscriptions, are presented here.

*Keywords***:** ostraca, epigraphy, Hieratic inscriptions, visible and near infrared photography, multispectral imaging**,** Qubur el-Walaydah

1. Introduction

Qubur el-Walaydah is a small Late Bronze, Iron I and Iron II village in south-west Israel. It is located on the eastern bank of Nahal Besor (Wadi el-Ghazze) between the large sites of Tell Jemmeh and Tell el-Far'ah South. The site was abandoned at the end of the 7th century BCE and never resettled (Lehmann *et al.* 2010, Lehmann *et al.* 2011).

Since 2007, the site has been excavated in a joint project by Ben-Gurion University (Israel) and the Universities of Leipzig and Rostock (Germany). During the 2010 excavation season, two Hieratic inscriptions were discovered, probably related to the Late Bronze III occupational phase (Wimmer and Lehmann in this volume). The inscriptions were written in black ink on clay potshards.[2]

The ink has already faded since the excavation, significantly limiting the inscriptions' legibility in standard color or gray scale digital images. Figures 1 and 2 compare the standard color images taken immediately after the excavation (left) with those taken a year later (right). We employed multispectral (MS) imaging and Potential Contrast (PC)[3] analysis to improve the inscriptions' legibility compared to standard digital images, following the method introduced in (Faigenbaum, Sober *et al.* 2012 and Sober, Faigenbaum *et al.* 2013). The resulting MS images are presented below. In several cases, faded and unrecognizable letters are clearly visible. The enhanced MS images have been of great importance to the process of deciphering the inscriptions.

2. The Imaging Procedure

Imaging in a nutshell

An image captured by a camera records the light reflected from objects in a scene. In other words,

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2 For an incised Proto-Canaanite inscription previously discovered at the site see (Cohen 1978, Cross 1980, Berlejung 2010).

3 The Potential Contrast is a computerized procedure that detects, within a set of images the image having potentially the best contrast (after certain image manipulations). For more details regarding this technique please see (Faigenbaum, Sober *et al.* 2012).

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Fig. 1 Ostracon No. 13.072–07-S05 from Qubur el-Walaydah: left – image taken immediately after the excavation; right – image taken a year after the inscription was unearthed.

Fig. 2 Inscription No. 13.056–01-S01 from Qubur el-Walaydah: left – image taken immediately after the excavation; right – image taken a year after the inscription was unearthed.

each point (pixel) in the image represents the light reflected from the corresponding point in space. This light can either belong to the visible light range (i.e., wavelengths of 350–750 nm, see Figure 3) or be outside of it (e.g., Infra Red [IR hereafter] – above 750 nm, Ultra Violet – below 350 nm).

A standard digital camera produces an RGB (red, green and blue) color image. This image consists of three color channels, corresponding to different ranges of the visible light (red: 600–700 nm, green: 500–600 nm, blue: 400–550 nm). A combination of these channels gives the viewer a full-color image. From the color image, one can also create a gray level image by averaging the RGB channels. Additionally, each channel can be treated as a separate gray level image.

MS imaging produces a more detailed image than standard photography. Instead of three channels (ranges of wavelengths) representing red, green and blue, MS imaging typically produces eight, twenty or even several hundred channels (depending on the spectral resolution, i.e., the

Fig. 3 The spectrum of visible light.

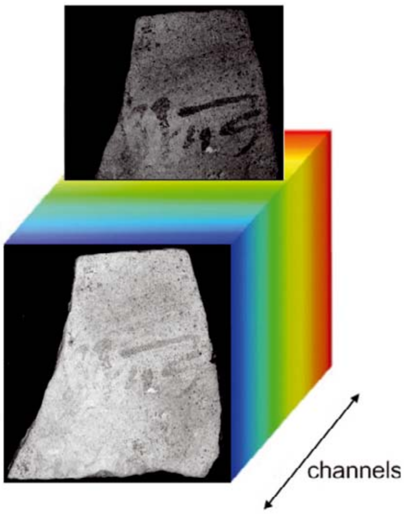

Fig. 4 An illustration of a multispectral cube.

wavelength range of each channel). The outcome of MS imaging is called a spectral cube (see Figure 4).

The imaging procedure

An experimental study (Faigenbaum, Sober *et al.* 2012) demonstrated that for each inscription, the optimal imaging wavelength is between 550 nm and 950 nm. Moreover, in order to capture the most favorable image, it is sufficient to use ten different band pass filters. Each of those filters allows only a specific light range to pass through to the camera sensors, producing ten images recording the reflection of each of these light ranges.

Following the recommended procedure, we used a standard digital camera, sensitive to the visible spectrum (i.e., 400–700 nm). The internal sensors of the camera can record up to as much as 1000 nm but digital camera manufacturers use IR cut filters to limit the sensitivity range to a maximum of 700 nm. Therefore, in order to enable the camera's IR wavelength sensitivity (i.e., up to 1000 nm), we removed the internal IR cut filter and replaced it with transparent glass. Thereafter, the spectrum was sliced into ten channels utilizing commercial external bandpass filters.

3. Results

Using the system described above, we produced a spectral cube of ten images for each inscription. We then used the Potential Contrast (PC) method to evaluate the legibility of each image in this relatively small spectral cube). As described in (Faigenbaum, Sober *et al.* 2012), the ostracon image resulting in the highest PC value has the optimum potential legibility. In the case of inscription No. 13.056–01-S01 we found that the optimal wavelength range is 700–860 nm, while for ostracon No. 13.072–07-S05 the range is 600–715 nm. Both of those ranges were covered by several filters. In order to improve the legibility of the image, we then performed contrast and brightness manipulations. These manipulations can be performed using any available image processing software (e. g., ImageJ, GIMP, Adobe Photoshop, etc.).

Figure 5 provides a comparison of a color image of inscription No. 13.056–01-S01, taken recently, with a multispectral image from the optimal wavelength range. It is apparent that the new image, acquired by the MS system, significantly improves the overall legibility.

In the case of Inscription 13.072–07-S05 (Figure 6), the reading of the beginning of the first line and the entire second line has been affected significantly by the MS images. A very important factor in the deciphering of the inscription was the variety of the optimal spectral images available. Several images were used to craft the hand-drawn facsimile of this inscription. For each region of the inscription, a different image was selected by the PC algorithm as the most legible. The reading is presented in (Wimmer and Lehmann in this volume).

4. Concluding Remarks

Following the study presented in (Faigenbaum, Sober *et al.* 2012), we performed MS imaging and analysis of two Hieratic inscriptions found at Qubur el-Walaydah during the excavation season of 2010. The legibility of the new images is of

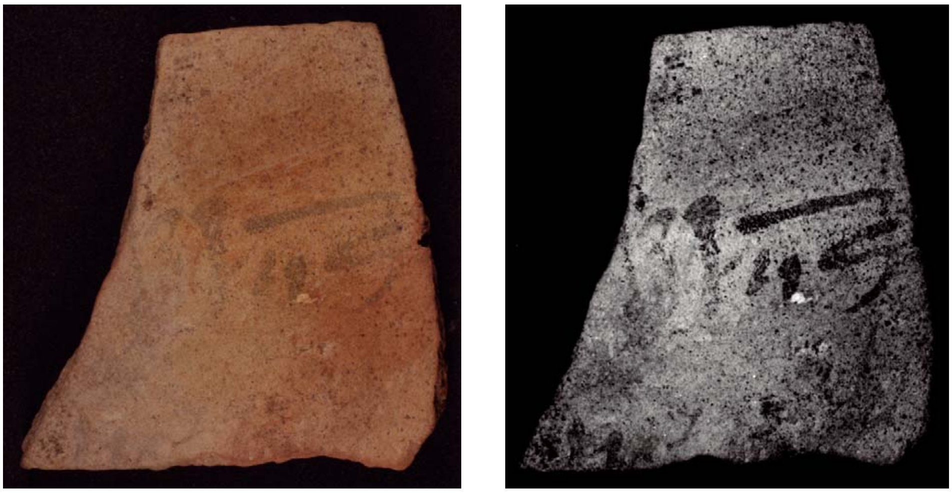

Fig. 5 Inscription No. 13.056–01-S01 from Qubur el-Walaydah: left – a color image taken a year after the inscription was unearthed; right – image taken with the MS system using the wavelength range of 670–715 nm.

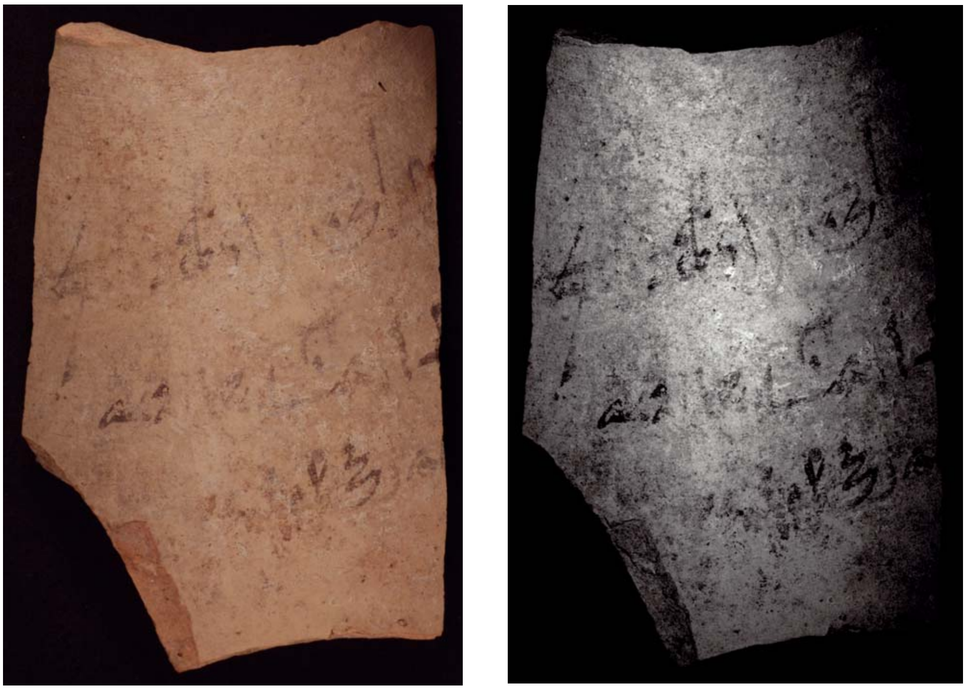

Fig.6 Ostracon No. 13.072–07-S05 from Qubur el-Walaydah: left – a color image taken a year after the inscription was unearthed; right – image taken with the MS system at a wavelength range of 635–690 nm.

higher quality even when compared to images taken shortly after the excavation. These images were central to the process of deciphering the inscriptions undertaken by Stefan Jakob Wimmer (this volume).

This paper, and previous research, emphasise the importance of producing MS images of any ostracon as soon as possible after its discovery.

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