

Toward the Electronic Publication of the Herculaneum Papyri

New digital imaging technology is unveiling previously illegible and even unseen text and images on ancient papyri from Herculaneum. Known fully as multispectral imaging (MSI), the technology, which was initially developed for planetary exploration, has been applied by scholars at Brigham Young University in Provo, Utah, USA, with astonishing success to the Dead Sea Scrolls, the Maya murals Bonampak, and to the carbonized scrolls of Petra. These initial successes at capturing the original ink, pigments, underpainting, and other details from deteriorating antiquities — and electronically preserving the resulting images for future study and appreciation — bode well for the continued use of MSI technology in archaeological fieldwork. This paper discusses this technology's application on the carbonized papyri of Herculaneum.

Multispectral imaging (MSI) is a technologically advanced method of capturing images in digital medium. Its original application was developed by NASA, for use in LANDSAT satellites for taking images of planets in our solar system¹. In MSI the full spectrum of light is divided into various narrow bands through the use of optical filters. Individual images of a given object — each captured at a different wavelength of light from ultraviolet through the visible to the near-infrared — can be conglomerated or “stacked” to form an “image cube”. Such a composite image can be superior to photographs, because it “produces a set of images with much more information than what a single black-and-white or color photograph yields. Examining these additional images, one can often see faint details emerge from the background at spectral locations where clutter disappears, ink becomes dark and the background light, or pigments appear”². The constituent images, where only a narrow sliver of the light-spectrum produces a single view of the object, afford researchers with a view that is superior to what the naked eye, which comprehends a broad swath of the visible spectrum, is able to distinguish.

In 1993 and 1994 the Dead Sea Scrolls became the first archaeological documents to be digitized with MSI. Greg Bearman, a physicist at NASA's Jet Propulsion Laboratory at the California Institute of Technology, conceived the idea that the Scrolls would respond better to MSI than they had to conventional infrared photography³. Various scholars, including researchers affiliated with Brigham Young University, confirmed the notion, estimating that readings of the Qumran texts were improved by as much as 20% through the digital images⁴. The badly scorched scrolls discovered in 1993 and excavated from the Byzantine church at Petra by the American Center of Oriental Research and the Department of Antiquities of Jordan⁵, became the next application of the MSI technology to texts. A team from the Foundation for Ancient

¹ For background in this area, see C. Elachi, *Introduction to the Physics and Techniques of Remote Sensing*, Wiley Series in Remote Sensing, New York 1987, especially 104–110.

² D. M. Chabries, et al., *Imaging the Past: Recent Applications of Multispectral Imaging Technology*, unpublished paper written in 2001. See also G. Bearman, et al., *Multi-spectral Imaging of Dead Sea Scrolls and Other Ancient Documents* (paper presented at the annual meeting of the Society of Biblical Literature, Washington, D.C., 1993); and *Archaeological Applications of Advanced Imaging Techniques*, *Biblical Archaeologist* 59, no. 1 (1996) 56–66.

³ What details are known of the original infrared photographing of the scrolls are summarized in G. Bearman, et al., *Imaging the Scrolls: Photographic and Direct Digital Acquisition*, in: *The Dead Sea Scrolls after Fifty Years*, ed. P. W. Flint and J. C. Vanderkam, Leiden 1998, 473–479.

⁴ M. Morgenstern, et al., *The Hitherto Unpublished Columns of the Genesis Apocryphon*, *Abr-Nahrain* 33 (1995) 30–54; W. Ginnell, *Report on Dead Sea Scroll Studies*, Getty Conservation Institute, Marina del Rey, CA, 1993; H. J. Plenderleith, *Comment on a Paper Entitled 'Recent Discoveries in Biblical Manuscripts'*, *Journal of Transactions of the Victoria Institute* 82 (1950) 146.

⁵ The papyri are presently at ACOR in Amman, Jordan. In accordance with a contract signed by ACOR, the Department of Antiquities of Jordan, and J. Frösén of the University of Helsinki and L. Koenen of the University of Michigan, publication of this archive has been assigned in equal portions to a Finnish team and an American team.

Religious and Mormon Studies (FARMS) and BYU's Center for the Preservation of Ancient Religious Texts (CPART, renamed in 2001 The Institute for the Study and Preservation of Ancient Religious Texts, ISPART) created diagnostic multi-spectral image cubes from samples of the Petra Scrolls at the ACOR facility in Amman, Jordan⁶. With funding from the National Geographic Society, the Getty Grant Program, Yale University, and Brigham Young University, scholars have also used MSI to help recover hidden details and to analyze underlying layers and pigments from murals amid the ancient Maya ruins at Bonampak, Chiapas, Mexico⁷.

Marcello Gigante, then director of the Centro Internazionale per lo Studio dei Papiri Ercolanesi (CISPE), upon hearing the report on work in progress delivered by Kamal, Ware, and Booras in the summer of 1998, began to press for the application of MSI on the carbonized Herculaneum Papyri⁸. Preliminary testing done later that year yielded compelling results⁹, and a contract was entered into by ISPART and the Italian Biblioteca Nazionale "Vittorio Emanuele III" at Naples, with Steve Booras appointed as manager of technical operations. Imaging the papyri began in September 1999; it was necessary to interrupt the project for an interval of several months; and, in April 2002, six months after the decease of Gigante, ISPART has concluded the capturing of images of all Herculaneum Papyri. In all, over 30,000 digital images have been made, which document all extant, unrolled portions of the papyri — full *cornici*, *scorze*, and also *pezzi* of papyri unrolled by the Oslo Method.

As anticipated, the digital images preserve enough data that they can be manipulated further by personal computer¹⁰, though in many cases even the raw, unenhanced images have provided greatly improved readings. One scholar has stated that "the quality of [the digital] images lies far above that of the hitherto available conventional photographs of the papyri"¹¹. Another concurs, calling the BYU images "even better pictures [than any previous photographs]" and praises them for "restor[ing] legibility to papyri so black that the human eye can discern no ink whatever"¹². It is now expected that all future work on Herculaneum papyrology will utilize and rely to some extent upon the new digital images. Further, scholars at BYU have hopes of contributing to the international effort to publish the papyri and related scholarship and returning to assist in ongoing work. The resulting images will form a complete, secure electronic archive of the collection that will help further the scholarly enterprise of Herculaneum papyrology for decades to come¹³.

⁶ O. S. Kamal, et al., *The Petra Church Scrolls: Multispectral Imaging Techniques* (paper presented at the XXII Congresso Internazionale di Papirologia, Firenze, 23–29 August 1998); and D. M. Chabries and S. W. Booras, *The Petra Scrolls*, International Society for Imaging Science and Technology PICS 2001 Conference Proceedings, Montreal 2001, 195–198.

⁷ G. A. Ware, et al., *Multispectral Analysis of Ancient Maya Pigments: Implications for the Naj Tunich Corpus*, in: IEEE Proceedings of IGARRS 2000, 2489–2491; O. S. Kamal, et al., *Multispectral Image Processing for Detail Reconstruction and Enhancement of Maya Murals from La Pasadita, Guatemala*, *Journal of Archaeological Science* 26 (1999) 1391–1401; J. E. Brady, et al., *Preclassic Cave Utilization Near Cobanerita, San Benito, Peten, Mexico* 19, no. 5 (1997) 91–96; and G. A. Ware, et al., *Multispectral Imaging and Spectral Classification of Naj Tunich Pigments*, International Society for Imaging Science and Technology 2001 PICS Conference Proceedings, 211–214. For a similar treatment of murals at La Pasadita, see Kamal et al., *Multispectral Image Processing*, 1391–1407. See Mary E. Miller, *Imaging Maya Art*, *Archaeology* 50, no. 3 (1997) 34–40. See also M. D. Coe, *The Maya*, 5th ed., New York 1993; and R. J. Sharer, *The Ancient Maya*, 5th ed., Stanford 1994.

⁸ Cite O. S. Kamal, et al., *The Petra Church Scrolls: Multispectral Imaging Techniques*, Atti del XXII Congresso Internazionale di Papirologia, Firenze, 23–29 Agosto 1998, I. Andorlini, et al., edd., Florence 2001.

⁹ See S. W. Booras and D. R. Seely, *Multispectral Imaging the Herculaneum Papyri*, *Cronache Ercolanesi* 29 (1999) 95–100.

¹⁰ Scholars have used either Adobe Photoshop or Lemke Software's GraphicConverter.

¹¹ Letter from K. Kleve to M. Giancaspro and M. Gigante, 23 April 1999 cited in Booras and Seely (above, note 9), 100.

¹² R. Janko, *Philodemus, On Poems, Book 1*, Oxford 2000, vii.

¹³ We acknowledge gratitude to Gene A. Ware, emeritus professor of engineering at Brigham Young University, for designing a substantial portion of the imaging hardware used at Herculaneum, Petra, and Bonampak and also for joining the expeditions to Petra and Bonampak to lend his crucial technical expertise. For assistance on the Herculaneum project, we wish to thank Mauro Giancaspro, director of the Italian Biblioteca Nazionale "Vittorio Emanuele III" at Naples; Agnese Travaglione, director of the Officina dei Papiri Ercolanesi at the Biblioteca Nazionale, and her staff;

Experience with the texts of the Dead Sea Scrolls, especially, had led to conjecture that full application of MSI, i. e. the construction of image cubes, would yield superfluous results. Preliminary tests determined that with the Herculaneum Papyri, by and large, the best response of ink and papyrus comes through the use of narrow band-pass filters at or around the 950 nm sector of visible light. In this narrow band of the light-spectrum is found the greatest contrast in reflectivity between the preserved ink and the carbonized papyrus. Imaging over the entire spectral range to obtain a full spectral cube, however, washes out the desirable contrast because part of the signal comes from the spectral range where the ink and parchment have the same reflectivity¹⁴. Further, our experience has shown that the carbon-based inks of the Herculaneum Papyri respond best, i. e. demonstrate better contrast to the papyrus, when imaged in the near-infrared, and worse as one moves toward ultraviolet¹⁵.

The equipment and setup for the Naples project remained essentially unchanged throughout its duration, even though in the end three separate periods of imaging had occurred. The original setup is depicted and its specifics are described at Cronache Ercolanesi 29 (1999) 96–97. The same photographic lens and lights were maintained throughout, although a variety of filters were used. As it became apparent that the wavelength around 950 nm was generally optimal for most papyri, filters with increasingly narrow bandwidths were applied. Further, the scientific grade Kodak digital camera used at the beginning of the project was eventually replaced with a more powerful camera by the same company. Bulky, desktop computer systems which first were used to drive the camera and to store data have been replaced by increasingly more portable and more powerful computers, including a laptop. The basic resolution of all images, however, has remained constant throughout at 300 dpi, and all digital images are archived in an uncompressed TIFF format.

The resultant images of the carbonized papyri from Herculaneum are of great potential benefit to scholars who will use them both around the world and at Naples. Limiting features of the digital images — such as their two-dimensionality opposed to the three-dimensionality of the actual papyri, or their occasional obscuring of both *sovraposti* and *sottoposti* — prompt Mario Capasso and others to advise particular caution¹⁶. Accordingly, even among scholars whose acceptance of the digital images has been most enthusiastic, the voice of caution has been raised. “Assurément, l’examen direct du papyrus reste irremplaçable, et devrait être décisive en dernier resort”¹⁷; and, further, “Come i microscopi bi-oculari, così anche le nuovissime fotografie non sostituiscono l’autoscopia, ma la integrano e la sostengono”¹⁸. Nevertheless, when caution is exercised, the digital images provide distinctly improved access to the texts of the Herculaneum papyri for many reasons, including enhanced legibility, portability, and reproducibility. Some of these are suggested in the following paragraphs.

Often a text is made more legible when the optical filter enhances contrast in reflectivity between carbonized papyrus and carbon-based ink. Thus, Figure 1, an unretouched digital image of P.Herc. 1084, illustrates the near obscurity of text on two fragments as they appear in visible light. Although Gigante’s *Catalogo* records that this text is “leggibile, discreto”¹⁹, it has never responded well to photography and discerning ink on its surface can not be done without some effort. The text has been edited, at least in

Francesca Longo Auricchio, director of the Centro Internazionale per lo Studio dei Papiri Ercolanesi, and Marcello Gigante, her predecessor whose foresight opened the way for the inception of the imaging of the Herculaneum; and David Blank, professor of ancient philosophy at the University of California at Los Angeles and at the University of Reading (UK), and other members of the Philodemus Project. We also acknowledge special gratitude to Knut Kleve, professor of classical and romance languages at the University of Oslo and conservator of the Herculaneum Papyri, for his help, advice, and gracious support.

¹⁴ Booras and Seely (above, note 9), 100.

¹⁵ F. Störmer, et al., *Ink in Herculaneum*, Cronache Ercolanesi 20 (1990) 183; and Booras and Seely (above, note 9), 94. Cf. Yoram Nir-El and Magen Broshi, *The Black Ink of the Qumran Scrolls*, Dead Sea Discoveries 3, no. 2 (1996) 157–167.

¹⁶ M. Capasso, interview with authors, Vienna, 28 July 2001. Capasso urges particular caution where the papyrus is not flat, is obscured by “sovraposti” and “sottoposti”, or where the edge between gold-beater’s skin and papyrus is not evident in the digital images.

¹⁷ D. Delattre, *Une révolution dans la papyrologie d’Herculaneum: l’imagerie multispectrale et les ‘Commentaires sur la musique IV de Philodème’*, paper presented at the 23. Internationaler Kongreß für Papyrologie, Wien, 22–28. Juli 2001.

¹⁸ M. Gigante, *Atakta CXXXIII*, Cronache Ercolanesi 31 (2001).

¹⁹ M. Gigante, *Catalogo dei Papiri Ercolanesi*, Naples 1979, 263.

parts²⁰; yet, no reasonable facsimile has been made available to scholars. In contrast (cf. Figure 2), the digital image captured at 950 nm is much more readily legible.

An unretouched electronic image may offer a higher degree of verisimilitude in respect to the original than do artist's renderings, and thus a scholar can present the evidence for readings more faithfully by means of the digital medium. In the past, scholars have attempted to retrace the images they see as a tool for illustrating the readings visible to them upon autopsy of the Herculaneum papyri. In spite of assumed efforts to reproduce these results reliably, scholars' renderings are subject to error and difficult for their peers to verify. A copy of pertinent images in electronic format can accompany any publication of P.Herc. texts. Indeed, the inclusion of a CD-ROM containing all texts pertaining to a given publication could be produced and included without great expense. With proper permissions and copyright clearances, numerous pertinent materials — i. e. both composite and constituent images for all portions of the target text, scanned copies of Kleve's microslides, scanned copies of Naples and/or Oxford *disegni*, digitized versions of pertinent articles and earlier editions of applicable texts, etc. — could be provided to offer full background for new publications.

Figure 3 presents an unretouched image of BYU Image no. 78-Cr08-02583-FS11-Fil8.tiff — i. e. one image of nine taken of P.Herc. 78, cornice 8, the 2,583rd image taken in sequence, at F-stop 11 through the 8th filter on equipment's wheel of interchangeable filters. (All BYU P.Herc. images have been shot with the Nikon f2.8 105mm lens specified in the preliminary report Booras and Seely²¹.) The image is shown precisely as it comes off the disk: upside-down and unframed, with vignetting visible in the corners. Locating a given image in respect to its proper place on its native papyrus is often done with great difficulty. Composite images of entire cornici can be stitched together from the individual, constituent pieces of by application of such image processing programs as PowerStitch 1.0 by Enroute. Figure 4 presents such a composite of the nine constituents of P.Herc. 78, cornice 8.

Further, MSI technology affords the researcher with the opportunity to capture instantaneously and to consult immediately the target text. Even if the results of infrared photography could equal those of the MSI applications, still the processing time and fallibility of infrared film are essentially eliminated when one uses the MSI technology. Equipped with MSI equipment, a scholar might simultaneously consult a papyrus through autopsy and the enhancements available in the digital medium. A conservator might use such equipment during removal of *sovrapposti* so as to document with unprecedented accuracy the individual steps of the process. Further, since reliable images of a given papyrus' text may be consulted with confidence, even at great distances from Naples, scholars will more likely consult the digital images thoroughly before traveling to Naples for confirmation of their readings.

The CD-ROM offers archivists and researchers a relatively stable and permanent medium for preserving reliable images of the rapidly deteriorating papyri in the Naples collection. Virtually every scholar who works with the papyri in the *Officina dei Papiri Ercolanesi* is acutely aware of the fragility of these delicate texts. Each consultation of the papyri subjects them to some disruption. Each year that passes brings them further ravages, even if they are subjected to no use; still, climactic changes accelerate deterioration. Through no fault of the *Officina's* talented staff, and through no harm inflicted by careful readers, each piece of papyrus is likely to crumble and decay each season. The digital images have created a virtually permanent record of the scrolls' condition at the moment of capture.

At the date of the 23rd International Papyrological Congress in Vienna, which occurred at a time when the BYU team was still in the process of capturing new images, it was premature to discuss the widespread dissemination of electronic P.Herc. images except through carefully controlled procedures. Scholars who have labored for years under conventional access to the P.Herc. texts would suffer from a potential compromise, were their scrolls to be made suddenly available. In deference to these concerns, no proposal has yet been made to make the electronic images available through an online clearinghouse. Moreover, so as to protect the varied interests of all involved parties, scholars who seek access to P.Herc. texts on CD-ROM must produce written approval for their use from the director of the *Biblioteca Nazionale*

²⁰ W. Crönert, *Neues über Epikur und einige herkulanensische Rollen*, *RhM* 56 (1901) 607–626; W. Crönert, *Lectiones Epicureae I*, *RhM* 61 (1906) 414–426; cf. G. Pasquali, *Ausonia* 2 (1908) col. 163; E. Spinelli, *Metrodoro contro i dialettici?*, *Cronache Ercolanesi* 16 (1986) 29–43; A. Tepedino Guerra, *Metrodoro 'Contra i dialettici?'* *CrErc* 22 (1992) 119–122.

²¹ Booras and Seely (above, note 9), 97.

at Naples and from the director of CISPE, before the disks are burned and distributed by ISPART. It is conceivable that, by the time the Proceedings are published, an equitable but more widely available means of distribution will exist.

Appendix

Figures



Fig. 1: P.Herc. 1084 Digital Image in Visible Light

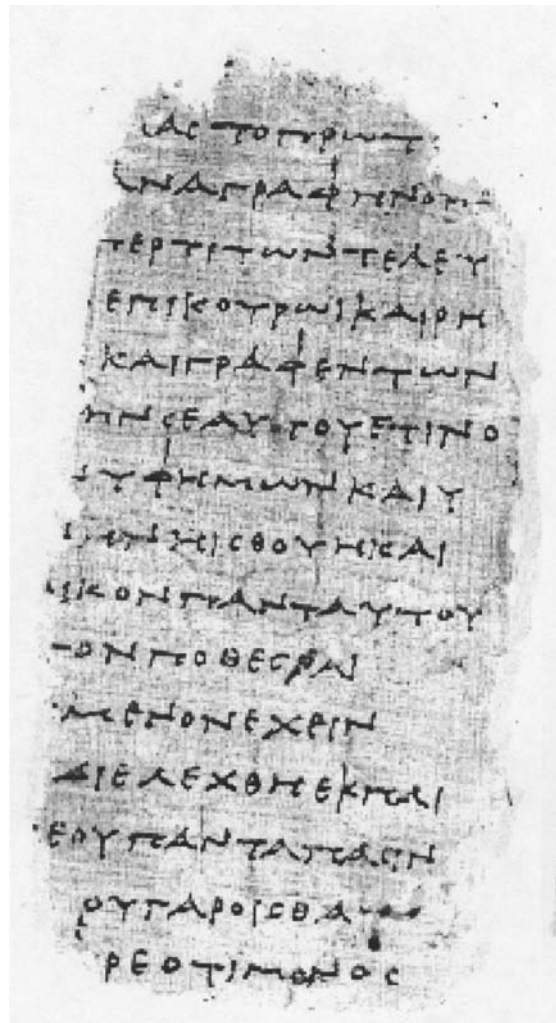


Fig. 2: P.Herc. 1084 Digital Image at 950 nm (Near-Infrared), unretouched