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The Sinai Palimpsests Project (2011–2016): Goals, Methods, and Contributions*

ST. CATHERINE'S MONASTERY OF THE SINAI, ITS LIBRARY, AND ITS PALIMPESTS

The Orthodox 'Sacred Monastery of the God-Trodden Mount Sinai', commonly known as St. Catherine's Monastery of the Sinai, maintains one of the world's oldest continually-operating libraries.¹ The Monastery was founded in the 6th century in a location where monks had been present for at least two centuries, and has operated since the 7th century within the context of Muslim rule. Protected by its remote location on Egypt's Sinai Peninsula and its centuries-old bond with its Muslim neighbors, the Monastery preserves more than 4,500 manuscripts dating from the 4th to the 19th centuries. The manuscripts are surprisingly diverse. They contain texts in 14 languages, and cover a range of genres, including Biblical texts, liturgy, hagiography, patristics, spirituality, and history, as well as a small but important number of classical poetic, scientific, and philosophical texts.² Together the manuscripts of St. Catherine's Monastery provide unparalleled evidence for the literature and history of Christians in the Eastern Mediterranean and shed light on the relations between Christian and Muslim communities.

Among the treasures of the Monastery library are 172 known palimpsests. Palimpsests are manuscripts made from recycled parchment. A scribe would remove bifolios from a codex, scrape and/or wash them to erase the writing, and then reuse the parchment to make a new manuscript. Among Sinai's 172 known palimpsests, only three had been extensively studied and published before the Sinai Palimpsests Project began in 2011, and among the many unpublished palimpsests, only a handful of their undertexts had ever been identified.³ The palimpsests of St. Catherine's Monastery preserve thousands of pages of previously unstudied texts from Antiquity and the Middle Ages.⁴

The Sinai Palimpsests Project constitutes a strong argument that future discoveries in manuscript studies lie less in the chance discovery of a buried cache of texts and more in the application of new technologies to manuscripts in collections we know. The project offers a model for future, large-scale programs to recover unreadable texts not only from palimpsests, but also from manuscripts either damaged by fire or water or rendered illegible due to the effects of time.

AN OPPORTUNE MOMENT

In spring 2007, Father Justin Sinaites, Librarian of St. Catherine's Monastery, visited The Walters Art Museum in Baltimore to observe the spectral imaging of the *Archimedes Palimpsest* and meet the scientists working to recover the erased texts of that famous palimpsest.⁵ Father Justin was prescient to visit. The innovations

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* This article is dedicated to the memory of Nikolas Zarkantzas, Associate Director of the Sinai Palimpsests Project, who passed away tragically on 15 August, 2016, at the age of 53. Without his leadership, the project would not have happened.

¹ For the history of the library, see now Giulia Rossetto, *Three Euchologia*, 17–50.

² Most of Sinai's manuscripts are in Greek, but substantial numbers of manuscripts are in Arabic, Syriac, Georgian, and Slavonic. Smaller numbers of manuscripts are in Christian Palestinian Aramaic, Latin, Ethiopic, and other languages, even Hebrew.

³ Three Sinai palimpsests published prior to the project: Sin. syr. 30 or *Sinaiticus Syrus*, a palimpsest preserving the oldest and most extensive copy of the Old Syriac Gospels (Lewis, *Old Syriac Gospels*); and Sin. geo. NF 13 and Sin. geo. NF 55, palimpsests preserving the only surviving works in Caucasian Albanian (Gippert *et al.*, *Caucasian Albanian Palimpsests*).

⁴ Conservatively calculated between 10,000 and 14,000 palimpsest pages, though the total is not yet known.

⁵ David Cooper, former Librarian at Corpus Christi College, Oxford University, accompanied Father Justin and contributed to the early discussions of a text recovery project at St. Catherine's Monastery.

achieved during the Archimedes Palimpsest Project provided the means to mount an ambitious project to recover thousands of pages of erased texts from the Monastery's many palimpsests.

PROJECT GOALS AND PARTNERS

After a pilot project in 2009 that demonstrated the feasibility of using advanced spectral imaging in the Sinai, St. Catherine's Monastery and EMEL reached agreement to undertake a five-year project (2011–2016) to recover erased texts from palimpsests in the Monastery's library.⁶ The project was funded by a generous grant of \$2.1 million from the Arcadia Fund, London. With the agreement of the Monastery, the UCLA Library joined the project in 2013 to archive project data and host it online for access by researchers.

The goals of the project were straightforward:

1. Render the erased texts of Sinai palimpsests legible using spectral imaging
2. Identify and paleographically describe the erased texts, as possible
3. Publish resulting images online, made accessible by a searchable catalogue

Work on the project was also informed by two secondary or instrumental goals:

1. Improve the efficiency of spectral imaging for application at the 'collection level'
2. Expand the toolset for imaging palimpsests by responding to new challenges

The first of these secondary goals was especially important. Before the Sinai Palimpsests Project, spectral imaging had been applied mostly to 'celebrity palimpsests', that is, palimpsests where the erased texts were at least partly identified and recognized as important, but not sufficiently legible for transcription or reconstruction. Spectral imaging can be expensive and labour intensive, not only in the capture of images but even more so in the processing of the captured data to create derivative images, 'processed images', that maximize the legibility of the erased texts. Only celebrity palimpsests could attract the investment necessary for spectral imaging. However, libraries in Europe, the Caucasus, the Middle East, and elsewhere hold thousands of palimpsest folios with undertexts that are unidentified or insufficiently studied. Many important texts from Antiquity and the Middle Ages may still lie unrecognized.

In light of the above, efforts to reduce costs and improve efficiency are needed, so that spectral imaging can be applied broadly and cost effectively to entire collections of palimpsests, as well as manuscripts rendered illegible by other causes, such as water or fire damage. Here St. Catherine's Monastery played a unique role. The universal recognition of the importance of the Monastery's library attracted the interest and the funding to support an ambitious multi-year project to recover hundreds of undertexts from its palimpsests. Since so little was known about the contents of Sinai's palimpsests, no attempt was made during the project to select palimpsests with especially interesting undertexts. Palimpsests were selected for imaging based on their physical stability and on their (suspected) undertext language, since we wanted the project to represent each of the languages in Sinai's library proportionally.

By imaging a large volume of diverse palimpsests, the project delivered to scholars not only new copies of texts from Late Antiquity and the Middle Ages—including previously-unattested works—but also broad data to explore questions about the creation and circulation of palimpsests, the selection of manuscripts for palimpsestation, and the occasions or factors that motivated palimpsestation.

⁶ The Early Manuscripts Electronic Library and the Library of the University of California Los Angeles thank His Eminence Damianos Archbishop of Sinai, Faran and Raitho, the Holy Council of St. Catherine's Monastery of the Sinai, and Father Justin Sinaites, Monastery Librarian, for their collaboration and enthusiasm which made the Sinai Palimpsests Project possible. EMEL and the UCLA Library also thank the Arcadia Fund (London) for its generous and faithful support over the five years of the project.

METHODS AND PROCEDURES⁷

The application of spectral imaging to a large and diverse body of palimpsests required a disciplined and efficient workflow and tools for processing large quantities of spectral data.⁸ A text recovery project of this magnitude would have been impossible without the capability to batch process large quantities of spectral data and achieve legible images (see 3a below).

The work of the Sinai Palimpsests Project proceeded in five steps. The progress of images and metadata for each palimpsest folio through these five steps was tracked by a single project database.⁹

1. *Evaluation and data entry.* Before a manuscript was imaged, Father Justin, Monastery Librarian, evaluated it to determine if it could be safely handled. Claudia Rapp, Project Scholarly Director, then created a detailed codicological analysis and established the conjoints of each recto and verso. Knowing which texts appear on the same bifolio was critical to reconstructing the undertexts of a palimpsest codex. During the codicological analysis, a database record was created for each component of a manuscript to be spectrally imaged. This enhanced the efficiency and accuracy of the imaging.

2. *Image capture.* EMEL's imaging team consisted of two camera operators from Greece,¹⁰ and the quality of the captured data testifies to their outstanding work through 60 weeks onsite. Logistics on the ground were provided by the Jebelya Bedouin and the staff of the Monastery's hostel. The spectral imaging system was based on the innovations of the Archimedes Palimpsest Project, with improvements and additions made over the course of the project in Sinai.¹¹ The imaging system was mounted on a computer-controlled cradle designed to support fragile codices during imaging.¹²

Each recto and each verso was imaged 28 to 33 times (by comparison, the Archimedes Palimpsest Project produced 16 images per folio), using five modalities of image capture:

- a. *'Standard' spectral imaging.* Each page was illuminated with 12 narrow bands or wavelengths of light from the ultraviolet (365 nm) to the infrared (940 nm).
- b. *Raking illumination*, i.e., light projected onto the parchment at a low angle of incidence to discern surface texture, such as traces of lines or of erasures.
- c. *Spectral fluorescence imaging.* When parchment is illuminated with short-wavelength light (ultraviolet or blue), it absorbs some of the short-wavelength light and emits light at a longer wavelength. For example, when parchment is illuminated with ultraviolet light, it fluoresces or 'glows' yellow. Since the fluorescent light comes from within the parchment, even the faint traces of erased ink on the surface of the parchment suppress the fluorescent emission and become more visible. We used a colour filter wheel that rotates in front of the camera to analyze the colour components of the fluorescence. Images of the separate colour components of the fluorescent emission of the parchment revealed different features of the undertext.
- d. *UV reflectance imaging.* The filter wheel included an ultraviolet pass filter that blocks all the visible light of fluorescence and transmits to the camera only ultraviolet light reflected off the surface of the parchment. This often provides the best images of the erased text where the parchment has suffered abrasion or been severely damaged.

⁷ The following section was adapted from Rapp and Phelps, *The Sinai Palimpsests Project*.

⁸ The overall project workflow and data management procedures were designed primarily by Michael Toth of R.B. Toth Associates and Doug Emery now of the University of Pennsylvania.

⁹ Designed by Doug Emery in consultation with Claudia Rapp (University of Vienna) and other project leaders and administered by Susan Marshall (EMEL Data Operations Manager).

¹⁰ Lead Camera Operator Damianos Kasotakis, now EMEL's Director of Imaging, and Second Camera Operator Evangelos Theodorou.

¹¹ The spectral imaging system featured spectral light sources (reflective, raking and transmissive) by William Christens-Barry of Equipoise Imaging LLC and a 40mp monochrome camera and PhotoShoot software that integrated camera and lights by MegaVision.

¹² The Preservation Book Cradle by Stokes Imaging (Austin, Texas), based on a design by Alan Buchanan (Alan Buchanan Designs).

e. *Spectral transmissive illumination* was newly developed for the project.¹³ Where iron gall ink severely eroded the flesh side of parchment, often the remaining residues of the erased ink are insufficient to be elucidated by spectral imaging with a reflective light source. But since the parchment is thinner where iron gall ink eroded it (known in German as ‘Tintenfraß’), backlighting the folio with infrared light often produced a remarkably legible image of the erased text.

At the conclusion of each spectral imaging session, the collected images and metadata were forwarded to EMEL’s Data Operations Manager, who verified the integrity of the data and harvested metadata for the project database.

3. *Image Processing* involves analyzing the captured images of a folio and combining data from multiple captured images in order to generate derivative images that maximize the legibility of the erased texts. For image processing, spectral data was shipped to four participating scientists (Keith Knox, Roger Easton, Jr., William Christens-Barry, and David Kelbe).

a. *Batch processing*. Project scientist Keith Knox developed image processing algorithms that exploited well-known reflective properties of iron gall ink and that could be applied in a semi-automated manner to all spectral data captured by the project. Since the majority of undertexts in Sinai’s palimpsests are iron gall ink (or behave like it), this batch processing generated legible images for 65% to 70% of the imaged pages.

Iron gall ink appears with the greatest contrast in short wavelength light (ultraviolet and blue) and becomes less visible in longer wavelengths (red and infrared), ultimately disappearing at approximately 1200 nm. In palimpsests, as the image sequences progress from shorter to longer wavelength light, both the overtext and the undertext tend to disappear, but the undertext disappears first because it is fainter. Batch processing algorithms combined data from an ultraviolet or blue image where both undertext and overtext appear with a red or infrared image where only the overtext appears, in order to isolate the undertext and distinguish it from the overtext. For each palimpsest page, the software produced 25 or more processed images, based on different combinations of long and short wavelength images. Many combinations of captured images were necessary to produce legible results for the many different undertexts encountered by the project.

b. *Supervised Processing*. If batch processing did not yield legible results, the folio was referred to participating scientists Roger Easton, Jr., William Christens-Barry, and David Kelbe. In manual, labour-intensive processing, these scientists used a variety of methods to try to elucidate the undertext of difficult folios, often in close collaboration with the scholars, another hallmark of the project. In most cases, they used statistical processes—principle component analysis (PCA) or independent component analysis (ICA)—which isolated different features in the ‘stack’ of 28 to 33 captured images of each page, such as the parchment, the overtext, and the undertext. Due to the volume of data, it was impossible to apply supervised processing to all pages that warranted it. This is one area where work remains to be done.

Processed images were forwarded to EMEL’s Data Operations Manager, who then distributed them to 27 participating scholars, based on their language and scripts of expertise.

4. *Cataloguing*. Under the direction of Claudia Rapp, Project Scholarly Director (University of Vienna), an international team of 27 experts in the various languages and scripts represented in the palimpsests created catalogue descriptions for the undertexts, analyzing the scripts and identifying the texts.¹⁴ For this purpose, the

¹³ William Christens-Barry of Equipoise Imaging LLC developed a first-of-its-kind spectral transmissive light source that was wedge-shaped so that it could be inserted behind the folios of a codex. MegaVision has now developed a transmissive spectral light source used by EMEL.

¹⁴ Those who contributed their scholarly expertise are (in alphabetical order): Zaza Aleksidze, André Binggeli, Sebastian Brock, Michelle P. Brown, Guglielmo Cavallo, Steve Delamarter, Alain J. Desreumaux, Ernst Gamillscheg, David Ganz, Paul Géhin, Jost Gippert, Sidney Griffith, Getatchew Haile, Dieter Harlfinger, Hikmat Kashouh, Vasilios Katsaros, Grigory Kessel, Daniela Mairhofer, Heinz Miklas, Christa Müller-Kessler, Panayotis Nikopoulos, Pasquale Orsini, Bernard Outtier, Giulia Rossetto, Alexander Treiger, Agamemnon Tselikas, and Nigel Wilson.

project designed a sophisticated electronic database of palimpsests, building on previous work by Doug Emery for the Archimedes Palimpsest Project and the Walters Art Museum.¹⁵

5. *Online Publication.* On behalf of St. Catherine’s Monastery of the Sinai, the UCLA Library is hosting an online digital library of the Monastery’s palimpsests imaged by the project (www.sinaipalimpsests.org).¹⁶ The digital library includes processed images and descriptive metadata (not editions) for each manuscript and for each recto and verso. All project data has been deposited for long-term preservation with the UCLA Library and at the Holy Monastery in Sinai.

PROJECT OUTPUT

From 2011 through 2015, the project conducted 20 spectral imaging sessions at St. Catherine’s Monastery for a total of 60 weeks onsite. More than 40 persons contributed to the collection, management, processing, interpretation, and publication of project data, including camera operators, data managers, imaging scientists, technicians, scholars, and librarians.

These collective efforts generated:

- Spectral data for 6,800 palimpsest pages, representing 74 palimpsest codices
- More than 200,000 raw images (approximately 30 raw images/page)
- Approximately 212,000 processed images. Batch processing generated approximately 28 processed images per page, based on different combinations of raw images
- 50TB of data, including approximately 25TB of raw data and 25TB of processed images
- Identification of 307 discrete erased texts in 11 languages

SOME CHARACTERISTICS OF THE RECOVERED ERASED TEXTS

The diversity of the recovered undertexts in language, date, and content is remarkable. The distribution of languages among the recovered undertexts is as follows:

Greek undertexts	3,058 manuscript sides
Syriac	1,617
Georgian	710
Christian Palestinian Aramaic	479
Arabic	436
Caucasian Albanian	276
Slavonic	115
Armenian	118
Latin	83
Ethiopic (Ge’ez)	34
Coptic	2

The recovered undertexts constitute a substantial corpus of mostly unstudied texts from the first millennium. Based on dates assigned by participating scholars, the dates of copying of the recovered texts range from the 5th to the 13th centuries, and more than 100 of the recovered undertexts were copied in the 6th century or earlier.¹⁷

¹⁵ Emery and Rapp, *Katlon*.

¹⁶ UCLA Library personnel who contributed substantially to the online publication of project data include Stephen Davison (now of the California Institute of Technology), Todd Grappone, Elizabeth McAulay, Kristian Allen, Kevin Clarke, and Mark Matney.

¹⁷ While most dates are based on paleographical analysis, at least two undertexts include colophons with dates. Undertexts written in early or archaic Christian Palestinian Aramaic script are not included in this count of undertexts from the 6th century or earlier, since the potential date range for this script is very broad.

The diversity of content and genres among the recovered undertexts reflects the contents and genres of the Monastery's library, even though there are significant differences.

- A surprisingly large percentage—43%—of the identified undertexts are Biblical, including lectionaries (29% New Testament and 14% Old Testament).
- 11 of the undertexts are classical works in Greek or in Syriac translation. 8 of these 11 classical texts are medical, and 6 of the 11 were previously unknown.¹⁸

The rest of the undertexts include liturgical, hagiographical, patristic, ascetic, and spiritual texts in various languages.

As would be expected, the extent of preservation of the undertexts varies widely. Some undertexts are substantially preserved, and fortunately these include copies of previously unknown works. Examples include:

- 92 pages of a previously unknown Christian poem that mentions Old Testament characters (Greek, 6th to 7th century, found in Sin. geo. 49 + Sin. geo. NF frg. 73a)
- 96 pages of a previously unknown commentary on the Old Testament (Syriac, 6th to 7th century, found in Sin. ar. 514)
- 74 pages of a previously unknown Judeo-Arabic translation of Genesis and Exodus (10th–11th century, found in Sin. gr. 930 [*Diktyon* 59305])

Of course, most of the undertexts preserve only a portion of a much larger work, and the smallest undertexts may preserve only a few lines from a not-yet-identified work. Even where only a few lines are preserved, an undertext may contribute substantially to our knowledge of the transmission and circulation of a work or to the history of languages and scripts used in the Monastery and its environment through the centuries.¹⁹

The identifications of text and script for each recto and each verso are published in the online database, along with relevant bibliographic information. In addition, the participating scholars have begun to publish the results of their work on the palimpsests that they have worked to identify, including in some cases the creation of new text editions.

CONTRIBUTIONS TO SCHOLARSHIP

The Sinai Palimpsests Project provided scholars with images and descriptions of 307 erased texts from Late Antiquity and the Middle Ages preserved among the palimpsests of St. Catherine's Monastery. A large percentage of these undertexts fit one or more of the following categories: the oldest witness to a known ancient text; the first instance of a known ancient text in a particular language (e.g., translations of Greek works into Christian Palestinian Aramaic); and the discovery of a heretofore unknown text from Christian, Jewish, or Classical antiquity.

Even where scholars judge the contents of some undertexts to be less intrinsically interesting, the relationships between undertexts and overtexts in a palimpsest codex provide opportunity to study patterns of textual transmission and the relationships between communities who created the under- and overtexts.

The undertexts of Sinai's palimpsests also provide new samples of scripts in which various languages were written during the first millennium. In some cases, the relationship between overtext and undertext may provide new, more reliable criteria for the dating of a script style. For example, an overtext in a script with a relatively secure date may provide a *terminus ante quem* for a script in the undertext with an insecure date.

Finally, the project provides new information about the history of St. Catherine's Monastery and the central cultural role it has played through the ages.

CONTRIBUTIONS TO THE SPECTRAL IMAGING OF MANUSCRIPTS

The innovations of the Archimedes Palimpsest Project were a rare boon for manuscript scholars. Normally, those in the humanities must find creative ways to use imaging technologies originally developed for remote

¹⁸ Among the spectacular new findings are pieces of a previously unknown poem in hexameters that mentions the childhood of the god Dionysus. See Rossetto, *Fragments from the Orphic Rhapsodies?* and Rossetto *et al.*, *A Revised Text*.

¹⁹ Rapp, *Secluded Place or Global Magnet?* See also the contribution of Claudia Rapp in this volume.

sensing or medical research. But after the *Archimedes Palimpsest* was purchased at auction, its owner provided approximately ten years of funding to a team of scientists to develop the means to recover its erased texts. The resulting innovations provide manuscript scholars with spectral imaging solutions developed specifically within and for their field. This injected new energy into the field of manuscript imaging.

The Sinai Palimpsests Project followed on the heels of the Archimedes Palimpsest Project and fulfilled an important role. The project provided a funded five-year program wherein the scientists of the Archimedes Palimpsest Project could continue to improve and supplement their spectral imaging solutions. For example, in its final stages the Archimedes Palimpsest Project demonstrated the utility of spectral fluorescence imaging to recover erased texts, and then the Sinai Palimpsests Project provided the context where this imaging method was implemented programmatically with purpose-built equipment. In Sinai, spectral fluorescence imaging provided the data most important for recovering the greatest number of undertexts. The Sinai Palimpsests Project also added spectral transmissive illumination to the essential toolkit for palimpsest imaging. The project experimented with transmissive illumination during its 2009 pilot phase and introduced a spectral transmissive light source in 2011.

THE FUTURE OF THE SINAI PALIMPSESTS PROJECT

We hope that the impact of the project on scholarship and on the spectral imaging of cultural heritage is only beginning. The following are agendas for future research.

1. *Application of 'big data' questions to project metadata.* Metadata about such a large quantity of diverse palimpsests offers researchers opportunity to pose questions that take into account the totality of project data. Questions may address how manuscripts were selected for palimpsestation, the conditions that contributed to palimpsestation, the circulation of palimpsests or of erased parchment, and the relationships between undertexts and overtexts and between the communities that produced them. For a first foray, see the contributions of Rapp and Vollandt in this volume. It may eventually be possible to suggest criteria to distinguish between palimpsests created in Sinai and palimpsests brought to the Monastery.

2. *Materials analysis.* The raw spectral data may be used to typify the inks of both the overtexts and the undertexts of the palimpsests. Such research may reveal a great deal about the history and provenance of the palimpsests. Although the data from spectral imaging is insufficient to identify ink types with precision, the spectral data may be used to sort inks into broad classes and to identify outlying inks which respond to spectral illumination differently than others. More precise tools (e.g., X-ray fluorescence and Raman spectroscopy) may then be applied to sample inks from each class and to outlying inks.

3. *New image processing of the most difficult-to-read undertexts.* Many important undertexts among Sinai's palimpsests remain very difficult to read, even after the application of image processing methods available during the project (2011 to 2016). Since the conclusion of the project, new image processing methods have become available that can be applied to the original project data and improve the legibility of important undertexts. Additional image processing may make possible the identification of undertexts now listed as 'unidentified', or enable the transcription and reconstruction of important undertexts which have been identified, but until now have not been rendered sufficiently legible for transcription.

4. *Resumption of spectral imaging of palimpsests at St. Catherine's Monastery.* Over five years, the Sinai Palimpsests Project imaged 74 palimpsests (6,800 pages) out of a total of 172 known palimpsests preserved in the Monastery library. Almost 100 palimpsests have not yet been spectrally imaged, constituting potentially 8,000 pages of still unstudied Late Antique and Medieval texts. Since the selection of palimpsests for imaging during the project was based on their state of conservation and the undertext languages they included and not on their importance to scholars (which was unknown), many important undertexts may lie yet unrecognized.

THE SINAI LIBRARY DIGITIZATION PROJECT

In 2018, St. Catherine's Monastery, EMEL, and the UCLA Library embarked upon a new collaboration to digitize the Monastery's extensive manuscript library, beginning with its Arabic and Syriac manuscripts. Why are the parties undertaking an ambitious digitization project, rather than completing the spectral imaging of the Monastery's palimpsests? The answer is two-fold. First, since scholars often cannot visit the Monastery due to the perceived volatility of the region, both the parties and funders emphasized the wisdom of a large-scale digitization program to make the contents of the Monastery's extensive manuscript library accessible to researchers unable to visit Sinai. Second, just as archaeologists do not excavate the entirety of an ancient city at once, it is prudent after five years of imaging to step back and allow imaging technologies to advance and offer new capabilities before returning to the task of imaging more of Sinai's palimpsests.

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