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manuscript cultures

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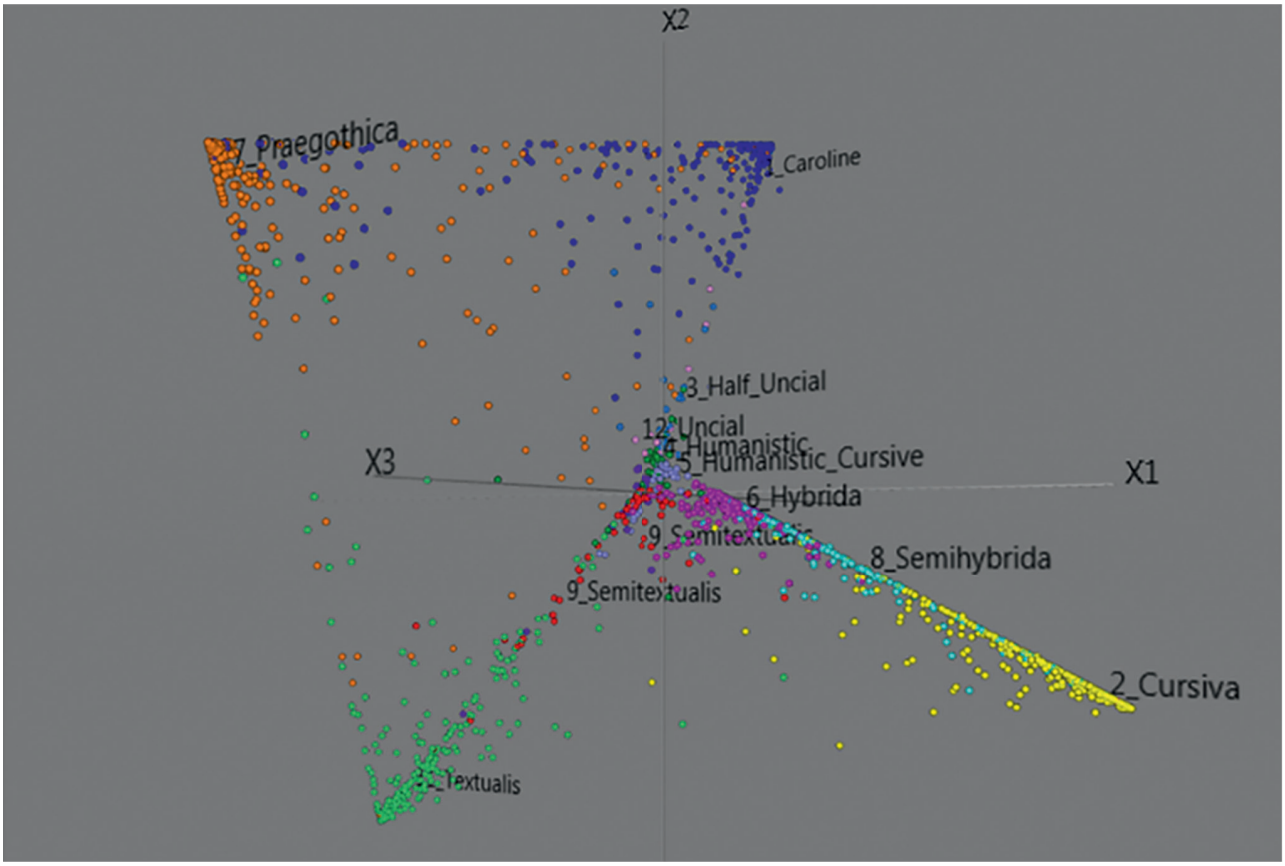

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Natural Sciences, Technology and Informatics in Manuscript Analysis
Edited by Oliver Hahn, Volker Märgner, Ira Rabin, and H. Siegfried Stiehl

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Image of ICDAR2017 Tensmeyer's distance matrix (axes 2 and (1 and 3)), see article by Dominique Stutzmann, Christopher Tensmeyer and Vincent Christlein in this volume.

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Article

Illuminating Techniques from the Sinai Desert: Spectral Imaging Inside one of the Oldest Libraries in the World Brings back to Life Re-written and Forgotten Texts. Review of the Imaging Techniques and the Global Advantages on the Field that were Gained from the Sinai Palimpsests Project

Damianos Kasotakis, Michael Phelps, Ken Boydston | Early Manuscripts Electronic Library, California – MegaVision, California

Understanding the location of the very important collection of Saint Catherine's is the first step towards building a framework for the successful digitization of its collection. The Sinai desert is a low humidity environment with granite mountains surrounding the old monastery in this remote area of the Sinai Peninsula. On a first look it appears as an unfriendly place for humans to survive, but the history of the 1500 years old Justinian fortress tells us otherwise. By a closer observation of the monastery's library we find treasures hidden from the outside world surviving alongside the monks for centuries. Among those treasures we find the palimpsest manuscripts, which are manuscripts that have been erased and re-written, sometimes with more than one layer of script. During the last century there have been more attempts to make the erased text legible with various means. With the Sinai Palimpsests Project, it has been the first time that the palimpsest collection was systematically digitally imaged with non-destructive techniques.

The Sinai Palimpsests Project began identifying technologies for the recovery of those erased texts in 2009 as pilot stage. In December 2011 the project began systematically imaging palimpsests in the Library area, and was concluded in 2016 after five years, with the unreserved support and understanding of the monks of the Sinai Brotherhood, His Eminence the Archbishop, the Librarian Father Justin, and the support of the Egyptian Government.

110 palimpsested manuscripts were know until then, but were not cataloged and studied page by page. After five years, we knew of 160 palimpsest manuscripts, and it is possible that the number may approach 200 if the entire collection of the Monastery is examined page-by-page. During our work and sometimes by mistake due to a simple misread of a manuscript number, we discovered other new palimpsests that were not known until then, with the tools we had developed we were able to catalog those manuscripts as palimpsests in a new digital database.

By August 2016 when the imaging project concluded, 74 palimpsests and the total of 6800 pages had been cataloged and spectrally imaged, resulting in more than 50 TB of data including the processed images.

Metadata describing the manuscript to be imaged are recorded before imaging. A codicological description of the manuscript as a whole was recorded, and then a database entry was created for each page or other manuscript component, including the categorization of each manuscript page by language. Features of the folio are recorded such as: the flesh or hair side, the color of the ink, the attributes of the script, as well as other observations that may be useful during the photography or image processing of the texts. For example, knowing that a page was a flesh side is important for the image processing team to know if good results can be extracted by using transmissive illumination images.

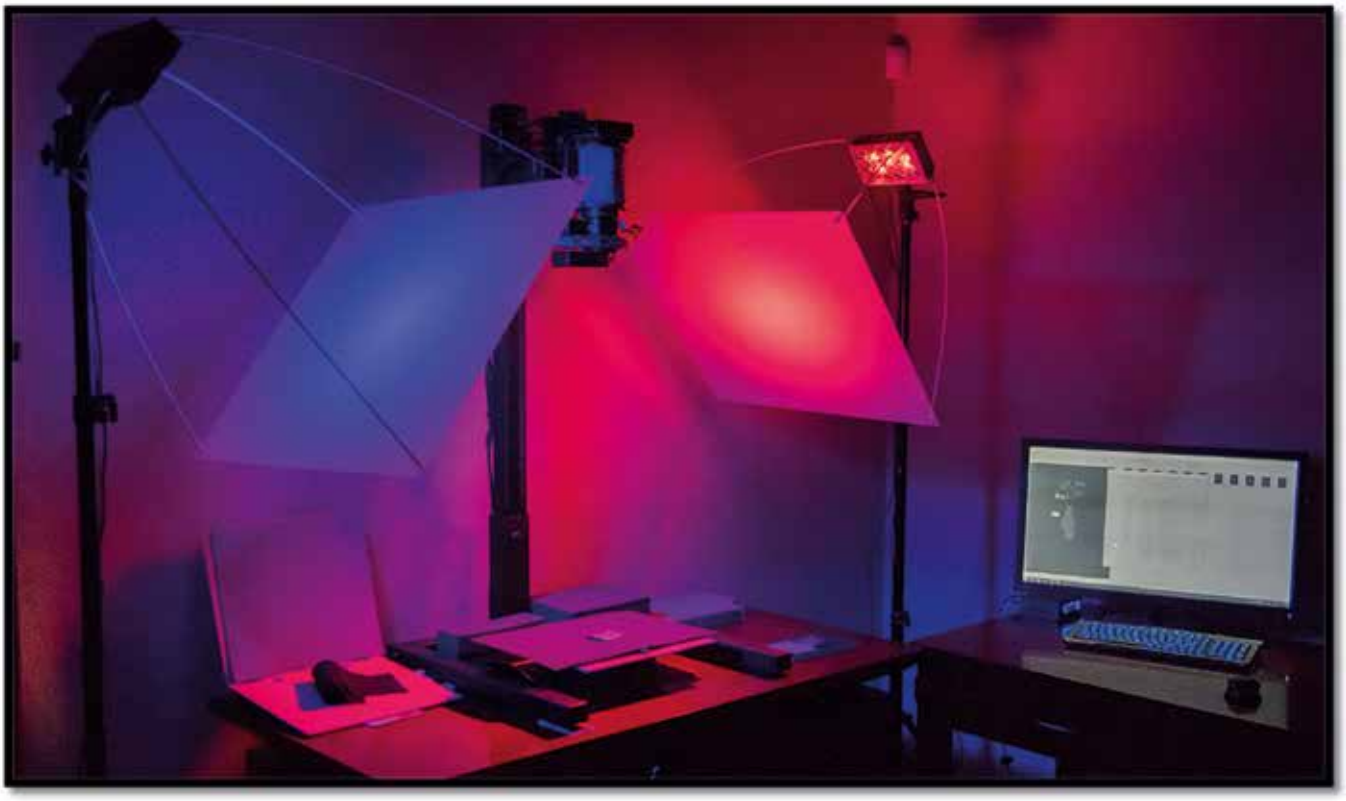


Fig. 1: MegaVision Spectral Imaging System.

Our database called KatIkon was created specifically for the Sinai Palimpsests Project. This database allows us to create a Shotlist that acts as a guidance tool for the photography team. This Shotlist includes not just the order of folios that have to be imaged, but all the necessary metadata for each manuscript folio, so that this information can be embedded during the imaging sequence while the image files are created. It's important to highlight the significance of embedding metadata during the capture process that follows the object with systematic checks of integrity along the data flow.

During the spectral imaging process, we acquire the basic foundation for the image processing of palimpsest texts. It is here that we create the raw-digital-material called RAW photos.

A general setup of the Mega Vision Spectral Imaging System in a copy stand type can be seen in Fig. 1. Visible in Fig. 1 are the LED light sources, the diffusers that help us have an even distribution of light on our scene, the E7 digital back, the filter wheel, the lens, and the capture computer controlling all of the above.

The optical unit of the imaging system is a custom designed 120mm apochromatic lens. This apochromatic lens is corrected in three wavelengths (UV-IR-VIS). Thus we minimize the magnification and focus changes between the UV-IR and VIS spectrum, a change that would introduce the common problem of miss-registration of data between fluorescent and reflectance shots or any need to refocus between IR and UV. The lens is a custom-built lens that was made specifically with multispectral applications in mind and uses a central, Copal 0, Schneider electronic leaf shutter. The lens design utilizes nine elements in seven groups. Six of them are special low dispersion (ED) glass, and the rear element is aspheric.

During our spectral photography in the Sinai, we recorded 33 different black-and-white photos for each manuscript page, using a 50.1 megapixels camera manufactured by MegaVision Inc. that houses an achromatic, silicon, Kodak CCD Imaging Sensor (KAF-50100) with 8176(H) x 6132 (V) pixels. Advantages of using a CCD array vs a CMOS one is seen in the near infrared spectrum where the CCD is slightly more sensitive. More specifically the spectral range of the sensor is between 350-1100nm.

RAW photos are digital files that have not been processed at all, they are uncompressed, unpacked, weight 100 megabytes each, are in -.DNG- format, and hold a dynamic range of 12 bits per channel.

This sensor does not have a Bayer filter. A Bayer filter, encountered in all of modern digital cameras – even our

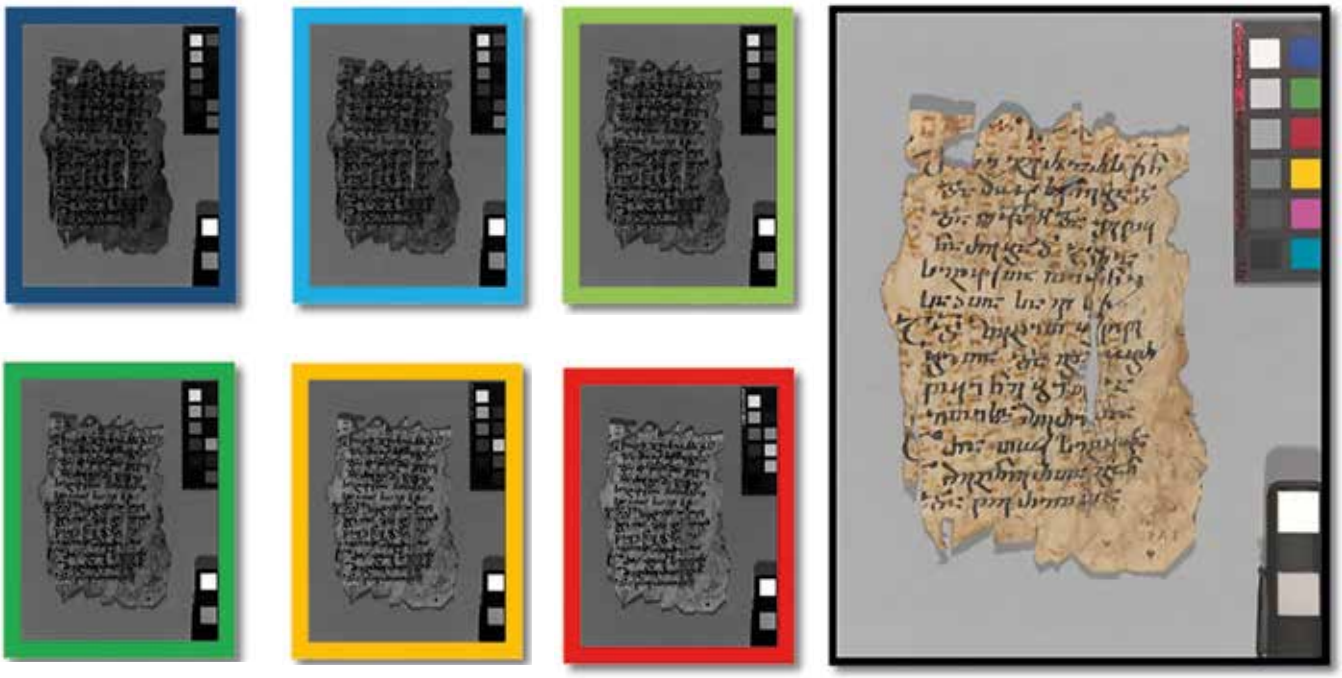


Fig. 2: Color image produced by combination of visible wavelengths. 7 visible wavelengths are used to produce the color image, in this example only 6 pictures are visible for reasons of spacing.

cellphones – would filter the light only through Red-Green-Blue and would have great losses both in the recording of the remaining colors and in the light intensity (in brightness) which is lost through the filters.

With this sensor we record information in the gray-scale, as we record light intensity. As a result, we have a better resolution, and we are truly using the 50,000,000 pixels of our E7 digital back.

This very high resolution gives us the opportunity to study very closely one by one the elements of the text we are trying to retrieve. Many palimpsest manuscripts are very old objects that have been handled again and again, reused and re-written. Many times, the condition of the manuscript is not optimal, with text running into the margins. This is where high special resolution images are important to have solid proof that even a single letter can be identified correctly by a scholar.

For each shot of the 33 of each page, the manuscript is illuminated by a different wavelength of light and in some cases also by different angles. Two raking lights at 15 degrees, two Main lights at 45 degrees, one transmissive light source. More specifically the lights that illuminated the Sinai palimpsest manuscripts had twelve different wavelengths. Modern MegaVision systems use up to 16 or 20 different wavelengths, something that is a result of the Sinai Palimpsests Project demanding more and more data to be recorded for future analysis. This is a highlight for EMEL (Early Manuscript Electronic Library) and its associates, leading developments and contributions on the field of Spectral Imaging. With EMEL's work through the Sinai Palimpsests Project on-site solutions were developed and drove the technology from which the rest of the world is benefiting. Using LED technology, we avoid the production of heat on the surface of the manuscript. The range of light we used, ranges from ultraviolet 365nm to infrared 940nm, covering in between the visible to the human eye spectrum by using seven visible wavelengths ranging from 400nm to 700nm. The necessity of LED illumination in a dark room must be emphasized and our responsibility to perform noninvasive and non-destructive examinations.

There are four different imaging principles in the system: reflectance, fluorescence, raking, transmissive.

Ultraviolet illumination makes the parchment 'fluoresce', since parchment absorbs the short UV wavelengths and re-emits back at longer wavelengths, which are visible to the eye and can be captured by a digital sensor. Areas of the parchment that had previous erased ink on them react differently as a matter of fluorescence from the parchment. This difference is essential in recovering erased writing and is captured in our pictures and can later help us while processing the data. In this way we can differentiate the two-dimensional picture that we have captured into different

groups: parchment with no ink, parchment with erased ink, newer writing ink.

Multiple individual visible wavelengths of light, when combined, produce a very accurate representation of the actual color of the object. Where Bayer-filter digital cameras use only three colors (Red, Green, Blue) to produce a color image, the Spectral Imaging System uses seven colors (Fig. 2) (Royal Blue, Light Blue, Cyan, Green, Amber, Red, and Dark Red) and more recent ones use up to twelve. This is achieved by a combination of seven different grey scale pictures captured under conditions of a dark room with the only illumination coming from those specific wavelengths, configured manually according to L*a*b* readings of the digital pictures, and white balanced according to L*a*b* measurements from color targets (more specifically: the MacBeth color target). Calibration of all of our photos can be traced back using unique serial codes of the color targets which are manufactured under specific standards, thus accurate reproduction of our results can be achieved at any given time. The MegaVision digital back and software can talk to each other in a way that if needed can capture new calibration files, and compare them to older calibrations in tables of numbers for each individual color patch, since what we have as a system is essentially a high-resolution colorimeter.

In cases of manuscripts where the ink has eroded the parchment surface, as we say 'the ink has eaten into the parchment' we use a specially build surface that illuminates the manuscript from its backside. In this way, the area of the letters where the parchment has become thinner the light penetrates it more easily. Our experience has shown that this technique yields significantly better results if the text was written on the flesh side. The transmissive light source used in Sinai was built by William Christens-Barry and featured four visible wavelengths and four IR wavelengths, though only the longest IR wavelength (940 nm) has proven to be consistently useful in processing. For this reason, recent transmissive light sources by MegaVision reduce the number of wavelengths.

The digitization process was made possible using equipment that already existed at St. Catherine's, as well as equipment that was specifically designed for this project. One of the pre-existing equipment was the manuscript support mechanism for the digitization of fragile manuscript codices called the Preservation Book Cradle by Stokes Imaging. The Stokes Cradle is a support mechanism (book-cradle) that is considered to be one of the best options on supporting fragile codices and ideal for the collection of St. Catherine's.

This mechanism mimics the natural movement of the spine of the manuscript codices. In this way sensitive codices are not harmed during digitization or put under any stress, since the book-cradle can support books that open even at a ~90-degree angle (or even a little less).

The processes are lengthy as a matter of time, first with the spectral digital imaging of manuscripts that can take up to 6-10 minutes per page in this specific project (6 minutes of capturing data and 1-4 minutes of material handling), and secondly with the equally demanding task of image processing (less than one minute on batch processing or up to 180 minutes and more for statistical image processing routines). These lengthy steps finally lead us from 33 different black-and-white photographs, to one or two final results where the erased writing becomes as legible as possible with high quality images that can be archived and reexamined objectively by a different number of scholars or scientists around the globe.

PICTURE CREDITS

Fig. 1: © Damianos Kasotakis, MegaVision Spectral.

Fig. 2: © St Catherine's Monastery, Mt Sinai, Egypt. Used with permission.

Written Artefacts as Cultural Heritage

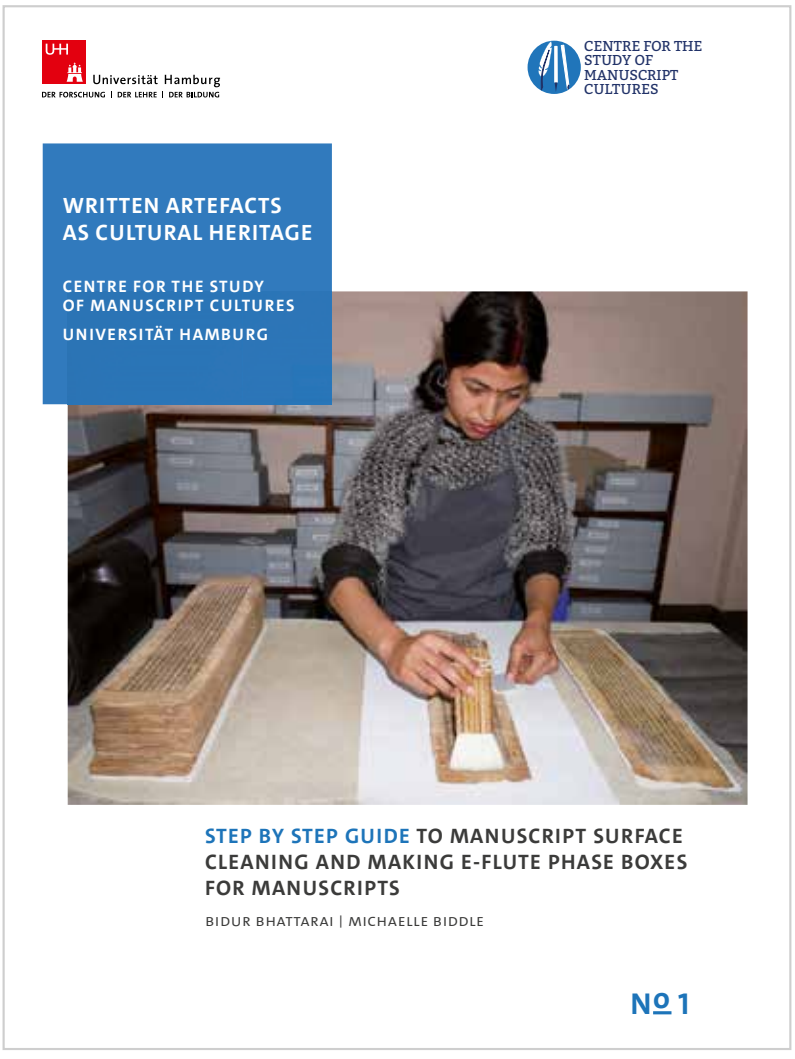
Ed. by Michael Friedrich and Doreen Schröter

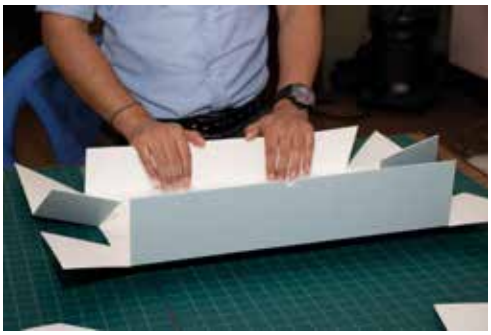
Written Artefacts as Cultural Heritage was established in 2020. The series is dedicated to the double role of written artefacts as representations and generators of humankind's cultural heritage. Its thematic scope embraces aspects of preservation, the identity-defining role of artefacts as well as ethical questions.

The mix of practical guides, colloquium papers and project reports is specifically intended for staff at libraries and archives, curators at museums and art galleries, and scholars working in the fields of manuscript cultures and heritage studies.

Every volume of *Written Artefacts as Cultural Heritage* has been peer-reviewed and is openly accesible. There is an online and a printed version..

If you wish to receive a copy or to present your research, please contact the editorial office:
https://www.csmc.uni-hamburg.de/publications/cultural-heritage.html





manuscript cultures (mc)

Editors: Michael Friedrich and Jörg B. Quenzer
Editorial office: Irina Wandrey

CSMC's academic journal was established as newsletter of the research unit 'Manuscript Cultures in Asia and Africa' in 2008 and transformed into a scholarly journal with the appearance of volume 4 in 2011. *manuscript cultures* publishes exhibition catalogues and articles contributing to the study of written artefacts. This field of study embraces disciplines such as art history, codicology, epigraphy, history, material analysis, palaeography and philology, informatics and multispectral imaging.

manuscript cultures encourages comparative approaches, without regional, linguistic, temporal or other limitations on the objects studied; it contributes to a larger historical and systematic survey of the role of written artefacts in ancient and modern cultures, and in so doing provides a new foundation for ongoing discussions in cultural studies.

Every volume of *manuscript cultures* has been peer-reviewed and is openly accessible:
https://www.csmc.uni-hamburg.de/publications/mc.html

If you wish to receive a copy or to present your research in our journal, please contact the editorial office:
irina.wandrey@uni-hamburg.de

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Studies in Manuscript Cultures (SMC)

Ed. by Michael Friedrich, Harunaga Isaacson, and Jörg B. Quenzer

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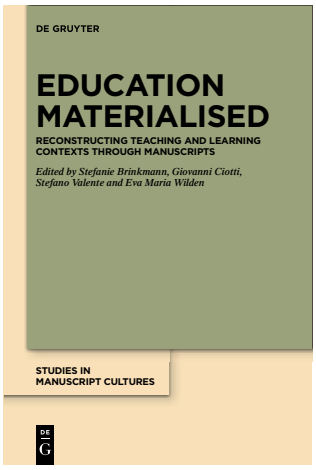
Forthcoming



23 – *Education Materialised: Reconstructing Teaching and Learning Contexts through Manuscripts,* edited by Stefanie Brinkmann, Giovanni Ciotti, Stefano Valente and Eva Maria Wilden

Manuscripts have played a crucial role in the educational practices of virtually all cultures that have a history of using them. As learning and teaching tools, manuscripts become primary witnesses for reconstructing and studying didactic and research activities and methodologies from elementary levels to the most advanced.
The present volume investigates the relation between manuscripts and educational practices focusing on four particular research topics: educational settings: teachers, students and their manuscripts; organising knowledge: syllabi; exegetical practices: annotations; modifying tradition: adaptations.
The volume offers a number of case studies stretching across geophysical boundaries from Western Europe to South-East Asia, with a time span ranging from the second millennium BCE to the twentieth century CE.

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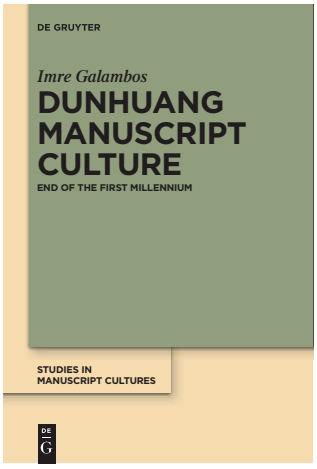

22 – *Dunhuang Manuscript Culture: End of the First Millennium*, by Imre Galambos

Dunhuang Manuscript Culture explores the world of Chinese manuscripts from ninth–tenth century Dunhuang, an oasis city along the network of pre-modern routes known today collectively as the Silk Roads. The manuscripts have been discovered in 1900 in a sealed-off side-chamber of a Buddhist cave temple, where they had lain undisturbed for for almost nine hundred years. The discovery comprised tens of thousands of texts, written in over twenty different languages and scripts, including Chinese, Tibetan, Old Uighur, Khotanese, Sogdian and Sanskrit. This study centres around four groups of manuscripts from the mid-ninth to the late tenth centuries, a period when the region was an independent kingdom ruled by local families. The central argument is that the manuscripts attest to the unique cultural diversity of the region during this period, exhibiting – alongside obvious Chinese elements – the heavy influence of Central Asian cultures. As a result, it was much less 'Chinese' than commonly portrayed in modern scholarship. The book makes a contribution to the study of cultural and linguistic interaction along the Silk Roads.

Studies in Manuscript Cultures (SMC)

Ed. by Michael Friedrich, Harunaga Isaacson, and Jörg B. Quenzer

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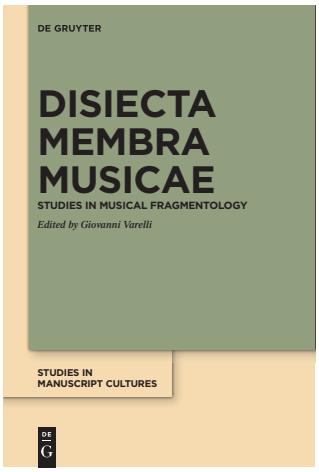
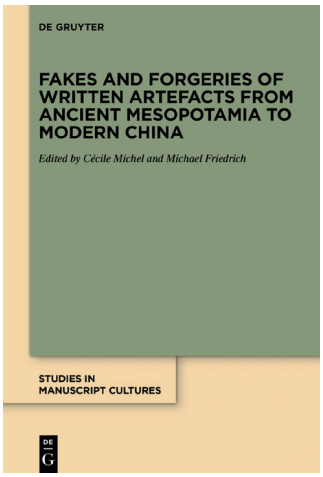


21 – *Disiecta Membra Musicae: Studies in Musical Fragmentology*, edited by Giovanni Varelli

Although fragments from music manuscripts have occupied a place of considerable importance since the very early days of modern musicology, a collective, up-to-date, and comprehensive discussion of the various techniques and approaches for their study was lacking. On-line resources have also become increasingly crucial for the identification, study, and textual/musical reconstruction of fragmentary sources. *Disiecta Membra Musicae. Studies in Musical Fragmentology* aims at reviewing the state of the art in the study of medieval music fragments in Europe, the variety of methodologies for studying the repertory and its transmission, musical palaeography, codicology, liturgy, historical and cultural contexts, etc. This collection of essays provides an opportunity to reflect also on broader issues, such as the role of fragments in last century's musicology, how fragmentary material shaped our conception of the written transmission of early European music, and how new fragments are being discovered in the digital age. Known fragments and new technology, new discoveries and traditional methodology alternate in this collection of essays, whose topics range from plainchant to *ars nova* and fifteenth- to sixteenth-century polyphony.

New release



20 – *Fakes and Forgeries of Written Artefacts from Ancient Mesopotamia to Modern China,* edited by Cécile Michel and Michael Friedrich

Fakes and forgeries are objects of fascination. This volume contains a serie of thirteen articles devoted to fakes and forgeries of written artefacts from th beginnings of writing in Mesopotamia to modern China. The studies empha sise the subtle distinctions conveyed by an established vocabulary relating t the reproduction of ancient artefacts and production of artefacts claiming t be ancient: from copies, replicas and imitations to fakes and forgeries. Fake are often a response to a demand from the public or scholarly milieu, or ever both. The motives behind their production may be economic, political, reli gious or personal – aspiring to fame or simply playing a joke. Fakes may be revealed by combining the study of their contents, codicological, epigraphi and palaeographic analyses, and scientific investigations. However, certain fa mous unsolved cases still continue to defy technology today, no matter hov advanced it is. Nowadays, one can find fakes in museums and private collec tions alike; they abound on the antique market, mixed with real artefacts tha have often been looted. The scientific community's attitude to such objects calls for ethical reflection.

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