New Technical Methods for the Study of Damaged Manuscripts (demonstrated on Glagolitic material from Mt. Sinai)

Heinz Miklas, Melanie Gau

Institute of Slavonic Studies, University of Vienna, Austria

The Glagolitic manuscripts of St. Catherine's monastery on Mt. Sinai

Aside from unique works of art, Saint Catherine's monastery at the foot of Mount Sinai holds the oldest continuously growing and functioning monastic library in the world, containing nearly 4,000 codices and book-scrolls in thirteen languages dating from the 4th century onward. Since the famous find of 1975, the manuscript collection has been divided into two parts.

To the old collection of 43 Slavic units the new findings added a further 42 items, among them six Glagolitic manuscripts of the 10th-11th/12th century. Two of them turned out to be parts of already known mss. (*Psalterium* and *Euchologium Sinaiticum* – Sin. slav. 1/N and 2/N), the rest was entirely new (codd. Sin. slav. 3/N-5/N and three small bifolia with medical prescriptions, attached to the *Psalterium Demetrii Sinaitici* – Sin. slav. 3/N). While the three Glagolitic sources of the old collection have already been edited, an edition of the newly found Glagolitic mss. is still in progress.

The project and its present results

In 1992, I. Tarnanidis and F. V. Mareš undertook the first steps towards preparing an edition of the most exciting of the new finds, the Glagolitic Sacramentary (*Missale Sinaiticum* – Sin. slav. 5/N). The decipherment of pictures the two had made of the manuscript was started at the end of 1995 by H. Miklas and V. Sadovski. On a second journey to St. Catherine's in 1996 I. Tarnanidis and H. Miklas managed to take a new series of photographs and write an overall description of the fragment, which also led to the detection of a re-written part of the text. However, due to the extremely bad state of the fragment its decipherment progressed very slowly, and even the new pictures proved to be insufficient for the many tasks connected with the Missal.

Thus, it was necessary to enlarge the project and make use of digital techniques to improve the quality of the data. After receiving a grant from the Austrian Science Fund (Project No. P19608-G12, cf.

http://www.prip.tuwien.ac.at/research/current-projects/sinai), in January 2007 the third phase of the project began with the combined efforts of a philological team at the University of Vienna and two technical teams at the Vienna University of Technology and the Vienna Academy of Fine Arts.[1]

Since then, work has progressed in three directions: (a) mere philological steps, (b) combined philological and technical steps, concerning the computer processing of manuscript-images, and (c) technical steps concerning the analysis of the materials used for writing and illuminating the manuscripts. Here only the latter steps will be discussed.

(1) *Corpus of Glagolitic data:* The first task consisted in the collection, digitization and systematization of available photographs of the Sinaitic Euchologies and other Glagolitic manuscripts. This corpus was subsequently used for tests and for the development of special computer tools.

(2) *Character extraction:* Next the data for character analysis were prepared, both for project purposes and computer processing of the Glagolitic script in general: From each manuscript of the corpus series, 10 glyph samples were extracted. For the automatic extraction of glyphs from image files the computer tool *cut_character* was developed.

(3) *Graphetic character description:* Based on H. Miklas' earlier research, we developed a catalogue of features for the graphetic description of scripts according to linguistic and computational aspects. The catalogue is divided into two subcategories: one describing the characters statically, i.e. the state as it is perceived, the other dynamically, i.e. its production (how it was made). For storage and evaluation of the character features the computer experts created the database *character db*.

For further expertise on the classification of the glyphs, a professional calligrapher was consulted, who also provided additional testing material written in different inks, with various writing tools, and on various media.

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(4) *Image acquisition:* For the acquisition of digital and multispectral images a system with a spectral range from 300nm (ultraviolet) to 1000nm (near infrared) was developed. It consists of a Nikon D2X (spectral response: visible) and a Hamamatsu C9300-124 camera (spectral response: 300-1000nm). Besides RGB images the Nikon camera also captures UV fluorescence images.

Then, a set of optical filters was obtained and tested to select the best spectral ranges for latent texts of damaged or re-written manuscripts. Contrary, e.g., to the Archimedes-project,[2] we selected 7 ranges to take images in the red, blue, green (450nm, 550nm, 650nm bandpass, 50nm width) and VIS channel, as well as IR reflectography (low pass filter 780nm, 800nm), UV reflectography (high pass filter 400nm), and UV fluorescence images (low pass filter 400nm). Then a portable framework was worked out to hold both cameras, the manuscript and part of the lighting system. For the multispectral capturing a filter wheel was mounted in front of the Hamamatsu camera, in which the 7 filters were embedded.

(5) *Image registration and basic enhancement:* For registration, i.e. aligning all images of same series to one reference image, a new algorithm was developed. Algorithms have also been developed for enhancing the readability by combining images from different spectral bands.

(6) *Digitization and analysis of the Glagolitic manuscripts on Mt. Sinai:* After testing the equipment, during a ten days' stay at St. Catherine's last autumn (Sept. 22nd until Oct. 2nd) part of our group[3] copied the relevant manuscripts, examined their materials (support, inks and pigments, remnants of binding) via soft x-rays-fluorescence (XRF) analysis and supplied some further codicological data.

Three of the manuscripts were digitized in their entirety: the *Missal*, the *Psalterium Demetrii*, and the medical folios. In the other cases images were taken only of those parts that are either badly preserved or contain palimpsests: the new parts of the *Sinaitic Euchology*, and the *Psalterium Sinaiticum*, as well as the old part of the same Psalter (Sin. slav. 38).

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[2] R. L. Easton, K. T. Knox, and W. A. Christens-Barry: Multispectral Imaging of the Archimedes Palimpsest. – In: *32nd Applied Image Pattern Recognition Workshop (AIPR 2003).* Washington DC: IEEE Computer Society, 2003, 111-118.

[3] The members Miklas, Sadovski; Lettner, Kleber; Schreiner, and Hammerschmid.

(7) *Post-processing:* In Vienna the new image corpus underwent a complex process of post-processing by assembling, sorting, turning, aligning, etc. (cf. step 5).

(8) *Further developments:* Concomitant with the post-processing, further algorithms have been developed to enhance the readability of latent texts using false colours, to analyze the page layout and the ruling, to describe and extract perceived (static) strokes and to investigate stroke endings (writing tool recognition).

(9) *Material analysis:* Meanwhile, the XRF-analysis yielded the main components as well as minor and trace constituents of the areas analysed: For the red parts minium (red lead oxide), for the green a copper containing pigment (either malachite or verdigris), and for the blue ultramarine (lapis lazuli) were found. For the yellow parts no differences to the elements detected in the parchment could be found, implying that a yellow organic dye was applied. Only in a few cases were the elements arsenic and sulphur detected, indicating the presence of orpiment (arsenic sulphide). As for text inks, only iron gall inks (mixed with carbon ink?) of various chemical compositions could be identified. Further examination is still to be done.

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Новые технические методы для изучения поврежденных рукописей (на глаголическом материале Синайского монастыря)

Хайнц Миклас, Мелани Гау

Институт славистики, Венский университет, Австрия

Древние рукописи не всегда представлены в том виде, в котором их можно без труда читать и издавать. Описываемый проект посвящен улучшению и расширению использования не разрушающих объекты технических средств, предназначенных для изучения поврежденных письменных памятников. Чтобы получить максимально качественную основу для компьютерной обработки материала, мы пользуемся не только цифровой съемкой с высоким разрешением, но и мультиспектральной съемкой в нормальном освещении и в ультрафиолетовом излучении. С применением разработанных алгоритмов полученные изображения регистрируются и накладываются одно на другое; затем трудно доступные для расшифровки изображения выявляются фальшивыми красками и весь материал сегментируется в строки и буквы для анализа почерков, компановки и других операций. Метод рентгено-флуоресценции мы используем для исследования письменного материала, и в первую очередь – для определения чернил и пигментов красок.