Textual History of the Bible

4.1.3.4 Codicology and the Sciences

(3,717 words)

Part of 4 Science and Technology - 4.1 Scientific Methodologies and Technology - 4.1.3 Analysis and Reconstruction

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Digital technologies and the internet have fundamentally changed the study and analysis of manuscripts. Digital tools and resources in use today contribute to the imaging, preservation, analysis, access, and distribution of data relating to the biblical texts that help us in the tasks of textual criticism. The conversion of catalogues into machine-readable data and the creation of new databases forces us to apply consistent methodologies in recording, describing, and encoding manuscript related information. Technological tools and standards have been developed that are now in use across divergent academic schools and regional traditions. Digital facsimiles and metadata are accessible via internet portals and virtual archives.

The application of scientific methods or tools to manuscripts is nothing new. Many incidents from the nineteenth century are attested where scholars used chemical substances in order to recover erased colophons or notes of ownership – often with disastrous consequences. For example, using a particular mix of gall acid and spirits, the antiquarian Charles Graves managed to retrieve the names of the master scribe Ferdomnach and the abbot Torbach in the famous Book of Armagh from 807–808 C.E. – containing the only surviving early Irish manuscript of the complete New Testament – and inadvertently destroyed any remaining evidence or chance of recovering the name of a second scribe.[1] Acid and chemicals of the past have long been replaced by non-destructive and non-invasive technologies – some of which are not without methodologic shortcomings, such as being non-repetitive.

Technological innovation and cutting edge research in the broad field of document analysis and recognition is presented and discussed in venues far away from the humanities, in publications and conferences of associations of engineers such as the Association for Computing Machinery (ACM), the Institute of Electrical and Electronics Engineers (IEEE) or, more specifically, at the International Conference on Document Analysis and Recognition (ICDAR). Since the end of the twentieth century humanities researchers have been increasingly applying computational and scientific tools and methods for the study and analysis of historical documents. Many of these often isolated initiatives have been gathered and documented in the four volumes of *Codicology and Palaeography in the Digital Age* (2009–2017) and in publications of the Centre for the Study of Manuscript Cultures such as the journal *manuscript cultures*.[2]

4.1.3.4.1 Digital Facsimiles

At present, the study of a manuscript usually starts with a *digital facsimile*. In-house or external reproduction services within archives and research libraries produce and provide high resolution scans that can be easily shared and viewed on a computer screen. Increasingly, libraries and archives publish digital facsimiles in part or in whole online – on a European level most recently since the Commission recommendation of 27 October 2011 and the Council conclusions of 10 May 2012 on the digitisation and online accessibility of cultural material and digital preservation.[3]

A pioneer in digitizing (from September 2000) a complete library of medieval manuscripts, the CEEC – Codices Electronici Ecclesiae Coloniensis project allows full access to images and catalogue data of about four hundred codices from the end of the sixth to sixteenth century C.E., many of which include biblical texts.[4]

Standards and guidelines for digital reproduction of manuscripts have been issued by research funding institutions or libraries and archives associations.[5] Book tables and special devices are designed to handle the codices with appropriate care.[6] Under harmless and stable light conditions high-resolution images are produced in an uncompressed format (such as RAW, TIFF or FITS). From these archive files derivatives are generated in more lightweight formats (such as JPEG) which still allow for deep magnification and observation of small details, otherwise invisible to the eye. Nonetheless, digital surrogates should be treated with caution because technical distortions can lead to the unintentional introduction of artefacts and errors.[7] Ideally, with the digital surrogates, a full record of information is provided about the decisions involved in setting up the parameters for digitizing.[8]

In order to support interoperability between image repositories and to allow stable and precise *image annotation and references*, a growing consortium of important research libraries is developing and producing the so-called International Image Interoperability Framework (IIIF).[9]

Besides conventional digital reproduction, advanced non-destructive *optical technologies* such as *Infrared*, *Multi- and Hyperspectral Imaging* (IR, MSI & HIS; 4.1.1.4) are commonly applied for more in-depth studies of codices and other text bearing objects. Capturing non-visible ranges of the spectrum, these technologies allow for measuring reflectance characteristics of manuscript page surface and can help to identify ink, recover faded or hidden text and draw conclusions about the place and date of production.[10] Similarly, Reflectance Transformation Imaging (RTI; 4.1.1.5) provides detailed images of shapes, colours and surface textures along with illumination from different angles, showing details that are often unavailable to the naked eye.[11] Easy-to-learn and inexpensive to implement, RTI imaging has proved to be very useful for the study and restoration of, e.g., illuminated manuscripts, papyri and inscriptions. For this, RTI technology is a valid alternative to 3D acquisition in some cultural heritage scenarios. 3D technology itself has been successfully applied for reconstructing and virtually flattening fire-damaged and buckled parchment.[12]

4.1.3.4.2 Radiography and Thermography

In the mid-1940s *beta radiography* (a type of x-ray photography) was tested in the USA for revealing differences in paper thickness. In the late 1950s Russian scientists published the first high quality and high contrast images of watermarks and paper mould.[13] Since then x-ray technologies have been refined to allow more efficient methods such as electron and soft-x-ray radiography.[14] An alternative technology, thermography, has been used in watermark studies, avoiding the implications of radioactive sources.[15] In recent years, x-ray spectrometry has been used to determine the chemical composition of ink and other remains on a manuscript or papyrus surface.[16] Measuring x-ray fluorescence, salt crystals on fragments on the Dead Sea Scrolls have been discerned. These results are important indicators to draw conclusions about production and original composition.[17] The same technology proves especially effective in recovering erased writings from palimpsest manuscripts.[18] The use of x-ray phase-contrast tomography on the carbonized ancient papyrus scrolls of Herculaneum has revealed letters hidden within the precious artefacts without unrolling them.[19]

4.1.3.4.3 Layout Analysis

Based on larger numbers of digital manuscripts, automatic *layout analysis* has been carried out in several research projects for two main purposes: (a) to detect layout elements and measurable features in order to generate new descriptive metadata[20] and (b) to identify text blocks and lines as a pre-processing step for handwritten text recognition (HTR). The latter has seen significant advances in the past few years, especially in the context of the European e-Infrastructure project READ,[21] combining pattern recognition technologies with machine learning algorithms based on artificial neural networks.[22] Current experiences using the project's comprehensive platform Transkribus produce transcripts of medieval documents with a character error rate (CER) of less than 10%. An indispensable prerequisite for this degree of accuracy – which is still far below the results of optical character recognition (OCR) from printed texts – is large amounts of training data ("ground truth"), i.e., accurate transcripts of homogeneous documents produced by humans.

4.1.3.4.4 Computer-Assisted Palaeography

Apart from the recognition of handwritten texts, image analysis technologies have been used for automatically clustering ancient and medieval scripts and analysing the handwriting of individual scribes or scriptoriums. In the so-called Dagstuhl Manifesto published in 2013 leading experts in the field of *computer-assisted palaeography* documented the potential and limits of tools and algorithms to provide scholars with quantitative evidences for palaeographic arguments.[23] Despite notable successes, serious challenges remain. Among others, there is the "black box" problem: Software produces results without giving any indication of how those results have been obtained. On the other hand, palaeographers are used to working with terminologies and categories that are hardly objective; authoritative attributions and classifications by expert palaeographers have a long-standing tradition in palaeography which is yet to be overcome. Recent experiments geared towards an automatic identification of script types in medieval manuscripts adapt and combine, again, technologies from the field of pattern recognition and artificial intelligence.[24] As to the attribution of scribes (even across multiple scripts), the digital resource and database DigiPal offers a digital framework for analyzing and describing handwriting and decoration referring to conceptual models and semantic labels, while still providing sufficient rigor to significantly reduce ambiguities.[25]

4.1.3.4.5 Materials Analysis

In the mid-1990s a group of researchers successfully extracted *DNA* (4.1.3.4.3) from parchment fragments of the Judean desert.[26] Since then several tests and experiments with medieval parchment manuscripts have proven successful, extracting and analysing genetic information and opening up a wide horizon for research on parchment production and the potential influence of diet, urbanisation, animal husbandry and trade.[27] However, as promising as those attempts are, two major problems have prevented the creation of extensive DNA data collections: The method is destructive; for the extraction of the DNA parchment samples of at least 0.5 x 0.5 cm or 5 mg need to be cut out of the respective manuscript leaf. The second shortcoming involves the adequate storage of the extracted DNA, which needs to be frozen to preserve its integrity.

In a recent study, *protein* from parchment surfaces has been extracted by using an electrostatic charge generated by gentle rubbing of a PVC eraser on the membrane surface – a common practice used by conservators to clean a manuscript. Using this novel non-invasive and low-cost method, seventy-two pocket Bibles originating in thirteenth-century France, England, and Italy and two hundred ninety-three additional parchment samples have been analysed. As a result, the use of more than one mammal species in a single codex could be identified, consistent with the local availability of hides. These results further suggest that ultrafine vellum does not necessarily derive from the use of abortive or new born animals with ultrathin hides (so-called "uterine vellum"), but could reflect a production process that allowed the skins of maturing animals of several species to be rendered into vellum of equal quality and fineness.[28] The same researchers applied the so-called tribolectric, eraser-based technique to a twelfth-century copy of the Gospel of Luke to uncover an unexpected pattern of interleaved calfskin and sheepskin, with some leaves of goatskin, considered to be of minor quality and used "as a last resort."[29] The method has also been extended to include the analysis of biomolecular information of manuscript users, which accumulated over the 1,000-year lifespan of the York Gospels.[30]

4.1.3.4.6 Description and Transcription

In the past decades, an international consortium of textual scholars, the Text Encoding Initiative (TEI), has developed an encoding standard for the systematic *description and transcription* of manuscripts.[31] The TEI guidelines are accepted by cataloguers, researchers, and funding institutions[32] as the *de facto* standard for capturing, enriching and exchanging manuscript transcriptions and metadata in a structured and machine-readable way. A special interest group (SIG) is continuously enhancing the standard with regard to codicological phenomena and research questions.

A principal physical feature of the medieval codex is the gathering structure. Several attempts have been undertaken to describe, visualize, and communicate the gathering of quires and folios, also known as collation, in a formalised way. VisColl has been recently presented as a tool designed to visualize the physical construction of codices suggesting, for this purpose, a TEI conformant encoding model overcoming both differences and shortcomings of traditional collation formulas.[33]

In the past decades, material sciences and informational technologies have widened the scope and greatly enhanced the methods and results of codicological research. Collaborative work practices among archivists, conservators, textual scholars, and scientists are predominant. This pertains to material investigations and the development of new tools (as described above), to digital publications (such as most notably the digital edition of the Codex Sinaiticus[34]), to virtual research environments (such as the Greek New Testament Virtual Manuscript Room[35]) and, ultimately, to the integration of digital catalogues, archives, and databases to allow access to massive amounts of codicological information.

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Notes

1. See Sharpe, “Palaeographical Considerations.”

2. See especially vol. 7, 2014; [http://www.manuscript-cultures.uni-hamburg.de/mc_e.html]. All hyperlinks in this article were accessed last on November 3rd, 2017.

3. Commission recommendation of October 27th, 2011 on the digitisation and online accessibility of cultural material and digital preservation, OJ L 283, 29.10.2011, 39–45 [http://data.europa.eu/eli/reco/2011/711/oj]. Council conclusions of May 10th, 2012 on the digitisation and online accessibility of cultural material and digital preservation, OJ C 169, 15.6.2012, 5–8 [http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52012XG0615(02)].

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5. See, for example, the *DFG Practical Guide on Digitisation for the funding area Scientific Library Services and Information Systems*.

6. Such as the Graz Book Table (see Mayer, “Digitalisierung mittelalterlicher Handschriften an der Universitätsbibliothek Graz”).

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18. Deckers and Glaser, “Zum Einsatz von Synchrotronstrahlung”; Glaser and Deckers, “The Basics of Fast-scanning XRF Element Mapping.”

19. Mocella et al., “Revealing Letters in Rolled Herculaneum Papyri.”

20. Baechler and Ingold, “Multi Resolution Layout Analysis”; cf. Eichenberger et al., “DivaDesk,” and Busch and Chandna, “eCodicology” (regrettably, the software presented by the latter is not available).

21. *READ* (*Recognition and Enrichment of Archival Document*) [https://read.transkribus.eu/].

22. Giotis et al., “A Survey of Document Image Word Spotting Techniques.”

23. Hassner et al., “Computation and Palaeography.”

24. Kestemont et al., "Artificial Paleography;" cf. Stutzmann, “Clustering of Medieval Scripts”; Schaßan, “Some Roads to Script Classification.”

25. See Stokes, “Scribal Attribution across Multiple Scripts,” esp. footnote 15.

26. Woodward et al., “Analysis of Parchment Fragments from the Judean Desert.”

27. See Stinson, “Knowledge of the Flesh”; Stinson, “Counting Sheep.”

28. Fiddyment et al., “Animal Origin of 13th-century Uterine Vellum”; all manuscript data files of this research are deposited in the Archaeological Data Service (ADS), and can be accessed through doi:10.5284/1035166.

29. Gibbons, “Goats, Bookworms, a Monk's Kiss.”

30. Teasdale et al., “The York Gospels.”

31. *Text Coding Initiative* [http://www.tei-c.org]; in the TEI guidelines see esp. chapter 10 “Manuscript Description”: [http://www.tei-c.org/release/doc/tei-p5-doc/en/html/MS.html].

32. *DFG-Praxisregeln “Digitalisierung,”* Addendum B: “METS/TEI-Spezifikation für die Darstellung von digitalisierten Handschriften,” DFG-Vordruck 12.151 (December 2016) [http://www.dfg.de/formulare/12_151/12_151_de.pdf].

33. Porter, Campagnolo, and Connelly, “VisColl.”

34. *Codex Sinaiticus* [http://www.codexsinaiticus.com]; cf. Schnöpf, review of *Codex Sinaiticus*.

35. *New Testament Virtual Manuscript Room* [http://ntvmr.uni-muenster.de].

Cite this page

Franz Fischer, “4.1.3.4 Codicology and the Sciences”, in: *Textual History of the Bible*, General Editor Armin Lange. Consulted online on 26 June 2018 <http://dx.doi.org/10.1163/2452-4107_thb_COM_225907>
First published online: 2017