JIABS

Journal of the International
Association of Buddhist Studies

Volume 36/37 2013/2014 (2015)

The *Journal of the International Association of Buddhist Studies* (ISSN 0193-600XX) is the organ of the International Association of Buddhist Studies, Inc. As a peer-reviewed journal, it welcomes scholarly contributions pertaining to all facets of Buddhist Studies. JIABS is published yearly.

The JIABS is now available online in open access at http://journals.ub.uni-heidelberg.de/index.php/jiabs. Articles become available online for free 24 months after their appearance in print. Current articles are not accessible online. Subscribers can choose between receiving new issues in print or as PDF.

Manuscripts should preferably be submitted as e-mail attachments to: *editors@iabsinfo.net* as one single file, complete with footnotes and references, in two different formats: in PDF-format, and in Rich-Text-Format (RTF) or Open-Document-Format (created e.g. by Open Office).

Address subscription orders and dues, changes of address, and business correspondence (including advertising orders) to:

Dr. Danielle Feller,
IABS Assistant-Treasurer, IABS
Department of Slavic and South Asian Studies (SLAS)
Anthropole
University of Lausanne
CH-1015 Lausanne, Switzerland
E-mail: *iabs.treasurer@unil.ch*
Web: http://www.iabsinfo.net

Subscriptions to JIABS are USD 65 per year for individuals and USD 105 per year for libraries and other institutions. For informations on membership in IABS, see back cover.

EDITORIAL BOARD

KELLNER Birgit
STRAUCH Ingo
Joint Editors

BUSWELL Robert
CHEN Jinhua
COLLINS Steven
COX Collett
GÓMEZ Luis O.
HARRISON Paul
VON HINÜBER Oskar
JACKSON Roger
JAINI Padmanabh S.
KATSURA Shōryū
KUO Li-ying
LOPEZ, Jr. Donald S.
MACDONALD Alexander
SCHERRER-SCHAUB Cristina
SEYFORT RUEGG David
SHARF Robert
STEINKELLNER Ernst
TILLEMANS Tom

Cover: Cristina Scherrer-Schaub

Font: "Gandhari Unicode" designed by Andrew Glass (http://andrewglass.org/fonts.php)

© Copyright 2015 by the International Association of Buddhist Studies, Inc.

Print: Ferdinand Berger & Söhne GesmbH, A-3580 Horn

JIABS

Journal of the International
Association of Buddhist Studies

Volume 36/37 2013/2014 (2015)

Conference

Authors and Editors in the Literary Traditions of Asian Buddhism

Guest editors
Cathy Cantwell, Jowita Kramer, Robert Mayer,
and Stefano Zacchetti

Recovering Lost Writing and Beyond

Multispectral Imaging for Text-related and Codicological Studies of Tibetan Paper and Sanskrit Palm-Leaf Manuscripts

Orna Almogi, Martin Delhey,
Claire MacDonald, Boryana Pouvkova [1]

1 Introductory Remarks

This article presents and discusses some preliminary findings of a collaborative research project involving text-related and codicological studies and multispectral imaging of select Tibetan paper and Sanskrit palm-leaf manuscripts stored at the National Archives, Kathmandu (NAK) and Kaiser Library, Kathmandu (KL). The multispectral imaging was executed in March 2013 during a research trip of a team from the Centre for the Study of Manuscript Cultures (CSMC), University of Hamburg, which included members of the Tibetological and Indological sub-projects, as well as

[1] The findings presented in this article are the results of an ongoing research generously funded by the DFG (SFB 950/CSMC). The subprojects involved in the present article are "A Twelfth-Century East Indian Monastic Library and its Fate," "Doxographical Organisational Schemes in Manuscripts and Xylographs of the Collection of the Ancient Tantras," and "Methods of Analyzing Manuscripts for Recovering Lost Writing." We would like to take this opportunity to thank the National Archives and the Kaiser Library for granting us access to the manuscripts, and the National Archives for allowing us the use of their space and for helping us in various matters. Our thanks also go to Bidur Bhattarai, Christina Kaminski, and Dr. Irina Wandrey (CSMC), Dr. Albrecht Hanisch (NRC, Kathmandu), and the German Embassy in Kathmandu for their invaluable help in organisational and logistical matters, which greatly contributed to the success of our trip. Finally, we would like to thank Prof. Dr. Harunaga Isaacson for reading § 4 of this article and making some helpful suggestions for improvements.

the sub-projects of multispectral imaging and material analysis.[2] In the following sections we shall first provide a brief overview of multispectral imaging and its applications and briefly present the system we have employed during our research trip to Kathmandu (MacDonald and Pouvkova). This will be followed by a discussion of select examples from the Tibetan material, including a brief introduction to the collection examined, presentation of the problems, and the purpose of the imaging (Almogi). Next, select examples from Sanskrit manuscripts will be presented with likewise a brief discussion of the material and problems involved (Delhey). We shall conclude with some general remarks summarising the hitherto achieved results.

2 Multispectral Imaging

2.1 Multispectral Imaging and Its Applications

Multispectral imaging is a technique and field of study that captures and utilises images beyond the visual spectrum and has many applications in areas as diverse as remote sensing, astronomy, and medical imaging. When used to study manuscripts, multispectral imaging can allow the recovery of writing of various kinds (text, musical notes, illustrations, and similar). The illegibility of the text can be due to damage to the writing support (including paper, parchment, palm leaves, etc.) caused by water, mould, fire and the like, due to fading of the ink, or due to intentional erasing or obscuring of the writing by the scribe, editor or reader. Each image taken under slightly different lighting conditions reveals a slightly different set of data. These images can often help scholars read previously illegible writing directly from them, and, if necessary, additional image processing can further improve the readability. Two aspects of imaging were particularly important to our undertaking with the Tibetan and Sanskrit manuscripts: (1) Fluorescence can help reveal faded or erased writing by causing the material support

[2] The findings of the material analysis undertaken with the Tibetan paper and Sanskrit palm-leaf manuscripts are presented in two separate articles also published in the present JIABS issue.

to fluoresce or emit light of a longer wavelength than it was illuminated with, thereby making it appear to glow, while leaving any writing dark. (2) Imaging under multiple wavelengths can distinguish between two kinds of ink, and thus help decipher corrections and deliberately obscured writings.

2.2 Description of System and Method

The imaging system[3] used employs a 39-megapixel monochromatic camera and a series of LEDs emitting light at wavelengths from 365nm (ultraviolet) to 1050nm (near infrared). Colour images can be created by illuminating an object with 6 visible LEDs. As shown in fig. 1 below, the camera is mounted onto the Traveller's Conservation Copy Stand[4] which includes a cradle to hold the manuscripts, and a wheel of five filters is positioned in front of the camera lens. On either side of the cradle there are diffusion panels to ensure that the light illuminating the manuscript is dispersed evenly. Beyond the diffusion panels there are two panels of LEDs, one featuring 6 infrared and the other with 6 visible and one ultraviolet emitting LEDs.

The lights and filter wheel were used to take 20 images of each page, or, because of the shape of the palm-leaf and Tibetan paper manuscripts, a set of one third of three pages (on this issue, see the following section 2.3). Additionally, the use of filters allows the capture of both reflectance and fluorescence images. Most of the light that reaches the target will either reflect off of it, transmit through it, or be absorbed by the paper or palm leaf and re-emitted at a lower energy (longer wavelength) as fluorescence, so for example, blue light will fluoresce into green and red, but not UV. Fluorescence is especially useful for manuscript imaging as the light can only be emitted from areas that are not covered by ink or other blocking substance. Areas that are covered with ink remain

---

[3] The system was developed by MegaVison.

[4] The Traveller's Conservation Copy Stand was developed by Manfred Mayer at the University Library Graz, Austria on behalf of the VESTIGIA – Manuscript Research Centre.

dark while the material support appears to glow, allowing the camera to capture an image showing the dark writing distinctly against a light background.

Even in cases where no single reflectance or fluorescence image reveals lost writing sufficiently, the images are all slightly different from each other, and those differences can be exploited with processing methods such as Principal Component Analysis and Independent Component Analysis in the software package ENVI, or even colour management in Adobe Photoshop. Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are statistical processing methods based on eigenvector rotation. For both methods all images are saved together in one file, and are processed as a single data set, rather than each individual image being processed one at a time. The resulting output of both methods is a set of output images equal to the number of input images. The images produced by PCA display the amount of variance amongst all the images by finding orthogonal vectors through the data with the first image showing the highest amount of variance, and the last the least. ICA works in a somewhat similar way. However, rather than basing the output results on variance, it assumes all output images are statistically independent of each other.[5] Changing the size and region of the input images changes the statistics present within that area, and so a single image set can produce many output images of both varying size and usefulness.

Colour spaces and colour models are methods of describing colours based on numbers so that they can be reproduced accurately. Ideally, a specific colour could be displayed identically in any colour space, such as RGB (red, green and blue) or CMKY (cyan, magenta, black and yellow), to name the two most well known. However, some colour models prove better for certain applications, for example, CMKY is typically used in printing.

Lab colour space is another such model for describing colour. Instead of describing how much of a particular colour should be added or subtracted from black or white, it is an opponent colour

[5] See Easton and Kelbe 2014.

Fig. 1. Diagram of set up.

space based on the balance between 'opposite' colours. Lab colour space is comprised of three axes, the first being lightless, L, which describes how dark a given colour is, the second axis, a, describes a point on the red-green spectrum, and the final axis, b, describes the balance between yellow and blue.[6]

Photoshop allows the user to work in several different colour spaces, although RGB is the default. By converting an image to Lab space, a user can adjust colours based on colour opponent balances rather than the amount of colour present in an image. This technique was found to be especially important when trying to recover writing in a chromatic ink that had all but faded away. While the human visual system may not have been able to detect the remnants of ink from the background, a computer may be able to, and by adjusting the balance between red and green or yellow and blue, the writing can emerge (such as in the figs. 21–23 for NAK 5–20, *Trisamayarājaṭīkā* 18v, 9r, 8r, respectively).

---

6 Tkalcic and Tasic 2003.

2.3 Some General Remarks on Multispectral Imaging of Tibetan Paper and Sanskrit Palm-leaf Manuscripts

Once the imaging of the Tibetan and Sanskrit manuscripts in the NAK started, a number of challenges were realised. Many of the manuscripts appeared significantly different under varying ambient lighting conditions, making it difficult to judge whether a folio needed multispectral imaging, or simply to be studied in specific, controlled lighting conditions. Being as time efficient as possible was also a priority, so it was decided that it would be better to take a sampling from many volumes and sources rather than image entire works.

The somewhat unusual oblong shape of the palm-leaf folios and the Tibetan paper folios modelled after them meant that it was not possible to fit an entire page into the camera's field of view, and it became necessary to take three partial images of each page, with the intent to stitch the images together later. To be as time-effective as possible, three pages were arranged across the imaging area for each set of images, albeit only a third of each of those pages was imaged at a time. While this improved our efficiency and increased the number of pages we could examine, it also meant that each image set we took contained portions from multiple pages, making the organisation of the images somewhat more difficult. In addition, the textured grain of the palm leaves runs parallel to the long edge of the leaf, and in some of the pages we examined, the ink had been smeared either accidently or as part of the act of erasing and as a result settled firmly into the grooves. This left the remnants of text with a set of distinct, well defined lines across them, obscuring the writing and overwhelming the image.

3 Multispectral Imaging of Tibetan Paper Manuscripts

In the following section, several examples for recovering lost text with the help of multispectral imaging of Tibetan paper manuscripts will be presented and discussed. The examples have been chosen from a larger number of multispectral images of select folios from the NAK set of the *rNying ma rgyud 'bum* (NyGB) that

were taken during the research trip.[7] The first examples (§ 3.1) concern text lost due to damage to the writing support and ink through poor storage conditions including water and mould, whereas the later ones (§ 3.2) focus on instances of text lost due to deliberate erasure or masking either by the scribes or by the editors and proofreaders. While the former merely serve as examples for increasing or recovering the legibility, the latter go beyond the sheer recovering of damaged or lost text and are aimed at demonstrating how multispectral images can help to shed light on various issues concerning Tibetan manuscript culture in general and the production of the NAK set in particular.

3.1 Recovering Text Lost Due to Damage to the Writing Support and Ink

The NAK set has unfortunately been damaged over the years since its production due to unfavourable climate conditions and obviously also inadequate storage. The greatest damage has been caused by insect infestation, which is unfortunately irreversible. Moreover, we sadly also witness excessive damage by water and mould which impair the legibility in numerous folios throughout the set. While paper that had been eaten by insects, and along with it also the text written on it, cannot be regained, multispectral imaging has proven to be a very powerful and effective method in recovering text lost or damaged due to poor storage conditions in the case of Tibetan paper manuscripts, provided, of course, the writing support has remained more or less intact. Very good results could be gained particularly in cases of damage caused by water or mould.

The recovered text in the following example of text lost due to water damage begins to be revealed in the farther infrared bands. However, it is clearest in this post processed PCA image (fig. 2).

---

[7] For more on the NAK set, see the article by Almogi, Kindzorra, Hahn, and Rabin in the present JIABS issue. A detailed study of this set, including a catalogue, is currently under preparation and will be published in Almogi forthcoming-b; a discussion of its special features and placement within the overall transmission of the NyGB will be published in Almogi forthcoming-a.

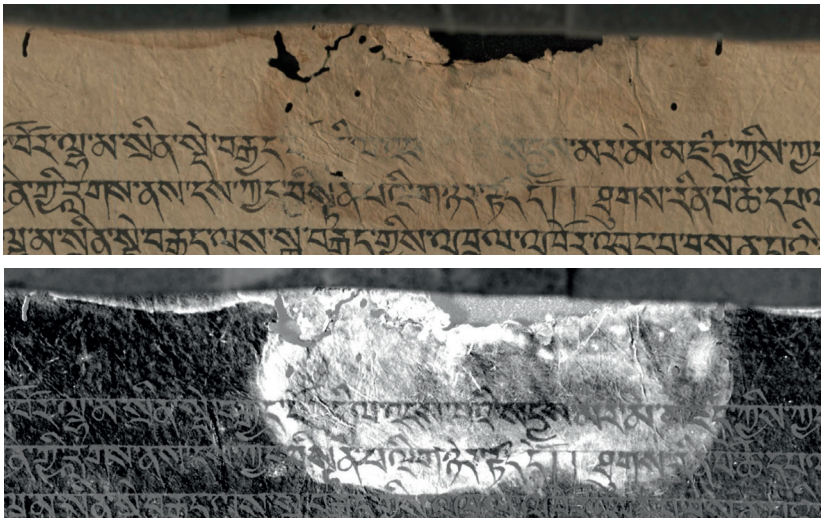

Fig. 2. NAK NyGB, Ja 29v; top: colour image of text lost due to water damage; bottom: the recovered text in a processed PCA image.

In the case shown below (fig. 3), the legibility of the text is impaired by mould. While the mould does not completely obscure the writing, this example suggests that infrared imaging could be a solution for much more severe mould damage as well. The infrared image provides high contrast between the writing and the paper, and the mould becomes less prevalent the further into infrared it is imaged under.[8]

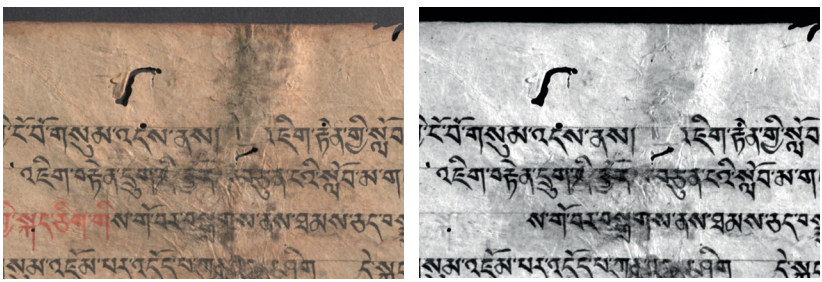

Fig. 3. NAK NyGB, Tha 8v; left: colour image of damage caused by mould; right: the recovered text at 940 nm (infrared).

[8] Regarding the disappearing of the red ink under infrared as can be seen in fig. 3 (also fig. 6), see below § 3.2.1.

3.2 Recovering Text Lost Due to Deliberate Erasure or Masking

The NAK set is incomplete (out of the presumably originally 37 volumes, only 35 volumes are present; moreover, there are two additional volumes).[9] On top of the problems observed in regard to the number of volumes (and to the volume numbers assigned to them), the set is also somewhat disorganised in regard to the sequence of the individual folios. Disorganisation related to the folios is reflected in numerous cases of confusion regarding the foliation and the subsequent scribal or editorial corrections of folio numbers throughout the set.

The organisational deficiencies regarding the assignment of volume and folio numbers clearly have their origin at the time of the set's production. A detailed description of all inconsistencies cannot be given within the framework of the present article, but in order to demonstrate the nature and the scale of the problem and how multispectral imaging can help us, at least in some cases, better understand the production process of the NAK set, select examples will be presented in the following. However, it should be pointed out, that in cases of erasure or masking, the results are at times not as good as in instances of damage caused by water or mould, particularly when the erasure involved the rubbing off of entire layers of the paper or when the masking was executed in the same type of ink that has been used for the writing.

3.2.1 Inconsistencies in the Assignment of Volume Numbers

While the volumes of the NAK set (presumably originally 37 in total) should have been assigned the numbers Ka–Ji (i.e. exactly like in the case of the Nubri edition), in several cases the same volume number has been assigned twice, and in two other cases the volume number has probably not been assigned at all:

---

[9] For more on the possibility of external volumes, see the article by Almogi, Kindzorra, Hahn, and Rabin in the present JIABS issue.

(a) In three cases two volumes have been assigned the same number, namely, Ja, Tha, and Ma. These are respectively referred to as Ja & Ja2 (=Zha), Tha & Tha2, and Ma & Ma2 (< Pha).

(b) Of the above three cases, the situation with Ma is a bit more complex. The volume we designate Ma2 (< Pha) is incomplete, the first 191 folios being missing. Moreover, the volume had been initially assigned the number Pha, which was then changed to Ma (fig. 6). The reason for this change is so far unclear, but perhaps two things should be pointed out in this regard: (i) Most of the texts contained therein are found in volume Ma of the Rig 'dzin Tshe dbang nor bu edition. (ii) All five texts contained therein (fols. 192–390) match the first five texts in volume Pha of the Nubri edition (fols. 1–212). Provided more pieces of the puzzle would surface in the future, these two facts could offer significant insight, not only as to the history of the transmission of this cluster of texts, but particularly in connection with the history of the transmission and production of the NAK set and perhaps of the entire Tibetan-Nepalese borderlands group of the NyGB.[10]

(c) Volume Wa may have not been initially assigned a number at all. Its first 68 folios have erroneously been assigned the number Tsa (in numerous cases, however, it seems to be Ca rather than Tsa). At some point, they all have been corrected to Wa, but folios 69 onward have remained without a volume number at all. The reason for this confusion is so far unclear, but as we shall see below, there had been additional confusion regarding the volume number Tsa/Ca.

(d) The last volume, which should have borne the number Ji, also appears not to have been initially assigned a volume number. The first two illuminated folios do not bear any volume number, while the following ones up to the tenth folio bear, once again (!), the volume number Ca. A closer examination discloses that the first two illuminated folios do not belong to this volume but are in fact the first two folios of volume Tsa, in which these, as well as all folios up to number 48, are indeed missing (the remaining

[10] A scheme for the grouping of the available NyGB editions according to the history of their transmission will be presented and discussed in Almogi forthcoming-a.

Fig. 4. NAK NyGB Wa: corrections of volume number (executed in different manners); top: Wa (< Tsa) 1r (left); Wa (< Ca) 2r (right); bottom: Wa (< Ca) 3r.

46 folios could not be located so far). Thus, for a reason that is yet to be clarified, the first two folios of volume Tsa were apparently misplaced and affixed to Ji already during the time of production. It is very probable that the misplacement occurred during the process of illuminating the folios, an undertaking which most likely had been executed in a separate location by artists who had been solely assigned with this task. If we now disregard the confusion between Ca and Tsa (which can be easily explained graphically), it appears that someone had started adding the volume number Tsa/Ca to the rest of the folios in the volume, but soon realised the error. (Note that only one folio is missing from volume Ji, so that we have two folios bearing the number 2.) Also interesting to note is the fact that in the Nubri edition, which clearly belongs to the same group of transmission and in which the assignment of the volume numbers is generally unproblematic, the last volume has been erroneously assigned the number Da instead of Ji (the latter of which is indeed confirmed by the *dkar chag* transmitted together with the Nubri set).[11]

[11] For more on this *dkar chag*, see Ehrhard 1997. An annotated critical edition of it together with the identification of the parallel texts in the NAK set will be published in Almogi (forthcoming-b).

Fig. 5. NAK NyGB Ji; left: illuminated folio 2r (folio originally belonged to Tsa), no volume number is given; right: 2r (i.e. the original fol. 2 of vol. Ji), volume number erroneously given as Ca.

The NAK set presents an illuminated edition of the NyGB, as the first two written pages of most of its volumes (i.e. fols. 1v and 2r) are written with golden ink on black paper and bear painted illustrations on both left and right edges.[12] Considering the great importance for the rNying ma tradition of the textual material contained in the NyGB and the fact that our set is an illuminated edition, there is no doubt that the production of this set had been conceived as a prestigious undertaking and that important political or religious local figures were behind it.[13] The poor organisational concept demonstrated throughout the set, however, seems to point to editorial and logistical skill deficiency. This is obviously unexpected from a project of such an importance, although it could perhaps be partly explained by the fact that it was apparently produced far away from the big religious and political centres.

One of the aims of our multispectral imaging has been to try and find out whether there is a repeated pattern of these irregularities that could help us better understand the reasons behind the organisational deficiencies. Carbon ink, which is the type of ink commonly employed in Tibetan manuscripts, remains the same throughout all the wavelengths used. While this makes the distinction between carbon and iron gall inks, for example, quite straight-

[12] On the problem of the irregularities observed in the illuminated folios in terms of quality (and to a certain extent also style), see the article by Almogi, Kindzorra, Hahn, and Rabin in the present JIABS issue.

[13] On the possible figure behind the production of the NAK set, see Ehrhard 1997.

forward, it also means that it is not always possible to distinguish between two different instances of carbon ink from each other. Fig. 6 shows an example of how two different types of black ink can be distinguished. This particular case is discussed in detail in the article on the material analysis of this same NyGB set (also published in the present JIABS issue), where it is shown on the basis of the material analysis that this correction (as do several others) has been written in a plant ink with traces of carbon. The multispectral images shown below support the finding by the material analysis.[14]

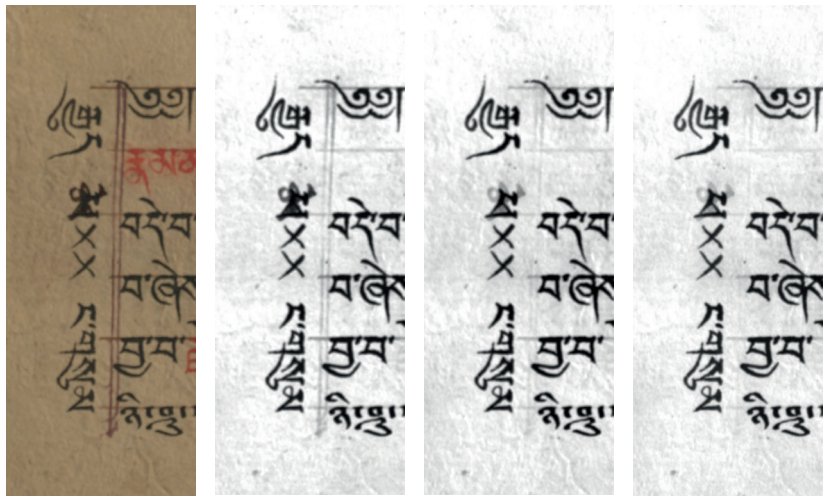

Fig. 6. NAK NyGB, Ma2 253r; from left to right: colour, 700nm, 870nm, 1050nm (infrared).

A particularly useful aspect of imaging with near infrared is that carbon ink reacts differently than iron gall and organic inks when illuminated. As the images move from visible red light (625nm) to the next, longer wavelength used (700nm), iron gall and organic inks will begin to disappear, and will become fainter the further into the infrared they are imaged under. Fig. 6

[14] For more on the corrections' ink used by the editors and proofreaders, see the article by Almogi, Kindzorra, Hahn, and Rabin in the present JIABS issue.

shows the character Ma (indicating the volume number) gradually disappearing, which reveals that it is written in a different, non- or not entirely carbon based, type of black ink than the rest of the text. This, in turn, supports the assumption that the correction of the volume number from Pha to Ma was made at a later stage, and not by the scribe at the time of copying. The same perhaps can be said in regard to all other corrections and additions that were written with plant ink, which could be thus clearly differentiated from those made by carbon ink. While the former were presumably made by editors during the proofreading, the latter are possibly corrections made during or immediately after the process of copying by the scribes themselves. One cannot of course rule out the possibility that some of the editors or proofreaders have also used carbon ink, and further evidence should therefore be taken into consideration in case of corrections executed in this type of ink, including palaeographical and codicological evidence. For example, in cases where corrections of folio numbers were merely executed in a small number of successive folios, while the numbers of the preceding and following folios bear no corrections, it is likely that the mistake in the foliation was discovered and corrected by the scribe (provided, of course, no palaeographical evidences speak against it). Likewise, in cases where the foliation of an entire text has been changed, it is more likely that the text was relocated by the editors, who then changed the foliation accordingly (unless, of course, the palaeographical evidence seem to contradict this assumption). In addition, in some instances, although the correction's ink is carbon-based, it is clearly distinguishable from the one used for the original writing, possibly one made according to a slightly different formula, which serves as a further evidence that the correction was made at a later point (see, for example, figs. 13, 15, 16, and the discussion following them).

Regarding the red ink used for rubrication seen in the above example, as one can see in the images (fig. 6, also fig. 3), the red ink visible in the colour image (left) appears to disappear under infrared (right), suggesting that it could be cinnabar, since the only other red ink used for rubrication found in the NAK set was iden-

tified as red lead, which absorbs near infrared and appears black.[15] As confirmed by the material analysis of the red inks found in the NAK set, cinnabar (pure or with lead oxide) seems to have been used for rubrication throughout (with an exception observed in volume La, where the one examined instance of red ink used for rubrication was identified as red lead).[16] These findings stand of course in agreement with the fact that cinnabar is known to have been the commonly used red ink for writing within the Tibetan cultural sphere.

3.2.2 Inconsistencies in the Foliation

The NAK set commonly has a consecutive foliation within the individual volumes – typically found in the left marginal caption of the recto of each folio – where the numbers are written out in words. The hundreds, however, are often represented by the logogram *x*. (In addition, the set is foliated with Indic numerals, but since it is probably an addition made by its later Nepalese owners, it has no relevance for our discussion.) Nonetheless, there are numerous examples of problems in the Tibetan foliations throughout the set, including irregularities in the sequence of numbers (which has often resulted in scribal or editorial corrections), occasional separate foliation, no foliation at all in some portions, and the usage of different conventions for the foliation. The following are several examples of these scribal and editorial deficiencies accompanied by multispectral images with the help of which the original foliation has been made legible (at least in part).

---

[15] Fiske and Stiber Morenus 2004.

[16] Cinnabar has been used throughout the set for the frames as well. The only exceptions observed are the red frames of vols. La and Ra, which were found to have been executed in a dye. For the material analysis of the black and red inks, see the article by Almogi, Kindzorra, Hahn, and Rabin in the present JIABS issue.

3.2.2.1 Disruption of and Irregularities in the Sequence of the Folio Numbers

In several occasions, folio numbers are either missing or repeated, while the text itself is complete (i.e. no folios are missing or duplicated). Notably, some of these irregularities involve bundles of 10 folios, which suggest that the distribution of labour among the (teams of) scribes possibly followed a system of 10-folio bundles. In volume Ka, for example, the folio numbers 390–399 are missing, although no text is actually omitted (i.e. the text on folio 400 is a direct continuation of the text on folio 389). In volume Ja2 (=Zha) the folios 171–181 have initially been given the numbers 187–197, which have then been corrected. Like in other cases throughout the set, the corrections of the numbers of these folios have been executed in various manners, including erasure, modification and addition of syllables, while the act of erasing has been executed either by way of peeling off of the ink (and paper) or by employing a deletion mark. The correction in folio 171 (< 187) – that is, from *x gya bdun* to *x don gcig* – was made presumably by way of erasing the syllable *gya*, modifying the syllable *bdun* to *don* by erasing the prefix *b* and the vowel *u* and adding instead the vowel *o*, and finally adding the syllable *gcig*, so that the number reads *x ~~gya bdu~~on gcig* (fig. 7, left). The peeling off of the ink (and paper) in this case is so deep that the initial number, apart from few fragments, is hardly recognisable. Unfortunately we did not take multispectral image of this folio. However, as we are clearly anticipating here the original number 187, we are able to reconstruct the no-longer legible number and the manner in which the correction was executed, partly with the help of the still visible fragments of the erased syllables. The correction of the original numbers 188–197 has been executed by inserting a deletion mark (dotted line) above the syllables to be deleted and by adding the correct number after them, so that the number in folio 172, for example, reads: *x ~~gya brgyad~~ / don gnyis* (fig. 7, right). Both methods have been used side by side for correcting folio numbers throughout the collection (a combination of the two is also observed). The former has been obviously employed in cases where the syllable to be erased and the syllable to be added in its place bore graphical similarities. While in the latter case, which

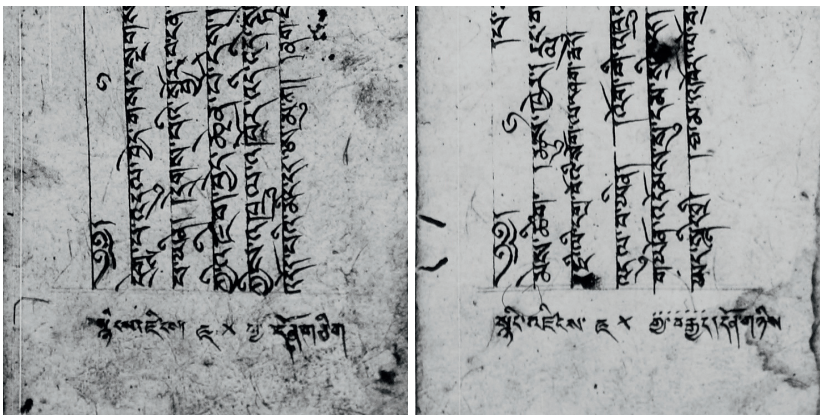

Fig. 7. NAK NyGB Ja2; left: 171r, *x don gcig* (< 187r, *x gya bdun*), correction by way of erasure, modification, and addition of syllables: *x ~~gya bdun~~on gcig*; right: 172r, *x don gnyis* (< 188, *x gya brgyad*), correction by employment of a deletion mark (dotted line) above the wrong number and insertion of the correct number, so that both are visible: *x ~~gya brgyad~~ / don gnyis*.

involves the employment of a deletion mark, the process of correction is transparent, in the former one, which involves the erasure and modification of syllables, we often cannot read the originally assigned folio number, and these were the cases in which we turned to multispectral imaging for help. Also to be noted is that we observe a change of the scribal hand in folio 171, which could serve as a further support for the hypothesis of a distribution of labour following a system of 10-folio bundles (note, however, that in folios 167–170 we observe a hand that is different from the one found in the preceding folios). Further support for this hypothesis found in this particular case is that the marginal title also changes from folio 171 onwards from simply *rgyud* to *snying 'dzings*, although it is the same text.

When taking multispectral images, two characters of the same substance will react similarly to any light they are illuminated with and will appear the same in the captured images. However, it may be possible to enhance the erased writing, and the difference between the clearer characters representing the correction and the original, erased ones may become more apparent, or at the least, both characters will be easier to read, as is shown in the numerous

examples provided below. Folios with erased writing pose an especially difficult challenge as the method of erasing used actually removes and peels off layers of paper. This is akin to physically cutting the paper with the ink out of the manuscript rather than simply erasing it.

The numbers of folios 320–336 in volume Ma have been corrected by way of erasure, during which layers of the paper have been peeled off to the extent that the originally assigned numbers have become completely unrecognisable. During our initial examination of the pertinent multispectral images, we have managed to determine with some level of certainly only a few of the erased numbers. On this basis, we carefully suggested that the original numbers assigned to folios 320–336 probably were 391–407. Examining each of the multispectral images once again, in several cases the anticipated erased numbers could be confirmed (figs. 8, 9, 10).

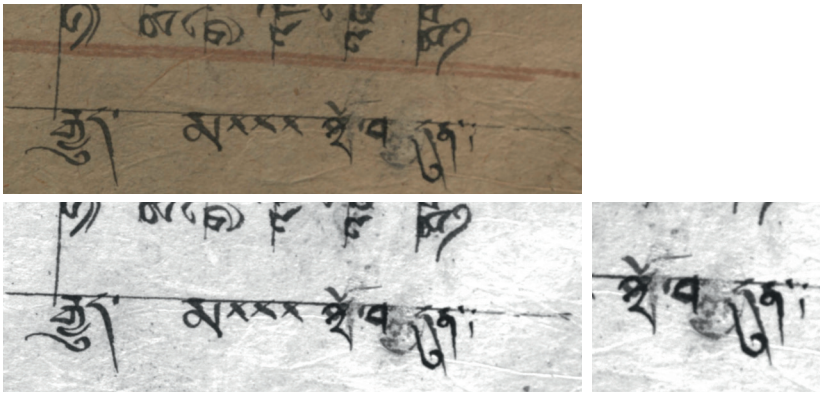

Fig. 8. NAK NyGB, Ma 327r, *xxx nyer*[17] *bdun* (< 398r, *xxx go brgyad*), correction by erasure and modification: *xxx ~~go~~nye brgya~~d~~dun* (note the partial erasure of the vowel *o* in *go*, thereby transforming it to *e*); 1050nm.

[17] Note that the syllable *nyer*, representing "twenty" is written by way of orthographic abbreviation (*skung yig*), in which the suffix *r* is written as a subscript.

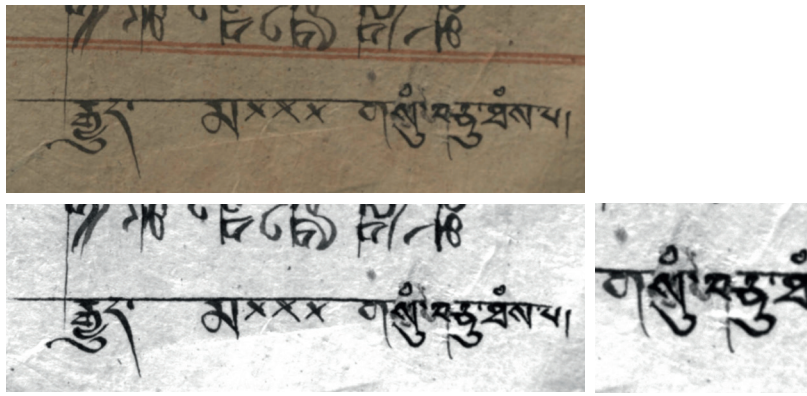

Fig. 9. NAK NyGB, Ma 330r, *xxx gsuṃ bcu thas* [=*tham*] *pa* (< 401r, *xxxx gcig*, note that there are no traces for the presumably erased fourth *x*), correction by partial erasure and modification: *xxxx g~~cig~~suṃ bcu thas* [=*tham*] *pa*; colour, 1050nm (infrared).

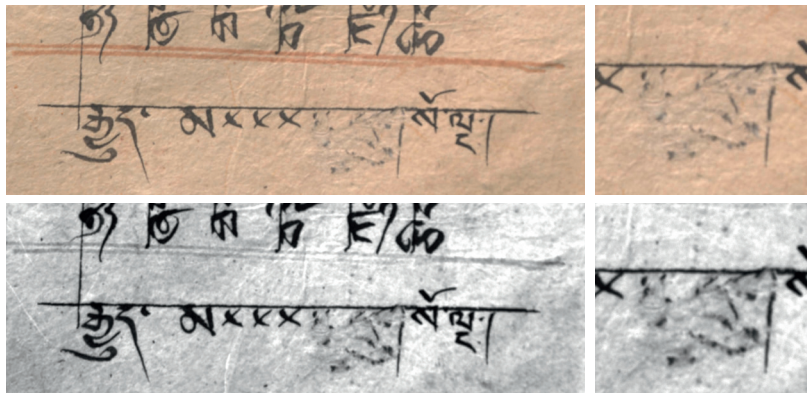

Fig. 10. NAK NyGB, Ma 335r, *xxx so lnga* (< 406r, *xxxx drug*), correction by erasure and addition: *xxxx ~~drug~~ so lnga*/; top: colour; bottom: Blue fluorescing into Red.

The fact that folios 320–336 contain a complete textual unit (i.e. the last text in this volume) and the fact that the hand is clearly different than that found in the preceding text suggest that they were written out independently from the preceding folios (either in the same or in a different location). Since there is no evidence for a correction of the volume number, we may assume that either there had been an error regarding the assignment of these folio numbers, which was

then corrected, or that the volume actually contained more texts (and hence more folios), which were then removed (i.e. those which would have originally made up folios 320–390), and the numbers of the remaining last folios, originally 391–407, had to be accordingly changed to 320–336. Currently we have neither codicological nor textual-historical evidence to support either of these assumptions. However, we may have here another instance supporting the hypothesis that folios were divided between the various scriptoriums or individual scribes in bundles of 10 (that is, in addition to the fact that the division of labour apparently also followed textual units consisting in individual texts or clusters of texts).

Another good example of recovering erased folio numbers that may provide further insight into the processes of compilation and production of the NAK set is the case of folios 82–87 in volume Ja2 (=Zha). The original numbers can hardly be deciphered even with the help of multispectral imaging due to the massive peeling off of the paper as a result of the erasure. It seems, however, that the syllables representing the "ones" have been corrected from "three" to "two," "four" to "three" and so forth, while it is unclear whether the syllable representing the "tens" (i.e. here the syllable *gya*, representing 80) is at all a correction. Provided the syllable *gya* does not represent a correction, it appears that in this case the scribe has erroneously skipped one number (since the first 81 folios are missing it is impossible to know in which folio the error occurred), and as a result folios 82–87 were first erroneously assigned the numbers 83–88, which were then corrected once the error has been discovered. However, since the space between the syllable *ja* (signifying the volume number) and the folio number is smaller than observed elsewhere, it is possible that the syllable *gya* has been added as a part of the correction and the original folio numbers were 3–8 (> 82–87), which would mean that this textual unit initially had a separate foliation (which is conceivable considering the length of the text in question). This, in turn, would suggest that the correction of the folio numbers in this case was not the result of a scribal error, but of compilatory changes. The image below (fig. 11) shows the correction of the folio number 85. Due to the massive peeling off of the paper in the course of the erasure, the initially

written number – presumably 86 or 6 – is hardly recognisable even with the help of multispectral imaging.

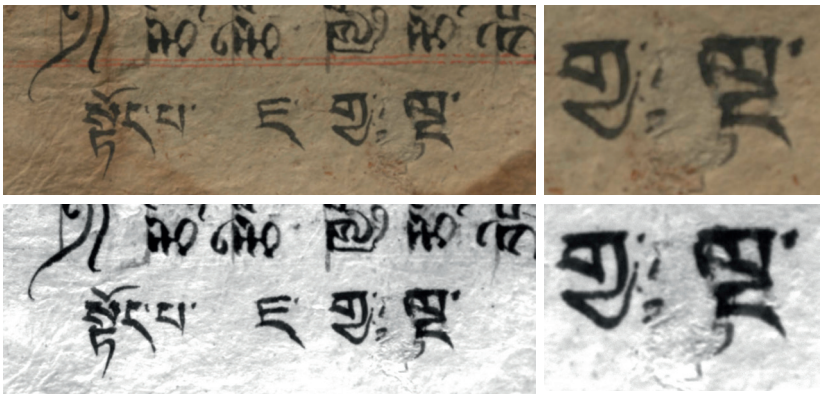

Fig. 11. NAK NyGB, Ja2 (=Zha) 85r, *gya lnga* (< 86r?, *gya*? *drug*?/6r?, *drug*?), colour, 1050nm (infrared).

Notably, folio 87r (< 88r?/8r?) is the folio on which the work ends, and it appears that originally the folio number was followed by the syllable *byon* (thus reading either *gya brgyad byon* or *brgyad byon*). The syllable *byon*, as is well known, suggests that this folio was the last folio of a codicological unit (fig. 12), and in the NAK set it is commonly employed to mark the last folio in a volume (due to the lack of uniformity in the set regarding various codicological features, however, exceptions cannot be ruled out also in this case).

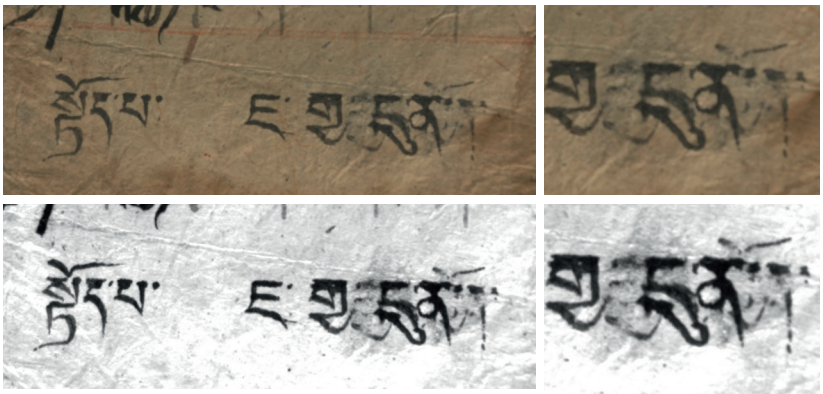

Fig. 12: NAK NyGB, Ja2 (=Zha) 87r, *gya dun* [=*bdun*] ~~*byon*~~ (< 88r?, *gya*? *brgyad byon*/*brgyad byon*); 1050nm.

Indeed, the following work – which presumably began on folio 88 (folios 88 & 89 are unfortunately missing) and in which the hand is clearly different than the one observed in the previous text – appears to have originally had a foliation starting with 1, which was then changed to 88 (< 1), 89 (< 2), and so forth. While the corrections of the numbers on folios 90 (< 3) and 91 (< 4) were made by erasing and overwriting (fig. 13), from folio 95 (< 8) to 104 (< 17) they were made by employing a deletion mark (i.e. dotted line above the syllables to be deleted), so that both numbers are clearly visible (fig. 14), or by a combination of erasing, modifying and adding (fig. 15).[18]

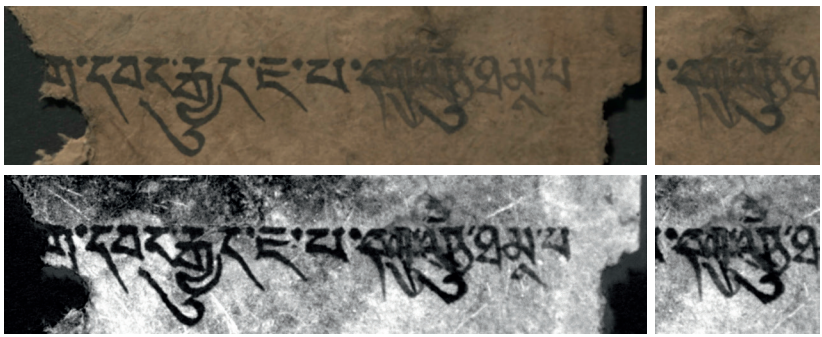

Fig. 13. NAK NyGB, Ja2 90r, *dgu bcu tham pa* (< 3, *gsum*); top: colour; bottom: processed ICA images.

[18] Note that the left halves of folios 98–100 are completely broken off, so that we could only assume that the corrections on these folios have been done in the same way. The left edges of the remaining folios are likewise partially broken off, particularly the bottom corner, so that often the correction is only partly legible (as in fig. 14). In some cases, in which the correction was completely lost, the correct folio numbers were written in the upper corner of the folio to the left of the marginal title by an unknown hand (possibly during the microfilming by the NGMPP).

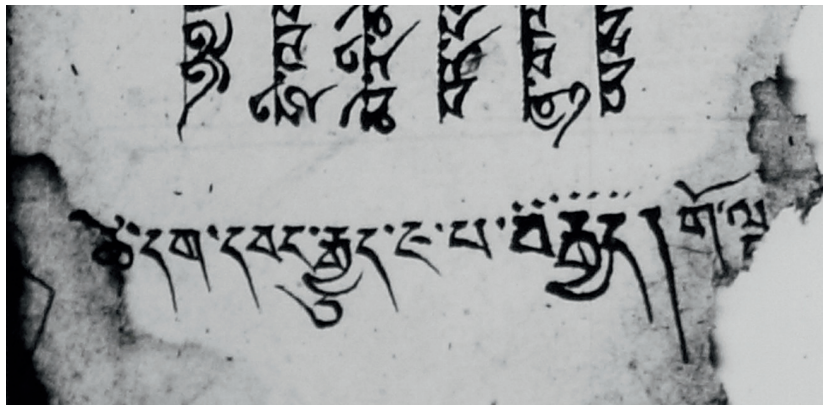

Fig. 14. NAK NyGB, Ja2 95r, *go lnga* (partly broken off) (< 8, *brgyad*), correction by deletion mark and addition: ~~*brgyad*~~ / *go lnga*.

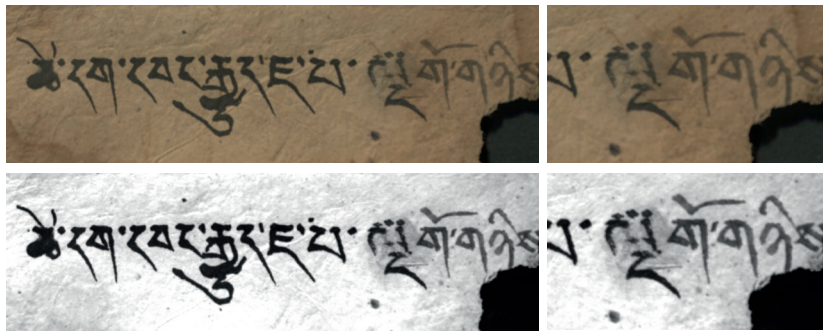

Fig. 15. NAK NyGB, Ja2 (=Zha) 92r (< 5), 1050nm (infrared).

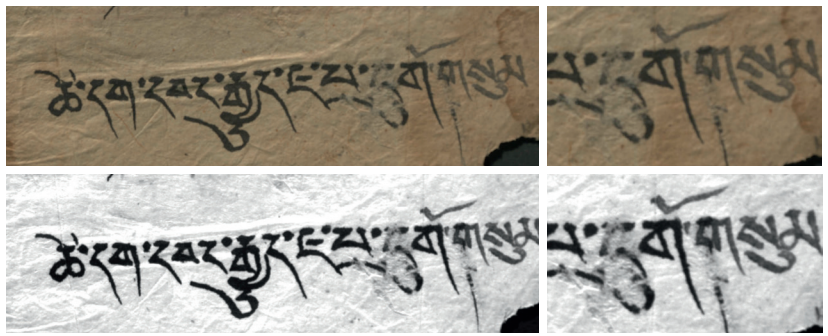

Fig. 16. NAK NyGB, Ja2 (=Zha) 93r, *go gsum* (< 6, *drug*), correction by erasure, modification and addition: ~~*dru*~~*go gsum*; 1050nm.

The corrections to the folio numbers in volume Ja2 (=Zha) presented in the above two examples could have different reasons, although they occur in successive folios. Regarding the correction of the folio numbers 82–87, if we assume the original folio numbers to have been 83–88, since the ink used for the correction is of the same type as the one used for the initial writing, albeit slightly different (i.e. carbon-based, but perhaps of a slightly different formula?), and since the hand could have possibly been the same (the corrected text is too short to allow a thorough palaeographical comparison!), it is possible that it goes back to scribal error and that it was the scribe who at some point detected the error and corrected it. If we, however, assume the original numbers to be 3–8, we are clearly confronted here with issues concerning the process of compilation of the entire volume. Nonetheless, until the missing first 81 folios are recovered, we will not be able to provide a more decisive explanation in this regard.

Moreover, folios 105 onwards seem to have borne the correct number from the outset, since no corrections are evident. This may suggest that the decision to add the work(s) contained in the first 87 folios to this volume (provided such a decision has taken place) was made either (a) after the copying of the initially first 17 folios (now folios 88–104), in the case that the foliation was done simultaneously with the writing of each folio, or (b) after the foliation of the first 17 folios in the case that the foliation was done only after the completion of the volume (or at least of each textual unit). In the example shown above (fig. 16), the multispectral images suggest that the ink used for the correction (i.e. the vowel *o* in *go* and the syllable *gsum*) is slightly different from that used for the main text and the initial foliation. This seems to be confirmed also by images of the corrections of the other folio numbers in this particular cluster (such as of the number 92 shown in fig. 15). Since the ink is clearly visible under infrared illumination, it must be carbon-based as well. However, it is reflecting slightly more visible and infrared light than the neighbouring text, making it appear lighter, which could suggest it is from a different batch of ink with a slightly different composition. This, in turn, would suggest that the corrections of these folio numbers were not executed at the time of copying, but

some time afterwards. The above two examples, like the problem concerning the number assigned to this volume (i.e. Ja instead of Zha), are clearly further testimonies to the complex compilatory process of this particular volume.

Another example of foliation irregularities is found in volume Ha, where folio number 219 is followed by folio numbers 201, 202, and so on (i.e. instead of 220, 221, and so on). We have not taken multispectral images of these instances, but they will be nonetheless presented here in order to demonstrate one further example that could provide a further evidence that the NAK set is not simply a mere copy of another NyGB edition, but is the result of a more complex, partly independent compilatory process. It is obvious that from folio 201 onwards there had initially been a separate foliation beginning with the folio number 1, and that the logogram *xx*, representing "two hundreds," is a later insertion. The insertion of the logogram *xx*, however, has not been executed in a uniform manner, obviously due to space limitations (fig. 17). That this group of works initially had a separate foliation is notably also supported by the fact that the equivalent works in the Nubri edition likewise have a separate foliation. However, unlike in the Nubri edition, where the last three works have each a separate foliation, in the NAK set they have been foliated successively (i.e. [20]1–[2]55).

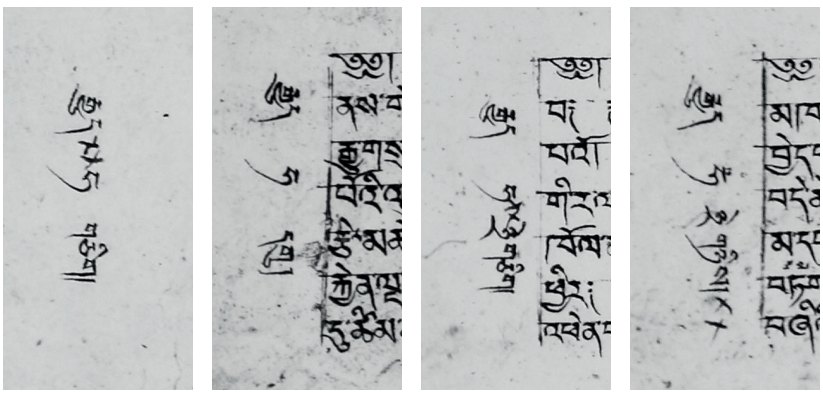

Fig. 17. NAK NyGB, Ha, from left: 201r (< 1) [=220], *xx* inserted before the vol. no.; [2]09r (< 9) [=228], *xx* not inserted at all; 221r (< 21) [=230], *xx* inserted after the vol. no.; 222r (< 22) [=231], *xx* inserted after the original folio number.

As to the question concerning the origin of this last section containing three works – that is, as regard to whether its production and the correction of the foliation were done in a different scriptorium than the rest of the volume – a material analysis, particularly of the inks, could have perhaps provided some clues. Due to time constraints, however, the undertaking of such an analysis in these folios was not possible.

3.2.2.2 Different Conventions of Foliation

The foliation is likewise inconsistent in terms of the conventions used throughout the set. The above example is only one illustration of this phenomenon. While in that case the inconsistencies are clearly due to corrections and to the limitation of space resulting from them, in other instances the reasons are not always clear. In volume Ca, to give one more example, there are several conventions of the foliation. While up to folio 100 we have the usual foliation with numerals expressed in words written in *dbu can* (with the logogram *x* representing each hundred) on the marginal caption commonly found on the left side of the recto of each folio (and in Indic numerals on the verso), from folio 101 onwards various conventions are found (whereas the common marginal caption is missing). The numbers there are given in either Indic numeral graphemes or in Tibetan words written in *dbu med* (the ones in *dbu med* seems to be found only among the first folios), while in both cases the "hundreds" are represented by the logogram *x* (on some folios the *x* stands to the right of the numerals instead of to their left, and in some cases, however, it is missing altogether). In some other instances all numbers are given in numeral graphemes. Moreover, occasionally the folio number is completely missing from the left margin of the recto. In addition, one also finds a parallel numbering in Indic numeral graphemes on the top left corner of either the recto or verso or both, starting from 1 (i.e. the folio numbered 101 on the margin is numbered 1 on the left corner, etc.). Whether folios 101 onwards were written down at the same time that the entire set was produced (possibly in a different scriptorium), or whether they were a later addition is unclear. In any case, it seems that the numbers found on the top left corner were assigned first but were

provisional, and that the numbers found in the margin are a later addition. These instances of irregularities in the foliation present an ideal case for combining further material analysis of the inks and multispectral imaging, which may offer some answers to the questions previously posed.

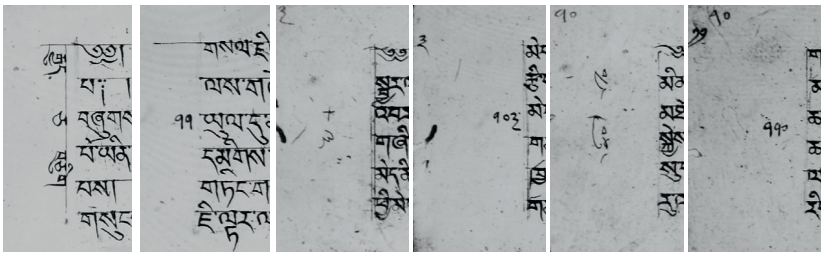

Fig. 18. NAK NyGB, Ca: from left: 11r: in Tibetan words in dBu can within the marginal caption; 11v: in Indic numerals in the left margin; 103r: in Tibetan numerals (hundred represented by *x*) in the left margin plus in Indic numerals in the upper left corner reading 3 instead of 103; 103v: in Tibetan numerals in the left margin plus in Indic numerals in upper left corner reading 3 instead of 103; 110r: in Tibetan words in dBu med in the left margin plus in Indic numerals in the upper left corner reading 10 instead of 110; 110v: in Indic numerals in the left margin plus in Indic numerals in the upper left corner reading 10 instead of 110.

4 Multispectral Imaging of Sanskrit Palm-leaf Manuscripts

In the discipline of classical Indology we have to deal with the fact that a plethora of important texts are still 'hidden' in manuscripts without having ever been critically edited, translated or otherwise studied in a critical-historical fashion. Moreover, the manuscripts are often stored in such a way that their condition is continually deteriorating. Therefore, it is only natural that manuscripts have largely been used as textual witnesses, that is, as mere containers of texts in a certain state of transmission, rather than as products of material culture that deserve to be examined in their own right. In our ongoing research work, the main emphasis is laid on the latter approach, as will be shown in some more detail below. However, given the situation sketched above, the more traditional scholarly objective remains still very important.

In this section, samples from a corpus that consists of (a) five manuscripts written in the famous Indian Buddhist monastery

Vikramaśīla and (b) fifteen to twenty seemingly closely related manuscripts are presented.[19] One of the five Vikramaśīla manuscripts can serve as a good example for the importance of manuscripts as containers of textual witnesses. In the National Archives of Kathmandu, folios 2, 3, 5–9, 11–15, 18 and 19 of the originally 19 folios of the Buddhist Tantric text *Trisamayarājaṭīkā* are preserved under the accession number NAK 5–20.[20] We are dealing here with the 12th century *codex unicus* of an anonymous commentary on the *Trisamayarājatantra*. The latter work is one of the earliest scriptures belonging to the esoteric-ritualistic branch of Buddhism. No manuscript of its original Sanskrit text is preserved. The commentary, in turn, is only extant in Sanskrit; no translation into Tibetan or any other language is known.[21] Moreover, as can be seen above, more than 20% of the folios are lost. It goes without saying that it is of crucial importance to recover, if possible, at least those letters which have become illegible by damage, for instance, from water or mould.[22] Accordingly, all extant (and accessible)[23] folios have been imaged with the multispectral imaging system described previously in this paper. In this way, Harunaga Isaacson, who is preparing a critical edition of the *Trisamayarājaṭīkā*,[24] received valuable support in his endeavour. In § 4.1, a sample is given of the successful recovery of some damaged and therefore indecipherable letters.

---

[19] For much more detailed information on this corpus, see the article by Delhey, Kindzorra, Hahn, and Rabin in the present issue of the JIABS.

[20] Many stray folios from other manuscripts of our corpus can also be found under this accession number. Moreover, it should be noted that folio 4 of the *Trisamayarājaṭīkā* is preserved as stray folio in a manuscript which is stored in Tibet.

[21] Tsukamoto et al. 1989: 68; Isaacson 2007: 308 n. 50; cf. also the Internet reference below (n. 23).

[22] Luckily, there is no loss of text due to broken off edges or holes in these extant folios.

[23] I.e. all extant folios except folio 4 (for which see n. 20 above).

[24] See http://www.tantric-studies.uni-hamburg.de/en/research/projects/trisamayaraja.html, last visited 13-11-2014.

The main objective of our ongoing research project, however, is to gain information about the physical organisation of knowledge in Vikramaśīla and about the history of its manuscripts, including their production and use in this monastery as well as their fate after they had been taken away and brought to other places. For this research, scribal colophons, notes in the margins of the folios or on folio 1 recto[25] are as important as the wording of the main body of text. The scribal colophons – which are, of course, particularly interesting for the earliest 'life' of the respective manuscripts and the place they occupied in the manuscript culture of our East Indian monastery – follow directly at the end of the texts, only separated by one to several segmentation marks. No cases of an illegible colophon had to be dealt with.

Secondary notes placed on folio 1 recto are of special interest as traces of secondary uses and the subsequent history of the respective manuscript. It is, for instance, interesting to note that some of the manuscripts of our corpus bear titles in the Tibetan language. The first page of a Sanskrit manuscript of the *Catuṣpīṭhanibandha* (preserved as stray folio in KL 231), for instance, contains, as has already been noted by Péter-Dániel Szántó,[26] the Tibetan translation of the title of the work (written in the Tibetan dBu med, or cursive, script): *gdan bzhi rgyud kyi 'grel pa 'dra* ("this looks like a commentary of the *Catuṣpīṭhatantra*"). This either is indicative of the fact that the manuscript had first been brought to Tibet and only afterwards to its present storing-place in Kathmandu or suggests that a Tibetan visitor to the Kathmandu Valley made use of these Sanskrit documents.[27] Regarding the illegible parts of these notes, no decisive progress was made by multispectral imaging. An

[25] In our palm-leaf manuscripts, folio 1 recto was usually left blank in the beginning, with the initial scribal invocation and the text only starting on the verso page. The empty space on the recto page was later on often filled up with manifold different kinds of texts and notes.

[26] Szántó 2012: vol. 1, 100.

[27] Regarding the first alternative, it should be noted that it is also possible that the manuscripts were first brought to Kathmandu, then to Tibet and finally back to Kathmandu again. I (M. Delhey) will deal with these questions in detail on another occasion.

example will be given in § 4.2, accompanied by an explanation of the reasons why multispectral imaging was not a good fit for cases like this.[28] The situation is, however, entirely different with some marginal notes, as the samples of §§ 4.3–4.5 will show.

4.1 NAK 5–20, Trisamayarājaṭīkā, folio 15v

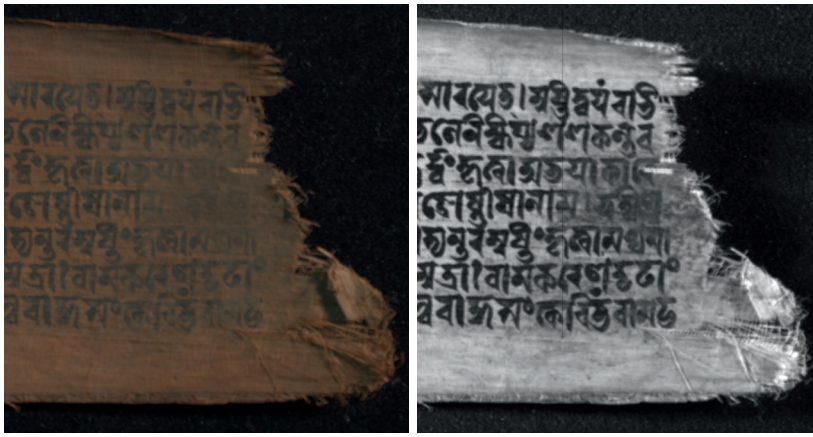

Fig. 19. NAK 5–20, *Trisamayarājaṭīkā* 15v, colour and at 940nm (infrared).

In this example (fig. 19), the broken off parts from the right margin of the folio are irretrievably lost. The main body of text is not affected by this loss. However, some of the last letters in the lines have become hard to read. In particular, the last three letters in line 4 are indecipherable to the naked eye. Imaging under near infrared, particularly under 940nm, helps the reader distinguish between the palm leaf, which reflects the infrared radiation, and the carbon ink, which absorbs it. In this way, we were able to recover the last letters of line 4 with a fairly high degree of certainty. Obviously, the text contains here the Sanskrit word *dakṣiṇa*° (used as the first member

[28] It might be useful to mention briefly two other similar examples: (1) Folio 1r of a manuscript of the *Laghutantraṭīkā* (KL 225) contains an easily readable secondary Sanskrit verse of an edifying nature and beneath it an illegible Tibetan note. (2) The folio *Catuṣpīṭhanibandha* 1r in KL 231 contains, besides the legible remark already cited above, a second Tibetan note which is only partly decipherable and rather enigmatic (see Szántó 2012: vol. 1, 100 f.). In both cases, no significant progress could be made by multispectral imaging.

of a compound) meaning "right" (as opposed to left). We are dealing in this text passage with a description of esoteric ritual gestures (*mudrā*). Therefore, the word *dakṣiṇa* makes sense here – without, however, having been the only possible reconstruction, before it was uncovered by multispectral imaging.

4.2 KL 231, Ratnāvalī Hevajrapañjikā, folio 1r

Fig. 20. KL 231, *Ratnāvalī Hevajrapañjikā* 1r; colour and at 1050nm (infrared).

The Sanskrit manuscript of the exegetical Tantric text *Ratnāvalī Hevajrapañjikā* belongs to the five items in our corpus that can be shown to have been produced in the East Indian monastery Vikramaśīla, probably during the 12th century CE. The blank folio page 1 recto contains some illegible text in Tibetan language and script (fig. 20). The improvements made by multispectral imaging are recognisable but not sufficient to render the text decipherable.

Multispectral imaging aids in recovering lost and unreadable writing by making it possible to distinguish different inks, paints, etc. from one another and the support they are written on. As long as each has a different reflectance and fluorescence signature, those differences can be captured and exploited. For example, enhancing the difference between faded, unreadable writing and the support it is written on is what makes that writing visible again. The closer two inks are to one another, the more difficult it is to distinguish between them, and it becomes even more difficult, if not impossible to differentiate between layers of the same ink.

In cases such as those mentioned above, the obscuring ink and the writing ink are too similar to distinguish from each other, and it remains unclear whether the writing ink has been smeared rather than erased (or smeared in the process of erasing), or whether another ink was added and then smeared. In either case, the smeared ink has firmly settled into the grain of the palm leaf and is just as strong and dark as the original writing. Although imaging in infrared appears to have improved the separation of ink and palm leaf, it is not enough to make the text readable.

4.3 NAK 5–20, Trisamayarājaṭīkā, folio 18v

In the conventional colour photographs as well as in personal inspection, the marginal remark written with a red substance in the top of the folio page was only partly decipherable. The example below (fig. 21) shows four different instances of the same page. The first is an attempt to show how the note appeared under the ambient lighting conditions in the archive. The second image is the colour image taken by the multispectral imaging system using the 39MP E6 sensor and six different visible wavelengths (compared to the three used in commercial cameras, the top image). From the 20 images taken, the blue fluorescence image (that is, blue light absorbed by the manuscript and reemitted as green) showed the best initial results. After processing using PCA (see § 2.2), the final image in fig. 21 was obtained, with the best contrast and legibility.

With help of the new, multispectral images the decipherment of the whole remark poses no great problems anymore. The Sanskrit text runs in Roman transliteration as follows: *trisamayarājaṭīkā iva bhāti*. This can be translated as: "[This] seems to be *the* [commentary entitled] *Trisamayarājaṭīkā* (or '… *a* commentary on the *Trisamayarāja*[*tantra*]')." The note is written in Devanāgarī script and has certainly been written in Nepal, centuries after the manuscript came into being (the main body of the text exhibits a Proto-Bengali hand of the 12th century). It is probable that this remark has been added by a late pre-modern or early modern scholar, collector, archivist or librarian. The immediately following folio contains the original colophon in which the text title *Trisamayarājaṭīkā* is

mentioned. Therefore, it is somewhat astonishing that the author of this remark seems to have been rather uncertain whether his assumption was correct. Perhaps the person who wrote the note was rather unfamiliar with the script of the original manuscript. At any rate, it is possible that the writer of this note or another person later tried to erase it, because it was considered superfluous in view of the explicit colophon. Such an attempt to erase the note might be responsible for the fact that it has become partly illegible.

Fig. 21. NAK 5–20, *Trisamayarājaṭīkā* 18v.

4.4 NAK 5–20, Trisamayarājaṭīkā, folio 9r

Like in the example dealt with above (§ 4.3), the marginal note found in the present example (fig. 22) is written with a red substance in Devanāgarī letters, possibly by the same hand. Without the help of multispectral imaging, the letters are completely illegible. In the new image, however, the note can be deciphered without any prob-

lems whatsoever, using colour space manipulation, explained previously in § 2.2 and with further details of this example at the end of § 4.5. It simply consists of the word *catuṣpīṭhanibandhaḥ*. This is the title of a Buddhist Tantric exegetical text. However, this is obviously an erroneous identification. This folio page contains again text from the *Trisamayarājaṭīkā*. The error is probably due to the similarity, particularly regarding the layout and also the contents, to a manuscript of the *Catuṣpīṭhanibandha*, which is also part of our corpus and has already been mentioned above in another context. It seems that the author of this remark or another person has recognised the mistake and has (quite successfully) tried to erase it.

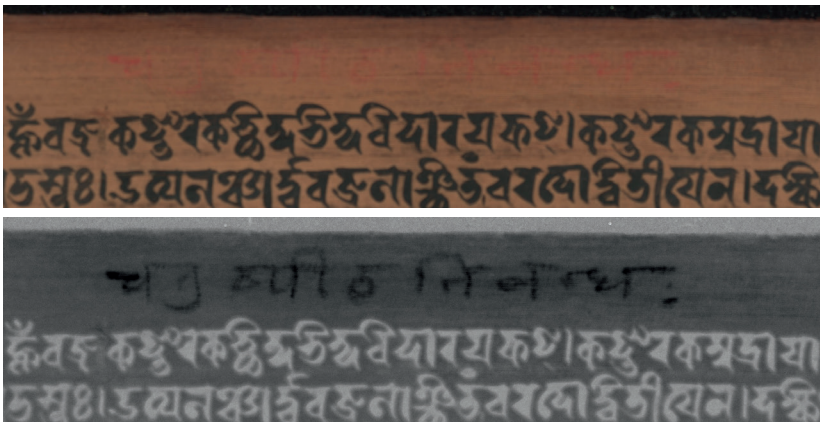

Fig. 22. NAK 5–20, *Trisamayarājaṭīkā* 9r – recovered with Lab colour space in photoshop.

4.5 NAK 5–20, Trisamayarājaṭīkā, folio 8r

This sample (fig. 23) is for two reasons particularly interesting. To begin with, the marginal note is completely invisible to the naked eye. Accordingly, we only came to know about its existence serendipitously thanks to the images produced with the new technology. Moreover, unlike in the two cases presented in §§ 4.3 and 4.4, this marginal note can, from a palaeographical point of view, be fairly old.

The remark is very hard to decipher even after the use of our sophisticated technical device. However, it seems to be an ordinary

marginal correction of a scribal mistake in line 3 (see fig. 23, last image, immediately after the binding hole). This is suggested by the fact that the marginal note obviously ends with the number 3. It was a widespread custom in India to add the line number after a marginal note in order to make clear to which place in the text the note refers. However, the faulty letters in line 3 have also been overwritten; the *post correctionem* reading is *iyan tāvat*. The correction in the upper margin seemingly offers a similar or even the same text, as far as one can judge from the decipherable parts. If this is true, one probably has to assume that the marginal correction was added first; then the correction was made again directly in line 3 and afterwards the now superfluous marginal correction has been erased. The correction in line 3 is clearly written in the same script as the whole text, that is, in the so-called Proto-Bengali script of the 12th century. If our assumption is true, the uncovered marginal note must belong to the same period. It is difficult to say why exactly the same correction was first entered in the margin and then also in the text. One possible reason is the fact that the correction in line 3 is (apart from the intervening binding hole) immediately preceded by more corrected text (see fig. 23, last image). When the first corrector or a second one noticed that more text is faulty than originally recognised, he might have decided to make the other corrections in line 3 rather than in the margin and to use this opportunity to integrate the original marginal correction in line 3 as well. However, one should perhaps leave this matter open, until further similar cases of correction have been analysed.[29]

---

[29] In this connection, attention may be drawn in passing to a manuscript of the *Laghutantraṭīkā* which also belongs to our corpus of manuscripts as referred to in the beginning of § 4. As already noted by Szántó (2012: vol. 1: 100), two very similar folios numbered 17 of a manuscript of this text are preserved in different bundles in the Kaiser Library (KL 134 and 225). Szántó (ibid.) has also already mentioned that both folios end with the same words. However, they also *begin* with the same words. Moreover, one of these two folios has numerous, partly very long, additions (of erroneously omitted text, as it seems) and corrections of letters in the margins (which are partly very hard to read), while the other version of this folio seems to contain the words and letters of the notes as well (note, however, that I [M. Delhey] have only checked it in some cases), but integrated at the appropriate places in the

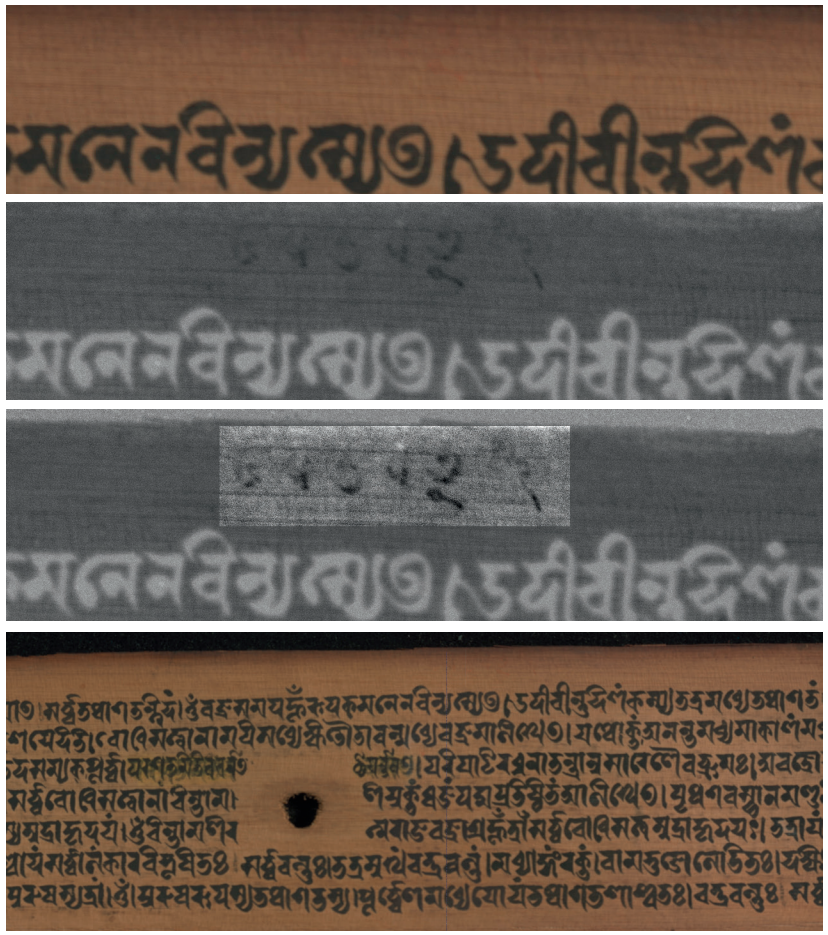

Fig. 23. NAK 5–20, *Trisamayarājaṭīkā* 8r.

running text. It is most natural to interpret this phenomenon in the following way: This folio has been rewritten after the marginal notes have been made. In this particular case the reason for this procedure seems to be quite obvious. The many corrections in the margins made the use of the folio rather inconvenient. Additionally, aesthetic considerations might have been involved. Unfortunately, these interesting folios came to my (M. Delhey) attention only after our return from Kathmandu. It would be worthwhile to examine these folios in detail, including the attempt to recover more text from the annotations with multispectral imaging.

As mentioned above, the correction displayed in fig. 23 was invisible and not even known to be there until work began on the title in fig. 22. Since three folios had been imaged at a time, and the two pages in figs. 22 and 23 were in sequence, both folios were present in the image when the Lab space colour balance adjustments were made. Figs. 22 and 23 were processed using only colour images, suggesting that similar results could be obtained without use of multispectral imaging. These images, however, were constructed from six visible bands rather than the usual three (red, green and blue), and the monochromatic nature of the camera means that no mosaicing method was necessary to combine the three images, preserving resolution and colour accuracy.

It is entirely possible though, that with a decent, commercial camera or even with images obtained from a library or archive, (although this would require working with images with as little compression as possible) one would be able to achieve comparable results for enhancing coloured inks using methods similar to the one outlined here.

5 Concluding Remarks

In this article, we have presented various examples of the successful application of multispectral imaging of Tibetan paper and Sanskrit palm-leaf manuscripts, ranging from increasing legibility to recovering entirely invisible text, including cases when this has been completely unexpected. We have demonstrated that multispectral imaging can be very helpful in recovering text lost due to various kinds of damage, including damage to the writing support and ink caused by water and mould and damage caused by deliberate erasure or masking. However, we have also shown that the text cannot always be recovered, either because the damage of the manuscript is too severe or due to the nature of the damage (for instance, masking of the text with identical ink).

We hope to have also been able to show that multispectral imaging can be helpful in recovering important textual witnesses and in shedding light on codicological questions like processes of compilation and productions of manuscripts, particularly regard-

ing possible division of labour between the scribes or scriptoriums, and editorial processes of proofreading, correction and (re)organisation. One does not need to have a very lively imagination to think of cases in which the insights might be of tremendous historical relevance, involving cases such as instances of deliberate change and manipulation by later users.

General Abbreviations

CMKY	Cyan, Magenta, Black and Yellow
CSMC	Centre for the Study of Manuscript Cultures, University of Hamburg
ICA	Independent Component Analysis
KL	Kaiser Library, Kathmandu
NAK	National Archives, Kathmandu
NyGB	*rNying ma rgyud 'bum*
PCA	Principal Component Analysis
RGB	Red, Green and Blue

Bibliography

Almogi, Orna (forthcoming-a). "The National Archives' (Kathmandu) Set of the *rNying ma rgyud 'bum*: Some Clues for Its Origin and the History of Its Transmission." In Orna Almogi (ed.), *Manuscript and Xylograph Traditions in the Tibetan Cultural Sphere*. Indian and Tibetan Studies Series. Hamburg: Department for Indian and Tibetan Studies, University of Hamburg.

Almogi, Orna (forthcoming-b). *The Collection of the Ancient Tantras* (*rNying ma rgyud 'bum*): *The History of Its Emergence*, *Production*, *and Transmission*. Indian and Tibetan Studies Series. Hamburg: Department for Indian and Tibetan Studies, University of Hamburg.

Easton, Roger L., Kelbe, David. 2014. "Statistical Processing of Spectral Imagery to Recover Writings from Erased or Damaged Manuscripts." *manuscript cultures* 7: 35–46.

Ehrhard, Franz-Karl. 1997. "Recently Discovered Manuscripts of the *rNying ma rgyud 'bum* from Nepal." In H. Krasser, M. T. Much, E. Steinkellner, and H. Tauscher (eds.), *Tibetan Studies*: *Proceedings of the 7th Seminar of the International Association for Tibetan Studies*, *Graz 1995*. 2 vols. Vienna: Verlag der Östrerreichischen Akademie der Wissenschaften, vol. 1, 253–267.

Fiske, Betty and Linda Stiber Morenus. 2004. "Ultraviolet and Infrared Examination of Japanese Woodblock Prints: Identifying Reds and Blues." *The Book and Paper Group Annual* 23: 21–32.

Isaacson, Harunaga. 2007. "First Yoga: A commentary on the *ādiyoga* section of Ratnākaraśānti's *Bhramahara* (Studies in Ratnākaraśānti's tantric works IV)." In B. Kellner, H. Krasser, H. Lasic, M. T. Much, and H. Tauscher (eds.), *Pramāṇakīrtiḥ. Papers dedicated to Ernst Steinkellner on the occasion of his 70th birthday*. Wiener Studien zur Tibetologie und Buddhismuskunde 70.1. Vienna: Arbeitskreis für Tibetische und Buddhistische Studien, Universität Wien, part 1, 285–314.

rNying ma rgyud 'bum (NyGB). NAK = National Archives Ms Edition. 37 (?) vols. (incomplete). Stored at the National Archives Kathmandu, Nepal (Ms no. 5). Microfilmed by the Nepal-German Manuscript Preservation Project (NGMPP), 1989: Reel Nos. AT 1/1–AT 25; Nubri = Nubri Ms Edition. 37 vols. In the possession of Lopon Gyurmed, Nubri (Samagaon), Nepal. Microfilmed by the Nepal-German Manuscript Preservation Project (NGMPP), 1993: Reel Nos. L 426/4–L 448/1.

Szántó, Péter-Dániel. 2012. *Selected Chapters from the Catuṣpīṭhatantra*. 2 vols. DPhil Thesis. Oxford: University of Oxford.

Tkalcic, Marko and Jurij F. Tasic (eds.). 2003. "Colour spaces: perceptual, historical and applicational background." In *The IEEE Region 8 EUROCON 2003. Computer as a Tool*. 22–24 *Sept. 2003. Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia. Proceedings*. 2 vols. Piscataway, NJ: IEEE, vol. 1, 304–308.

Tsukamoto, Keishō 塚本 啓祥, Yūkei Matsunaga 松永有慶, and Hirofumi Isoda 磯田熙文 (eds.). 1989. 梵語仏典の研究 IV 密教経典篇 (*A Descriptive Bibliography of the Sanskrit Buddhist Literature*. Vol. IV: *The Buddhist Tantra*). Kyoto: Heirakuji Shoten.