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Restoration, Reconstruction, and Revisionism: Altering Our Virtual Perception of Damaged Manuscripts

Abstract: The answers to questions about the boundaries of digital retrieval of damaged manuscript content are extremely fluid, dependent on ethical and aesthetic expectations and the intended end-use of the edited images. Digital intervention is currently the only way to restore the contents of many manuscripts to usability. The chapter examines the Forensic Reconstruction of damaged manuscript leaves through a combination of various digital and analog evidence; in particular, what is achievable, the ethical constraints and practical decisions informing the end result, and the palaeographical value of the outputs.

Recent work on reconstructing the Sadler Partbooks (Bodleian Library MSS Mus. e. 1–5) found the team of editors reconsidering the poorly-defined and little-travelled field of ethics in digital restoration/reconstruction in search of a solution that would allow the end result of their work to benefit the greatest constituency of end users. Even in an ideal world of unlimited time and money the answers to many questions have extremely fluid boundaries, dependent not only on ethical considerations but also on aesthetics, expectation and the intended end-use of the edited images. Adding the constraints of time and cost that come with working in the real world to idealised goals of content-recovery may result in digital editors feeling as if they have been painted into a corner. Being forced to form a policy on the type of work done on an image by simple logistics can however be both illuminating and liberating. So many manuscripts from so many periods have suffered damage that make them unreadable – from acid burn to scraping or dismemberment and re-use as binding reinforcement – that digital intervention is currently the only way to recover their contents, so we need to be

Note: I am grateful for the opportunity to re-examine the corpus of edited images in the DIAMM collection that now spans two decades of work from my earliest experiments in the digital repair to the most recent innovations. All the edited images shown here are the work of the author unless specifically noted otherwise.

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informed about the tools and techniques we have at our disposal and their practical viability.

It is now over 21 years since the Digital Image Archive of Medieval Music (DIAMM) came into existence, and over 20 years since we 'captured' our first digital image of a manuscript. In the first phase of the project we aimed to digitise every fragment in the UK up to 1400, adding fragments from other periods if they were in libraries we were already visiting. Complete manuscripts were avoided at this stage because the technology available for imaging at this level required a scanning back; with this technology a shot of a single leaf could take around 6 minutes, or 15 minutes under UV light (because of the increased exposure time required), making the digitisation of large numbers of leaves impractical because of cost. The second phase extended our remit to European fragments and intact manuscripts in the UK, which involved shoots of several large manuscripts such as the Eton and Lambeth choirbooks.[1] Further phases focused on creating an acceptable online delivery mechanism but added manuscripts and fragments as permitted, while fruitful collaborations with other projects created a steady feed to the image repository. It became clear fairly soon that the website was used as much for access to the metadata as for the images, and attention shifted more proactively to that side of the content.[2] DIAMM is now the only reference source that lists all known polyphonic sources up to 1600, having added over 350 newly discovered fragments and intact manuscripts to the lists published in *RISM* and the *Census Catalogue*, which were the only comprehensive listings prior to DIAMM.[3]

A distinguishing aspect of the project from its inception was not only early adoption of the use of high-resolution digital imaging at a time when many major institutions had not yet embraced it, but also the possibility that in the digital medium the images could be manipulated and edited if the original manuscripts were too damaged to read. We generally use digital surrogates much as we used analogue ones in the past: simply as a representation of the manuscript as it looks to the naked eye, but to the digital editor these images represent a far richer repository of information than analogue photographs, since the depth of information they store far outstrips that visible to the naked eye. Image-processing

1 Windsor, Eton College Library MS 178, and London, Lambeth Palace Library, MS 1.

2 Being unable to update the online content with any ease was a major problem, solved by a new technical partnership that resulted in an entirely 'live' database. Contributions and corrections are submitted daily by a user base that reached just under 30,000 in the last year, with a high of 4,500 genuine hits during February 2019.

3 See *RISM* B/IV, 1–4; Wathey 1993; *Census*.

software can differentiate between shades of one colour that the unassisted eye cannot, and this is fertile ground for the retrieval of information that has apparently been lost to natural decay or wilful damage.

We might assume that the further we go back in time, the more fragmentary our witnesses become, but the proportion of fragments to complete sources up to 1400 is very similar to the proportions 1400-1550.

After 1550 there is a dramatic increase in the number of surviving complete sources, somewhat inflated by the rise in partbook copying (where what would previously have been one manuscript is now 4–8 separate books), and the consideration of individual partbooks in a set by DIAMM (for technical and practical reasons such as geographic dispersal) as individual manuscripts rather than being grouped together as single sources. The level of wilful damage increases as we go back in time, partly because of the structural usefulness and reusability of parchment as opposed to paper: techniques for retrieving what survives become more drastic the earlier the source. The advent of paper as the preferred medium for writing brought its own problems, particularly those of acidity of materials, but also the long- and short-term fragility of paper compared with the relatively tough animal skins it replaced.

There is a persistent belief that what survives of medieval polyphony is only the tip of a much larger iceberg of lost works, but this impression is belied by the number of fragmentary sources for which there are concordances. It is rare for a new source to be discovered that preserves completely unknown works.[4] It seems, in polyphony at least, that the iceberg may be inverted, and what has survived in terms of repertory is considerably more than what has been lost, it is merely the number of witnesses that have been depleted.

1 Digital intervention

The majority of users of digital images tend not to do anything more than look at them because a high-resolution colour image can be enlarged and is therefore significantly better than its analogue counterpart. What happens though when the new surrogate still does not deliver what is needed to decipher the text?

Early experiments in digital recovery were often far more successful than anticipated: by using the capacity of the software to differentiate between very similar colours, ink marks that could not be seen by the naked eye could be

4 Cuthbert 2009.

retrieved. Even uninvested in the outcome however, an editor can be misled by what they think they can discern, so the most difficult aspect of digital recovery is attempting not to recover that which we expect to see, but leaving the machine to find what is actually there. On the whole, sampling colours from pen marks that are undisputed avoids the trap of restoring to expectation rather than on the basis of what is unquestionably there. British Library Add. Ms. 41340, a lifted pastedown, yielded an unexpected block of text in a void in the music that was picked up by colour-selecting based on the visible note-heads (Fig. 1).

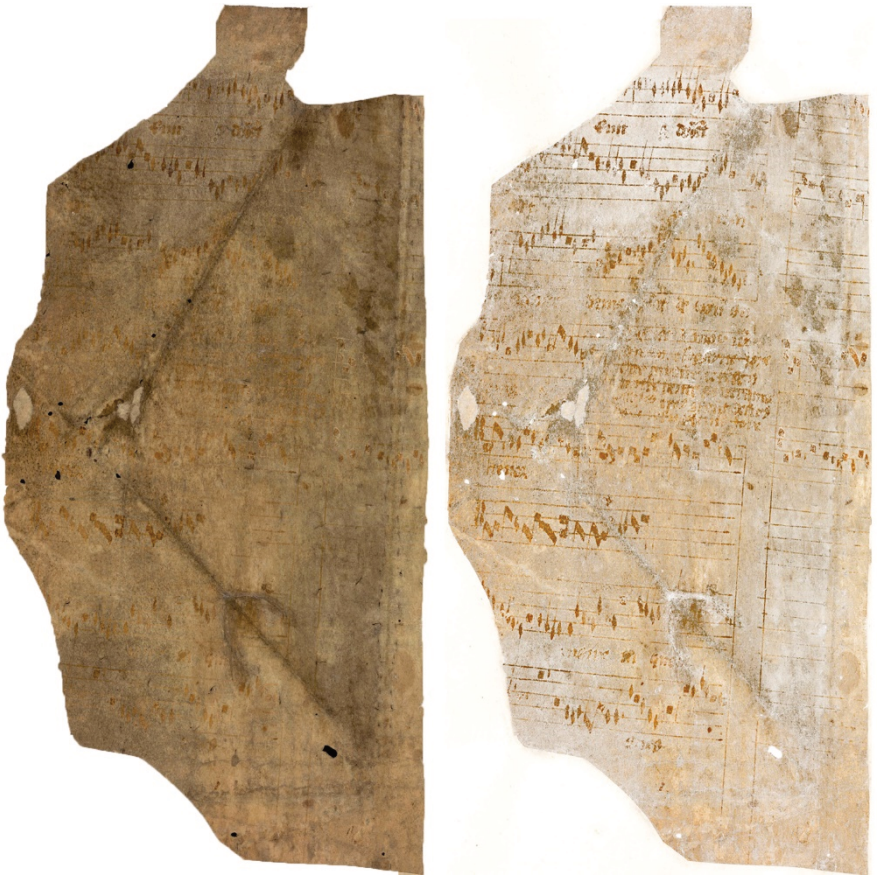

Fig. 1: London, British Library, Add. Ms. 41340; © London, The British Library: digital editing by Andrew Wathey.

A more complex array of problems arises in cases where the parchment leaves of a music manuscript have been reused, and the overlaid text may be as important to its own adherents as the lost text is to those who wish to read that. Until the advent of high-resolution colour imaging ultra-violet (UV) was considered the only useful form of photographic investigation for palimpsests. However, UV created the issue that the overwriting would darken as much as (or more than) the palimpsest, causing frustrating levels of interference in what could be read. This was the case particularly when the overlaid text was similar in colour and chemical composition to that which it replaced. Oxford, Corpus Christi College, MS 144 showed that, as long as the resolution was sufficient, RGB images were more useful than the UV, since they could be edited to remove the overwritten text, and the colour selection subtlety of the software could 'find' the lost text just as well as the UV had.[5] Staged reconstruction of the image below (Fig. 2) shows removal of the overwriting by replacing it with pattern created from the background, then lightening of the background to improve contrast and finally an editorial overlay in which the voids in the note-heads caused by the missing overwriting are filled in manually.

When I first started editing digital image to improve readability I proposed that a restored image should leave the user in no doubt about the fact that it did not represent the original in its present state. This was a response to concern expressed by a single library that if people visited a manuscript after seeing improved images of it they might blame its condition on poor husbandry, so the use of unlikely colours (green, purple) was implemented when selecting and highlighting or retrieving faded or erased ink. Thus, anything which was revealed by a digital process is visually signalled to the end user so that they can evaluate the data based on whether it has been artificially enhanced or not. This method had the unanticipated benefit of making recovered pen-strokes easier to read than simply improving their natural colour since it enables the brain to extrapolate more information than it can when attempting to differentiate between similar colours. At the time I felt that images manipulated in this way were not suitable to publish in print as a permanent record of the document because they looked crude and, despite the improvement in legibility, they seemed to imply disrespect of the original document in a way that might invite criticism.

5 RGB is the term used for digital colour images, and is based on the Red-Green-Blue colour space used for capture by digital cameras. Print outputs are usually converted to CMYK (Cyan, Magenta, Yellow, blacK).

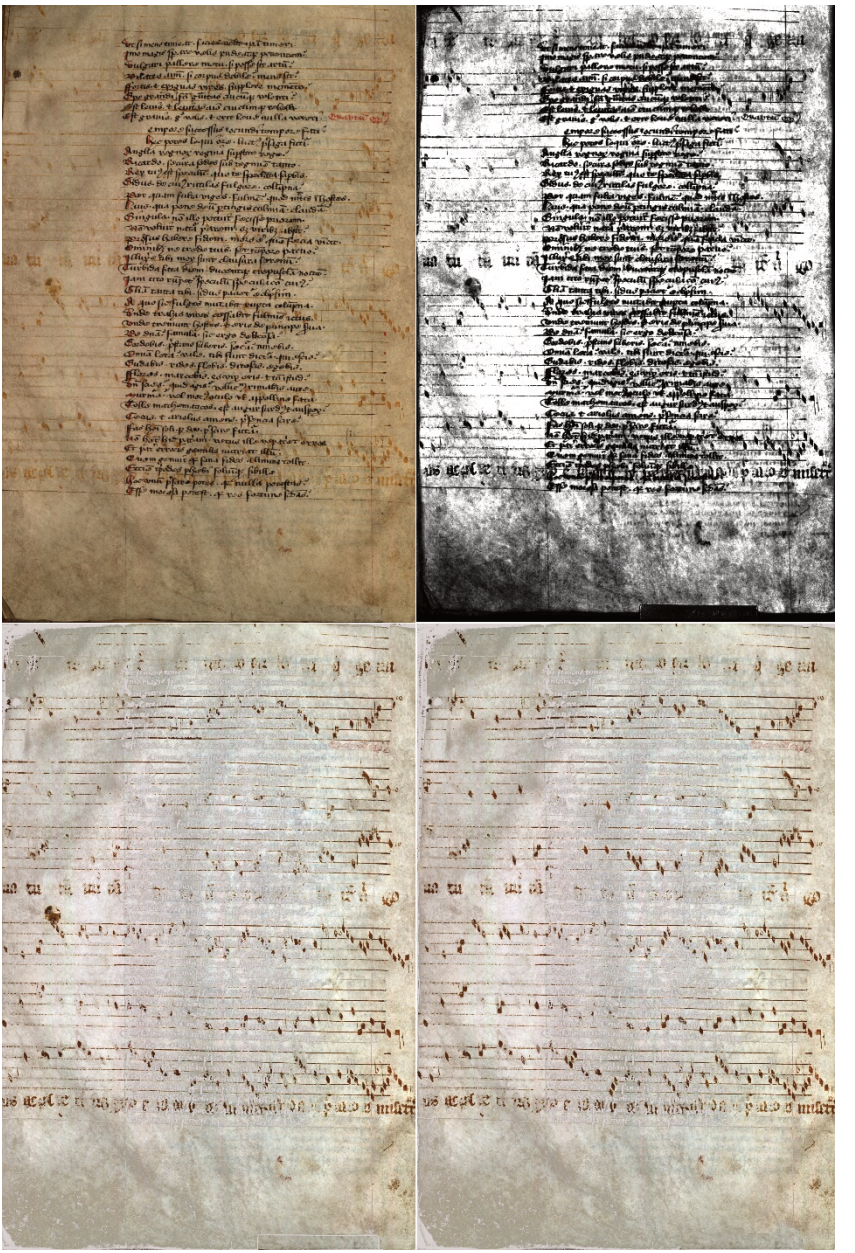

Fig. 2: Oxford, Corpus Christi College, MS 144, from top left to bottom right: original RGB; UV; edited RGB; editorially repaired RGB (gaps in noteheads filled); © Oxford, Corpus Christi Library.

The rear cover of a document wrapper in Stratford (Fig. 3) provides another example of the way in which the greater acuity of the software over the eye may return unexpected results, and the way in which 'incorrect' colour supports the reading. The bright colours allow the reader to differentiate between background and retrieved ink marks very easily, particularly if the background colour is also eliminated.

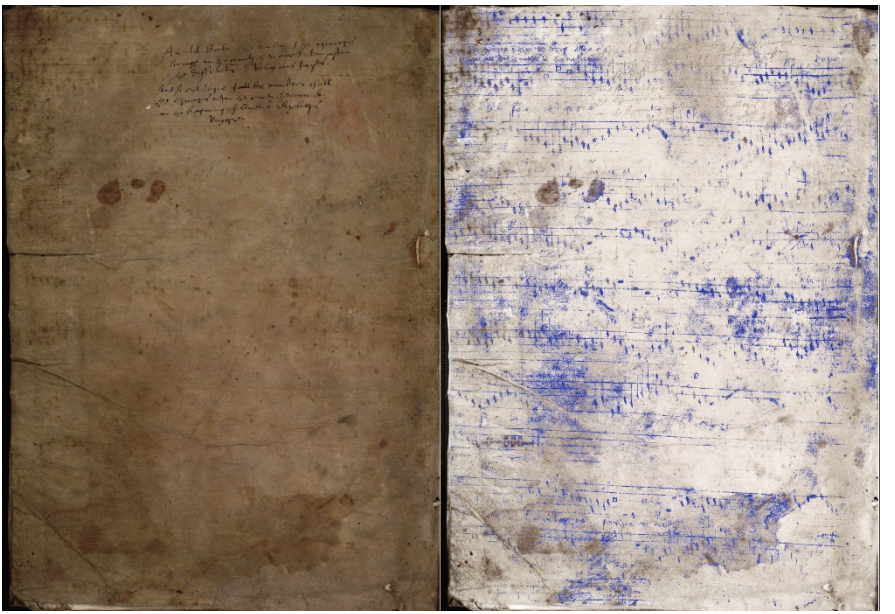

Fig. 3: Stratford, Shakespeare Birthplace Trust, DR37 Vol. 41, back of wrapper, outside face: before and after digital editing; original image © Stratford, Shakespeare Birthplace Trust.

The rising scale of notes visible in the centre of the top third of the page correlates to notes written on the reverse, so are the result of showthrough. Showthrough on the verso may therefore provide an additional clue to the writing on the front that is rubbed off, so instead of ignoring (or eliminating) it these colours may be selected, inverted, and used to confirm or improve the reading on the front. Using information from another page changes the nature of the editorial intervention, even if that page is the reverse of the primary, although we are still using layers of photographic evidence that originate in the source. Lifting notation offset onto a binding board and reuniting it with the lifted endpaper involves a similar process, but this is one of conflation rather than adjustment of what is there but too subtle to be seen by the naked eye (Fig. 4).

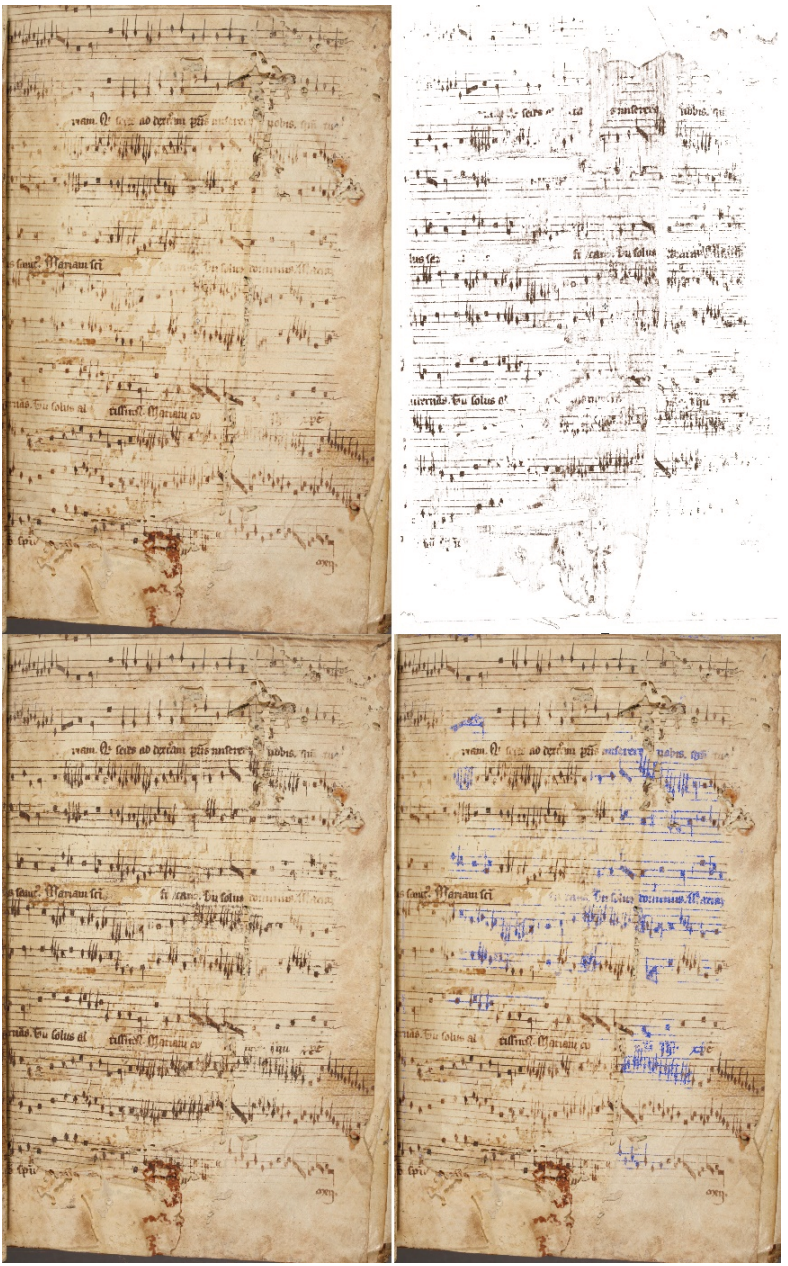

Fig. 4: Oxford, Bodleian Library, Bodley 384: original; notation lifted from the board and flipped; original plus overlaid offset; colour selection instead of overlay; © Oxford, Bodleian Library.

The lifted offset has many problems in this case: the position of the pastedown shifted while *in situ* so there is double offset in places. When inverted and overlaid on the image of the pasted leaf considerable distortion is apparent, probably caused by the lifting process. This made re-laying the offset on its parent leaf not only difficult but unsatisfactory, since it involved so much reshaping that the exact positioning was questionable. Even after considerable time attempting to align the layers note-by-note the result conveys little or nothing that could not be seen on the original image and in some cases creates confusion where none existed before. A limited colour selection focussed on the more damaged areas of the leaf seems more revealing.

There are techniques that require considerable editorial decision-making and active intervention with respect to individual notes and these are usually employed with manuscripts that have suffered the most extreme forms of damage. As a result these techniques are used where the reading is most in question and therefore most at risk of misinterpretation, or perhaps 'over-interpretation'. In such cases one might decide that the editing must be supervised or supplemented by an expert reader whose knowledge of the repertory enables the editor to make critical judgements about content. However, a potential issue of expert readers is that they might be misled by their familiarity with the context, and therefore by their expectation of what *should* be written on a leaf.[6] The person who undertakes the digital recovery should therefore not be the person who is most invested in the outcome. The digital reconstruction of Hugh Aston's *Te Deum* in the Sadler partbooks rendered the only possible reading at one disputed point as one that was technically flawed.[7] The Sadler witness may of course be a poor transmission of a better original, now lost, but there is no doubt that the recovered reading is what the original scribe recorded.

While musicologists have been tinkering with digital manuscript images on an individual basis for the last 20 years, the software has benefited from continuous development towards automating repair processes. For example, if I wish to remove something on an image that I have decided is a later accretion, the software will now offer me context-sensitive erasure. The results are extraordinary both in the subtlety with which they sample the surrounding material to create a likely solution and the ease with which the process is accomplished (select,

6 More than once I have found myself faced with a source that emphatically does not record what the expert believes it should. Copying errors are uncommon, but they do occur, or perhaps the composer just didn't write what we now consider to be grammatically appropriate.

7 Oxford, Bodleian Library Mus. e. 1–5.

delete), allowing us to hide foreign objects holding the leaf in place or wormholes with equal facility. Usually, the smaller the area, the more convincing the result (Fig. 5).

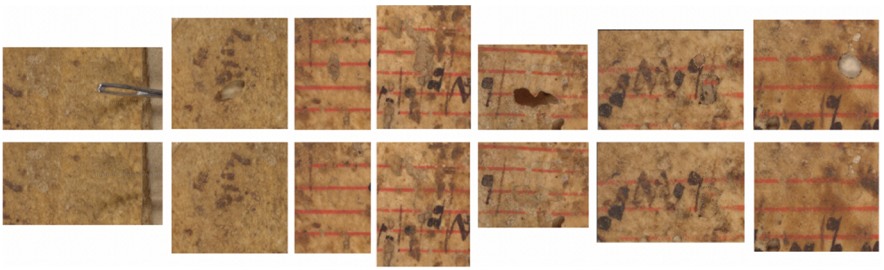

Fig. 5: Worcester, Cathedral Archives, MS Q19, front endpaper, details: before/after clippings of computationally-calculated repairs; © Worcester, Cathedral Archives.

If the solution offered by the computation is unsatisfactory the process can be repeated with varied selections until it renders a result that is more acceptable (Figs 6 and 7).

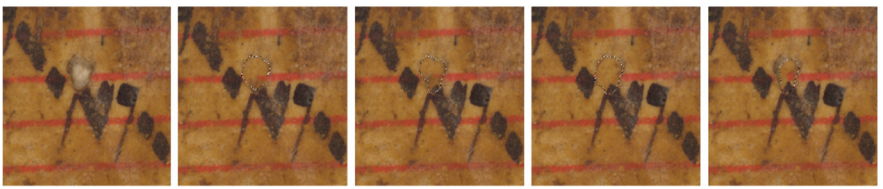

Fig. 6: Worcester, Cathedral Archives, MS Q19, front endpaper, detail: wormhole with different solutions offered by Photoshop software; © Worcester, Cathedral Archives.

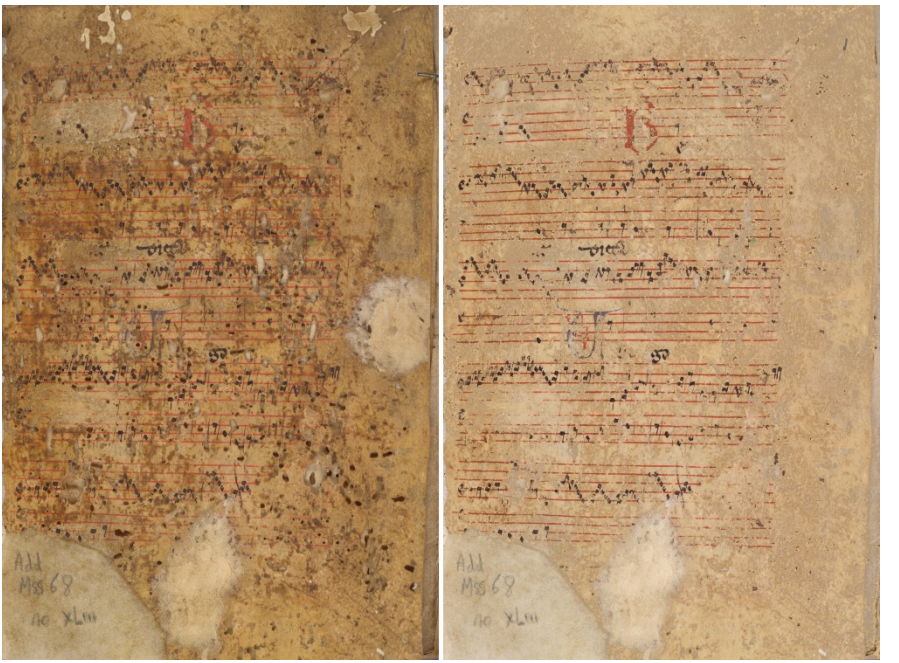

Fig. 7: Worcester, Cathedral Archives, MS Q19, front endpaper: original, and edited version with content-aware machine-generated wormhole repair and manually defined colour-fill; © Worcester, Cathedral Archives.

In this case, an improvement to the texture of the document allows us to read it more easily. However, this relatively facile process is fraught with problems. A wormhole that has been 'fixed' may have destroyed a notehead, but without the wormhole the user is not alerted to the potential for a lacuna. If a repair is good enough the reader is too easily misled into believing there was nothing there in the first place, so an editor could very easily present a desired result that falsely represents the witness. Fig. 7 is offered here as an example of the extent to which an entirely computer-determined reconstruction, with no human input aside from the selection of the area that needs to be repaired, is becoming increasingly possible. When used alongside the original, this edited version may support a better reading, but *only* alongside the original.

Binding strips can suffer from both glue damage and stretching and shrinkage that makes even conjunct strips difficult to re-align. They can however be 'warped' back into shape using a distorting tool, though this is fundamentally

cosmetic, since it is not difficult to adjust the eye to read across a disjunct break in a leaf as long as there are no lacunae (Fig. 8).

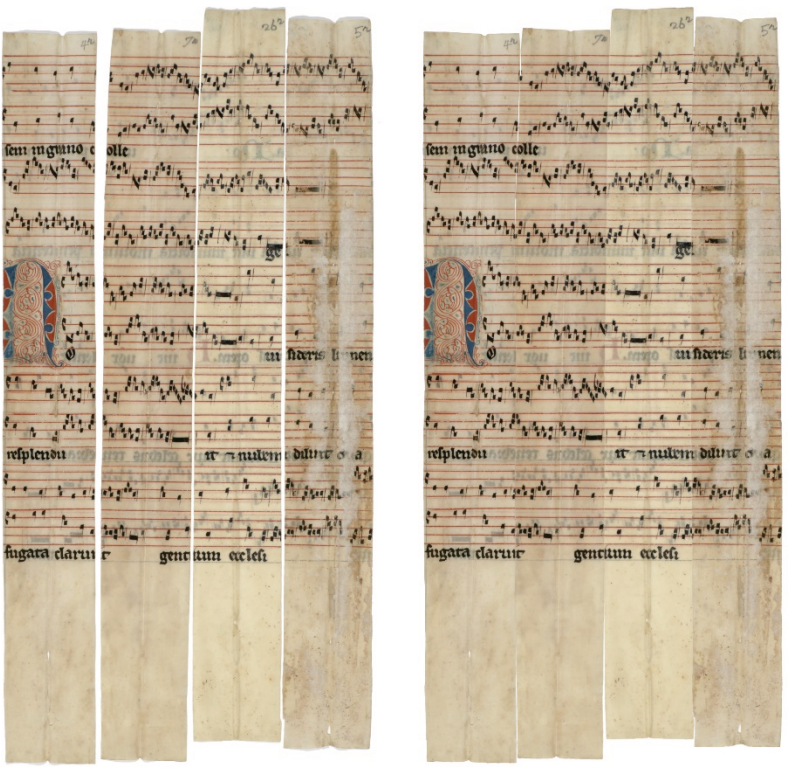

Fig. 8: Cambridge, Jesus College, QB1, fragment H: laid side by side and digitally joined with slight warping to improve fit; © Cambridge, Jesus College.

Although a colour master image is considered essential in recovering lost text digitally, a surprising amount can be achieved if the only available image is monochrome. In the case of Harvard, Houghton Library Typ. 122, the leaf is pasted to an endboard and could not be lifted. The library's conservation department treated the leaf to make it temporarily more translucent, so that music on the back could be seen (in reverse), but this brief experiment was only recorded in monochrome. Once scanned to the digital medium the grayscale images could be edited to support the reading of at least some of the music on the hidden face of the leaf.

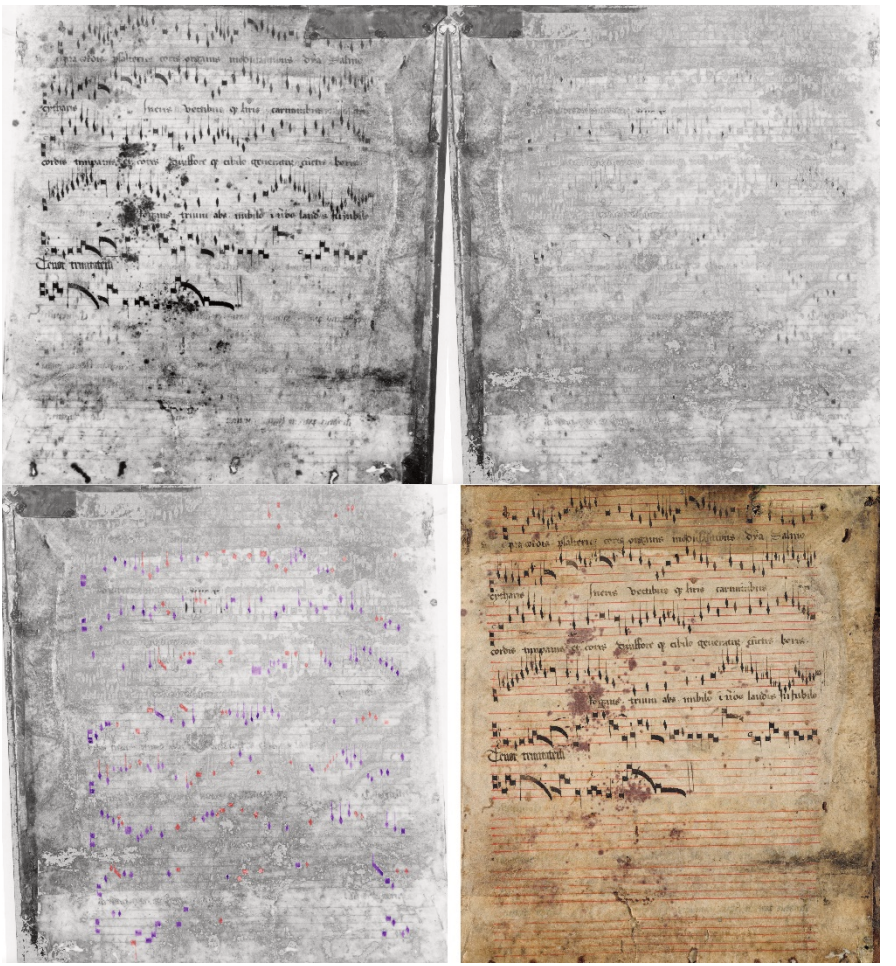

Fig. 9: Harvard, Houghton Library, Typ. 122; © Harvard, Houghton Library.

Fig. 9 shows the retrieval of data from the scan of the glossy b/w image taken when the leaf was treated; clockwise from the top left image: the monochrome image; mirror-inversion with the surface writing obscured/eliminated (though retained as a reference layer); the same image with notes that the editor could make out from the reverse picked out in two colours representing two levels of certainty. The stave lines appear to align closely between front and reverse; RGB image taken recently, the leaf still pasted down.

On the colour image there is an issue that cannot really be resolved without being able to see the reverse of the leaf, namely that some notes that may appear to be showthrough are in fact offsets from a lost facing page which is apparent in the confusion in the stave lines towards the foot of this page.

Different types of digital imaging essentially replicate what has been available in analogue imaging for the last century, the primary focus being accurate colour imaging. What has changed is the facility with which the images can be manipulated or combined, and this is what might provide new information. The types of documents where multispectral imaging (MSI) might be effective are extremely few (limited almost entirely to palimpsests or heavily rubbed sources), so the use of this technique has always been very limited, regardless of the complexity of the process and special equipment required. Multispectral imaging is not new, but there have been significant developments in the last decade, primarily emanating from the field of astronomy, where interference bandpass filters can be fine-tuned to pass extremely limited light spectra, allowing their use to identify single elements such as hydrogen or helium by their spectrum values when viewing or capturing the light output of a star. Contrary to its title, multi-spectral work is actually limited spectral imaging, but the name comes from the process of shooting a series of images either using different bandwidths of light generated by single-spectrum lighting or interference bandpass filters that limit the range of light reaching the camera from full-spectrum lighting. The 'multi-' in the title refers to the number of images taken, each of a limited band in the full RGB light spectrum. The technique will not always reveal information and there are cost and handling implications that must also be considered before attempting this specialised process.

2 The impact and repercussions of new techniques

The imaging work of Andreas Janke on the San Lorenzo palimpsest (SL) is one case where multispectral techniques have proven extremely successful, demonstrating the benefits of combining an old (but newly effective) technique with a new medium.[8] The images offer an unparalleled opportunity to access the contents of a manuscript that has been considered to all intents and purposes lost. The images are reproduced in an edition by John Nádas and Andreas Janke (who

8 Florence, Archivio del Capitolo di San Lorenzo, MS 2211, 'Campione de Beni del 1504'.

established the methodology) in bright prime colours that separate the different layers of activity in the manuscript.[9] This is, I believe, the first publication in which the editors have decided to reproduce images of an entire manuscript in a form that does not attempt to represent the way the manuscript looks in the analogue world. It is a persuasive advocate for the use of 'manipulated' images in preference to unedited RGB representations when dealing with a heavily damaged manuscript. Janke's work has been successful in revealing lost text, not only in SL, but I suspect this publication will be influential less for revealing the contents of a particular source, than for breaking the barrier of what we consider acceptable as a printed reproduction of a manuscript.[10] For the research community dependent on digital manipulation to access the content of a significant portion of their materials, the publication has stimulated a re-examination of attitudes to digital intervention and the ways in which we present our findings to our colleagues.

Janke cited the avoidance of misrepresentation as just one of his reasons for working in what he called 'false colour' in the SL photographs, though the bright prime colours also serve to differentiate layers of ink that to the eye would be difficult to separate if rendered in more natural shades. Rather than limiting the reproduction to only the palimpsest layer, he includes the overwriting, in a differently-coloured layer. His main argument for retaining the overwriting is based on the fact that without it a reader cannot determine whether pen marks (notes, rests, etc.) in the original source might have been lost either completely or partially because they were covered by the overwriting. Without access to the overlaid text, readers may be misled about the content, or at least cannot make an informed decision about what they see, since they lack a vital piece of the puzzle. This is precisely the problem encountered with the removal of wormholes shown in Fig. 5. Unless you can see where the overwriting (or the wormhole) is, you are not able to judge whether something might thereby have been omitted from the revealed text, and you cannot tell in advance where this might happen.

There is no suggestion that the San Lorenzo publication is a 'facsimile'. Something more visually conclusive would have been possible had the editors decided to integrate a further level of digital intervention but the issues of a fuller digital recovery of the manuscript were an editorial bridge that remained uncrossed. The publication is therefore a showcase for the capture and post-processing techniques developed by Janke's team in Hamburg. It is an accurate

9 Nádas/Janke 2016.

10 The methodology is examined in Janke/MacDonald 2014. The methodology was applied to another fragment and written up in Janke *et al*. 2018.

record of the object (albeit re-coloured),[11] based on technical conditions that capture different layers of information, and shows that much can be achieved without editorial changes, although obviously some decisions have to be made about which combination of images yield the best result. Janke's ongoing research into what can be achieved at the point of capture may result in a capture method that would obviate editorial intervention (which is always based on critical decisions) and this would be the ideal way of accessing texts in damaged sources. The SL images show that what can be achieved, at least at the moment, has limits. The results are still difficult to read and since every manuscript, and often every page, can present quite different technical challenges to retrieval, the Holy Grail of the 'single solution' is currently out of reach. However, as computers and software improve it may eventually be possible to create a suite of tools in which the technical side of the work is less visible. For now, though, digital editing is the only sensible course for publication of damaged sources for which reproduction as they currently appear has no value. Janke's relatively non-interventionist method expects – indeed requires – all the critical decisions about content to be made by the reader, a situation ethically preferable to one in which those decisions have been made for them. Even clearly indicated, editorial decisions cannot fail to influence the reader. Janke's method also obviates questions of whether the realisation of something the editor can see is based purely on physical evidence or involves some critical judgement.[12]

The question of what end-users want to see from reproduction of images of a manuscript as severely damaged as SL is problematic: some feel we could – and therefore should – go further editorially before publishing if doing so is more productive and not misleading; Janke and Nádas leave most decisions to the reader, but they have made it considerably easier to make those decisions than it was before. The answer seems to be to make both types of reproduction available: 'non-interventionist' photographic material, and some sort of edited version of the images that will make that material accessible to someone not expert in the particular field. The first purely presents the evidence, while the second draws it

11 Although Janke in private correspondence with the author has said that the output is not entirely unedited since 'processing, using statistical analysis, was involved. "photographic" does not summarize the technique'.

12 The main disadvantage in this approach is to the non-expert, who has to wait for the publication of a modern edition of the content, and there are many reasons why cutting the performer or non-expert off from the original notation is undesirable. In an environment where study of music from earlier periods is increasingly dropped from university curricula, the burden of making the content of these types of sources accessible falls increasingly on the diminishing number of people who can read them.

together with the critical apparatus of the expert to present a conclusion. The obvious delivery medium is the digital one, since in many cases there will be multiple surrogates, and possibly also multiple solutions. In terms of editing quite often one technique improves part of a page while disimproving another part; different techniques have to be used on different areas of the page; there may be a variety of 'solutions' to the content on the page. Selection for print can involve discarding some solutions of limited success in favour of one that elucidates the largest area of damage, even if doing so means that some small areas that could be retrieved with bespoke work are not revealed.

In the case of the Sadler books (see below) there were for some pages four different surrogates that contributed evidence to its final reconstruction, all of which should be accessible to those evaluating and using the result. The disadvantage of digital delivery is its impermanence: there is no guarantee that an online resource will still be here in ten years, or even in five, nor that a complex technical solution to delivery issues will not be broken by the next web architecture upgrade. Far from replacing print, the digital delivery world is increasingly aware of its ephemerality in comparison with print media. After all, an extraordinary amount of the medieval and early modern world has survived thanks to the culture of book production that preserved and disseminated its knowledge and artistic life. We can be sure that 99% of what is now on the web will not be there in 100 years (assuming the web itself is even there), but the likelihood of print publications still being on library shelves is high.

SL was photographed by DIAMM in 2011 with a very high-resolution scanning back in standard RGB mode (in analogue language, a colour photo).[13] Colour UVs were taken at the same time and these are rendered in monochrome since the limited wavelength is basically only delivering information in one colour. The RGB image can be edited to remove the overwriting, complete the stave lines from their remnants, and retrieve what is left of the lost music by employing a finely-tuned colour selection (Fig. 10); the result is shown in bright blue.

13 PhaseOne FX 144 Mpx scanning back. Only recently has PhaseOne produced a single-shot camera back that exceeds this resolution.

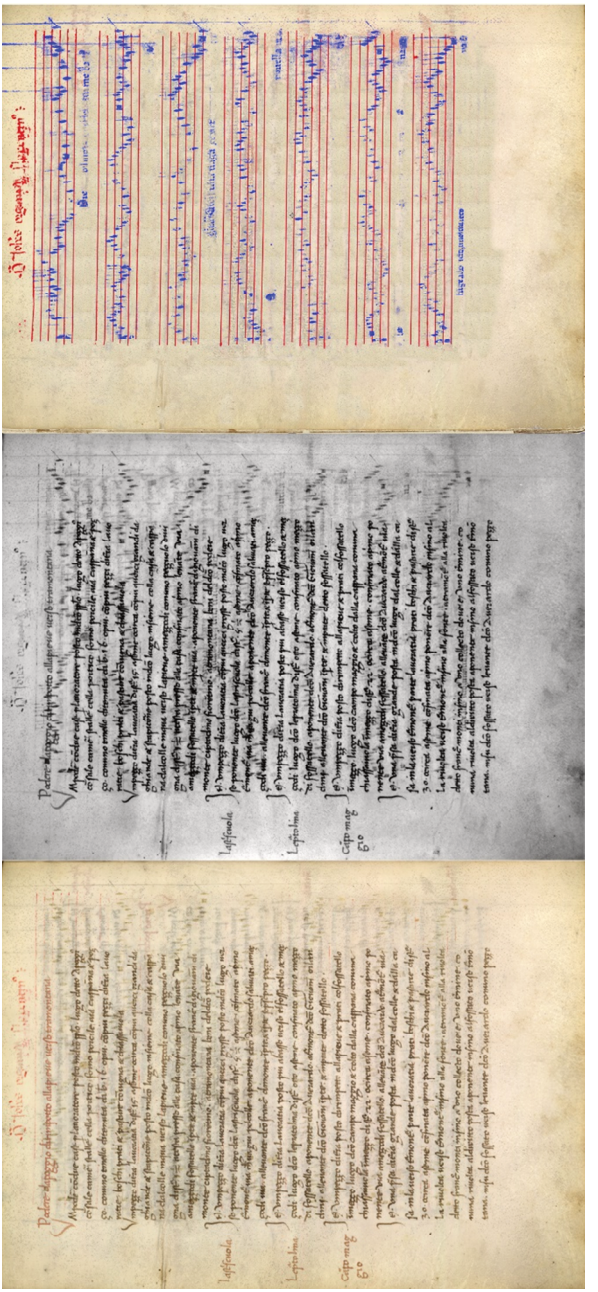

Fig. 10: Florence, Archivio del Capitolo di San Lorenzo, MS 2211, f. 22v: master RGB image; UV image; RGB image edited; © Florence, Archivio del Capitolo di San Lorenzo.

The ghost of the lost text is visible in the right-hand margin in the RGB image and in the body of the page have been found by colour-selecting on these notes. As in the case of Corpus Christi MS 144 (Fig. 2), the UV shows much of the palimpsest, but darkens the overwriting as well. There is no consistency between pages of SL in the extent of the damage, and this example is of a moderately good page. Many are far more intractable.

Janke's images show far more information than the RGB or UV images taken by DIAMM, but the overwriting, retained in yellow in his reproduction, interferes significantly with attempts at a reading. Even so, a forest of stems can now be added to the visible palimpsest, and the information from Janke's image can be added to that of the edited image. Bearing in mind Janke's concerns about notes hidden under the surface writing, if we interpose another layer of editing – call it 'restoration' or 'reconstruction' – there is also the need for some critical discrimination to deal with the inevitable lacunae, introducing another layer of complexity – and potentially error – to the reconstruction.[14]

The cuts and gaps in the noteheads caused by removal of the overwriting can be filled in if desired with a reasonably clear conscience. Fig. 11 shows the previous blue selection shown in Fig. 10 but now including additional stems, noteheads and text revealed on Janke's images. The middle image shows the top four stave-lines edited to infill cuts left by the removal of the overwriting. The final image shows the result rendered in more naturalistic colours. By removing the unusual colour, the reader may be misled into thinking that the rendering is more true to the original than it actually is.

14 There are numerous solutions to how one might present the reader with notes that must be there but cannot be seen, but these need not be discussed here.

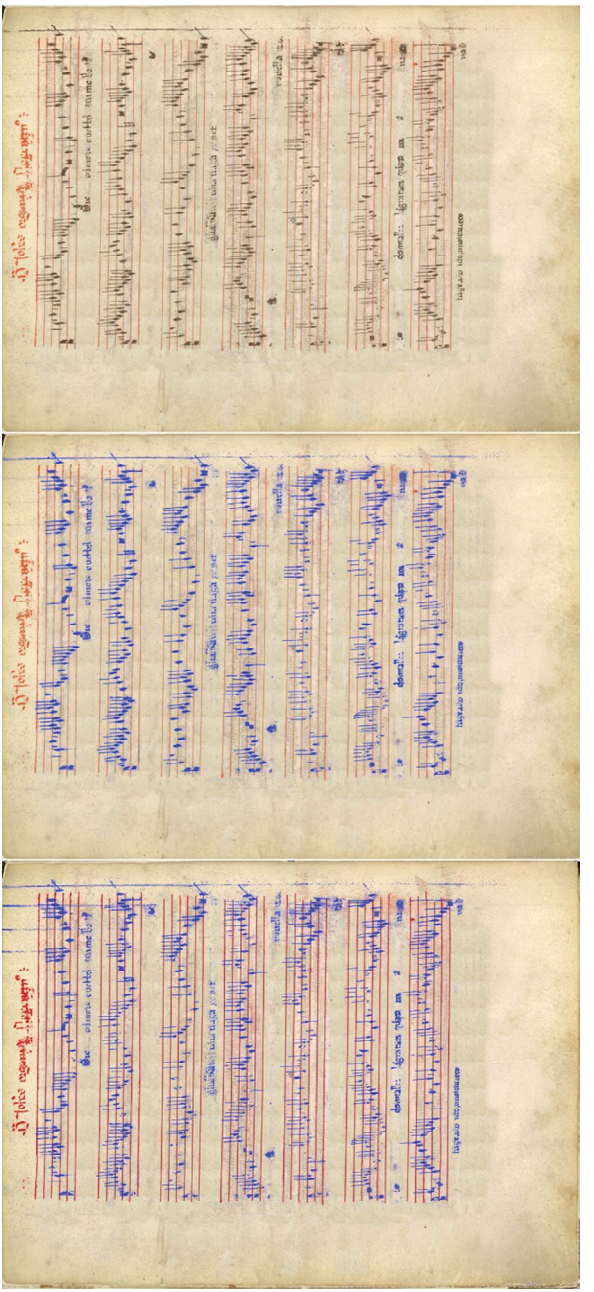

Fig. 11: Florence, Archivio del Capitolo di San Lorenzo, MS 2211, f. 22v, further edited; © Florence, Archivio del Capitolo di San Lorenzo.

This editing work has been extended to an end point that is more extreme than usual in order to explore the potential gains that might be achieved by combining the different layers of evidence now available, but every retrieved note, stem or line now visible can be justified by reference to some version of the original document, in RGB, UV or multispectral form. By combining automated and manual methods, we have the ability to create an image that can be read, and possibly played from, and can be made to approximate the appearance of the original had it not been damaged, if we wish. Even supported by Janke's data though, this rendering remains incomplete – and this is one of the less-damaged pages in the book. In many other pages the loss is much greater, so creating a usable reconstruction of the entire manuscript would require high levels of speculative suggestion from an editor, and only a few pages might offer reasonable levels of retrievable data.

The process above certainly involved quite heavy editing, so the way it is described is problematic, and the term 'restoration' is inappropriate. A more justifiable term for a process like this, since it is the result of a composite of information provided by a variety of surrogates that are combined with the aid of editorial decisions (about what to include and exclude) and editorial input to realise missing notes, would be *editorial reconstruction*.

A publication of a manuscript as extensive as SL, incorporating both Janke's approach and further digital retrieval to reconstruct the pages, might require unrealistic amounts of time and input from its editors.[15] This is true of the process of reconstructing the images, but the musicological input would probably be little more than that required to make a modern-notation edition of the music. The main argument against this level of intervention is that the editors make informed but, nevertheless, discriminatory decisions about the pitch and value of missing notes (which can be indicated in many ways). Any imposition by an editor, while not obviating the consideration of alternative readings, does tend to affect a reader's critical apparatus, particularly among less expert readers. Since so little of the original pen-strokes can be retrieved, is this level of editing even appropriate?

15 Each image would take about a day, but continuous work of this kind on a day-to-day basis is physically impossible.

3 Forensic reconstruction

The Sadler Partbooks (Oxford, Bodleian Library MSS Mus. e. 1–5), are a set of five sixteenth-century paper music books severely damaged by acid burn-through and lacing. Returning these books to readability and usability was a long-term project as the extent of the work was considerable, involving 700 images of pages in various states of disintegration and (il-)legibility. The bulk of the work was funded by the AHRC as part of the Tudor Partbooks project from 2014–2017, with refinement still ongoing. All aspects of the nature and extent of the digital intervention were qualified by practical considerations of time and manpower, as well as the end use to which the finished images might be put. These books would reach a wider public than one might encounter with medieval fragments, since a large constituency of amateur and professional musicians would potentially use the 'restored' books for performance.

SL and the Sadler partbooks represent polarised aspects of the legibility issue. In the case of Sadler there is too much ink, in the case of SL too little. In Sadler the interfering ink is coming through from beneath the text, in SL it is laid on top. In Sadler the destruction is incidental and unintentional, in SL it is deliberate: the intention was to obliterate the original text which is the one we now want to read. Despite these differences questions about intervention are much the same. Multispectral imaging was not attempted on Sadler because the process primarily enhances information that has been lost and therefore would not have been effective in a situation where the ink has effectively multiplied. MSI imaging would also not have revealed anything that was not shown in the infra-red spectrum. Infra-red imaging has limited applications, but in this case was extremely revealing. Moreover, for conservation reasons the Bodleian could not allow extra handling that extensive further imaging would necessitate and conservation must always take priority over the desire to have an ideal set of images of a manuscript. In this case, imaging work to the extent of that undertaken on SL would have been out of the question.

There is a conflict between scholar and owner/keeper that can never really be reconciled: the owner is concerned with preserving the object, but the scholar wants and needs to access the information that it contains. As manuscripts age and deteriorate, re-photographing using newly developed techniques is increasingly problematic; ultimately we may be forced to deal with some sources only from their basic RGB surrogates. Libraries have long understood that obtaining the highest possible resolution at the outset is a preservation priority. It is, therefore, incumbent on us to develop methods that retrieve as much information as possible from the basic imaging to support the conservation of the primary

source. The development of new photographic techniques is unlikely to find its way to the Sadler Partbooks, but to a great extent the work done by the Tudor Partbooks team should minimise that necessity.

The Sadler Partbooks were withdrawn from public access some time in the 1960s; only a monochrome microfilm has been available to readers for over 40 years, taken during conservation in the 1970s. Although a good portion of the text underlay is legible in the microfilm, the bulk of the music is completely obscured, as shown in Fig. 12. This set of manuscripts presented a major challenge for digital recovery, not only in the extent of the damage but in the scale of the job.

In order to facilitate access with images of a quality that would also allow digital intervention the Bodleian Library digitised the set of five books in high-resolution colour in 2014 (Fig. 13). The advantage of this set of surrogates over the microfilm is manifest. It can be extremely frustrating to attempt to read a manuscript in this condition. All the ink we needed to see was on the page but it was obscured by a great deal of other ink contemporary with the primary copying. In other sources where later copying has obscured earlier work it is possible to see degrees of colour separation due to age or the use of different materials. In this case the fact that the inks were contemporary meant that there was no colour separation that would have allowed us to separate layers of ink based on colour or intensity.

The process was therefore one of *removal* of the superfluous ink, rather than one of *retrieval* of lost ink. The editors had to remove the accretions and damage to the page in such a way that the end result was useful not only to the majority of the potential audience who would use the books as a musical repository, but also the smaller community who wished to study the books as a historical record of a particular place and time.[16]

16 The editing work involved a team of three in-house editors (two musicologists and one graphics expert who could read music), and 31 volunteer editors with various levels of expertise ranging from a graphic designer with an interest in playing early music from facsimile, to a marine engineer with no prior image-editing skills who could not read music, but had an excellent eye for shapes and pen-strokes.

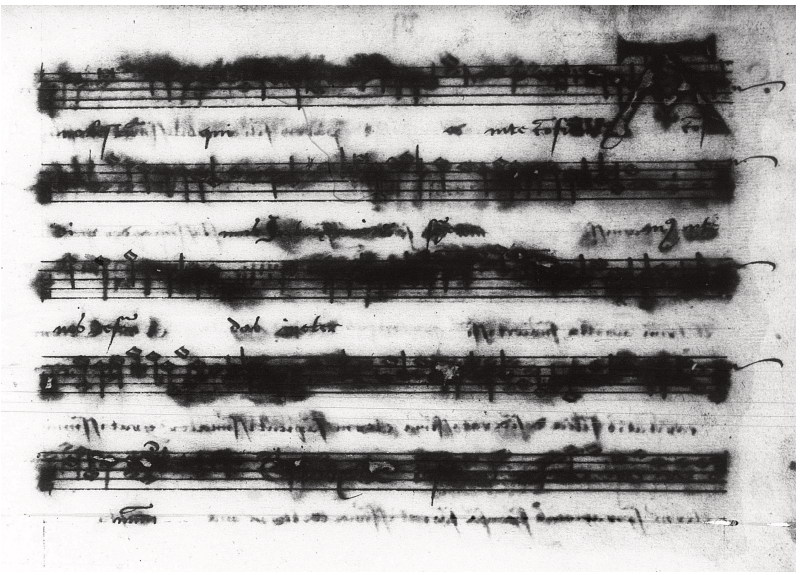

Fig. 12: Oxford, Bodleian Library, MS Mus. e. 2, f. 16r: microfilm image (*c.*1974); © Oxford, Bodleian Library.

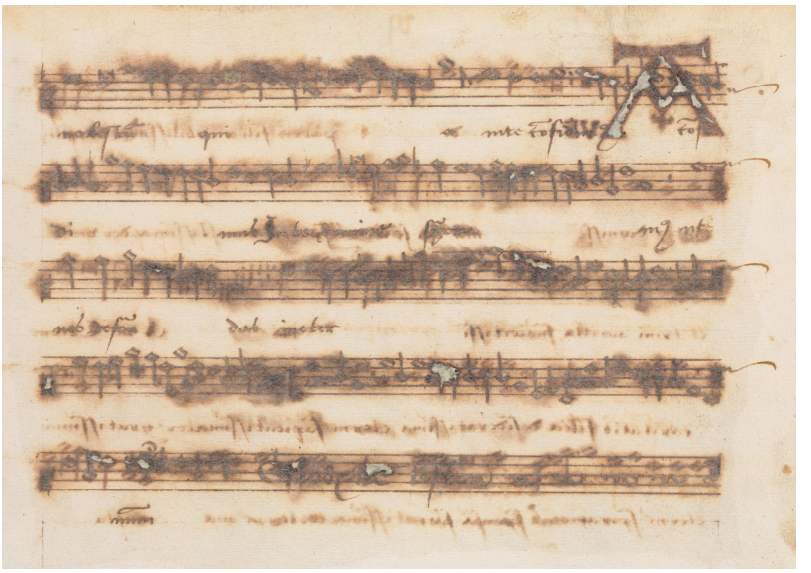

Fig. 13: Mus. e. 2, f. 16r: modern RGB digital image (2014); © Oxford, Bodleian Library.

My first attempts at repairing acid burn through in the late 1990s created images that despite being unattractive facilitated a reading (Fig. 14). These images were only intended for use by one person in order to make a modern edition, so there was little concern for the aesthetic appearance of the repaired page.

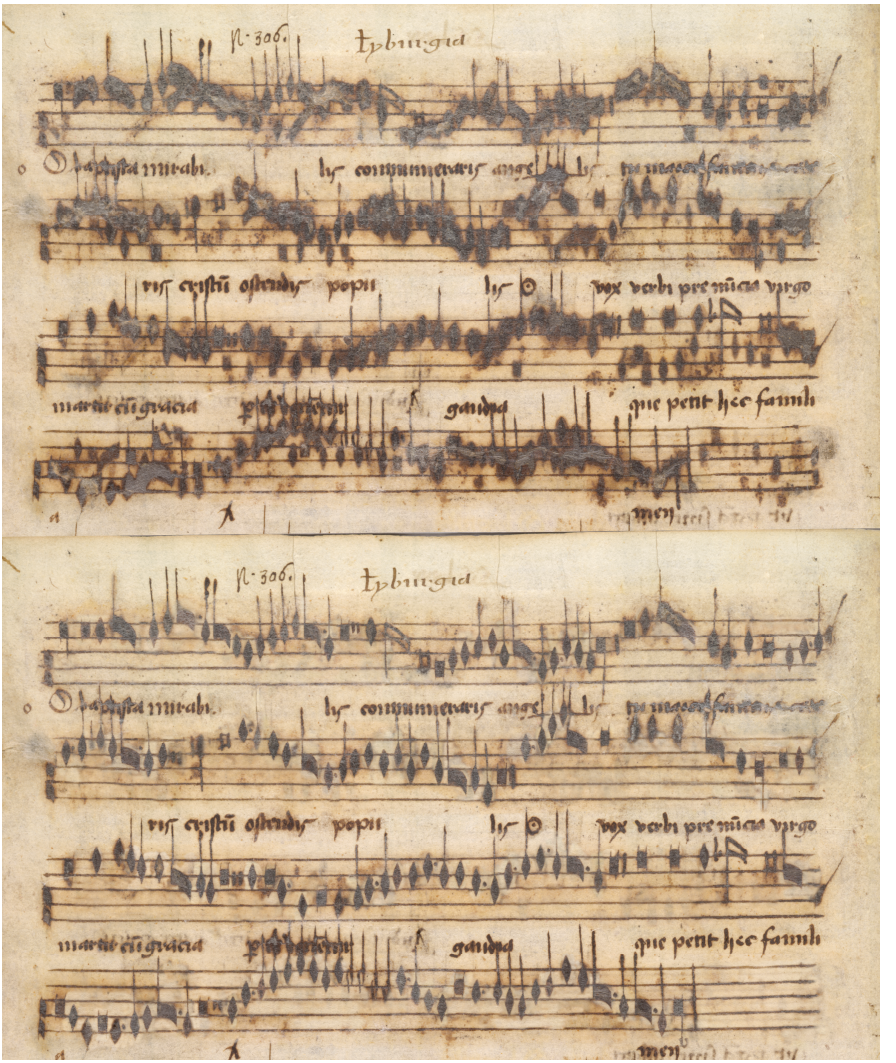

Fig. 14: Bologna, Museo Internazionale e Biblioteca della Musica, MS Q. 15, f. 309v: detail before and after editing; © Bologna, Museo Internazionale e Biblioteca della Musica.

Like SL however, the Sadler books are destined for paper publication,[17] and like SL the extent makes publishing images of the whole set in both their original state and post-editing impractical, to say nothing of being largely pointless, since so little of the original can be read.[18] The damage to individual pages is so variable that the intervention in each image had to be customised. There were some processes that could be semi-automated, but they still required manual refinement. The question of parity is particularly relevant in Sadler because of the large editorial team, but in this case the question is parity of final appearance, not that of methodology.

Restoration implies the return of an object to a previous state. At what point in a manuscript's life are we aiming in a repair of this sort? In this set of books there is really no 'original' we can recall since there is evidence that even at the time of copying there was some interference from showthrough. Attempting to create a snapshot of the books at any point in their history is impossible.

Descriptions of the books in sale catalogues prior to their acquisition by the Bodleian Library do not mention their physical condition, but James Burke's recent research relates that they went through various misadventures before acquisition that may have hastened their decay, including possibly surviving a warehouse fire.[19] The earliest photographic records indicate that showthrough was a very significant issue 100 years ago so there would be no point in 'restoring' the manuscripts to their state at that time. Ultimately, we can only attempt to create a factitious representation of how the manuscripts might look today had they not suffered the attrition caused by the heavy, acidic ink, and poor-quality paper. Fortunately, there was at least one scribe in the books whose legacy was a few pages that are almost undamaged; these leaves provided a template on which to base intervention policy for the other pages.

Fig. 15 shows an untouched image from the partbooks that was used as one of the baselines for the editing of the remaining leaves, including a scratched-off erasure at the end of line 3.

17 The reconstructed books will be published in Craig-McFeely/Range 2020.

18 The original images of the Sadler books are available online (without charge) for comparison, <https://www.diamm.ac.uk/sets/127> (accessed 16 June 2019).

19 Burke 2016.

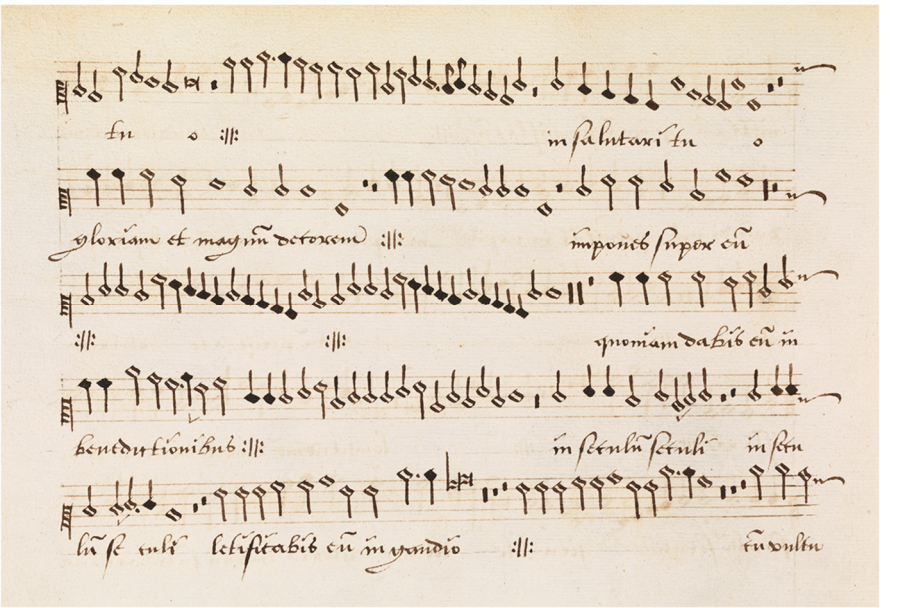

Fig. 15: Oxford, Bodleian Library, MS Mus. e. 2, f. 44v (un-edited image); © Oxford, Bodleian Library.

As well as baseline images from the books themselves, there are other sets of similar manuscripts from the same period and environment which are in excellent condition, so there are good contemporary models for the style of finish appropriate to the Sadler books.[20]

Around 98% of the notes and text on the reconstructed pages appear as the scribe wrote them, and in his original ink thanks to a staged process of *Forensic Reconstruction*.[21] This involved the collation of different layers of evidence, both direct and circumstantial, to create a representation of the content of each page that is as true as possible, not simply to the lost music but to the orthography and calligraphy of the original scribes, the process of copying, correcting and recopying, and the interactions of the various scribes and users of the books. The layers of evidence used in the reconstruction are described below.

20 Oxford, Christ Church, Mus. 979–83, 'Baldwin partbooks'; Oxford, Christ Church, Mus. 984–8, 'Dow partbooks'.

21 The technical process is discussed in more detail with accompanying images in Craig-McFeely 2018.

3.1 Master high-resolution RGB images

The modern colour digital images were of sufficient resolution that the images could be enlarged to allow scrutiny of very fine detail of the text that would not have been visible if examining the original leaves. The colour depth allowed image-processing software to determine colour separation where the naked eye could not. These images were the primary source of information. It was possible to read approximately 85% of the text from these pages, given enough time and with questioned readings supported by other surrogates or indirect sources of evidence such as concordances.

Magnified images showed crystals that had formed on the ink on the surface of the paper, assisting differentiation between the surface ink and the showthrough (Fig. 16). Unfortunately, 189 pages had been repaired and stabilised with Japanese tissue, sometimes covering only the most damaged sections, so the crystals were lost, making these pages particularly problematic since they were also usually the most damaged.

Fig. 16: Pen strokes delineated by superficial crystalline deposits; © Oxford, Bodleian Library.

The most severe areas of damage were on the staves; repairing this was challenging because of the small size of the units of information and their uniqueness in their context. The text underlay presented its own problems but the showthrough was less extreme and the texts were standard ones, so with internal word-repetition and texts repeated across the books the only difficulties were presented by the occasional misspelling perpetrated by a scribe (which was retained in the reconstruction).

3.2 TCM Photostats

In the early 1920s the Carnegie Trust offered a grant to the editors of the *Tudor Church Music* series (TCM) to make negative Photostats of the majority of the

pages of the Sadler books. These are preserved in Senate House Library in London.[22]

The Photostats show the manuscripts as they appeared nearly a century ago (Fig. 17): even when showthrough is apparent it is easier to differentiate between the surface writing and the showthrough in these surrogates, even in monochrome, than in the modern colour images. Once scanned, the images can be inverted to positive if required, though this rarely enhanced the reading. They provide a reference point to evaluate the rate of decay between the early 1920s and the 1970s conservation that stabilised the acidity. Many of the modern holes were considerably smaller 100 years ago, but a few areas are more difficult to read as they are obscured by gauze from an early unrecorded conservation (perhaps undertaken to stabilise the leaves for this reprography), some of which is visible in this image covering the last quarter of the top line of music.

22 London, Senate House Library, Tudor Church Music Box 48. The pages reproduced were: Mus. e. 1, fols 8v–10r, 12r–18v, 22r–40v, 42r–57v, 60r–61v, 66v–67v (of 75); Mus. e. 2, fols 6v–8r, 10v–17v, 22r–57v, 59v–61r, 66r–67v (of 75); Mus. e. 3, fols 6v–8r, 10v, 11v–17v, 21r–50v, 51v–58r, 59v–60v, 66rv (of 75); Mus. e. 4, fols 5v–7r, 9r–15v, 18v–56r, 57v–59r, 64v–66r (of 66); Mus. e. 5, fols 6v–8r, 10r–17r, 19v–20r, 22v–53v, 55rv, 60v–61v (of 69). The exact date of the imaging is unknown; the dating comes from identification of the handwriting of a librarian who retired in the late 1920s on labelling shown in the images. We are immensely grateful to the department of Special Collections in Senate House Library and their administrator, Charles Harrowell, who have preserved these Photostats and kindly allowed me to visit them with a high-resolution scanner to make scans for the reconstruction project. They have also given permission for the scans of the Photostats to be made available online alongside the original and reconstructed images, at diamm.ac.uk. Information about the TCM collection may be seen here: <http://www.senatehouselibrary.ac.uk/our-collections/special-collections/printed-special-collections/tudor-church-music-collection> (accessed 1 Nov. 2017).

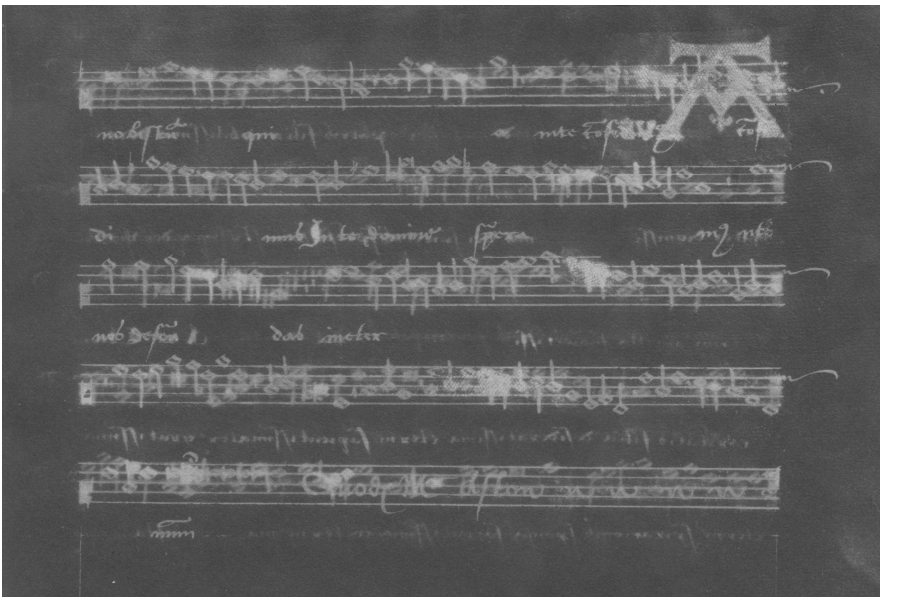

Fig. 17: Oxford, Bodleian Library, MS Mus. e. 2, f. 16r: TCM negative Photostat scanned at high resolution. (See Figs 12 and 13 for microfilm and RGB versions of the same leaf); © London, Senate House Library.

When lost or damaged notes on the RGB images were visible in the Photostats, editors could use them as a template to draw around the pen strokes after carefully-aligned superimposition, revealing on the master layer the pen-work of the original scribe with absolute confidence as to pitch, position and shape.

Superimposition is, however, far from straightforward. The changes wrought by time and interference between the manuscript and the Photostat prints were manifest: there was shrinkage and distortion in the manuscript due to the leaves no longer being stretched in a binding, with disintegration of the leaf structure as holes appeared, sometimes abetted by the conservation processes which could not always reliably retain the original shape of the leaves or the position of detached areas. The Photostats too are beginning to deteriorate, with cockling and shrinkage particularly around the edges, abetting the discrepancies between the shapes of the pages as shown in the new digital images and the scans of the Photostats. This meant that simply dropping one image on top of the other did not align staves and pen strokes. The superimposed image had to be subtly reshaped ('warped', in Photoshop terminology) to fit exactly over the notes of the master image, and even this process had to be limited by the amount of time

available when added to the time needed for reconstructive editing and the number of pages so edited. Rather than attempting to align all the notes on the page perfectly therefore, the alignment was fine-tuned primarily to areas where the reading was critical.[23]

3.3 Infra-red images

Infra-red imaging was undertaken on a very limited number of leaves towards the end of the project mainly to confirm areas that could not be read or extrapolated from the Photostats or RGB master images. Most of the remaining questioned readings were due to lacing, leaving only a few places where the paper remained intact but the RGB and Photostat images were indecipherable. Because of the fragility of the manuscript the number of pages to be re-shot was limited to 30, so only leaves where readings could not be confirmed in any other way were photographed under IR conditions (Fig. 18).[24] It was immediately apparent that the infra-red images provided us with far better information than any of the other surrogates, not only in clarifying the questioned readings, but in revealing the quality of the original penwork, and serendipitously confirming variations between ink types.[25] As far as the palaeography of the verbal text is concerned, the IR images revealed a more refined picture of the scribal work than had either the RGB or Photostat images: fine pen-strokes and elegant execution emerged that is obscured by the bleed of the ink into the paper at the point of writing due to the porous quality of the paper. These few images serve to demonstrate the value of infra-red imaging in clarifying damage caused by burn-through; it is rarely as successful in other types of damage.

23 Creating the facility for users to superimpose images online requires the same level of detailed work in creating the image sets; building an image viewer that would allow users to add layered images or apply a 'fade-through' option is a technical challenge with concomitant costs. A viewer offering this type of feature requires constant updates and maintenance to keep abreast of changes in web architecture, a cost rarely considered by end users.

24 Mus. e. 1: 13r, 13v, 19v, 20v, 22r, 32r; Mus. e. 2: 8r, 8v, 13r, 14r, 18v, 20r, 26v, 29v; Mus. e. 3: 10v, 18v, 20r, 21r, 30r, 31v, 71r; Mus. e. 4: 12r, 12v, 15r, 26r; Mus. e. 5: 10v, 17r, 19v, 44v.

25 The IR results obviated the need for further multispectral imaging, though that option was in any case not available because of limited access to the original leaves.

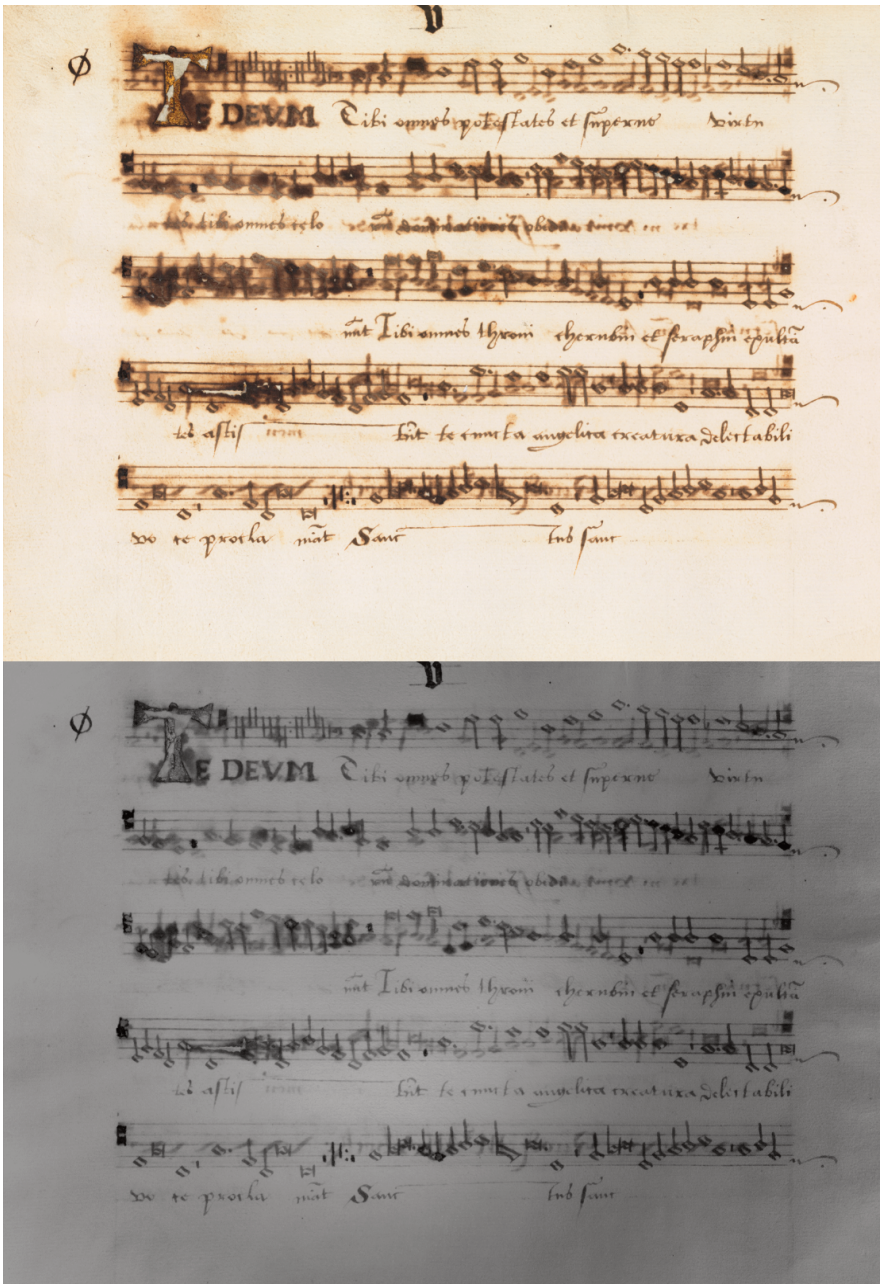

Fig. 18: Mus. e. 4, f. 12v: RGB image © Oxford, Bodleian Library; IR image © author.

Fig. 19 shows a detail of a page at different stages in data recovery leading to a final reading.

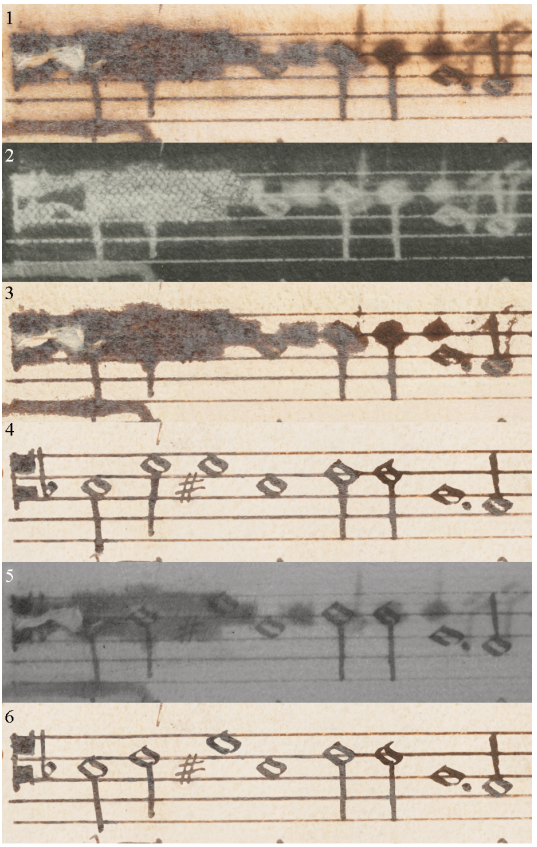

Fig. 19: Detail of Mus. e. 3, f. 10v: different stages in data recovery leading to a final reading; original image © Oxford, Bodleian Library; negative photostat © London, Senate House Library; other stages by the author.

1. The original image: the problem is caused by a large decorative final on the reverse, obscuring several notes and leaving a hole in the paper repaired by the conservator with a clot of tissue. The first part of the line also has tissue overlay, while the latter part is uncovered and therefore easier to read.
2. Scan of the negative Photostat. The void at the start of the line is slightly smaller, but the burn-through still hides at least three notes, with difficulty

in reading compounded by an earlier restoration using gauze overlay. The head of the antepenultimate note is just discernible as a void;

3. The first stage of editing on the RGB master which has replaced differentiated showthrough with a pattern-fill made from a clean part of the same page.
4. The first stage of recovery work: the number of notes hidden by the burn-through could be established from the syllabic word-underlay (not shown here), stems and general spacing; note values and pitch were difficult to determine but this shows a first attempt to interpret the variable densities in the dark area as note shapes appropriate to the horizontal context. The 'feet' of the sharp are just visible in the original RGB image and its overall shape and slant could be seen when enlarged, as could the shapes of the noteheads that were not obscured by the final. At this point concordances and editions are not consulted as those readings might influence the editor into seeing something that is not there, thus losing a variant reading;
5. The infra-red image supplies a clear reading of shape, pitch and value for the notes and sharp sign obscured by the final; all note-head shapes are clarified, particularly the position and shape of the dot following the penultimate note;
6. The final reconstruction corrects the pitch of the second note, position of third note and refines shapes of note heads, stems and other signs using the superimposed IR image as a template. The incorrect pitch of the second note in this detail was the only such error in the reconstruction across the manuscripts, demonstrating the palaeographical importance of the IR images.

3.4 Global adjustment versions

Adjustments to contrast can improve readability – but not aesthetic appearance – by increasing the visible separation of colours that are otherwise too close for differentiation by the naked eye (Fig. 20). In many cases pages which looked at first to be intractably damaged improved considerably in readability after the application of whole-page adjustments such as thresholding, level adjust, colour-balance or contrast adjust. The result was only used as a reading aid since it was strange in appearance and destroyed paler ink strokes.

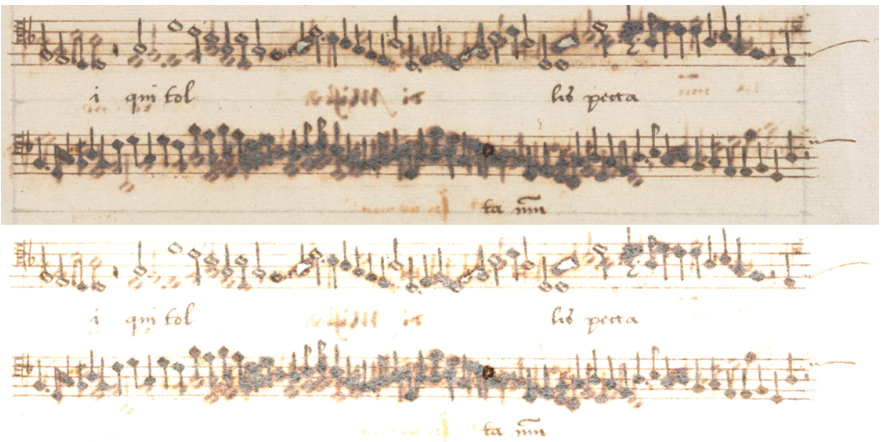

Fig. 20: Mus. e. 3, f. 71r detail: original image © Oxford, Bodleian Library and global-adjustment version.

3.5 Extrapolation or elimination

Some notes could not be convincingly retrieved from any of the surrogates, but it was possible to deduce both value and pitch from the visible context. In a string of minims, for example, a single missing notehead could be deduced in value from the tail and positioning within rhythmic perfection. To a great extent pitch could be determined from the length of the tail, as well as from eliminating pitches that were visibly clear of notes. An example of a tail-less note problem (either a breve or a semibreve) is shown in Fig. 21.

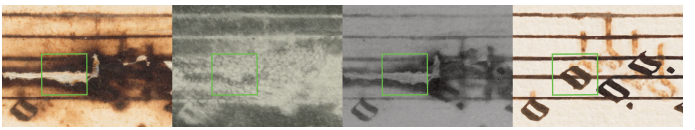

Fig. 21: Mus. e. 4, f. 12v (detail of line 4): original RGB © Oxford, Bodleian Library; negative photostat © London, Senate House Library; IR image © author; reconstruction (including erasure) © author.

The shape of only one note (boxed in the image) could not be confirmed by reference to any of the surrogates. However, this can be reconstructed following different criteria:

1. the missing note must be on the second stave line up, and is not in either of the vertically adjacent spaces;
2. it has no tail so must be a void breve or semibreve;
3. the context does not allow for a coloured note.[26]

The Photostat contributes nothing to the reading because of gauze overlay. The infra-red image however confirms the two semibreves (diamonds) following the boxed note and the absence of vertical downstrokes necessary if the missing note is a breve (a box shape). It confirms that the note is placed on the second line up and strongly suggests a diamond rather than box shape. The value of the note is confirmed by transcription of all parts, since any other value knocks the polyphony out of alignment. The missing note can only therefore be a semibreve on the second line up. Because nothing of the note survives, the reconstruction is effected by cloning the missing note from a matching value elsewhere on the same page (thus from the same scribe) and it is boxed to indicate that it is editorial and therefore should be excluded from palaeographical consideration of the page.

3.6 Contemporary concordances

Although the example above is of the only source for the tenor part of that work, concordant copies are not uncommon in the repertory surviving from this period. The Baldwin and Dow partbooks, and particularly the Baldwin set (though lacking its Tenor book), provided readings for a number of works that were close enough to the surviving Sadler version, including the position of occasional ligatures, that the few missing Sadler notes were highly unlikely to have recorded a variant reading.[27]

26 There are clearly tails erased above the note – the erasure of the note-heads originally miscopied here having contributed to the damaged area as the paper was scratched thinner and two layers of ink were applied on the upper face.

27 The newly recovered Tenor book in the Sadler set will be used in the musicological reconstruction of the missing Baldwin Tenor book.

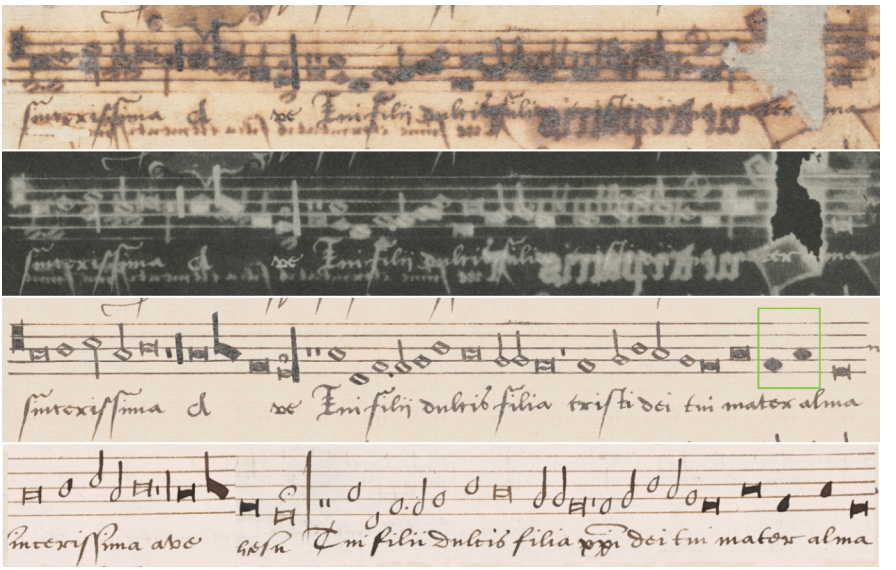

Fig. 22: Mus. e. 3, f. 22v (detail of line 3): original image © Oxford, Bodleian Library; Photostat © London, Senate House Library; reconstruction © author; concordance for the line from the corresponding Baldwin partbook © Oxford, Christ Church Library (line-ends do not correspond, so the line is joined after the first ligature to match the Sadler version).

Concordant sources were primarily used in supporting a questioned reading, but because of its closeness to the Sadler books in note values and cleffing the Baldwin partbooks were used to supply pitches and values for a number of notes that had been lost to disintegration in the Photostats. Notes reconstructed in this way were indicated by boxing as shown in Fig. 22. Because only a few works in the books are *unica* musicological reconstruction (i.e. reconstruction based entirely on stylistic appropriateness when no contemporary source was available) was not required; in places where the damage was so extreme that significant passages of music were lost, the missing notes were supplied by concordances.

3.7 Modern editions

Since the reconstruction team had access to images of sources that were concordant with Sadler when dealing with questioned readings, modern score editions were only made for works that had no concordant sources in order to ensure the music fitted together as it should. The Sadler copyists were far from completely accurate: many errors in copying remain and are not corrected in the

reconstructions. Instead the errors are footnoted so that performers are warned of the errors and given the correct reading.

The first question asked of the edited images is in relation to their palaeographical value: are they actually no better than a diplomatic typographical transcription? The notes in the Sadler books were revealed by painstakingly 'cleaning' around the original pen-strokes. This involved painting a paper pattern over the unwanted showthrough or bleed in a new layer, in order to hide it. Overcleaning was corrected by masking out unwanted areas of the overlaid pattern layer to 're-reveal' the original image. Where the note could not be seen on the original RGB image but could be seen on the Photostat or the IR image, the edges of the note shown on the alternative image were traced around, so that the pen stroke, as it should be, was left showing on the master image. If the shape was filled by tissue or void because of lacing the ink colour was filled in with a pattern created from ink fill elsewhere on the page, as close as possible to the missing note, and indicated with a coloured box. Very few notes were completely irretrievable and, in these cases, the replacements inserted are clearly marked.

Only damage related to acid decay was eliminated, and considerable care was taken to retain all other aspects of the books that reveal their copying and usage. Erasures were preserved, providing evidence that the underlay was copied in tandem with the music, as were other marks such as library stamps and fingerprints (see Figs 23–25).

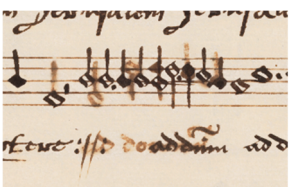

Fig. 23: Unedited erasure

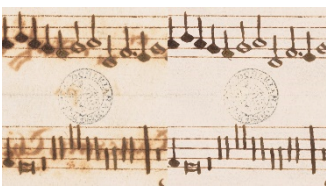

Fig. 24: Bodleian Library stamp

Fig. 25: Fingerprint

Damage that was not caused by acidity, such as water staining, was left visible even though it makes the leaf more difficult to read (see Fig. 26). This is because water staining is not the result of acid damage and in some cases it provides evidence of disturbance to the page order. Overwriting, which is almost easier to see on the unaltered images, is also preserved (see Fig. 27).

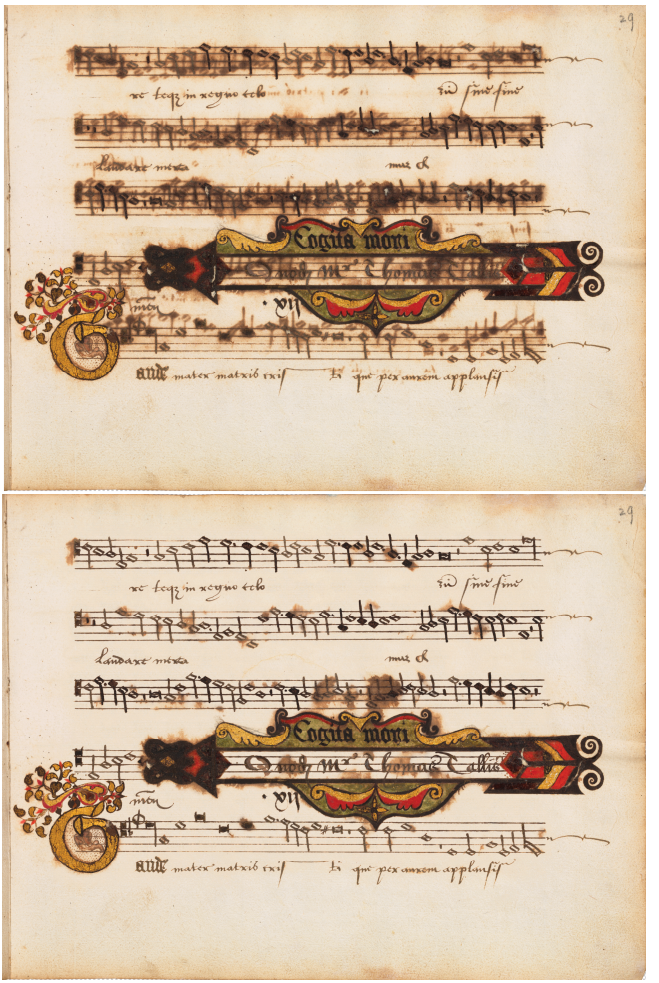

Fig. 26 Mus. e. 3, f. 29r: water staining; © Oxford, Bodleian Library.

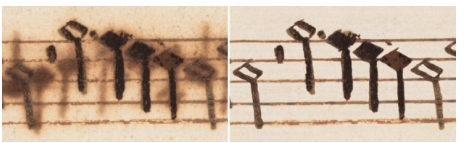

Fig. 27: Overwriting before and after repair; © Oxford, Bodleian Library.

The edited images are true enough to the original pen-strokes that it is now possible to examine the scribal activity in the manuscripts, revealing them to be the work of a number of scribes, a possibility that had not been considered since the books were first described in a nineteenth-century sale catalogue as being 'written by John Sadler'.[28]

Mus. e. 3, f. 22v is one of the most damaged leaves (see Fig. 28). However, all but three notes and a rest (indicated with green boxes) on this page could either be seen on the RGB master with some effort or on the Photostat. The values and pitches of the lost notes were supplied by a close concordance in the Baldwin books (shown in Fig. 22) and these shapes were cloned from others on the page.[29]

During a proofing playthrough using reconstructed images of leaves from the Sadler books one of the musicologists commented that it was almost impossible to tell that the images had been edited. Although flattering to the editors this is potentially a problem since, quite apart from the issue of misrepresentation, the reader may believe that the editorial intervention was very light, and therefore the reading is unquestionable. The problem of rendering has therefore circled back to that expressed earlier, that false colour (or pseudo-colour in the case of SL) ensures the reader cannot be misled in what they see, but the aesthetic effect is distressing. Although the process employed in reconstructing the Sadler books will be described in detail in the introductory study it is clear that this part of a publication is rarely read as closely as the author/editor might desire. In an attempt to counter the natural abhorrence we seem to have for reading an instruction manual (or in this case a technical description), the print publication of the Sadler books will include reproductions of some images in their original state in an appendix to each partbook. These should be more difficult to ignore than a wordy discussion of the editing process in the introductory volume, and certainly more visually indicative of the extent of the image editing.

28 See Burke 2016, 248.

29 Because the two versions of the work are so similar between the two partbook sets, the reconstructed tenor part in the Sadler partbooks can supply the missing part in the Baldwin set.

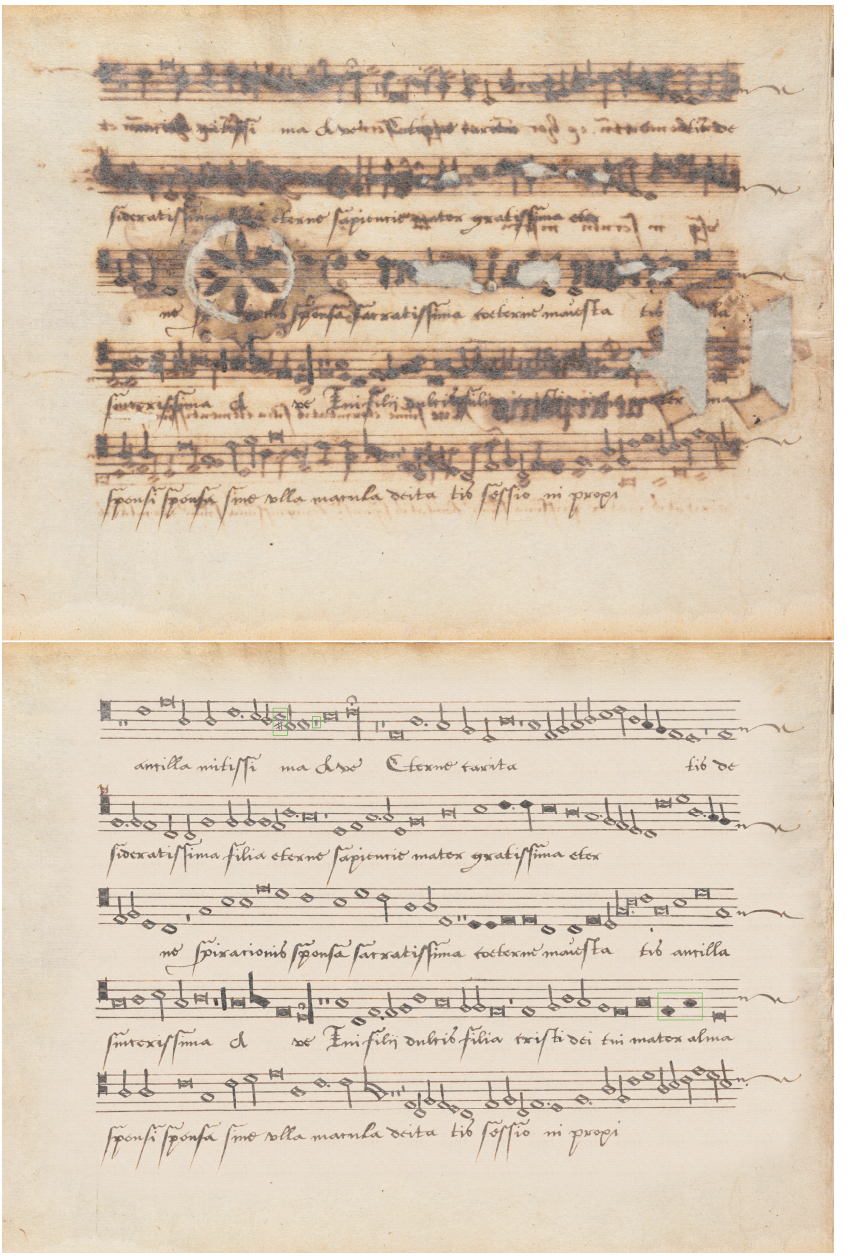

Fig. 28: Mus. e. 3, f. 22v: original RGB image © Oxford, Bodleian Library, and forensic reconstruction.

The checking process for the editing work was extensive: as well as repeatedly checking the edited version against the original and the other surrogates, the copy was read through against a reliable edition where one existed and, where one did not, a new edition was made from the Sadler books to ensure the parts would fit together correctly; printoffs were used for playing or singing by groups experienced in performing from facsimile. However, with so many pages and the number of notes on each page, it is statistically possible that a few errors remain.[30]

The editing work has been saved in layers in order to preserve a corpus of ground-truth data that will inform the development of automated processes which may eventually allow us to roll back the effects of attrition more easily and therefore cheaply. Speed and automation are essential in minimising costs, ultimately making it possible to repair more manuscripts in surrogacy, but fast automated processes have limited applications; an ideal situation would allow for many types of imaging and would combine automation with manual fine-tuning, aggregating every piece of evidence and every technique available, but the cost implications are significant.

4 Final outputs

Paper outputs are still preferred as representations of books, particularly those where the appearance is as interesting as the content. There is no other way to get a sense of the book as a physical object, but colour reproduction is expensive and one-off: once a set of edited images is published they will not be reprinted with minor improvements, something only easily done with web delivery.[31] Therefore at the point of publication the images need to show the maximum possible information. Because the original manuscript behind the images is going to continue to age and deteriorate, the print may also be the most important record of its contents.

Creating a universal digital solution to repair manuscript degradation and facilitate scholarly and wider access to otherwise-lost content is not viable. Damage is so particular to a source, and even to individual pages in a source that each image has to be considered individually. However there are clear signs that a

30 *Circa* 122,000 notes, rests and other musical symbols were individually edited.

31 Images of the Sadler partbooks both before and after reconstruction will be available on <www.diamm.ac.uk>, and eventually it will be possible to see these along with the Photostats and IR images in a form that will allow users to superimpose the images over one another.

higher level of automation – with or without manual assistance – may not be far away. In terms of output, there are now good precedents for a more interventionist approach to representations that can appear not only online but also in print, as the end-user community becomes acclimatised to the possibilities inherent in digital intervention and the sometimes alarming appearance of these methods; this type of output may also become more commonplace as tools emerge to enhance and accelerate the process.

In the world of fragment studies publication has often been impossible because of the illegibility of the documents. Fortunately colour reproduction is far cheaper than it was, and colour addresses issues of legibility for a large proportion of damaged sources. For those that remain illegible digital editing is proving invaluable and there are clear signs that digital intervention has come of age and will be increasingly espoused in the print medium in the future, where access to the content is not dependent on access to the web, and a sense of the physicality of the object can be communicated.

Abbreviations

RISM B/IV — *Répertoire international des sources musicales*, Series B/IV: *Manuscripts of polyphonic music, 11-16 centuries*, Munich/Duisburg: G. Henle Verlag, 5 vols.

- 1 Gilbert Reaney (ed.), *Manuscripts of Polyphonic Music. 11th-Early 14th Century*, 1966.
- 2 Gilbert Reaney (ed.), *Manuscripts of Polyphonic Music (c.1320-1400)*. With supplement to B/IV/1, 1969.
- 1-2 (suppl.) Andrew Wathey (ed.), *Manuscripts of Polyphonic Music. The British Isles, 1100–1400*, 1993.
- 3-4 Kurt von Fischer and Max Lütolf (eds), *Handschriften mit mehrstimmiger Musik des 14., 15., und 16. Jahrhunderts*, 2 vols., 1972.
- 5 Nanie Bridgman (ed.), *Manuscrits de musique polyphonique, XVe et XVIe siècles. Italie*, 1991.

Census — Charles E. Hamm and Herbert Kellman (eds), *Census-Catalogue of Manuscript Sources of Polyphonic Music 1400-1550*, 5 vols (Renaissance Manuscript Studies), Neuhausen-Stuttgart: American Institute of Musicology/ Hänssler Verlag, 1979–2000.

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