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## **The Mesoamerican codex re-entangled : production, use, and re-use of precolonial documents**

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## 6. Recovery of a Hidden Chapter in the life of Codex Añute

Codex Añute, or Ms. Arch. Selden (A.2) as it is catalogued at the Bodleian Library in Oxford, is unique even amongst such a small group as the Mesoamerican Codices. It is a palimpsest, meaning that underneath the gesso surface another series of images is to be found. This chapter reports on an ongoing effort to recover these sub-gesso images using advanced non-invasive techniques. The unique materiality of these documents makes this a challenging endeavour. The only published project to investigate this palimpsest was undertaken during the 1950's at a time when technical capabilities were limited, but also at a time when a concern for conservation had not led to the implementation of strict regulations for research. Taking lessons from this project, a new project was set up by the collaboration of Leiden University, University of Delft, and the Bodleian Library in affiliation with an intervention of the Italian MOLAB. At the University of Delft, Tim Zaman has developed new techniques specifically for the investigation of this document. Although the interpretation of the results of this inter-university collaborative non-invasive investigation is still ongoing, the final part of this chapter will try to draw some general conclusions about the nature of the hidden text.

### 6.1 DESCRIPTION OF THE CODEX

The codex Añute came to its current location after it was bequeathed to the Bodleian Library by John Selden as part of his massive collection of over 8000 printed books and thousands of manuscripts upon his death on November 30th 1654 (Philip, 1983, p. 48). Because it was part of this important donation, it is also known as Codex Selden, or by its library shelfmark: MS. Arch. Selden. A. 2 (S.C. 3135).<sup>55</sup>

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55. This is the correct format for this shelfmark as provided by Dr. Barker-Benfield of the Bodleian Libraries. The notation given by Caso – “Codex Selden 3135, A.2” (Caso, 1964) – is erroneous as 3135 is only the running number of the summary catalogue.

Like with the other Mesoamerican manuscripts that entered the United Kingdom, not much happened with the codex Añute until it was published in facsimile by Lord Kingsborough (1831) (see chapter 5). It would take another hundred years, however, before it received true scholarly attention (see Glass, 1975, p. 196). These earlier investigations were not yet able to securely identify the origins of this document (see Spinden, 1933), though with the work of Alfonso Caso (1949, 1964) it finally became clear that this document was Mixtec.

The document known today as the codex Añute is technically a colonial document, though in style, materiality, and in content it has all the characteristics of a precolonial manuscript. It is a historical codex, dealing with the dynasty of a relatively small town which is identified by a glyph of a mountain spewing sand. This “sand belching mountain” has been identified by Smith (1983) as the town of Magdalena Jaltepec (see also Jansen & Pérez Jiménez, 2007b, p. 23). Jaltepec – or Xaltepec – means mountain of sand and is a Nahuatl translation of the Nuú Dzauí (Mixtec) name Añute, “Place of Sand”. This prompted Jansen and Pérez Jiménez (2004) to propose renaming the document the codex Añute. A complete translation of this codex can be found in Jansen and Pérez Jiménez (2007b). It is known to be a colonial document, because it refers in its last two pages to events such as births, marriages, and deaths during the early colonial period. Besides the correlation of dates, the fact that some of the later people involved are also known from Spanish records – having been baptized and given a Spanish name – is further evidence that the document is colonial in origin (Jansen & Pérez Jiménez, 2007b, p. 285). This codex is different from the other known codices as it is the only codex that has to be read completely<sup>56</sup> from the bottom to the top. It is made

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56. As opposed to some other documents such as the Codex Yoalli-Ehecatl which require the reader to turn the codex for the reading of particular sections.



Figure 6.1 left: pages 1 and 2 recto of the Codex Añute showing the present day palette; right: detail of page 12 recto showing the last remnants of the original blue and green colours (photo by the author, courtesy of Bodleian Libraries, University of Oxford).

on six pieces of leather connected end-to-end to form a long strip of approximately 27.5 by 550 cm. The document itself was folded into 20 almost perfectly square pages. Although the last two pieces of leather are thinner than the first four (as was shown in chapter 3) and there is an empty space at the end of the document for future additions, it seems that the later text was made in one hand as one single project. It was, therefore, not a continuous, documentary project to which new texts were being systematically added over a longer period of time, which could have been one explanation for the addition of two sheets of different and inferior sheets of leather. The reverse side of the document is only covered with a roughly applied white gesso layer, which was not used as a writing surface. As has been shown in chapter 2, this layer is needed to give strength to the support. It seems unlikely that the codex in its final form had a cover, as on the outside of the first page a large year sign is drawn which seems to take the place of a cover. Furthermore, the leather on the last pages is too thin to support an attached heavy cover.

The codex Añute is not in the best condition. First of all, the execution of the drawings is in itself of a sub-par quality. Individual lines are shaky and not of a consistent thickness, while the colours used to colour-in the figures often run over the black lines or over other colours (see figure 3.13). Contrast this with the Codex Mictlan, for example, in which the individual

sheets of leather are difficult to recognize as the overlapping sections have been trimmed down and carefully smoothed. In the Añute, the sheets of leather are clearly visible. These overlapping sections distort the drawings to some extent, but, more importantly, they are areas susceptible to degradation as the difference in thickness leads to increased localised friction as seen in chapter 3. Due to the thin leather used on the last pages, the conservation state of these pages is poor. This thin leather is flexible, meaning that it bends easily, causing the covering gesso to crack and flake off. The conservation of the colours in this document is not good either. The present day document as can be seen in figure 6.1 (top) contains only black, yellow, red, a greenish brown colour, and a cream colour, together with diluted variants such as grey and pink. In one particular section in the lower register of page 12, the original colours are visible (see figure 6.1 below). The brown colour can thus be seen to be a degraded form of green, while the cream colour can be seen to be a degraded blue. Both of these colours, then, can be explained as a degradation of blue, because the green colour itself would have been achieved through a simple combination of the yellow and the blue paint.

Gesso also flakes off on the reverse of the document. Even prior to the Second World War both Thomas Athol Joyce and Guda v. Giffen-Duyvis noticed that traces of paint could be seen through the cracks in



Figure 6.2: Reverse of pages 11 and 10 verso, showing the areas where the gesso was removed during the 1950's investigation (courtesy of Bodleian Libraries, University of Oxford).

the gesso on the reverse of the document (see Dark & Plesters, 1958b). It was Alfonso Caso, however, who first recognised the potential importance of these covered paintings. In 1952, the famous Mexican archaeologists arranged with Mr Brauholtz to have the document pass onto the British Museum after the 30th International Congress of Americanists at Cambridge, where the document had been exhibited (Dark & Plesters, 1958b, p. 531). While at the British Museum, it was subjected to a number of investigative techniques in order to reveal the nature of the palimpsest.

## 6.2 THE INVESTIGATION OF THE AÑUTE PALIMPSEST IN THE 1950'S

The investigation performed in the 1950's, partially at the British Museum and partially at the National Gallery, was published as one ten page article in the Proceedings of the International Congress of Americanists in 1958 (Dark & Plesters, 1958b). One of the main reasons for the lack of further publication on the matter may be the devastating review by Caso (1959) of a book on the interpretation of the two Mixtec codices at the Bodleian Library written by

Dark (1958). The critique that Dark had on Caso's reconstructions of the histories in the Mixtec codices was not appreciated by the Mexican archaeologist. It seems, in fact, that Dark was so discouraged by Caso's negative review, that he discontinued his work on the study of Mesoamerican cultures. An informative, though unpublished, report on the investigation of the palimpsest is held at the Bodleian Library (Dark & Plesters, 1958a). It appears that this report formed the foundation for their later article, though it contains some important details that do not appear in the shorter article. These two sources, combined with the also unpublished infrared photos made during this investigation, are able to give a better insight into their methods and their findings. These photos were held partially at the Bodleian Library, while others are still in the possession of the National Gallery.

The first investigation, performed at the British Library, was carried out by Dr. Plenderleith. His aim was to confirm the palimpsest nature of the document. He used benzol to make the gesso more translucent and was able to see black lines and red colours through a binocular microscope (Dark & Plesters, 1958a, p. 4). Having thus confirmed that



Figure 6.3: IR photo taken at the National Gallery of page 11 verso after treatment by Dr. Plenderleith (courtesy of Bodleian Libraries, University of Oxford).

the codex is a palimpsest, he set out to physically remove the covering gesso layer on page 11 verso using bauxite blast and on a section of page 10 verso using scalpel and bedacryl varnish (Dark & Plesters, 1958a, p. 4) (see figure 6.2).

The codex was subsequently returned to the Bodleian library, but was in 1956 transferred to

the National Gallery, which had better equipment for further study. At this point, it was unclear what the composition of the paints was and thus there was still hope that X-ray based techniques could work to reveal at least part of the palimpsest. This proved not to be the case. With the permission of the curators of the Bodleian Library, cross-sections and samples of less than 1mm<sup>2</sup> were taken to determine

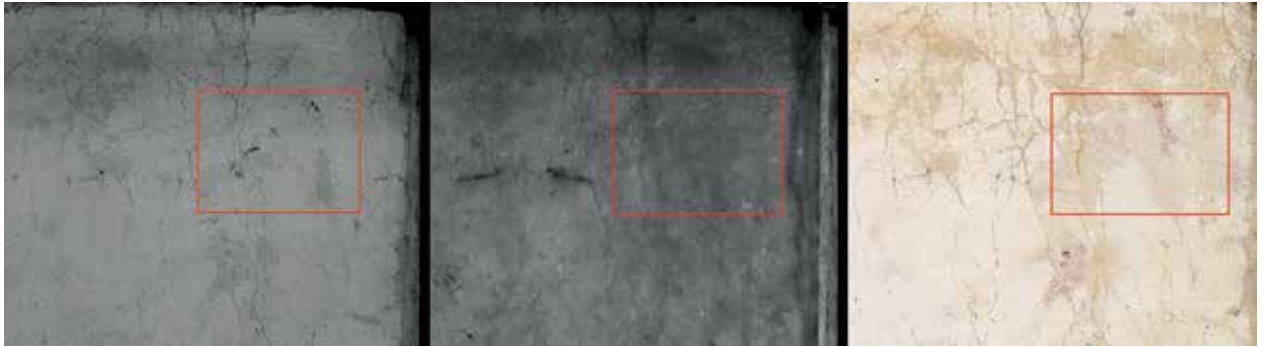


Figure 6.4: Comparison of images taken at different stages of the 1950's investigation (left: image recorded as number 6) (middle: image recorded as number 4) and the present day state (courtesy of Bodleian Libraries, University of Oxford).

the composition of the paints as well as the structure of the document. However, it was not possible to determine the complete composition of the paints, though it could be seen that the red colour was the same in the hidden images as it was on the visible images on the front. The black was determined to be carbon black, but the yellow and blue could not be securely identified, though they were determined to be organic (Dark & Plesters, 1958b, pp. 532-533). This explains why X-rays did not yield any results. Because of the presence of carbon black and the lack of mineral pigments, it was decided to first attempt to recover the palimpsest using infrared photography (see figure 6.3). Three photos were made of page 1, 2, and 5 of the verso side. The photos themselves showed very little results. The next step was to attempt to increase the penetrability of the gesso for the infrared radiation. One way to do this is to coat the surface with a material with a high refractive index. According to Dark and Plesters (1958a), this method was deemed not to be damaging to the codex. At first, a white spirit and later xylene thinned with an odourless kerosene were applied to reduce evaporation due to the heat of the infrared source and to create a temporary coating of the surface (Dark & Plesters, 1958a note 6). Infrared photos were then made while the pages were wet. This worked to some extent, though still the underlying designs could not be made clearly visible. Still, the determination of researchers to uncover the secrets of the palimpsest did not waver and subsequent to the failure infrared investigation they decided to subject page 5 verso to a number of tests to see if the thickness of the gesso

layer could be reduced in a safe way. Introduction of vibrations with a vibrator; dampening with water; followed by dry rubbing cotton wool; and stripping film were all tested on the page, but none gave satisfactory results (Dark & Plesters, 1958a, p. 10). A third infrared photo was made of this page after wetting it with the xylene solution for a second time. But this was once again unsuccessful and so after these photographs were completed the codex was returned to the Bodleian Library. Dark and Plesters state in both their preliminary report and in the published article that the underlying images were probably erased by the creator of the later document and that it was therefore useless to attempt any further recovery of the palimpsest.

Was this conclusion warranted? On page 11 verso, it is indeed clear that there is little paint still attached to the surface as was stated in the preliminary report (Dark & Plesters, 1958a, p. 11). An examination of the areas laid bare by the investigation on page 5 also shows only smudged red stains instead of clear paint layers. It must be taken into account, however, that the techniques for the removal of the gesso layer were highly invasive. Bauxite blast and scraping or removal through vibration of the layer is much more likely to remove both the covering gesso layer and the underlying gesso layer together from the skin, than it is to separate two layers of gesso from one another. What is left, as is especially clear on page 5, is the leather with some remnants of paint that seeped through the first gesso layer and thus stained the leather itself. The carbon black paint is

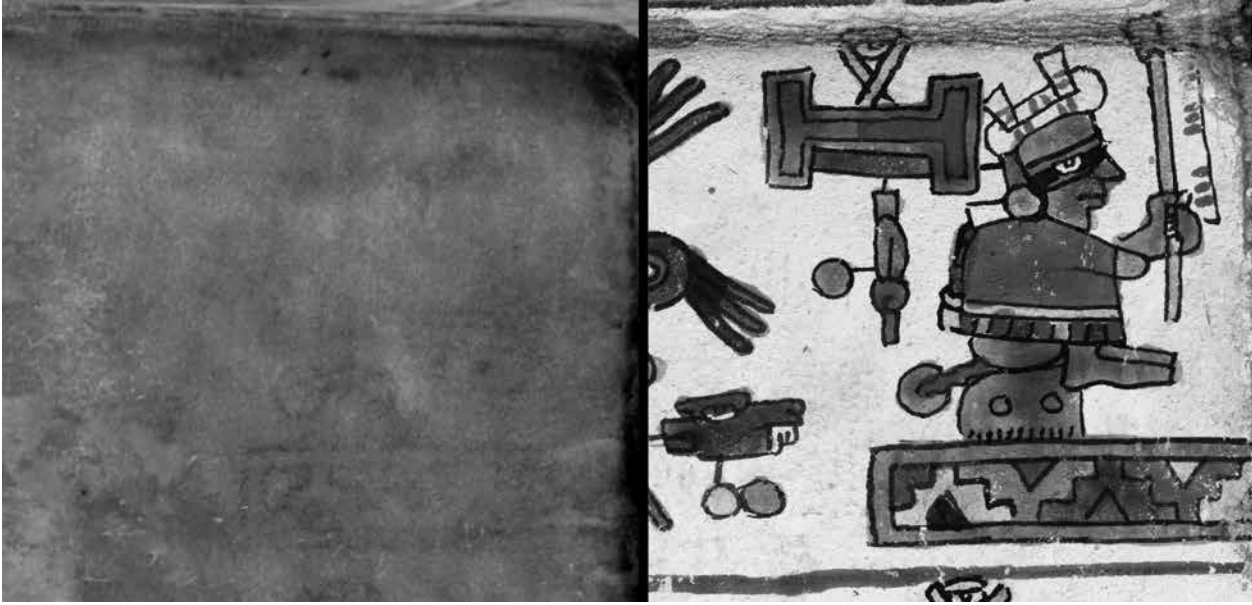


Figure 6.5: Comparison of Infrared image interpreted as positive result and the design on the front of that page (flipped for comparison) (courtesy of Bodleian Libraries, University of Oxford).

described as rather coarse lamp-black. As such, it is unable to penetrate into the gesso, but rather lies on top of it. When covered with a second layer of gesso it lies sandwiched in-between the two layers. Even a slight removal of the lower layer of gesso would, therefore, mean that the carbon would be completely destroyed. This is clearly seen if the infrared photos of the intervention on page 5 verso are compared (see figure 6.4).

It seems that the numbering of the infrared images was confused at some point at the National Gallery: the image recorded as image 4 is actually number 6 and vice versa. This can be determined by the fact that on image 6 cracks in the gesso layer are visible in areas where image 4 shows no gesso layer at all. Image 4 can also be compared to modern colour photos which indicate the same shapes of removed gesso. Although they considered it an improvement, the removal of gesso on page 5 can be shown to be highly destructive. In Figure 6.4, it can be clearly seen that the area in the red square originally contained traces of black pigment, all of which were lost by the time the last infrared photo was made. The present-day photo shows this area to be completely bare.

The statement of Dark and Plesters (1958b, pp. 533-534) that the wear of the hidden image can in no way be attributed to the thinning of the gesso layer is thus clearly false. It may be doubted whether or not the hidden images are as worn and smudged as they suggest, if it is taken into account that both xylene and white spirit act as paint solvents. The success that Dark and Plesters claim to have had with the final thinning of the gesso on page 5 verso (1958a, p. 10; 1958b, p. 533) is based on a misinterpretation of the data. The figure they refer to as visible in the top right corner of that page is in fact not an image of the palimpsest but a design that shines through from the front side (see figure 6.5).

A fortunate accidental discovery was made on the front of the document when this side was being observed to monitor the effect of the wetting with xylene. When the page was wet and thus more transparent, it was observed that on traces of black outlines could be seen as well. This would imply that the scribe who made the later codex used a book that had text on both sides. The infrared photos taken of two pages on the recto side are suggestive, as there are indeed traces of hidden drawings, though the possibility still exists that these are traces of

pentimenti or corrections rather than truly different designs. The fact that the design shines through on page 5 does not bode well. If there were other figures hidden underneath the picture on the front, these figures would have to be more clearly visible than the surface drawings. It can thus be concluded that the study by Dark and Plesters only had limited value for the interpretation of the state and the extent of the palimpsest in the Codex Añute.

### 6.3 THE TECHNIQUES OF THE 2012-2016

#### SCIENCE4ARTS INVESTIGATION

Much has changed since the 1950's, both in technical capabilities and in conservation concerns. Technological advances have made it easier to investigate the material composition and properties of objects, while at the same time rigorous conservation policies limit these possibilities, as they often demand fully non-invasive investigation. As such, the taking of samples or the physical removal of the covering gesso layer as was done in the 1950's is no longer an option. Getting better insight into the nature of the Añute palimpsest and possibly uncovering some parts of the hidden imagery thus must be done with non-invasive electromagnetic radiation based techniques. This radiation needs to penetrate the surface and interact in a way with the material which can be registered. The infrared photography used in the 1950's uses this principle as well. The basic principle is that the carbon black will absorb the infrared radiation while the white layer will reflect it, which can be registered with a camera sensitive to infrared radiation. Infrared has the advantage over, for example, visible light in that it is able to penetrate many materials, especially at higher wavelengths. X-rays also penetrate materials, though these do not interact well with any of the organic materials, due to the low molecular weight of these chemical substances.

Although their representativeness is circumspect, the treated pages 11 and 10 verso form the clearest indication at hand for the state of the images of the palimpsest. The black outlines are so severely damaged on the uncovered areas that it seems unlikely this was all due to the intervention of Dr.

Plenderleith. It is, therefore, to be expected that the carbon-black outlines of the figures on other pages were at least partially removed. In order to reconstruct the images, it was therefore necessary to gain a picture of the other colours. As can be seen in figure 6.2, there are red, orange, and yellow areas visible. These colours were considered to be organic from the start of the project, based on the analysis of Dark and Plesters and as the result of a comparison of Añute with other known codices. This was later confirmed by the MOLAB team.<sup>57</sup> At the beginning of this project, no technique was though capable of revealing such organic materials below a gesso surface. It was thus clear that some new technology needed to be developed in order to do this. As a result, the challenge of the project became twofold. On the one hand, the staff at the Bodleian Library needed to be convinced of the necessity of this investigation and the potential benefits; while, on the other hand, the effectiveness and applicability of the proposed techniques for doing the investigation needed to be proven. The rather dismissive attitude to the potential of this palimpsest after the investigation in the 1950's had left the Bodleian Library sceptical of such investigative procedures. As any investigation of the original documents is potentially damaging to these fragile objects, they are closely guarded and access is strictly regulated.

One advantage of modern technology over those available during the 1950's is the ability to investigate and edit images digitally. For example, by redrawing the outlines of the figures after close study of high resolution digital images it was possible to reconstruct part of page 11 verso. This showed the potential information that could be gained from this document digitally, and this in itself warranted the investigation of the original document further, provided that a technique was available that had a chance of finding new information on the still covered images.

A new technique was initially thought of by Prof. Schmidt-Ott (TU Delft, The Netherlands) and was given the name of Photothermal tomography (PTT).

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57. These results are to date unpublished. However, a preliminary report was provided by the team.

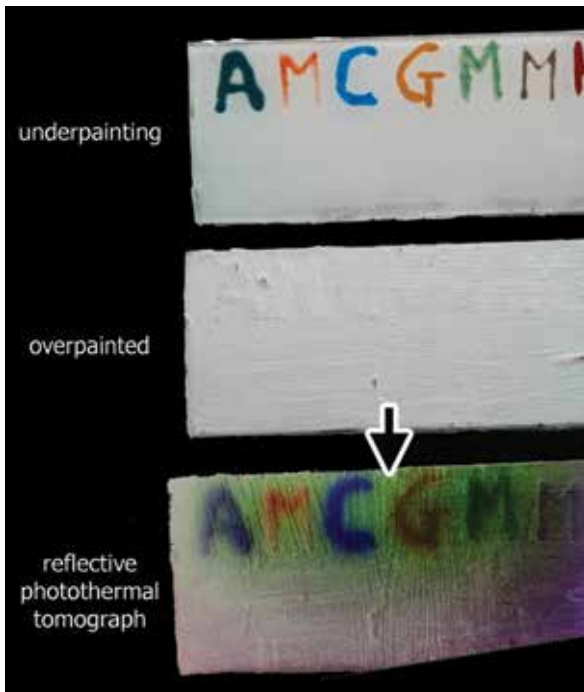


Figure 6.6: Early tests on sample show the effectiveness of Photothermal tomography (image made by T. Zaman).

In order to make sub-surface images visible, PTT relies on the registration of thermal energy generated by the absorption of visible light. When visible light hits an object, part of it is absorbed while the rest is reflected. The human eye registers the reflected wavelengths and constructs an image out of it. The absorption of visible light generates warmth, as the energy of the radiation is transformed into thermal energy. If one were able to register the amount of thermal energy created in this manner, it would be possible to determine the relative lightness or darkness of the object compared to its surroundings. In other words, if a white light is sent onto a white surface with a black line on it, a thermal camera will see little thermal energy coming from the white surface, but high thermal energy from the black line. As such, the thermal camera registers the inverse of a human eye.

An opaque solid reflects light rather than letting it through. On a molecular level, the light wave—or, more precisely, a photon—is absorbed by the electrons of

the surface molecules, which start to vibrate. Shortly after this, a photon is re-emitted out of the object. In a translucent object on the other hand, the vibration of the electrons is passed on from molecule to molecule until it reaches the other side of the object where it is emitted. In reality, no object is perfectly reflective or transmitting, but the light beam gradually loses its intensity as it travels through the surface. This process is called attenuation. The attenuation of the light also happens on the way back out of the object after it gets reflected by a sub-surface feature. As such seeing a sub-surface feature with the naked eye requires light travelling the distance from the surface to the sub-surface feature twice (in and out), without losing so much intensity through attenuation that our eyes cannot distinguish it anymore. If the intensity is too low, then the emitted light is no longer visible, as it is lost in the other light that is reflected off of the surface. The advantage of Photothermal tomography over our eyes or regular photography, then, is that the visible light only needs to make a one-way trip through the gesso surface, as the registered signal is not the returning light, but the thermal energy in the form of infrared radiation. Infrared radiation does not suffer from much attenuation in solids like gesso, making the signal relatively strong when it reaches the camera.

Colours can be reconstructed using this principle as well. For this task, the object is illuminated using different colours of light. Just like the human eye registers colours as the relative amount of red, green, and blue, the registration of the relative absorption of red, green, and blue light can be used to calculate the colour of a surface. Measuring the thermal energy of a blue surface will thus yield high results for red and green, but low results for blue, as red and green are absorbed, while blue light is reflected.

In order to test the applicability of this technique for the particularities of the codex, a testing prototype of the device was made. Its main component is a FLIR SC7000 infrared camera capable of recording minute temperature variations. These variations are so minute, however, that distortion can take place because of passing air flows. To prevent this from occurring, the particular model used for these tests had a lock-in function, meaning it could filter out the

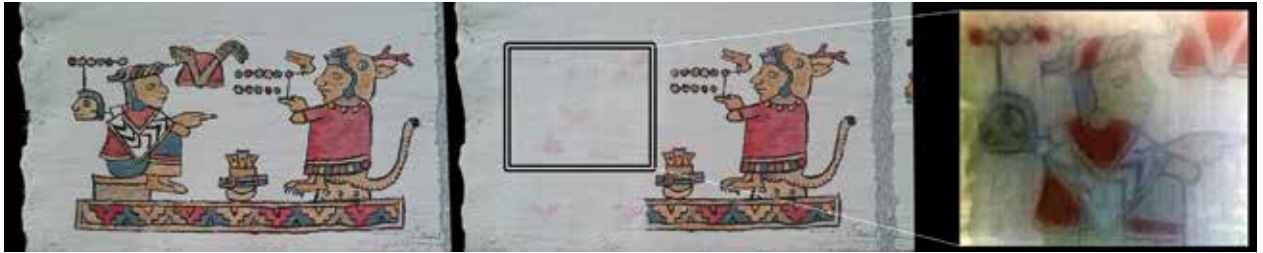


Figure 6.7: Test sample partially covered with new gesso layer and the resultant image from Photothermal tomography (image by Zaman).

signal from the environmental noise by amplification with a reference signal. This signal comes directly from the light source. For the early experiments, a beamer was used as a light source, as these are easily targeted sources for red, green, blue, and white light. Early tests were done on a sample: a glass plate on which letters had been written using different materials which was covered with a layer of lead white paint. These tests were very successful, as the full range of colours of the completely covered letters could be recovered (see figure 6.6).

With this proof of concept, a second step was to test the technique on a sample that was as close to the original codex as possible. At this stage, the results of the MOLAB investigation had not been published yet, and as a result the sample was made based on the results of Dark and Plesters (1958a, 1958b), combined with published information on the material composition of other codices. The sample was made on leather covered with a gesso made of gypsum and animal glue, on which two figures were drawn. These were made using carbon black; a yellow made from old fustic;<sup>58</sup> blue from a mix of indigo<sup>59</sup> and clay; and red from cochineal. The left of the two figures was covered with gesso until it was completely obscured. For the purpose of studying the effectiveness of this technique, the composition of the paints is almost of no consequence. This is because the production of thermal energy is dependent mostly on the absorption of visible light, a property that is directly related to the colour of the substance. Of greater importance to the effectiveness of this technique are the thermal and optical characteristics of the layer covering the

drawings. In figure 6.6, it can be seen that the thermal energy spreads through the material of the sample, giving the letters in the result a green halo. This spread of heat through the sample can obscure the signal. The attenuation is a property of the covering material as well, but this is also related to the thickness of the applied layer. It became clear during these secondary tests, that completely obscuring a drawing so that it was invisible even for the TTT can be done relatively easily by simply covering it with a much thicker layer. Nonetheless, it was possible to recover the hidden image on the sample (see figure 6.7). These tests also showed a secondary challenge to the PTT technique. As can be seen in the picture of the covered sample, the cochineal red paint bled through to the surface. It is clear that this happened because the cochineal paint was not well washed, meaning that it was composed of a mixture of pigment and dye (see chapter 2). When covered with a white layer, the dye stain would rise to the surface. The resultant differences in surface colour caused differences in the production of thermal energy at the surface, by direct absorption of the light in the red areas. In the resultant PTT image, the red has therefore a much stronger presence, which results in a suppression of the other colours.

With these tests the limit of what could be learned from tests on samples was reached. Since there was no possibility of taking samples of the original codices, there was no secure identification of the exact composition of the covering gesso. Besides this, there was no way to accurately measure the thickness of the layer over the entire document. Therefore there was no other way to proceed than to test the technique on the original codex.

58. At this point the Zacatlaxcalli was not yet available.

59. At this point Matlallin was not yet identified.



Figure 6.8: Setup of the Photothermal tomography prototype at Bodleian Library during the 2013 investigation of the Añute palimpsest (photo by T. Zaman).

In order to do this, however, not only the proof of concept of the technique needed to be provided to the Bodleian Library, but also a risk assessment of the technique. Since in PTT registration is done with a thermal camera, there is a continuous live application and monitoring of thermal fluctuations in the object. Thermal fluctuation in an object can in principle be very damaging to a fragile artefact. The thermal variation that is introduced by the pulsing light is, however, extremely low. The FLIR camera used in this setup measures thermal fluctuation in the order of  $0.001^{\circ}\text{C}$ . The maximum temperature fluctuation measured during testing was around  $0.05^{\circ}\text{C}$ . This is well within safety margins, as larger temperature fluctuations result from simply touching the object. But in addition to the thermal aspect, concerns about the exposure of the object to prolonged periods of intensive light could be raised. However, since the technique is only applied to the reverse of the codex,

which has no drawings on the surface, there is no danger of discoloration due to exposure to light.

With the obtained test results, a first investigation of the original codex was allowed in November 2013. During this visit the investigation of the MOLAB team also took place. Despite a planning meeting two weeks prior to the intervention, the codex Añute was only available for this investigation after the MOLAB finished its investigation. This meant a two hour window on the last day of the visit. Since the lock-in function requires the comparison of a measurement with a reference signal, a longer measurement results in better extraction of the signal from the background noise. Thus, there is a continuous tension between the number of images that can be taken in a given time and the quality of those recordings. In the two hours of the first visit, 41 images were taken. In order to reconstruct the colour, three images need to

be taken of each section (with red, green, and blue light). But since the light needed to be focused on a small area to make sure that a large enough amount of light penetrates the gesso layer, only a small area could be investigated at any one time. In figure 6.8, the prototype setup is shown. The resultant images were somewhat promising in the sense that they revealed some features that were not visible before. However, these features could not at that time be identified. The test was most successful in indicating where improvements to the technique's design were necessary. The issues that came up with the images taken mostly had to do with distortion due to the angle of the camera to the surface. As the camera could not be placed perpendicular to the surface, problems arose with focussing the image, as the camera had a low depth of field. And since the light source was also not perpendicular to the surface, attenuation in the surface was larger, because the light had to travel further through the surface.

It was decided that an integration of the light source and the camera was needed. First tests with a ring flash design around the lens of the camera proved ineffective, as the LED lights were not powerful enough to guarantee a high enough degree of penetration of the surface. Moreover, simply making use of stronger LED lights would result in the generation of too much heat by the light source itself, resulting in more noise when analysing the images that were acquired by means of PPT. A second prototype was a linear flash arrangement composed of a series of LED's in a tube that could be placed under the camera. This tube was cooled by fans on the sides, thus reducing the heat that would interfere with the measurement.

In March of 2015, a second investigation of the palimpsest by the Delft-Leiden team took place. In order to maximize chances of recovering new information, a range of auxiliary non-invasive techniques were also brought and calculated in the schedule. For the PTT, both the linear light source and the projector used earlier were brought. One advantage of the projector turned out to be the biggest issue with the linear flash arrangement: the ability to focus the produced light in a sufficient manner. Once the technique was tested again with the projector –

this time in a different configuration with both the camera and the light source virtually perpendicular to the surface and the light right next to it – a true stumbling block was discovered.

In the infrared images taken during the 1950's investigation, a specific black feature had been identified that was, as could be observed on the original codex, completely covered with gesso. This feature, therefore, would make for a good target for the testing of the PTT. In the area where the black feature was known to be, the PTT recording showed a colder area. Since the feature was black, this clearly should not be the case. Furthermore, this colder area did not have the shape of the feature seen in the 1950's IR image. The only explanation for this can be that the gesso surface contains internal faults which prevent the transmission of heat back to the surface. While we know that the technique itself functions, it thus turned out to be inapplicable on this specific case.

This set-back meant that the objectives of the intervention needed to be re-evaluated. The focus shifted away from the recovery of subsurface features to the recording of information visible at the surface. Techniques that were brought as auxiliary techniques in order to help the interpretation of the Photothermal results now became the new, main tools of the investigation. In many places, either because of the investigation in the 1950's or because of natural wear, part of the palimpsest had already become physically exposed. By recording these areas in as much detail as possible, a better understanding of the covered texts could still be attained. One of the ways in which these surface features could be recorded was RTI imaging. As described in chapter 5, RTI imaging is a technique that reconstructs surface texture from a series of regular photographs. It creates a dynamic image where the user can manipulate the position of the light source and thus interpret the surface features. This technique was first developed by Malzbender et al. (2001) under the name "polynomial texture mapping". Multiple images with known position of a light source are used to calculate the colour of each pixel under specific lighting conditions. In general, more input images amounts to a more detailed picture, if the position of the camera is consistent and the position of the light source known precisely.

Zaman had developed his own device to function as a light source: sixty circuit board struts with an LED on each assembled into a geodesic dome. Zaman mounted this dome directly onto the lens of the camera, which, in combination with the right lens, allowed pictures to be taken at a distance of about 30 cm from the object. The dome was connected to the camera so that once started, 60 pictures with varying illumination could be taken without further human interference, which would inevitably move the camera. These sixty images can then be turned into one composite RTI image. Because of the quality of the camera (50 megapixel Nikon D800) and the short distance at which the photographs were taken, the results are almost microscopic images. On the RTI images hairs embedded in the surface, as well as any other irregularities in the surface, can easily be distinguished. Surface topography can be of great importance for the interpretation of visual data. When a normal two-dimensional image is made where either the light source or the lens is positioned at an angle to the surface,<sup>60</sup> differences in height will cast shadows. Such surface shadows are captured by the camera and registered as areas that are darker than their surroundings. In practice, it can be difficult to distinguish between such shadows and areas that are darker because of painted features. And in the interpretation of the uncovered palimpsest, shadows are a major issue, because if not recognised as shadows they may result in faulty or flawed inferences on the part of the interpreter. Not only is the gesso layer removed in a very uneven manner, the uncovered leather exhibit folds. All of these features, then, need to be taken into account when reconstructing the outlines of the figures.

The fragmentary nature of the black outlines – as uncovered using infrared photography in the 1950's – suggested that modern techniques would not reveal much new data on the black outlines. Nonetheless, digital infrared photographs were taken of all pages, to give researchers a complete overview rather than forcing them to make do with information only about the six pages which were photographed in the 1950's.

60. In practice this is always the case as the light source is never located inside the lens. The RTI image does have the ability to calculate what the image looks like when the virtual light is positioned exactly in the middle of the image.

Insofar as they could be seen, the black outlines were fragmented on all the codex pages and no large features appeared. Owing to the same subsurface faults that prevented the transmission of heat back to the surface, however, the quality of the photographs taken using infrared radiation was rather limited.

While performing these investigations using (IR) photography, RTI imaging, and PTT, the department of conservation at the Bodleian Library obtained equipment for hyperspectral imaging. In hyperspectral imaging, a scanner detects the spectral response of the surface. For each pixel of the image, a complete spectral curve is thus known. The level of detail, as well as the range at which this data is gathered, depends on the type and model of scanner. The Headwall scanner used at the Bodleian Library (Hyperspec® VNIR E-Series) measured the spectral response between 380 and 1,000 nm in 923 steps.<sup>61</sup> This benchtop system had a scanner mounted vertically above a linear translation stage moving perpendicular to the scan line. This model takes a line scan of 1,600 pixels. The translation stage moves the object underneath the scanner. This results in scans of 1,600 by X pixels, where X is determined by the speed of the stage and the recording speed. In case of the scans made of the codex pages, each measured 1,600x~1,200 pixels.<sup>62</sup> The resultant data contains 923 data points for each of the resultant 1,920,000 pixels. These 1.8 billion data points can also be seen as a stack of images representing the reflection of the surface of the object under study if illuminated with only one of those 923 measured wavelengths. It is, then, not surprising that this so-called data cube is very large. Each of the scans made is between ten and twelve gigabytes. This fact, combined with the limited time left for this investigation and the fact that it was unknown what the investigation would yield, meant that not all pages were scanned during this 2015 intervention. Since the focus of investigation had shifted away from the recovery of

61. Information from Headwall Datasheet (see <http://www.headwallphotonics.com/spectral-imaging/hyperspectral/vnir>, accessed 07-12-2015).

62. Though the codex pages are square the capture was intentionally rectangular, this is because the lens of the scanner did not have a great depth of field meaning that at the edges of the line, the image became less sharp.

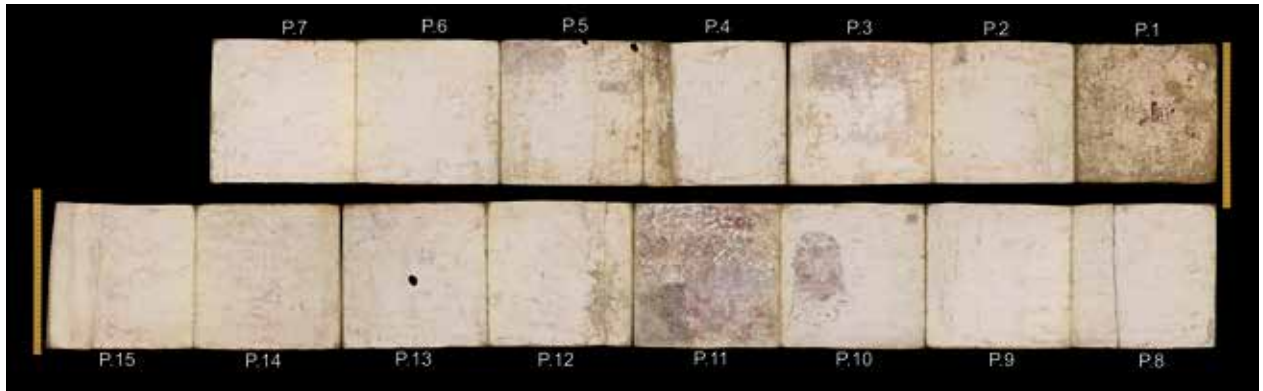


Figure 6.9: Overview of the reverse of Codex Añute, damaged areas are mostly concentrated in pages 1, 3, 5, 10, and 11 (images courtesy of Bodleian Libraries, University of Oxford).

the palimpsest towards the recording of the visible surface features, it was decided that those pages that were most damaged should be the main focus: i.e. page 11, 10, 5, 3, and 1 verso. After these pages were scanned there was some time to continue with pages 6 and 7, as well as two pages of the front: pages 1 and 2 recto. Even this limited endeavour resulted in a large amount of data that needed to be analysed using specialised software. One such piece of software is Exelis ENVI®, software originally designed to analyse hyperspectral imaging data from satellites. This software has many applications in data analysis, but the feature that yielded the best results in the case of our investigation was MNF or Minimum Noise Fraction Transform. This operation uses Principle Component Analysis to determine the spectral differences of the material investigated, after the noise has been filtered out.<sup>63</sup> In practical terms, this method generates a series of grey-scale images – or MNF bands – each representing the distribution of a computer-estimated unique spectrum. The MNF transform orders these images in a way that the noise increases in each following image. As such the most common spectra are in the first images. Since only few colours were used, only the first five or six bands contain much useful information. One of these is the distribution of white, which resulted in a more or less black and white picture of the surface.

63. For more on this operation see <http://www.exelisvis.com/docs/MinimumNoiseFractionTransform.html>, accessed 24-10-2015.

Comparison between these images can show not only the distribution of different colours, but can also indicate those areas where colours are mixed.

#### 6.4 THE VISIBLE AREAS

By bringing together all the information from the techniques discussed above, it has been possible to reconstruct part of the palimpsest. The most detailed reconstructions came from those areas that have been uncovered by the 1950's investigation, though other areas where the gesso is damaged were informative as well. Figure 6.9 shows an overview of the fifteen pages on the reverse that contain covered images. On the left of page 15, the first bit of added blank leather is visible. The areas with the most damage to the gesso and where parts of the hidden images are visible are page 1; the top and right of page 3; the top of page 5; the central area of page 10; and the entirety of page 11 (see figure 6.10).

Page 11 is most completely uncovered. While this means that it is probably one of the most damaged sections of the palimpsest (with the possible exception of the cover page 1 verso), it is also the easiest to investigate, because the damage allows for an almost complete overview of the entire page. This overview in turn can be utilised to help to shape the expectancy for what is to be found on the other pages. What is clear immediately from macroscopic investigation is that the pages are to be read in a horizontal manner in contrast to the text on the front

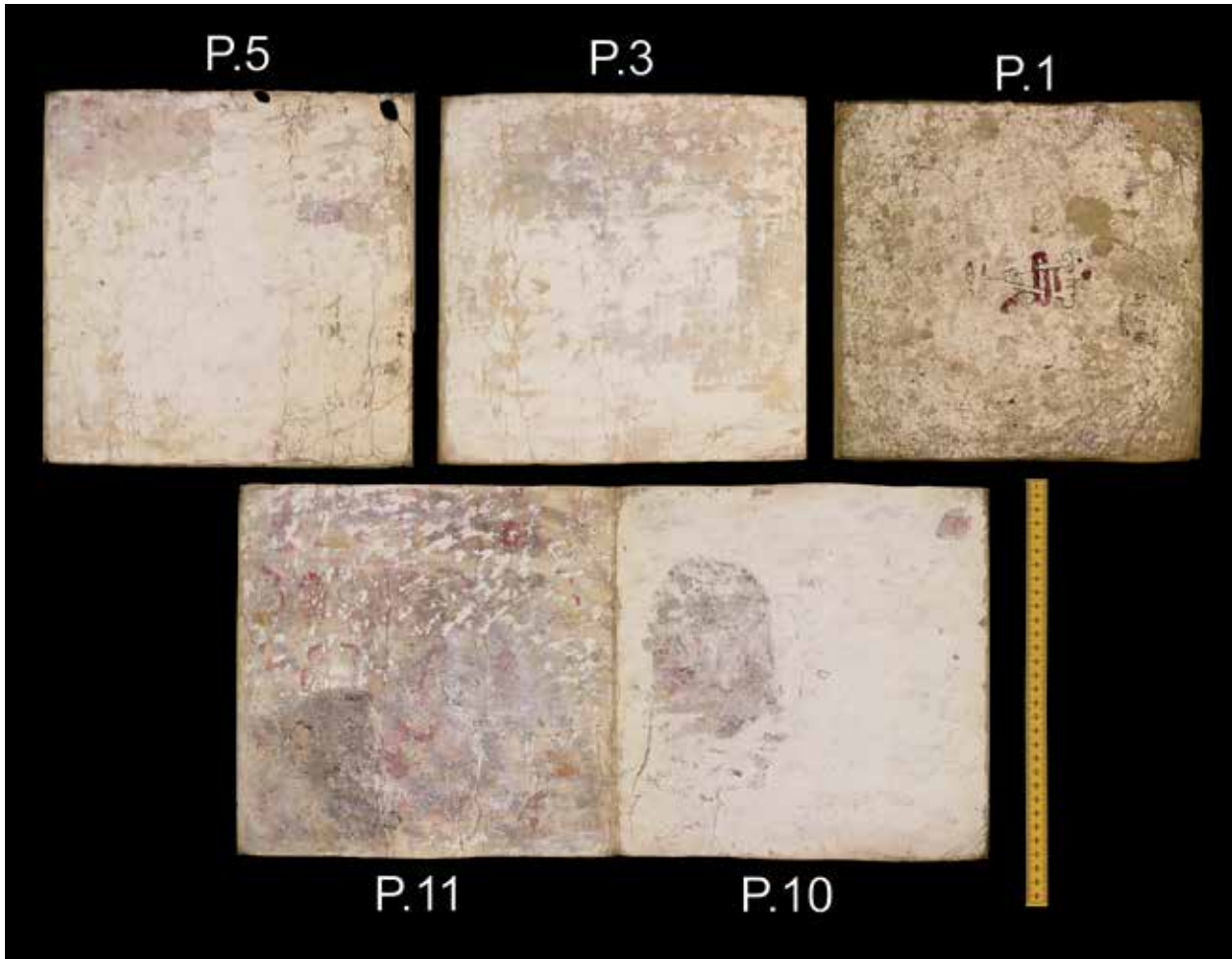


Figure 6.10: The uncovered areas of the Añute palimpsest (images of individual pages courtesy of Bodleian Libraries, University of Oxford).

which is read vertically. It is also immediately clear that page 11 is divided into five lines.

The process of reconstruction itself involves a continuous switching between the four techniques used to record surface information. As an example, the reconstruction of the central figure will be discussed in detail. After this, the general interpretation of the reconstruction as a whole will be explained.

On a normal photograph of the section, a sitting person facing right can already be distinguished (see figure 6.11 top left). This figure is in a relatively good condition. The person in the figure is sitting on his/her knees, in a position also found in the codex

Tonindeye (Nuttall), though in the case of the codex Tonindeye only women are depicted sitting like this (see figure 6.11 top right). We can infer, then, that the person in the figure on page 11 of Codex Añute is most likely a woman. She is depicted wearing a red quechquemilt and also has a red section on the top of her head. It is unclear whether this red section was red hair, part of a headdress, or if the red was simply a base over which some other, now removed, colours were painted. Somewhat less clearly visible, though still distinguishable, are her eye, the bridge of her nose, and her feet. As in the other codices most seated figures make specific hand gestures and so it stands to reason that the traces in front of her chest are remnants of her arms and hands, though the exact



Figure 6.11 left: central image of page 11 verso Codex Añute (courtesy Bodleian Libraries, University of Oxford); central: Lady 8 Eagle, of Codex Tonindeye (Nuttall) (after Anders, Jansen, & Pérez Jiménez, 1992 facsimile p.13); right: IR image from 1958 made with xylene covering the surface (courtesy of Bodleian Libraries, University of Oxford).

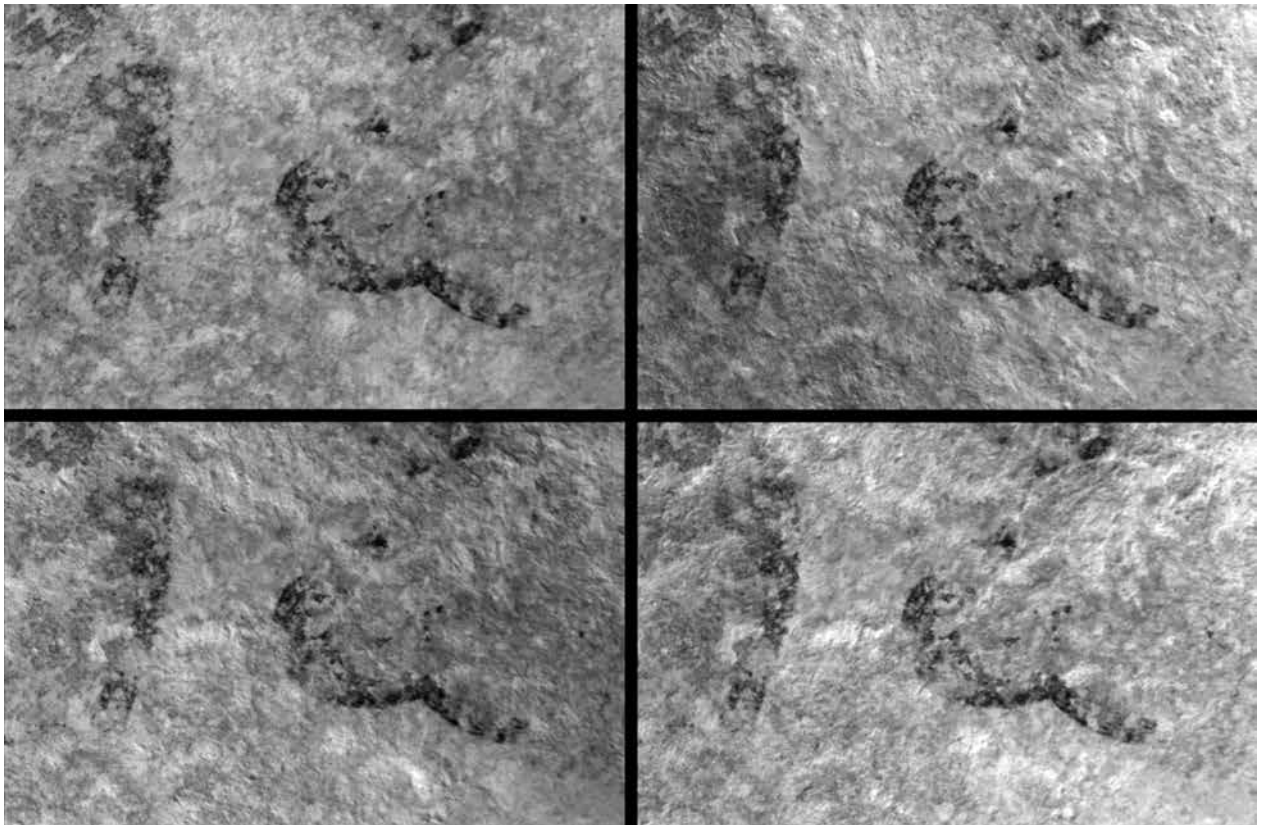


Figure 6.12: Macro images from the centre of page 11 verso of Codex Añute generated from RTI image, illuminated from four different angles (images by Zaman).

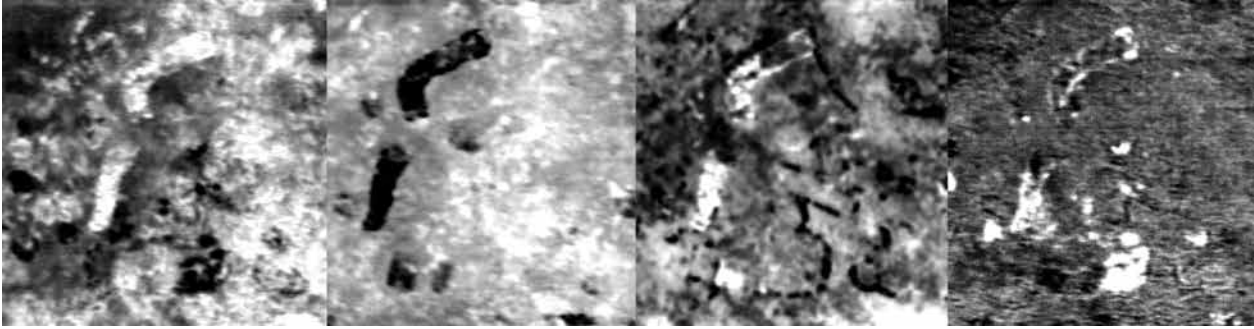


Figure 6.13: Results after noise reduction of hyperspectral image of central area on Codex Añute page 11 verso (images by the author).

posture cannot be seen here. It seems in this photo as though her chin is visible in the dark and rounded stain directly below her eyes. When this photo is compared with the infrared image that was made in the 1950's, however, this dark area is no longer visible (see figure 6.11).

In this photo, the codex had been wetted with xylene, which made it possible to look through the remnants of gesso and distinguish all traces of black outlines. Besides the outline of her face, the arm, stomach, and knees are also clearly visible. The hand too can be better distinguished and a stretched-out finger, as if she is pointing at something, can be seen. This gesture would indicate that this lady is instructing (see Jansen & Pérez Jiménez, 2011, p. 227). It seems that in the IR image a black line connects the knees of the female with a series of dots. This would indicate that her calendar name is to be found in front of her. If the RTI image of this section is studied more closely, however, it becomes clear that this dark line is a surface shadow, cast by an elongated remnant of the covering gesso.

Although the dynamism of the RTI image does not translate well into the static printed style of this work, the four images in figure 6.12 do show these differences in surface shadow, as each is illuminated from a different angle. By combining the RTI and the infrared photos with the hyperspectral imaging results (see figure 6.13), a more thorough reconstruction is possible. With this last technique in particular, it is possible to distinguish between visually similar materials. This can help, for example, to distinguish yellow paint from the yellowed leather background.

Since the surface of this image is very rough due to the scraping of the gesso, during the interpretation of the hyperspectral data it is important to refer to the RTI images as well. Combining all the data, it becomes possible to reconstruct this small section in more detail (see also figure 6.15 and Appendix C).

This same procedure has been repeated for all the figures on this page. Two issues make the interpretation of some sections more difficult, however: damage to the images and distortion of the hyperspectral imaging data. As can be seen in figure 6.10, the damage to this page, as well as the thickness of the remaining gesso, is variable. On the top register, it seems that the investigators in the 1950's went rather deep with their removal techniques. As a result, there is a lot of bare leather visible and not that much remains of the designs. In the bottom left, on the other hand, it seems that the removal did not go that far. A large dark stain is visible, which was possibly caused by smearing the carbon black outlines that are most visible in this area when covering it with a new gesso layer. Furthermore, the hyperspectral data becomes less clear towards the upper and lower edges. This is because of distortion due to surface irregularities – such as flakes of unremoved gesso – is bigger when the angle between the surface and the camera is less than 90 degrees. Thus, the centre of the scan, above which the camera hangs, is quite clear, while at the top and bottom surface irregularities create shadows and other aberrations.

What is clear from the hyperspectral imaging data (see also figure 6.18) is that the reading lines continue on the right-hand side of the page. Thus, the

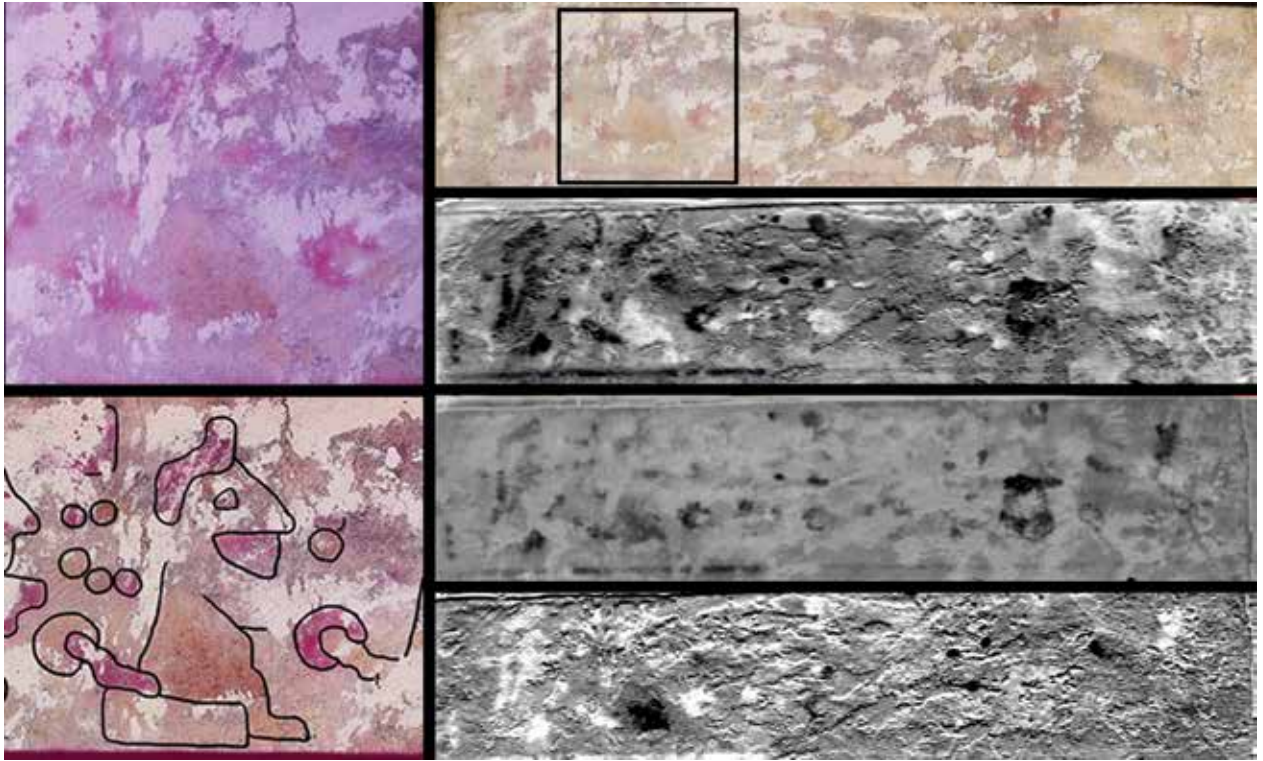


Figure 6.14: Compilation of photographs and hyperspectral imaging results of the top section of page 11 verso (by the author).

images in the palimpsest need to be read two pages at a time in a boustrophedon manner akin to the reading of the codex *Ñuu Tnoo-Ndisi Nu* (Bodley). For the purpose of interpreting an individual page – such as the uncovered page 11 – this makes everything a lot more difficult, because rather than having one continuous page, there are three sections of the narrative on each page. The top section of this page contains an important clue as to the direction of reading of this document. A series of persons is sitting in a row facing right. At least three of these have an element connected to their behind. This elongated element leads to a circular element of a different colour. This is the regular way of representing an umbilical cord (see figure 6.14). Parts of this diagnostic element can be seen at least three times, either in the form of the circular or crescent moon shape to which it connects, or as elongated element representing the cord itself. For the figure on the far left, one cannot be completely certain if he/she has an umbilical cord attached to its behind, as it is not visible how the yellow line behind the individual

ends. However, given that this figure is followed by at least three figures that display this umbilical cord very clearly, it is likely that this first person is also depicted as being born. The general rule is that persons being born are looking in the direction of reading (Jansen & Pérez Jiménez, 2011, p. 232). This would mean that the codex is read from left to right and that on these two pages 11 and 10 the order is top to bottom. This allows for the reconstruction of the full reading order of the entire document, assuming that there are no clean breaks like those found in the codex *Tonindeye*.

Even though they are not all clearly visible, it is possible to reconstruct six people on the top section of this page, the left four of which are likely being born. The reading order would suggest that their parents are depicted on page 12 on the top row. On the top right of page 11, there is again a person sitting facing right. He or she is facing right just like the others. The body as well as a feather-like headdress are depicted in red. It is unclear if this person is

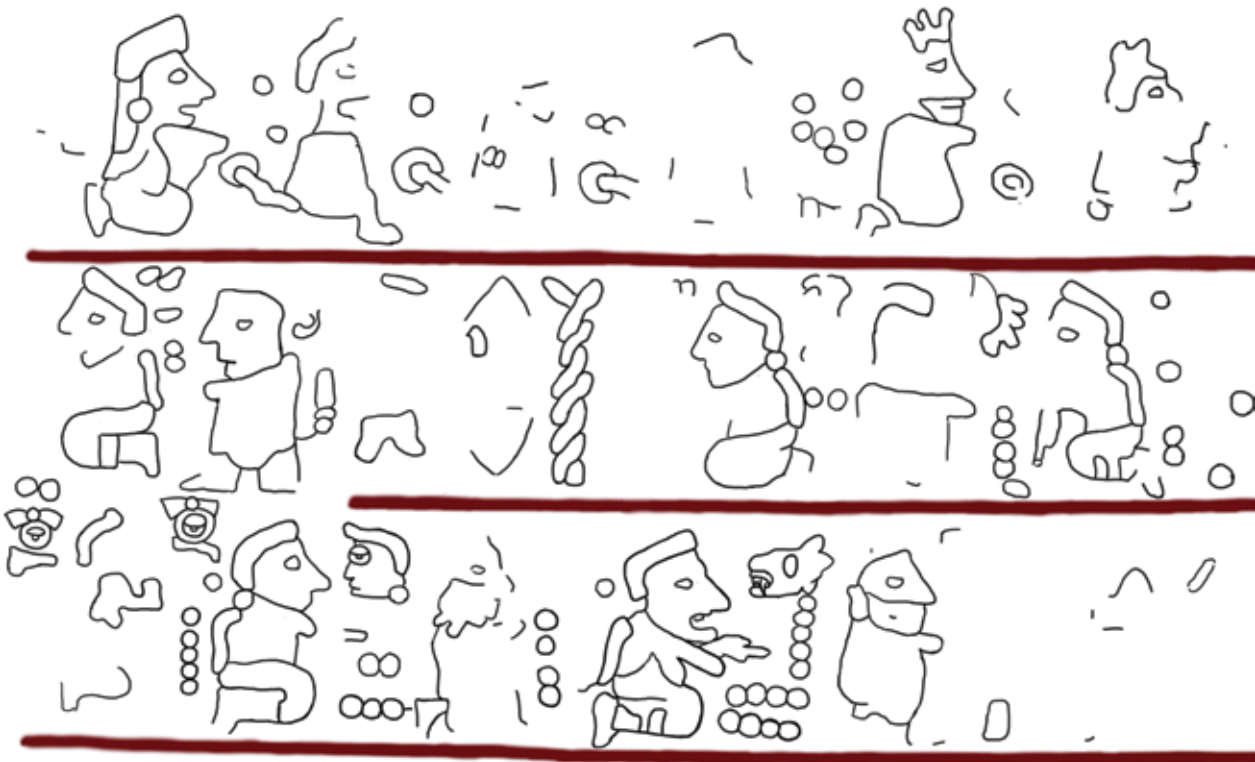


Figure 6.15: Drawn outlines of Codex Añute page 11 verso sections 1 and 2 (image by the author).

also part of the group being born or if this person represents the start of a different scene. Generally, a new scene coming after a depiction of persons being born would start with an action performed by one of these neonates, perhaps in later life. In that case there would be a repetition of an earlier depiction, most often of the oldest child; i.e. the one depicted first in the series. In order to check this hypothesis, the top of page 12 would have to be revealed to check if the person on the top left of page 11 verso is the first born or not. On the top right of this page a sixth figure was depicted. This is very difficult to reconstruct due to the damage in this area. It may be another person, though if so, it is impossible to determine the direction that he or she is facing, which makes it impossible to further determine the possible personal relation with the preceding figures. The identity of the persons on this line are also still a mystery. The calendar names, some of which can be localised, cannot be identified. Due to the damage to this page, they remain nothing more than a series of dots, the exact number of which cannot be

determined. Moreover, there is only an unidentifiable stain where the calendar glyphs used to be.

The second section (see figure 6.15) starts on the right of line two and runs until the right of line three. It starts with a woman, similar to the central figure described above, wearing a quechquemiltl, sitting on her knees, and facing left. She is pointing down with one hand, a gesture often made in marriage scenes in the codex Tonindeye – for example, on page 32 – or in the context of persons greeting each other (see Jansen & Pérez Jiménez, 2011, pp. 223-229). In front of her, barely visible in the regular photographs, are traces of what most likely is another person. This person is almost completely depicted in yellow with the exception of a red area on the top of the head. Considering the context of the noted hand gesture, it is likely that this person is facing right. The general shape of the figure in the hyperspectral results also makes this likely. Between these two figures there is a series of dots and a calendar sign that resembles an eagle looking upwards. The numeral that goes with

it is unclear and could be anywhere from five to ten. Since there are more numerals behind the Lady on the right, which is the regular place for the calendar name, it stands to reason that the name 5? Eagle?<sup>64</sup> belongs to the second person on this line. To the left of these first two persons, another left-facing woman is seated. Between the second and third person on this line a possible calendar name can be found. At least two dots can be seen, though there may be more. The calendar sign itself is illegible. In the centre of line two, a series of non-person glyphs can be located. Their meaning is unclear, though the two central elements look like a twisted cord and a giant flint. Following this, on the left side of the line, two more persons can be seen facing left. The first is most likely male, the second is clearly female. The first has a calendar name behind him that may be sign for Reed, though the numeral is hard to reconstruct. The lady has a calendar name 2? Rain?. On the following line, five more people can be seen facing right. The first seems to be standing and has a Tlaloc-type face. If there is consistency in the placing of the calendar names, the first person is named 2-13 Rain. The number is hard to distinguish because it is close to the edge of the page and there is a lot of wear there. Two dots are clearly visible above the Rain sign, while another series may be below it. It is unusual to have the numerals divided in such a way by the sign, though it is not unknown in the other codices (see Codex Añute page 4 Lord 10 Reed, for example). The second person on line 3 is lady 6? Rain. She is followed by what at first appears to be the face of a person looking at her. This would indicate a marriage and it has been interpreted in this way by Caso (1964). However, close study of all the available data shows that there is no body under the head, but rather a string of dot numerals. It, therefore, appears that this head is the sign for Monkey, belonging to the figure following it. This character is mostly depicted in yellow and is therefore difficult to distinguish from the background, though again it appears to be facing in the direction of reading. After this follows the central character discussed above, who cannot be identified beyond the fact that her calendar name has

64. In order to indicate the uncertainty of identifications of persons here, the question mark is placed behind uncertain identifications. If a sign is completely illegible, an X is used to indicate this. For some numerals, a range is indicated.

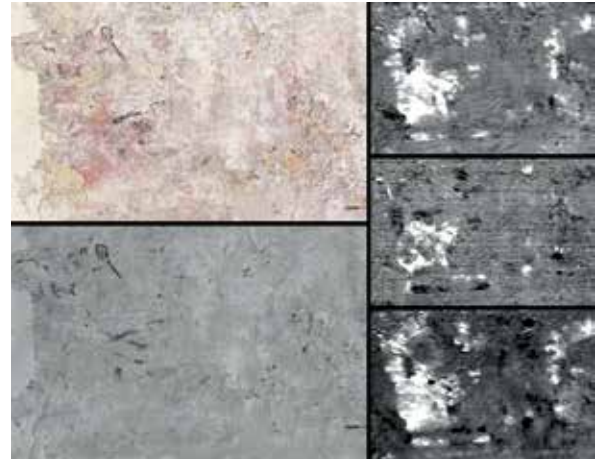


Figure 6.16: Exposed part of page 10 verso in different modes: visible light photography (top left, courtesy of Bodleian Libraries, University of Oxford); IR Imaging (bottom left); and three MNF bands of hyperspectral imaging (right).

a numeral of at least five, and the calendar sign is likely some mammal. She is followed by a person, most likely male, 13? Jaguar? A black feature seen in the IR images from the 1950's suggests that this person had a tooth sticking out of his mouth, identifying this character as an elderly man. To the right of him there is a very damaged section. In this section, very little paint traces remain. The IR data shows only fragments of black lines. It may be that this section contained a year sign, though it is difficult to be certain. This section continues on page 10 in the area that was cleaned there. Here again two persons are seen facing in the reading direction. Both of them are wearing a feathered headdress or eagle dress. In the infrared photos, the details of these feathers can be seen (see figure 6.16 bottom left). Since only such a small part of the page was uncovered, there is not much more that can be said about these two persons without further recovery of subsurface images.

The bottom two lines of page 11 verso (see figure 6.17) start with another continuous line of persons looking in the reading direction. Line 4 has seven such figures. The first has a body with an orange colour and may have a tail and a claw on his foot. This would give him a given name related to puma or jaguar. Unfortunately, his calendar name cannot be made out. He is followed by a figure of which the



Figure 6.17: Drawn outlines of Codex Añute page 11 verso section 3 (image by the author).

face can be clearly made out, though no identifying elements can be reconstructed. The third person is also very difficult to distinguish, and only what may be a feathered headdress or part of an eagle dress can be seen besides the rough outline of the face.

For this person, the calendar sign seems to be water, with a number 7. Following this is another likely male person. He seems to have an opened or differently coloured mouth. His calendar name can be rather securely identified as 6 Eagle. This Lord 6 Eagle is followed by three more persons. The first is in the middle of the darker area, which as mentioned before, seems to have this colour because less gesso has been removed here. On the one hand, this makes it more difficult to interpret, as there are more surface irregularities and parts still covered; on the other hand, there are a lot more black outlines visible in this area as well. This figure has a headdress similar to the third figure of this line. He may be wearing a full eagle dress. The location of his calendar name is due to the uneven surface hard to determine. It may well be that some of the circles here reconstructed

are actually part of the calendar sign. The last two persons on this line are Lord? 2-4? X and Lord? 1 Death. The first of these two has an eye in the shape of a knife. The left figure again seems to be wearing a feathered headdress or eagle suit. The first person on line 5 wears the clearest example of such a feathered headdress. Only very faint traces of the numeral of his calendar name can be seen, though these can again not be reconstructed, due to the wear at the edge of the page. He is followed by another person, probably male and also facing right. His calendar name is 4-9? House. This person is followed by a section that looks similar to that found on line 2. There may again be a twisted cord and a large flint design present, though here they are more difficult to reconstruct due to surface irregularities. On the far right of these otherwise uninterpretable designs, are the very vague remains of what may have been two figures facing each other. But the severe damage here does not allow for any further interpretation.

With this reconstruction of page 11 and a little of page 10 verso, a part of the style of the subsurface

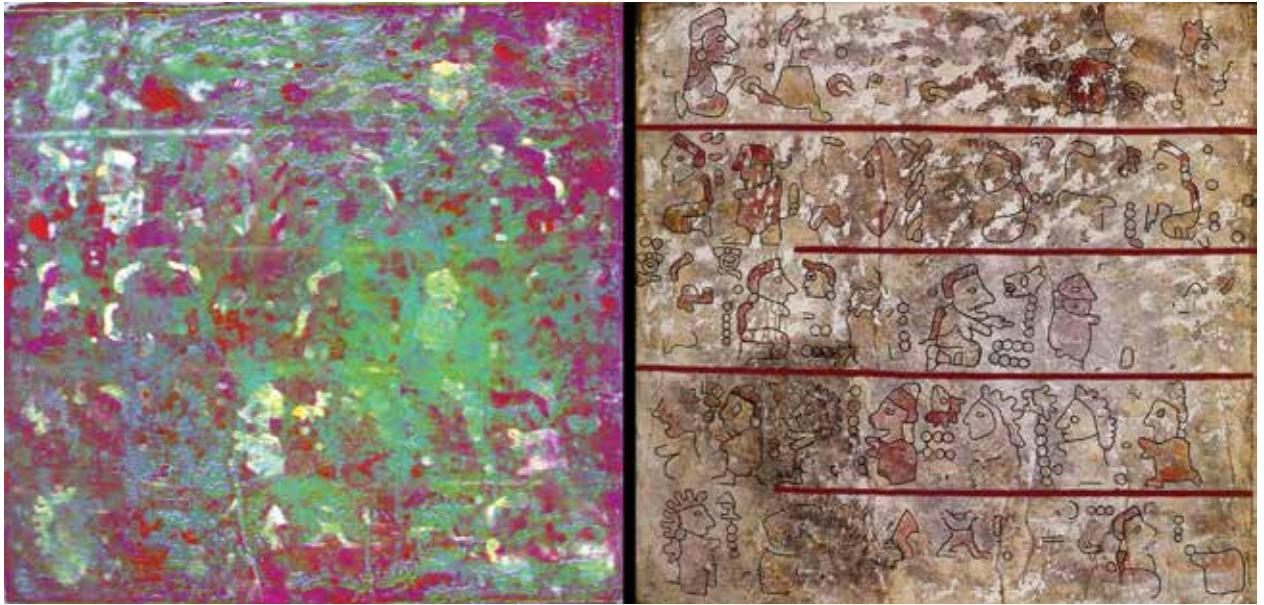


Figure 6.18: False-colour composite made with three hyperspectral minimum noise fractions of page 11 verso (images by the author)

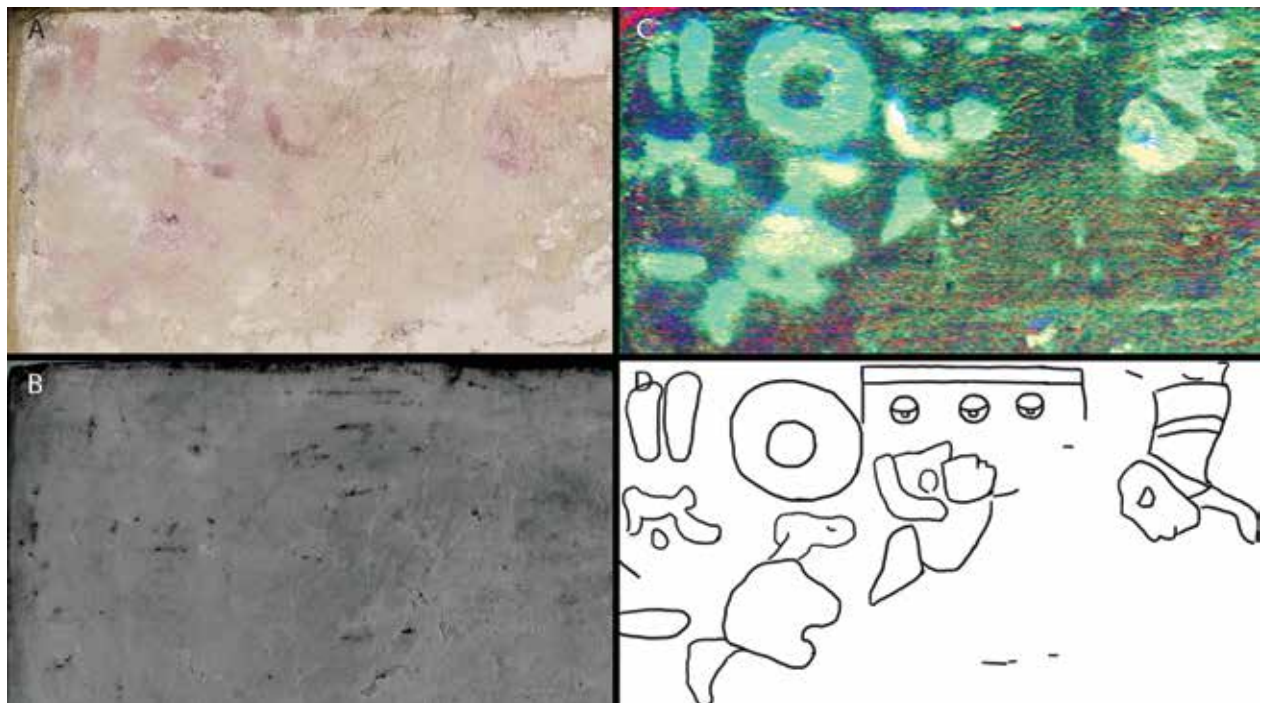


Figure 6.19: Top left of page 5 in four modes: normal photography (A, courtesy of Bodleian Libraries, University of Oxford); hyperspectral imaging (B); pre-1950's intervention infrared image (C, courtesy of Bodleian Libraries, University of Oxford); and (D) line drawing.

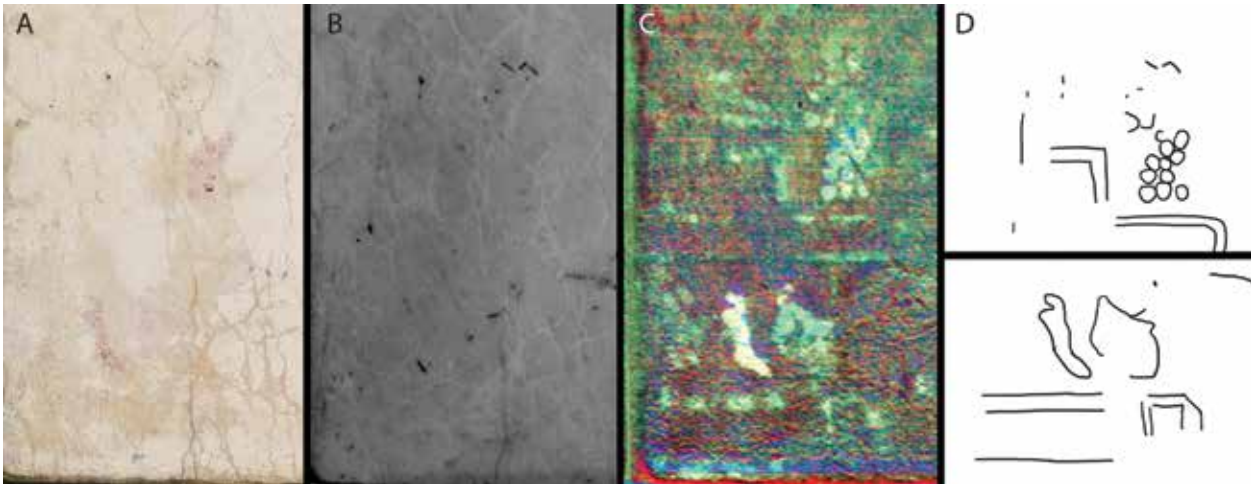


Figure 6.20: Bottom left of page 5 in four modes: normal photography (A, courtesy of Bodleian Libraries, University of Oxford); hyperspectral imaging (B); pre-1950's intervention infrared image (C, courtesy of Bodleian Libraries, University of Oxford); and (D) line drawing.

document has become clear. The other three sections that were partially uncovered can be interpreted using this information.

Page 5 was the test-ground for the investigators of the 1950s; multiple techniques were used to remove the gesso. Some of these techniques were more destructive than others. Three distinct sections were uncovered using these methods. When the document is held vertically – the orientation from which the palimpsest should be read – these sections are: the top left; the bottom left; and the mid right of the page. Although the investigators report a success with the recovery of a place frieze in the top left corner of page 5 (as shown above), they were not seeing remnants of the palimpsest, but were rather photographing infrared signals originating on the recto side. Thus, what they considered to be a new discovery was in fact a mirror image of the design on the front. That they were able to see this, shows that the document was thoroughly soaked in xylene. It also shows that in this section the removal of the gesso went too far. All that remains in this section are some traces of red paint that leached into the leather (see figure 6.19 top left). These sections can be more clearly distinguished in the hyperspectral imaging data. Furthermore, one infrared image of this page, made before the gesso was removed, indicates some areas where black lines used to run. Combining

these two sources of information, this section can be partially and tentatively reconstructed as can be seen in figure 6.19. What is visible in the section is a person looking up at a sky glyph, and another person coming down from it. Without the context of this scene it cannot be determined if this is part of the narrative or if this should be construed as part of someone's name. On the far left of the image, a large circular design can be seen. For this as well as the figures below and to the left, it is unclear what is represented. The circular design may be part of a solar design, used as part of a personal name. In other known cases of this design, however, rays of the sun are also usually incorporated, which are not seen here. Alternatively it could also be a shield, as seen for example on page 1 recto of codex Añute.

The bottom left of this page also has an exposed section (see figure 6.20). This section is located on the left parts of the bottom two reading lines. At the surface not much is visible at all, except for a series of small dots at the top of the exposed section and an elongated red stain at the bottom. In the hyperspectral image, more is visible and it can be seen that these scenes were rather complex. There are large rectangular designs at the bottom of each line which may be place glyphs or the base for a larger glyph such as those used for temples. On top of the bottom rectangle and connected to the elongated

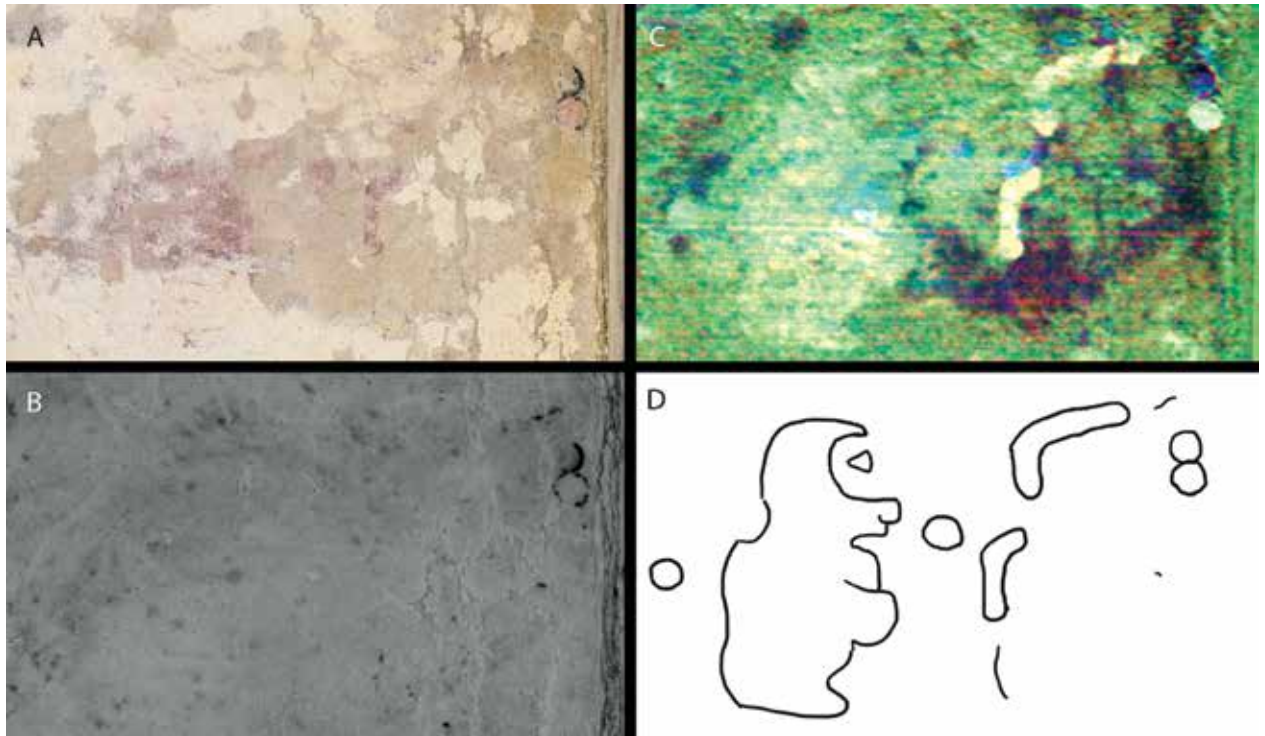


Figure 6.21: Mid-right of page 5 in four modes: normal photography (A, courtesy of Bodleian Libraries, University of Oxford); hyperspectral imaging (B); pre-1950's intervention infrared image (C, courtesy of Bodleian Libraries, University of Oxford); and (D) line drawing.

“stain”, a person may be sitting facing right. If so, the red stain may be part of his or her name. The series of dots is as intriguing as it is enigmatic. Series of small red dots may, perhaps, have been a decoration on clothing. Intricate designs are drawn on the dress of many persons in the Codex Ñuu Tnoo-Ndisi Nuu. If so, it may be that here a person is sitting in the entrance of a temple, a design commonly often encountered in the codices.

What is much clearer is the section on the mid-right of page 5 (see figure 6.21). Although the photograph only shows some red stains as well as the traces of two dots on the far right, the hyperspectral image reveals far more. Two persons, the right female and the left most likely male, can be seen. Some more dots indicate where calendar names are to be found, though none can be fully reconstructed. The figure on the right has no further identifiers than the quechquemilt and the red hair or headdress consistently seen on women. The left person, however, has a very clear circular decoration around his eye.

Multiple explanations can be given for this. The first would be the black “burned-face” motive used for Nahuatl speakers in the Mixtec codices; i.e. Mexicas or Toltecs (Jansen & Pérez Jiménez, 2011, p. 335). However, the infrared image shows no indication that there was a large amount of black concentrated in this area, thus making this interpretation unlikely. A more plausible explanation is that this person had a round Tlaloc-type goggle around his eye. However, the mouth of this person does not display any of the indicative attributes normally given to people named after rain or the rain diety.

Although it is not reported as the subject of extensive investigation, page 3 also shows a lot of damage. The entire top and right of the page is exposed. For this page there are no available infrared photos made with the aid of xylene in the 1950's, so all reconstructions have to be based on the hyperspectral data and regular visual data (see figure 6.22). The top of this page is the only part that yields some interpretable data. In the centre of this portion, a couple can be

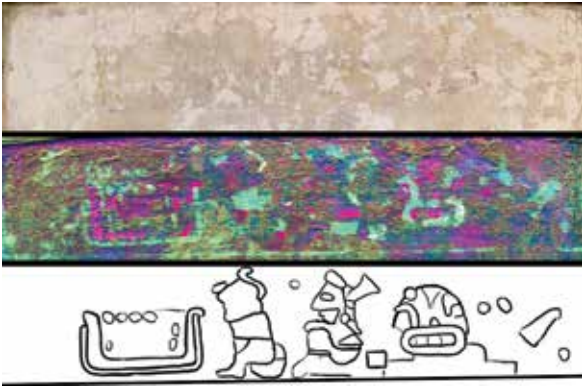


Figure 6.22: Top of page 3 in three modes: normal photography (top, courtesy of Bodleian Libraries, University of Oxford); hyperspectral imaging (middle); and line drawing.

seen, both looking against the direction of reading. This suggests that these people are parents that are included as a parentage statement, as is common in depictions of a marriage. On the left of this couple a glyph can be seen that looks a lot like a river design. On the right of the pair another figure may represent a mountain. Both the potential river and the mountain contain complex designs. These would identify them. However, considering the sheer amount of possible rivers and mountains already present in the codices, it is better to refrain from speculation about which mountain or river is represented here.

Page 1 verso is the current cover page of the codex. Because of this it is severely damaged. The main features are the A-O year sign 2 Flint, day 5 Reed, and the alphabetic text which reads: Don Diego hijo de don Domingo yuchaña (Jansen & Pérez Jiménez, 2007b, p. 31). Who this exactly was or what his relationship with this codex was is unknown. It is also unclear what the function of this year sign was, though it is likely that it refers to the event for which this codex was made (Jansen & Pérez Jiménez, 2007b, p. 164). Both these features are written on top of the gesso and thus clearly belong to the time period of creation and/or use of the known codex Añute on the recto side. Through the cracks in the surface, some remnants of subsurface paint can be seen, though the damage to the gesso is so extensive that not much remains to be analysed. Figure 6.23 shows one of the most complete elements on this page.



Figure 6.23: Detail of page 1 verso (courtesy of Bodleian Libraries, University of Oxford).

Going through every exposed detail on this page is not a very useful exercise as the details are too small to be informative. However, as the above images have shown, hyperspectral imaging is capable of collecting data from still covered areas as well.

## 6.5 HYPERSPECTRAL RESULTS

### REVEALING SUB-SURFACE IMAGES

As explained above, hyperspectral imaging is able to reveal differences in colour that the human eye cannot distinguish. As with Photothermal tomography, a part of the visible incoming light enters a surface and can thereby interact with the colours. This means that hyperspectral imaging can also, albeit to a very limited extent, see inside the surface. The complex mathematical processes of MNF transformation turned out to be capable of filtering out the resultant sub-surface signal from the surface noise, as long as there is not too much disturbance on the surface. As stated before, because of time constraints and because it was not at first expected that any subsurface results would be found using this technique, only seven pages of the reverse were scanned using hyperspectral imaging. These were page 1; 3; 5-7; 10; and 11. In the following, a description of the hyperspectral results will be given. These are illustrated with composite false colour images. To achieve this, multiple MNF band images were combined into one RGB image. Each band is manually adjusted to give the optimum amount of

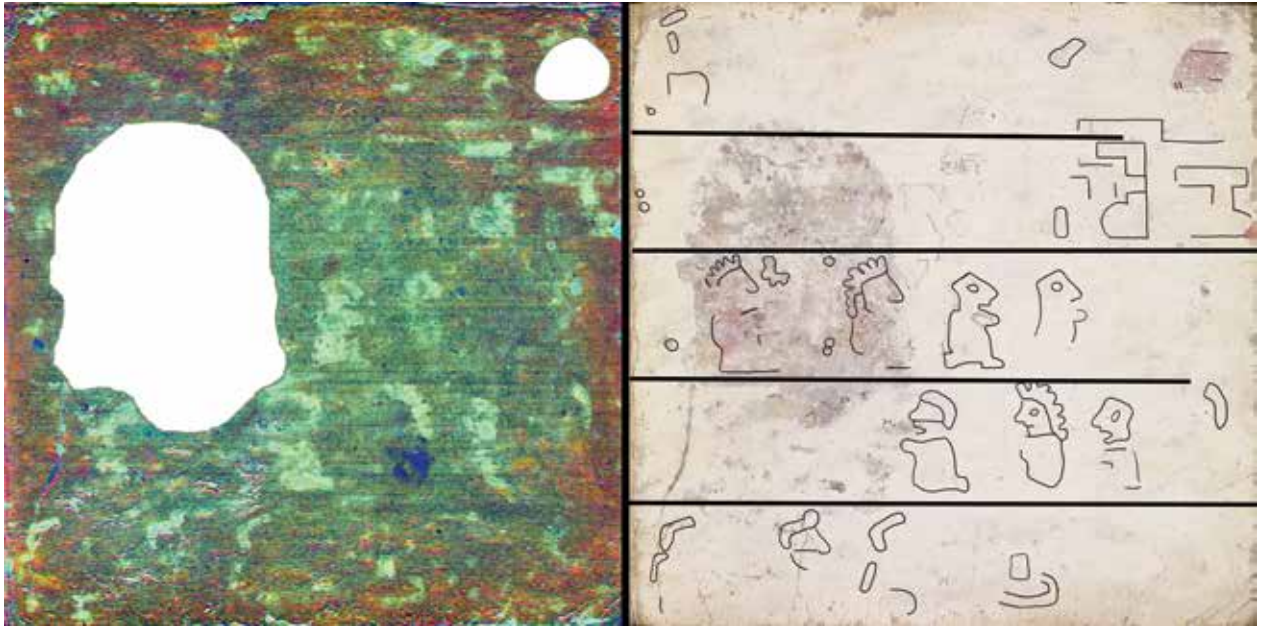


Figure 6.24: Hyperspectral results after MNF analysis and partial reconstruction of Codex Añute page 10 verso.

information using the custom stretch tool in ENVI, after this it was exported as a .tiff file and combined in Photoshop with the images of other bands. This procedure, however, also combines three noise signals. It was found that by reducing the resultant green and blue colours using the “selective colour” filter, this noise could be reduced. The description of the palimpsest as it is given here is based on what is seen in the hyperspectral imaging results, combined wherever possible with additional data from infrared or RTI imaging. The complexity of the hyperspectral and the RTI data does not allow for a complete presentation of the raw data on paper. This data can, however, be requested from the copyright holder: the Bodleian Library. In Appendix C, the reconstruction as proposed by the author and the false-colour hyperspectral images can be seen in more detail. It must be stressed that these drawings are based on a lot of interpretation of the data at hand. Additional data, especially the scans of the other pages, may in the future throw new light on these hidden images, which will necessitate alterations in these reconstructions.

In order to make these reconstructions in such a way that they follow the style of the original

Mesoamerican author, it is necessary to start with the visible drawings and work from there to the invisible. Page 11 and 10 can be used as a template that shows how the original painter drew his figures and, since hyperspectral imaging creates images of specific colours, what colours he or she used for which part. In figure 6.18 it could already be seen that the two main colours that are differentiated at the surface are yellow and red. On the exposed part of page 10, these same colours could also be differentiated. When the hyperspectral image of that page as a whole is analysed, however, it becomes clear that especially cochineal red can be found in areas that are still completely covered by gesso (see figure 6.24). Some traces of the yellow paint can be found as well, though these are much rarer. That these red signals can be rather well distinguished can be explained by the characteristic spectral response of cochineal. Based on the style of the drawings in page 11 verso, it can be seen that if only the cochineal can be retraced, already quite a few diagnostic features of, for example, persons can be recovered. Some persons have completely red faces, while others have specific headdresses in red, and most women are easily distinguished by the red quechquemilt and hair or headdress. Obviously, recovering only one

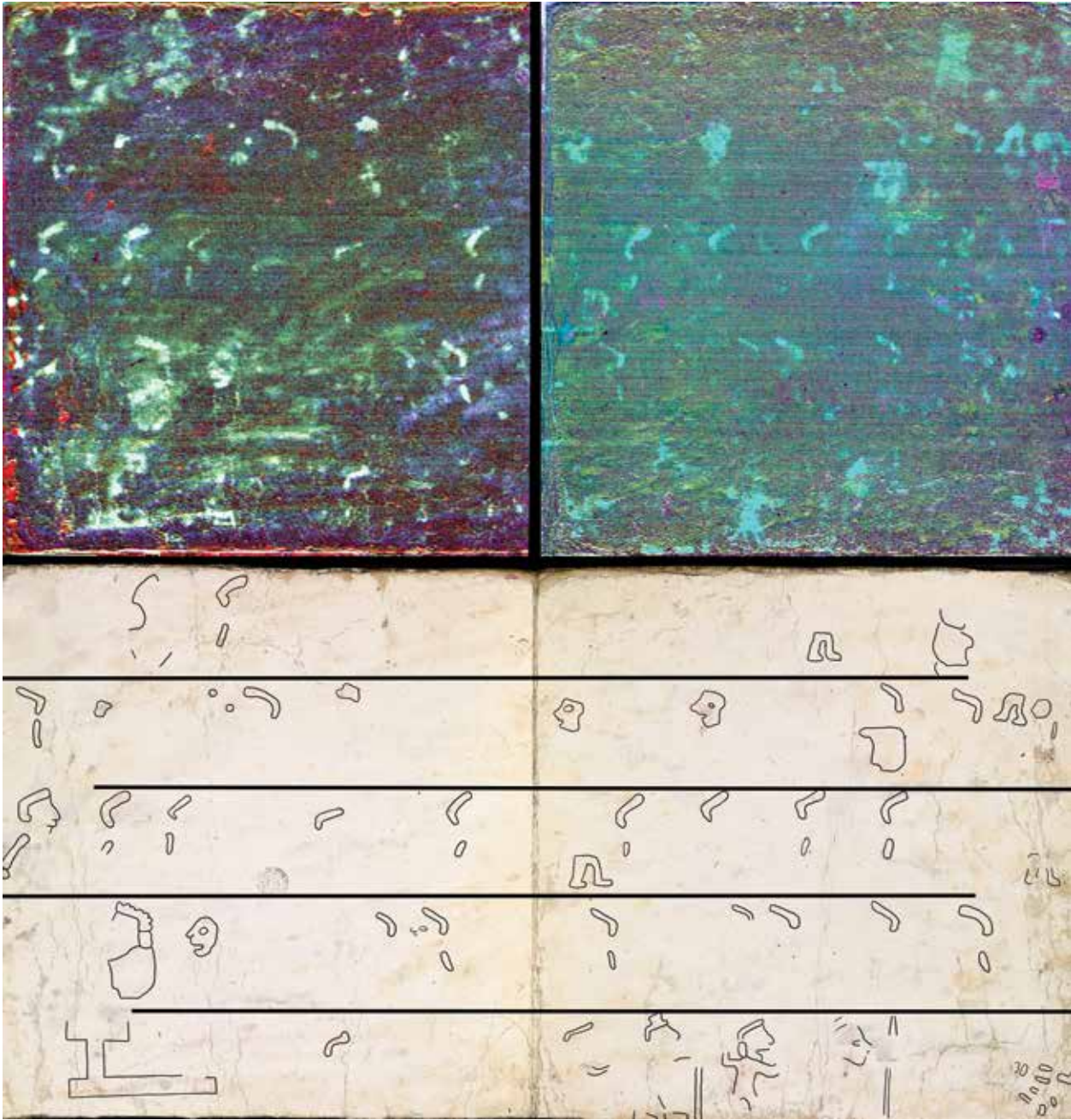


Figure 6.25: Hyperspectral results after MNF analysis and partial reconstruction of Codex Añute pages 6 and 7 verso.

of the colours means that for interpretation a lot of holes remain. It is, for example, never possible to give a certain identification of a person, as recovery of only red does not give certainty about calendar names. Nonetheless, the ability to recover the red paint does allow the recovery of many new scenes. In the following, a general description of the features of each page is given. More in-depth interpretation will have to wait until the document as a whole can be analysed. At this moment, the many holes in the data make it impossible to construct a true narrative. The first page to be analysed in this way was page 10. Because of the exposed paint of the surface, for the analysis of the subsurface features a new MNF analysis was done with the exposed areas masked. What can be seen in the resultant image (see figure 6.24) is that the two figures on the middle row that were exposed during the 1950's intervention are part of a longer sequence of people. They are followed by two seated persons, also facing right. To the right of this is a section that cannot be reconstructed, though there seems to be a rectangular feature on top of which something or someone is placed. This line continues on the third line with a series of persons facing left. At least four of these can be reconstructed, the third of which has a clearly differently coloured body, which is most likely yellow or orange. To the left of the fourth person, there is again a difficult to interpret area. It is striking though, that on page 11 line 4 and 5 there is again a series of individuals all facing the same direction. Such a long sequence of seated persons is unusual in the other codices. It is also striking to see that of the 17 persons found from page 10 line 3 until page 11 line 5 not one can be identified securely as female. On the fifth line of page 10 verso three figures can be found facing right. These can be only recognised by their red hair and their red quechquemiltl. The right side of this line is again illegible.

As for the top two rows, these are very much distorted by the presence of the black drawings that were made, possibly during the 1950's investigation. It can be seen that most of these drawings have no reflection of what is underneath here. Especially the almost Maya-looking face makes no sense in this location, being cut in two by the reading line.

Having established that hyperspectral imaging can find some of the colours hidden by the gesso surface, and knowing how some of this can be interpreted, the other scanned pages were analysed. Following the reading order of the document, the next section that was scanned was pages 7 to 5. The first thing that can be noted is that these pages follow the same reading-line order as established for pages 11 and 10. Thus, the reading begins in the top left of page 7 and continues in a boustrophedon manner to the bottom right of page 6, where it continues on the bottom left of page 5. Page 7 and 6 are depicted and discussed together (see figure 6.25).

On the top left of page 7, some large red features can be found. Although these cannot be interpreted securely, there is a similarity between this figure and the large flint-like sign depicted on page 11. This section is followed on the right by a person, only locatable by the clear red hair or headdress and red quechquemiltl. In the middle of the top line of page 6, what may be a pair of legs can be seen. On the far right of the same page, a seated person in red facing right can be partially seen.

On line 2 of these pages, at least seven figures, all facing left, can be located. For most of these figures, only the hair or headdress can be seen, though the third and fourth figure have a clear red face. The second visible face also has a red-coloured body, the position indicating that this person is likely male. There are large gaps between the persons, suggesting that there was more depicted than is here revealed. Especially between the second and third person and the sixth and seventh, there is an unusual – and ultimately wasteful – amount of space. Between the latter two some remnants of other colours can be seen, though they offer no clear indication as to their meaning. The third line is another unusual scene, as it shows a series of at least eight female figures facing the same direction. In most cases, there is not enough space between the eight female figures for any other figure. Only after the third and after the fourth person is there enough space for another feature. The motif seen in the middle of the top line of page 6 can be found three more times on page 6 (on the far right between lines 1 and 2; on the left on line 3; and on the right of line 3). If this is indeed a set of legs, it would

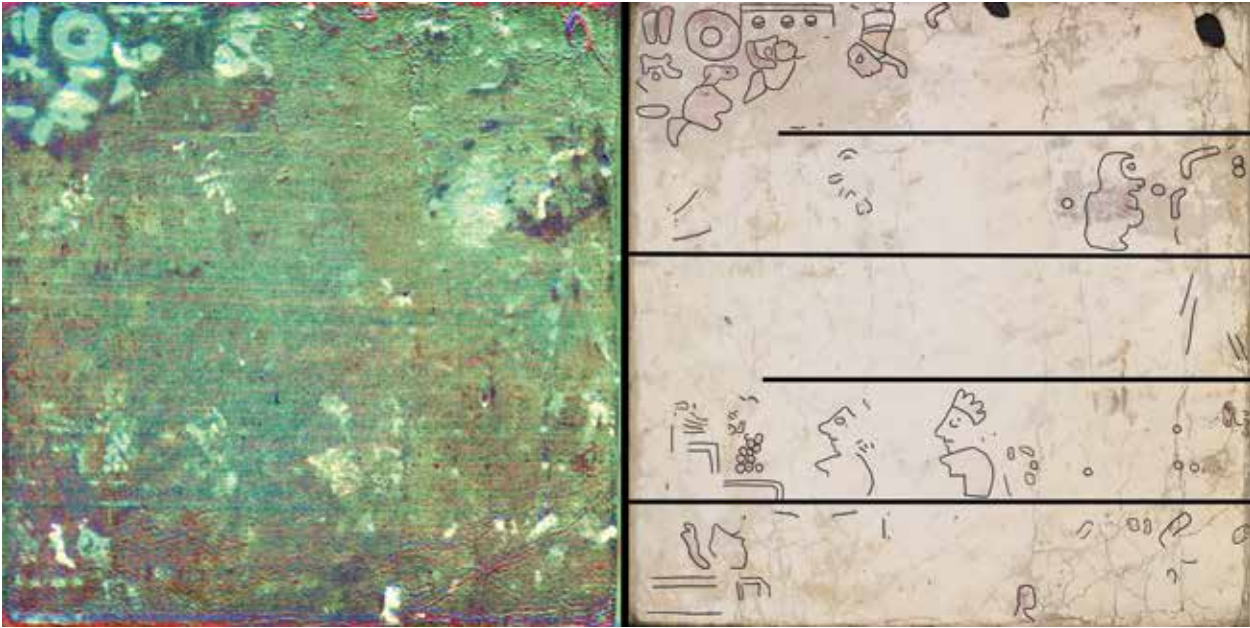


Figure 6.26: Hyperspectral results after MNF analysis and partial reconstruction of Codex Añute page 5 verso.

fit considering the size and position of this design in the rest of the composition. Since for many of these figures only the hair/headdress and the quechquemil can be seen, it could be that most figures on this page are in fact walking rather than sitting. On the fourth line again a series of persons can be located due to their hair/headdress. At least five can be seen on page 6 and a further two on page 7. On the left of these, there are two more figures clearly distinguishable by the red face and the red body and feather headdress. The bottom line starts off with a large red design. It is reminiscent of the way that ballcourts are generally depicted. On the page 7 section of line five, only one person can further be located by the presence of the hair/headdress design. On page 6, however, four persons can be distinguished. These are depicted standing upright and are holding something in their hands. Travellers are often depicted walking with sticks in their hands. It is more likely, however, that the figures depict warriors, as the third figure seems to have his hands raised, thus standing in a position similar to the warriors in codex Tonindeye page 75. On the far right of this line appears what may be a person wearing a striped suit. If this is indeed a person, he or she also has one arm raised as if holding something.

If this reconstruction is correct, then page 5 (see figure 6.26) would start with a series of warriors coming in from the bottom left. Page 5 has a rectangular feature in the bottom left corner which could well be a place name. On top of this rectangle a red elongated feature is visible. This feature looks like the way that blood is portrayed in the codex Ñuu Tnoo-Ndisi Nuu (Bodley) on, for instance, page 16 line 3 Lord 4 Water. Two possible explanations for this are that either the blood is related to what could be a person to the right of it, in the same way as it is in the example from the codex Ñuu Tnoo-Ndisi Nuu. In that case it would be part of the name. The other possibility would be that it is related to the place and that the feature to its right may not be a person but an identifier of the place. In that case, the blood could refer to a conquest by the warriors preceding it. The rest of the bottom line of page 5 is hard to interpret. Only one person can be located sitting on the far right, but unfortunately this individual has no further identifiers.

The next two lines form one continuous section. This section did not yield much information either, however, except for two persons clearly visible due to the red face paint and red body of the left one and the red body and headdress of the one on the right. They

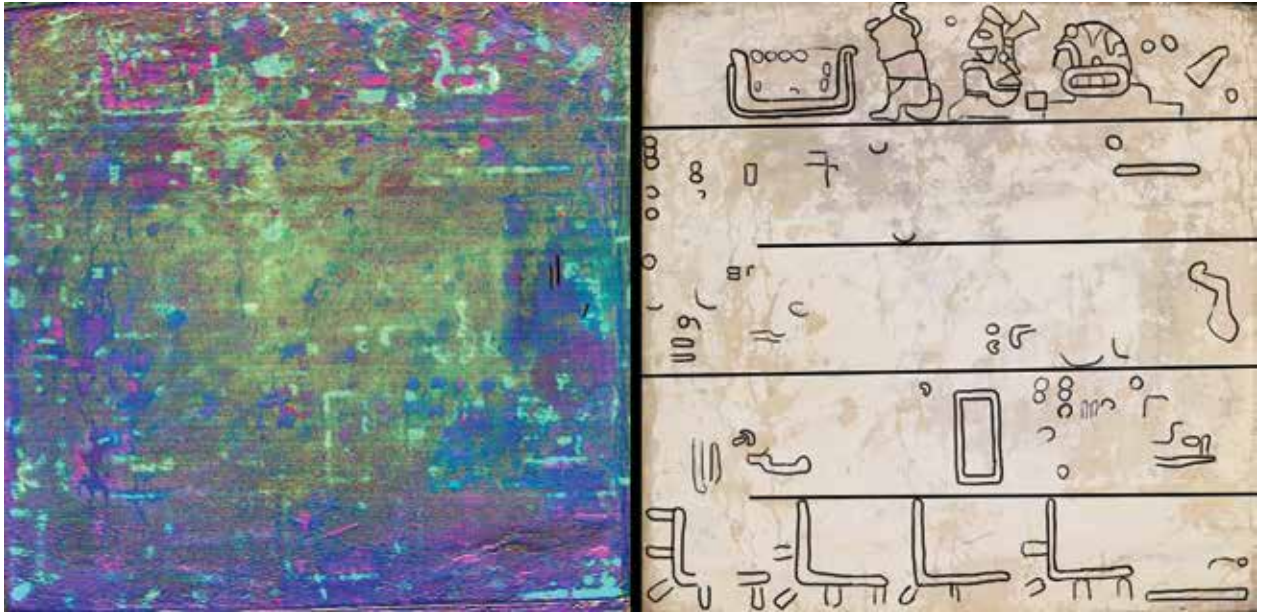


Figure 6.27: Hyperspectral results after MNF analysis and partial reconstruction of Codex Añute page 3 verso.

are both facing left, which is the direction of reading on this fourth line. What's more, they are facing the design discussed earlier, which may be someone or something placed on the first of a series of steps. If it is a person, then he or she is wearing clothing or has a body decorated with red dots. He or she would also be seated higher than the two facing him or her. It is possible, then, that the scene as a whole refers to a visit of the two depicted persons to a specific deity or priest in a temple. The third line of this page has only yielded very vague features. On the far right a large triangular shape appears. This could be part of a year sign, though that would make it very large, because as it is as it fills the entire line. The second line from the top begins with the exposed section discussed above. In this line, two persons are seated, looking against the reading direction. The rest of the line is illegible, though traces of red paint are visible in the central and left sections of the line. The top left corner of this page was already discussed above. And the top right section of this page did not yield further details that could be interpreted.

The next page scanned was page 3 verso (see figure 6.27). As stated above, the gesso layer on this page is rather damaged, though no invasive investigation

of this page was recorded. Because of this, there is a large difference in the amount of images that could be recovered in each section of the page. The difference in recoverable images has mostly to do with the amount of deterioration of the gesso surface. In the centre, for example, there were relatively few traces of images recovered, because here the gesso layer is rather thick. As a whole, page 3 is one of the few pages where more than one colour can be recovered, though this is mostly limited to the largely exposed top line. The two colours are here depicted in this image as cyan (depicting cochineal red) and magenta (depicting yellow). The dark blue areas are mostly areas of surface damage. The figures on the top line have already been discussed above. Although the second, third, and fourth line do contain many fragments of paint, not much can currently be made from this, besides a large rectangular shape in the centre of line four. On the bottom line, a series of four very similar figures can be reconstructed. These may represent rivers, depicted in a manner similar to that found in the Codex Ñuu Tnoo-Ndisi Nu, as cross sections cut in half.

The last page scanned – page 1 verso – is the extensively damaged cover. Even the hyperspectral

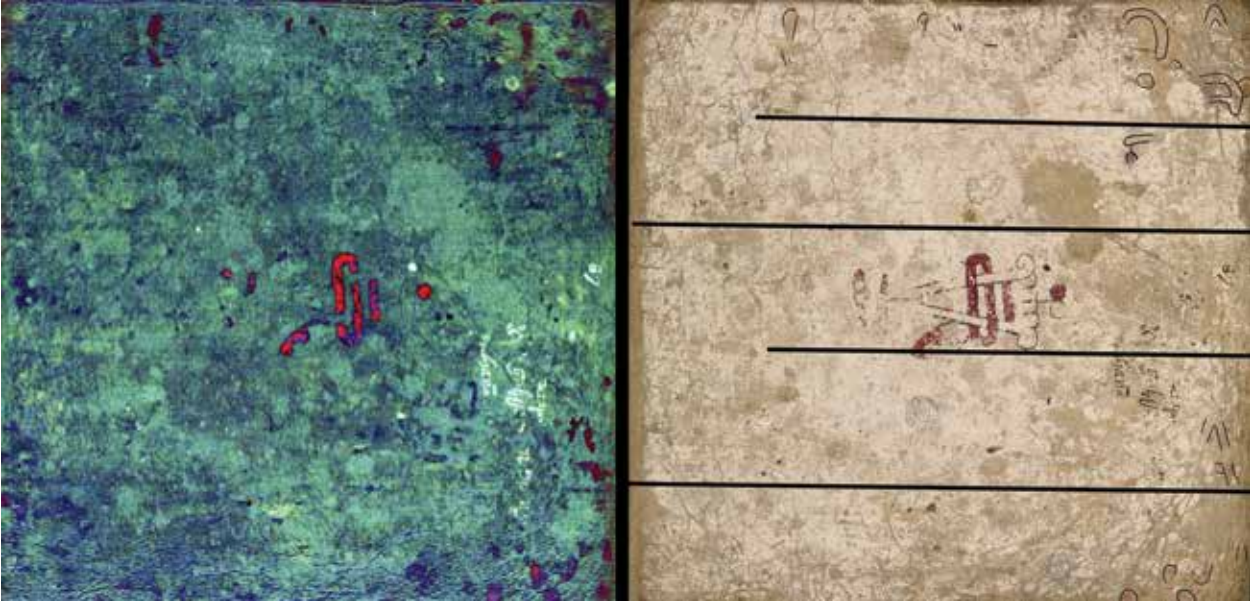


Figure 6.28: Hyperspectral results after MNF analysis and partial reconstruction of Codex Añute page 1 verso.

imaging data does not reveal much. Moreover, added to the damage is the distortion caused by both the A-O year sign and the alphabetic text. Because of the high signal that these surface colours give, the traces of the palimpsest disappear as background noise. The most important result of this scan, then, is that it illustrates the fact that this page cannot be the end of the text. The reading order on the other pages follows the pattern first seen on page 11 and 10. This means that the text on page 1 verso starts in the bottom left. As can be seen in figure 6.28, the reading line separating the bottom two lines continues right all the way to the edge of the page. From this it can be concluded that there must have been at least one more page. Considering the format of the text, it is almost a necessity that there was another page here. Without another page to the back of which a cover could have been attached, the texts would be exposed on the outside of the document. If indeed a cover was attached to the missing page, it is logical that it was cut off when the new codex Añute was made. Attaching a cover would require the use of a layer of glue, which would be difficult if not impossible to remove properly. That the text is not complete means that even if it were possible to reconstruct the entire palimpsest, it will probably not be possible to date the codex as precisely as has been

done for the known codex Añute. The top two rows of page 1 verso are as close to the end of the narrative as it is possible to get. This is assuming that the text does not continue on the verso side. It is still unclear if the front of this book also contains a palimpsest, because the surface drawings create such a large amount of noise here, that it has not been possible to sufficiently analyse these images yet.

Two further elements of this page are of interest. On the top right as well as on the right of line four, two triangular elements can be found which may be year signs. However, no calendar signs can be distinguished which would allow for a more useful reconstruction. In all four corners of the page, some further pictorial elements appear, none of which can be reconstructed any further due to the damage.

## DISCUSSION AND CONCLUSIONS

This chapter has shown that with the now available technological possibilities much more can be revealed about the palimpsest of the codex Añute. This can even be done in a completely non-invasive manner, which is a very important aspect as it points to the idea that new technological capabilities will be able to reveal even more in the future. Nonetheless, it is

important to investigate the palimpsest as thoroughly as possible, as the condition of the book continues to deteriorate. The tool that has yielded the best results thus far is hyperspectral imaging. This technique has been able to reveal much of the red paint that lies hidden underneath the gesso surface. Still, there are a number of ways in which the obtained results may be improved. First of all, the data acquisition can be improved by making scans of smaller areas, thus increasing detail. Problems that arose with focusing the lens because of the curvature of the surface and surface relief can also be solved by scanning a smaller area. Both of these solutions mean that more scans need to be made of each page, resulting in more data. Increasing the intensity of the light source may further help to improve the signal-to-noise ratio, thus allowing the recovery of weaker signals and, with that, possibly other colours as well.

Another way to possibly improve the results acquired by hyperspectral imaging is to better harness and exploit the potential of the data generated. With the current analysis, pictures are generated from the data, which are then manually combined and analysed by simply looking at the picture and manually draw the outlines of the figures. A different approach would be to analyse the data mathematically, for example, through a pattern recognition algorithm. This has only recently been applied to cultural heritage research in order to restore alphabetically written documents using multispectral images (see Hedjam & Cheriet, 2013).

Although not all information could be recovered from the palimpsest of the codex Añute, there is already a lot that has been learned about this covered text. The process of reconstructing these images needs to happen carefully, however, as it is easy to over-interpret the images. First of all, it is clear that the book is read in a boustrophedon manner over two pages, with the document held horizontally. It is in this sense much like the codex Ñuu Tnoo-Ndisi Nuu. It has also been shown that the palimpsest is not complete, as the part located on page 1 verso requires at least one more page to connect the observed reading lines. It is still unclear whether the front of the codex is also a palimpsest or not. If it is, then either the missing page after page 1 verso is the

end of the narrative or it is the section connecting the narrative on the front and the back. It may be possible to resolve this uncertainty by scanning the other pages on the verso side and determining if traces of a Mixtec origin narrative can be found there.

At least fifty new depictions of persons have been localised as a result of hyperspectral imaging investigations, even though many of these are only recognisable by their red hair or headdress. For the actual identification of the figures it would be essential to recover their calendar name, but this is not possible as it requires not only the identification of the calendar sign, but also the determination of the numeral that goes with it. As only the colour red is now recovered, it is never possible to be sure about the accompanying numeral of the calendar name. A rather curious observation is the fact that most of these figures look in the same direction. This may be explained by pure chance as the sections scanned may simply depict long series of individuals that are all incorporated in the same event. But it may also indicate that this codex uses a different way of writing and that things like marriage are depicted in a different, not yet recognised, way. If this were true it would represent a style of depiction unlike anything that is known from the other codices. Another striking difference from the known codices is that the persons recovered so far hardly ever sit on place glyphs. This may again be caused by chance, but it too could be the product of a different writing convention. To answer these questions, the remaining pages need to be scanned and analysed. If a complete overview can be given of even only the red paint, a lot more clarity about the structure of this text can surely be obtained. As a result of this new investigation, some new light can be shed on three phases in the biography of Codex Añute. On the one hand, a previously unknown phase in the life of this object is revealed by the investigation of the hidden images. Although with the current information it is still not possible to come to an interpretation of the text, if it can eventually be revealed it will undoubtedly shed new light on the history of Mesoamerican precolonial society. Seeing as there are no clear parallels to the known codex, and as has been shown in chapter 3 it is unlikely to have contradictory histories in such

manuscripts, it seems that this older text either contains an older history or at least a history with a different focus. Thus, we can say that the meaning of this object as a codex changed, since the contents radically changed. Besides this, a second part of the biography that is clearly embodied in this work is the point of transformation of the object itself. When and why this was done is unclear, though there seems to be a completely opposite rationale in the way of changing the story than was shown in codex Iya Nacuaa in chapter 4. Where the person editing the codex Iya Nacuaa did his or her best to keep the text legible and to preserve the text by removing things that could be deemed heretical, the writers of the later codex Añute were intent on covering the entire narrative up. To find out the cause of this difference in attitude, the text of the palimpsest would need to be investigated further and in more detail. And this is exactly where the present investigation touches upon a third biographical episode: the future. The technical investigation itself can be seen to add meaning to this codex. In fact, the images of the palimpsest only exist in the digital realm. This is a prelude for the future dealing with this book and possibly with the other codices. On the one hand there is a clear tendency to shift to the digital realm. Increasingly all types of cultural heritage become digitized. This has the major advantage that the object no longer needs to be handled for research purposes. But as this investigation has shown, in some cases the original object still holds many secrets that could be lost in a digitised world. Artistically, the codex can be considered one of the lesser texts and certainly the original object did not receive much scholarly attention. With this new information, however, this may all change.