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2. The Practice of Codex Making

In the previous chapter, an overview was given of the materials which can be identified, either directly or indirectly, as ingredients for the creation of codices. This was based on earlier (non-) invasive chemical or physical investigations of the originals, as well as on the materials known from historical sources and contemporary knowledge. Table 3 shows this full list of materials divided into five groups. Each group represents a specific stage of the creation process. The last two groups represent materials that may be used in any stage, but which leave too few traces to identify. This list forms the basis for a series of experiments with these materials and experimental replication of the production process of a codex. During the summer of 2015, collaboration with the RCE (Rijksdienst voor het Cultureel Erfgoed) researcher A. Ness Proaño Gaibor and the Museum Volkenkunde of Leiden allowed for full-scale reconstructions to be made of two pages of Codex Añute, two pages of Codex Yuta Tnoo-Ndisi Ñuu and 8 pages of Codex Tonalpouhqui. During this process, much was learned about the technology of codex making. For example, many of the materials in Table 3 are not directly usable when found in nature and need an often complex process of pre-processing before they can be used in codex making. In this sense, this process may be seen as a special form of experimental archaeology, if the term is understood to incorporate a more exploratory form of experimentation, as suggested by Hurcombe (2008). The difficulty is that because of the inability to take samples, only very few materials can be securely identified, which does not allow for the strict scientific control over the experiments that usually characterises experimental archaeology (Mathieu, 2002; Van Gijn, 2010, p. 30). In the general script proposed for experimental archaeology put forward by Lammers-Keijsers (2005), it is clear that the feedback loop which should allow for a testing of the experimental results against the original is not as strong as would be desirable. As Schiffer, Skibo, Boelke, Neupert, and Aronson (1994, p. 198) argue, archaeological experiments require a specific question to be answered, relating to production or use of an artefact. Because of the many unknown factors in this process, on both the level of ingredients and the tools used to make them, the question became very general: How could a similarly looking codex be made, using the materials and tools available in precolonial Mesoamerica?

For the experimental reproduction of a codex only those materials were used that are securely identified botanically, zoologically, or chemically and that are suitable for the making of a codex; i.e. those materials that are relatively stable and are available in the quantities needed. Some materials can today be bought (partially) pre-processed. For these materials the production process is well understood and their fabrication in a precolonial context can be made sense of without experimentally replicating the entire process. All of this allows for the formation of a complete overview of the technology, materials, knowledge, and skill involved in the making of a codex.

2.1 MAKING THE SUPPORT

As was shown in the previous chapter, there are two ways of making a support for a Mesoamerican book. One involves amate paper and the other a form of animal leather. The process of creating this amate paper has been documented both in colonial sources (Hernández et al., 1960a, pp. 85-90) and in more recent ethnographic and archaeological studies (M. D. Coe & Kerr, 1998, pp. 143-145; von Hagen, 1944, p. 57). In order to understand the full range of dependencies (sensu Hodder, 2012) of paper, it is worthwhile summarizing the procedure here. From the description by M. D. Coe and Kerr (1998), it is possible to distil seven steps:

- Cutting the branches;
- Stripping the bark lengthwise;
- Separating inner from outer bark after which the inner bark is soaked in water and the coagulating latex is removed;

Material	Identified Botanically, zoologically or chemically	Measured (non-invasive) investigation of the codices	Described in colonial/ ethnographic sources	Suitable (availability/ stability)
Support				
Deer leather	X	?	X	X
Pronghorn leather	X	?	-	X
Amate Paper	X	X	X	X
Chalk	X	X	X	X
Gypsum	X	X	X	X
Covers				
Jaguar Fur	X	X	-	X
Wooden cover	X	-	-	X
Mosaic	X	X	X	X
Gold	X	-	-	X
Pigments				
Carbon Black	X	X	X	X
Logwood	X	-	X	-
Brasilwood	X	-	X	-
Nacascolotl	?	-	X	?
Annatto	X	-	X	X
Cochineal	X	X	X	X
Zacatlaxcalli	X	?	X	X
Matlalin	X	?	X	X
Maya Blue	X	X	X	X
Xochipalli	X	-	X	?
Potonxihuitl	X	-	X	?
Pericon	X	-	X	?

Purpur	X	-	X	?
Red Ochre	X	X	X	X
Yellow ochre	X	-	X	X
Green earth	X	-	X	X
Adhesives				
Hide Glue	X	X	-	X
Mezquite	X	-	X	X
Tzacutli	X	-	X	X
Additives				
Alum	X	X	X	X
Copperas	X	-	X	X

Table 3. Overview of materials identified on the codices and likely alternatives.

- Nixtamalization of the fibres by boiling in alkali water;
- Rinsing of the now pliable fibres;
- Laying of the fibres on a board in a crosswise manner and beating them with a stone beater to felt the fibres together, thus forming the sheets of paper.
- Drying of the sheets in the sun to form the finished product.

Though von Hagen (1944, p. 57) suggests that for making paper "only two instruments are necessary", which are the board and the beater, the above procedure shows this to be untrue. Cutting and stripping the branches of its bark requires a cutting tool and nixtamalization requires clean water, a container, and an alkaline material. This alkaline substance was most likely lime[23] (Ca(OH)2). Perhaps as early as 1500 B.C. the process of nixtamalization had been invented, which allowed the processing of maize to release more protein for human consumption by the addition of lime (S. D. Coe, 1994, p. 14). Having such a high dependence on lime for the processing of everyday food items, makes it the most likely candidate when an alkali substance is required. Another possibility would be potash (K(OH)), which is made by leaching the lye from wood ash. The resulting solution is a stronger alkaline, thus making the process somewhat faster. However, the potash solution also poses greater health risks, which is one of the reasons why it is generally not used in the preparation of food.

As the process of making paper involves laying out the fibres on a board, which has a limited size, the size of the individual sheets of paper is also limited. For a full length codex, multiple sheets of paper needed to be attached end to end in order to make a single support. Unlike the leather codices, in the case of the Maya paper codices it is not visible where

23. Not to be confused with the lime fruit which is a strong acid rather than an alkali, and is furthermore not native to the Americas.

Figure 2.1: Scenes from codex Madrid (page 46) depicting deer caught in traps (after Fahsen & Matul, 2007).

different sheets of material were attached together. This is because when two sheets of paper need to be attached, the edges can be made wet, which will soften the fibres. And pounding the overlaying edges of the two sheets will effectively felt together the pieces of paper into one long piece.

As was shown in the previous chapter, two types of animal are possible sources for the skin on which the central Mexican codices are made: pronghorn and white-tailed deer. Neither of these animals can be domesticated and as such need to be hunted. White-tailed deer is a very adaptable species which has a very wide range, and could thus be caught in many areas throughout Mesoamerica. While most abundant in forested areas, the white-tailed deer can adapt to many environments, including man made agricultural landscape. Catching deer, however, is by no means a simple exercise, because of their speed and agility. Furthermore, while one may be able to shoot a deer with bow and arrow if the terrain is open enough to allow such a strategy, this will invariably damage the skin of the deer. None of the codices have any surface damage that could be attributed to the hunt itself, though some, such as the codex Ñuu Tnoo-Ndisi Nuu (Bodley) and the codex Tonindeye (Nuttall), do have holes in the surface. These holes can, however, be most straightforwardly explained by the tanning process. The reason for this is because they are very round holes, which were most likely caused by putting too much pressure on the tanning knife when the skin was under tension. A piercing wound of an arrow, even one made perfectly perpendicular to the skin, would in contrast leave a more elongated mark on the skin.

Other hunting techniques must thus be considered, such as trapping the animals. In the Codex Madrid (see figure 2.1), depictions of deer caught in a snare indicate how this may work. Trapping of this kind requires a rope tied into a noose and a flexible piece of wood set up into the ground or, as the images of the Madrid codex seem to suggest, bending down branches of trees. This wood is then bent to create a spring onto which the noose is connected. A trigger is needed which sets off the trap when the animal steps into the noose, releasing the bend wood and allowing it to spring up and tighten the noose around the paw of the animal. As an adult deer is quite strong, the use of a strong but flexible branch still attached to a tree is probably preferable over a loose branch that needs to be set up into the ground. The latter construction, however, is more useful for hunting smaller game such as rabbits and other rodents. Once caught it should be relatively easy to kill the animal as deer are prone to shock after panicking for some time in a trap. A second way of hunting deer is to make use of multiple hunters to drive the animals into a canyon where they can be easily shot with a bow and arrow or captured with lines, nets, or even by hand. This technique obviously relies on the topography of the region, which may explain the preference of traps in the rather flat Yucatec peninsula. Besides this obstacle, catching a male deer armed with antlers by hand or even in a net is not without obvious risk. Capturing a pronghorn may be done using similar techniques, although the more open habitat (see Chapter 1), makes both setting a trap and driving the animals into a confined space more difficult.

Once an animal is killed, it needs to be skinned quickly to avoid putrefaction. In order to have a skin that is of the optimum size and quality a specific way of skinning is usually applied. The way of cutting the skin is related to the growth of the skin of the animal, as it is the growth that determines the run of the fibres throughout the skin as well as its thickness. In a quadruped, the skin is thickest on the back of the animal, as this is the oldest part of the skin. The fibres radiate outwards from the top of the buttocks. Many strong fibres are located on the ridge of the spine. From the spinal ridge the fibres run down the sides of the animal towards the belly. The belly is the least strong part of the skin, so it is there that the skin of the animal would normally be split to leave the strong area on the back and sides intact. The optimal way of cutting a piece of leather for the creation of a codex would thus be to cut a rectangular piece of the back along the spine. Farnham (1922, pp. 27-28) uses a cow in his demonstration of how to skin an animal, but the basic principle is the same for any quadruped, especially those with horns. First the head is skinned by cutting down from the base of the horn, along the eye and across the nose and back between the horns. The skin can then be removed from the head. After this an incision is made down from the nose across the mouth and down through the belly all the way down to the tail. Another four incisions are made on the inside of the legs and the skin is severed at the hooves or paws. Once this is done the hide can be skinned from the sides after which, starting from the tail, the hide can be removed.

Once removed and cooled,[24] the skin can either be processed immediately or stored for later processing. It is unlikely that the processing of leather happened on an industrial scale in precolonial Mesoamerica. The main reason for this is simply because all the animals needed to be hunted and, unless a large group of hunters would supply one centralised tannery, the uncertainty of the hunt would lead to an unreliable flow of raw materials. Considering this and the fact that many tanning methods require preparation of tanning baths (see below) that could be used to tan multiple hides, it may well be that hides were stored until a specific number were available, after which all of these were tanned at once. If this was indeed the preferred method, some action would have needed to have been undertaken to temporarily protect the skin from decay. The most common way of preserving the stored skins is to salt the hide. The salt protects the skin from microbial decay by creating a saline environment which dehydrates any bacteria or fungi, thus preventing their growth and spread. This salt needs to be removed by washing in clear water before the process of tanning begins. This act of pre-tanning washing also rehydrates the hides so they became supple again.

The process by which precolonial Mesoamerican tanners tanned their hides is not clearly understood. While there are methods to investigate the tanning agents used in leathers, none of these are non-invasive, either involving taking samples or the application of a chemical substance that reacts chemically and discolours to indicate the presence or absence of a specific tanning agent (c.f. Driel-Murray, 2002). The historical sources are also remarkably silent on the subject of tanning. One reason for this may be that historically the profession of tanner was one of low esteem, as it involves close contact with putrefying matter, often using different types of excrement in the process. Secondly, since the animals available in pre-colonial Mesoamerica for making leather were relatively few and small, it is likely that Spanish chroniclers familiar with the European leather working tradition were not particularly impressed by the Mesoamerican's tanning capabilities.

Maldonado Alvarado and Maldonado Alvarado (2004) describe a number of methods for tanning leather that are used today in Oaxaca. This includes the full range of tanning techniques. The simplest is oil tanning, which is also described by Richter and Dettloff (2002, pp. 301-317) as the common way of processing deer skin by North American Midwest native peoples. Oil tanning involves dry or wet scraping, followed by brain tanning. Scraping is needed to remove fat and flesh from the inside as well as hairs from the outside of the skin. It can be done in either running water or while the skin is stretched on a frame. For the removal of hairs, the

24. The Mexican deer mostly lives in high, cooler, and wetter climates, thus allowing the skin to cool, but causing problems with drying the skin.

skin should be immersed in an alkali bath such as a lime or potash liquor (Thomson, 2006a, p. 105). This loosens the hairs after which they can be scraped off without damaging the skin underneath. After the skin is thoroughly cleaned, the actual tanning process can start. When tanning with oils the process is relatively simple, though labour intensive, as the oil simply needs to be rubbed into the skins. These oils then form a protective layer around the fibres of the leather protecting them from decay. This technique is thus suitable for the processing of small amounts of skins, as one would expect when the skins need to be hunted. When tanning larger numbers of skins, processing them one at a time becomes less desirable. The alternative is submerging a large amount of skins in a bath filled with tanning agents. This is a very long and slow process. In Medieval Europe, cleaned skins were laid in a pit with layers of vegetal tanning material – such as oak shavings – between each skin. This pit was subsequently filled with water and the skins left to soak up the tanning material for at least a year (Thomson, 2006b, p. 70).

There are many plants all over the world that contain substances that can be used to tan a skin, and Mesoamerica is no exception. The range of tannins found in plants and the new chemical bonds they create are thoroughly discussed in Covington (2006, pp. 23-26). Though there may be many plants in Mesoamerica that could theoretically be used to tan skins, the amount of tanning material needed is relatively large, therefore it is unlikely that rare or difficult to access materials would have been used. Maldonado Alvarado and Maldonado Alvarado (2004, p. 65) give the following examples of Mesoamerican vegetable tannins: "quebracho, mimosa, sauce, mangle, encino o timbre". Quebracho, a common word for a range of hardwoods (Schinopsis spp.); Mimosa, a genus of shrubs and herbs (Mimosa spp.); and Sauce or Willow (Salix spp.), each contain condensed tannins. These cause the leather to redden when exposed to light (Covington, 2006, p. 26). The documents studied at the Bodleian Library are not markedly reddened and it does not seem advantageous to create a reddened surface which potentially could stain the gypsum used to make the writing surface. Timbre is another common name that probably refers to Acaciella angustissima. This plant is also known as Ocpatli, Quapatli, or Palo de Pulque, as the root is used in the alcoholic drink pulque (Hernández et al., 1960b, pp. 119-120). Encino refers to Oak trees (Quercus spp.), of which several species are native to Mexico. The tanning properties of Oaks have long been exploited in Europe as well. Oak contains ellagitannins, hydrolysable tannins which do not necessarily change the colour of the leather on exposure to light (Covington, 2006, pp. 23-25). Another possibility is that these hides were tanned using minerals. Although (Maldonado Alvarado & Maldonado Alvarado, 2004, p. 65) name two minerals as the most well-known tanning agents – aluminium and chrome salts – tanning with the latter is a process that was only invented in the 19th century (Thomson, 2006b, p. 74). Alum on the other hand was available and used, especially as a mordant for the dyeing of cloth and the creation of paints (see below). Covington (2006, p. 29) argues that alum is actually not a good tanning agent if used by itself, as it does not bind well with the collagen and the alum can easily be washed out of the skin (the process is not really tanning but rather thawing).

After tanning, the excess tanning agent needs to be removed by washing and the leather needs to dry. This should be done on a frame on which the leather can be stretched by tying it up with ropes. By putting more tension on the body than on the limbs and head, the hide is pulled into a more square shape. If the leather is dried in the sun the risk exists that the surface dries too quickly, hardening it and trapping any remaining moisture underneath (Lockwood, 1912, p. 156). This will cause internal bacterial growth and damage, which will only become apparent later-on in the process when the hide is cut. During drying the leather can be rubbed with grease in order to improve the flexibility and suppleness, as well as to increase protection against water. Both vat tanning and oil tanning are laborious, long processes. Combining this with the uncertainty of the hunt makes good leather a valuable commodity. The 13.5 meter long codex Yuta Tnoo (Vindobonensis Mexicanus I) contains fifteen pieces of leather. It is very unlikely that the scribe who made this codex went out to hunt the fifteen deer needed and tanned each of them. Although not described in, for example, Sahagún's description of merchants or the market (Books 8 and

10), there must have been a lively trade in leather as well. Such a hypothesised leather trade was an important part of the Aztec tribute network, as the codex Mendoza (1541) shows.

Compared to paper, the production of "sheets" of leather for bookmaking purposes seems to be more laborious. However, it is also a stronger product, with less risk of tearing the material. Although the production of paper is rather specialised to the specific needs of writing, making leather is an almost natural by-product of hunting. Once available it must have been a small step to incorporate it as a surface for writing, one that may have started out as a form of decoration of for example leather clothing. The process by which paper is made is well understood and studied. The leather-making process is also well understood, as far as the general principles go, and unverifiable when it comes to specifics. Because of this, the process of making these materials was not part of the experimental replication. For the replication process, amate paper was used that was bought on a market in Oaxaca,[25] and leather tanned with natural materials was bought online.[26]

Unlike with paper, connecting "sheets" of leather does need an adhesive. For this task only glues of animal origin need to be considered. As has been shown in the previous chapter, the other glues available in Mesoamerica each have their downsides in either physical properties or in their way of being processed for their application to leather. As such, these other glues were excluded a priori from the experimental replication of the support. If an animal glue was used to create the bond between individual leather pieces, this means that its type and origin are impossible to identify non-invasively. Due to the composition of the glue, such investigation will only detect collagen and gelatine, which are also the building blocks of leather itself. The glue must be either skin or bone glue. Three different terrestrial animal glues are sold commercially today: bone glue; hide glue; and rabbit skin glue. Hide glue is today extracted from the skins of slaughtered livestock (cow in general) or the skin left-overs after processing of the hides. In the case of Mesoamerican cultures, it must have been a by-product of the hunt, as a way of recycling the scraps of skin left over after leather or fur production. The differences between rabbit skin glue and hide glue show that the properties of such glues are dependent on the properties of the skin itself. As was mentioned in the previous chapter, this is due to the differences in collagen in the skins. Bone glues are made of bones, sinews, and cartilage which all contain collagen. These contain other substances as well, however, making bone glue inferior in adhesive strength (Ebnesajjad & Landrock, 2008, p. 99; Kite, 2006a, p. 193). As the leather used in the codices is relatively heavy, the glue used needs to have a high structural strength. Therefore hide glue made from larger animals such as deer is the best choice.

Once the long strip of either leather or amate paper is completed, it needs to be covered with a layer of gesso. This gesso is a combination of a white inert powder and an adhesive. Again the adhesive is of an animal origin, likely also animal hide glue. For the experimental replication, four different surfaces were prepared: an amate surface covered with chalk and animal glue; and three leather surfaces covered with a mixture of chalk and gypsum. The gypsum was bought in purified form as dehydrated model plaster. If dehydrated gypsum is added to the glue it will crystalize inside the gesso and form clumps. To avoid this scenario, the gypsum needs to be submerged in a large amount of water for about a day and frequently stirred to avoid it setting on the bottom of the container. This process will result in what Cennini (1933, p. 71) called gesso sottile; i.e. thin or subtle gesso. The resultant gesso sottile was mixed with chalk, as the investigations of the original codices all showed that the gesso contained both gypsum and chalk. Three small samples were made with different ratios of gypsum and chalk to determine if there were noticeable differences depending on the concentrations used. One contained only gypsum, the other 25% chalk and the third

25. All thanks to Dr. A. Rojas Martínez Gracida for this supply of paper.
26. Supplied by skin and leather shop heartline http://www.huid-en-leerhandel-heartline.nl/.

50% chalk. A series of tests[27] was designed to see if the variations in surface had a significant impact on the behaviour of the paints applied to them (see section on paints below). No significant differences were encountered, though it was observed that the addition of chalk makes the mixture more opaque. It was decided to use a ratio of 25% chalk and 75% gypsum for all leather surfaces.

The leather surfaces were first covered with two layers of animal glue. This was done to reduce the absorption of gesso by the leather, so that less gesso needed to be applied. The first layer of glue was thin, made by mixing solid animal glue (bought in the form of grains[28]) with water at a ratio of 1:25. The second layer was thicker and had a water ratio of 1:10. Next to making the surface less absorbent, the glue had two other effects. First of all the leather surface becomes much darker in colour, and secondly it becomes very stiff. This is a major advantage for the codex, as a more rigid support makes it less likely that the gesso flakes off. It was observed that the glue has a tendency to warp the surface due to the shrinking effect of the glue. It is thus important to treat both sides at the same time. Weighing down the leather after it has dried will reduce the curling effect to a minimum. Before application of the glue and during and after drying, the support needs to be folded into pages. By doing this the surface regains its flexibility at the folds.

For the preparation of the gesso no recipe can be given. The starting point is animal skin glue which has a glue:water ratio of 1:10. At room temperature this has the consistency of a gel. It needs to be warmed up to about 40°C in order to liquefy it. If heated up too much, the collagen in the glue will break up and it will lose its adhesive strength. To this liquid glue the mixture of chalk and gypsum needs to be added until the mixture has the consistency of yoghurt. This may seem like a strange directive, however, the viscosity of the mixture is determined by many factors, of which the ratio between solid particle (gypsum and chalk) and the liquid (glue) is only one. Thus, there is no way to give a recipe in the form of grams of chalk and gypsum per litre of glue. Once made, the gesso must be applied on both sides, again to avoid warping of the surface. It must also be applied in two directions, both in horizontal and vertical lines over the surface, to give it strength. Once two layers are applied on both sides the whole needs to dry completely before the next layer is added to avoid locking moisture in the object. If needed, the surface can be sanded before adding a new layer of gesso. The total amount of layers needed is highly dependent on the thickness of the gesso. In general, however, it is better to add more, but thinner, layers, as this increases its strength.

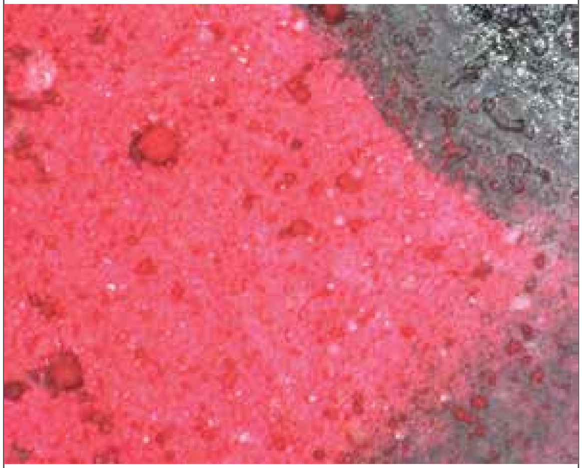
For the experimental replication, one support of about 100 cm long was made which was folded into 8 pages (plus six on the reverse as the outer two pages would be used to attach a cover). Each page measures approximately[29] 12.5 x 12.5 cm on which scenes of the Codex Tonalpouhqui could be copied. Two more surfaces were made: one the right size to copy two pages of the codex Añute and the other the size of two pages of the Codex Ñuu Tnoo-Ndisi Nuu.

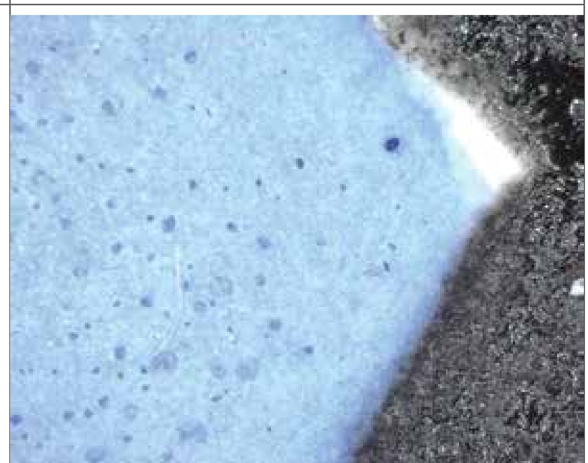
2.2 MAKING PAINT

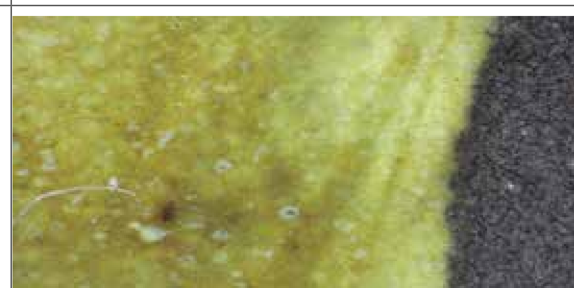
Once the surface was made, the next step was the application of paint. For this experimental replication, different paints were made and tested. Table 4 shows the pigments and colourants as they were tested on the three samples with differing concentrations of chalk and gypsum. The ingredients of these materials can be seen as well as the microscopic images of the coloured surface. It is clear that some colourants are better than others. For example, Tyrian Purple,

27. Twelve different organic paints and dyes were applied to the three samples with differing concentrations of gypsum and chalk. The resultant colours on the surface were compared visually. Subsequently the samples were compared microscopically, both in cross-section and at the surface. A final test was to determine the behavior of cochineal red on these surfaces. As will be discussed in chapter 3, on some of the codices this material is highly penetrative and stains the leather. A drop of distilled water was applied to a cross-section of each sample with a layer of cochineal red at the surface. Unless the cochineal is perfectly washed, the strong dye can be seen to bleed into the sample. There was no observable difference between the three tested concentrations, however.
28. Supplied by Verfmolen de Kat.

29. The folding of the leather, combined with the shrinkage of the leather due to the applied glue, caused some variation in the length of each page.

Number	Colourant	Ingredients and process	Microscopic image
1	Cochineal	Pure Carmine (bought) + binder	
2	Cochineal	Ground cochineal + demineralised water + Calcium Carbonate + Alum+binder	
3	Cochineal (dye)	Ground cochineal + demineralised water	

4	Zacatlaxcalli	Dried vines + water + potash + Alum+binder	
5	Zacatlaxcalli (dye)	Dried vines + water	
6	Commelina coelestis	Flowers + water + binder	

7	Delphinium spp. (dye)	Flowers + water	
8	Buckthorn (Rhamnus spp.)v	Ground berries + potash + alum +binder	
9	Mix of 6 and 8	2 mixtures, top mixed in separate container, bottom: layer of yellow covered with a layer of blue	 

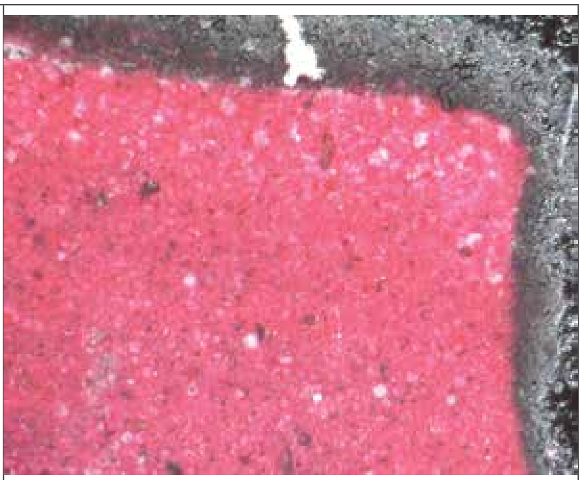
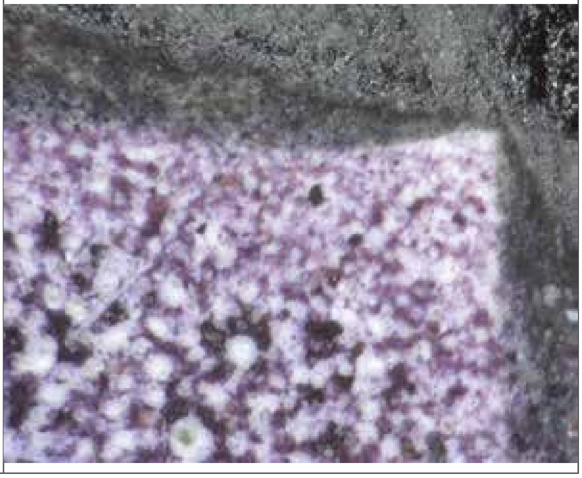
10	Cochineal	Mixture of 1 and 2	
11	Achiotte (Bixa orellana)	Boiled seed + water + potash + alum + binder	
12	Tyrian purple	Pigment + binder	

Table 4. The tested pigments and colourants with microscopic photographs.

though a very strong dye, cannot be used to make a good paint. Using cochineal as a direct dye (Table 4 no. 3) is likewise not advisable as it discolours rapidly. The comparison of numbers 6 and 7 shows the advantage of Commelina coelestis over other blue flowers such as the Delphinium spp., which can theoretically be used to make a blue paint (see Table 4 no. 7). These anthocyanins, as noted in chapter 1, fade very quickly. Commelina coelestis, however, is stable due to the metalloanthocyanins it contains. This table also shows the effect of the addition of certain additives that make a lake out of a dye (compare no. 4 and 5). Close observation of the original codices shows that greens are often made by mixing yellow and blue. This can be done in two ways, as can be seen in Table 4 no. 9.

The recipes for these paints were determined by two factors: stability and colour. All the materials used were organic. Except for Commelina and Tyrian Purple, they were all soluble colourants which need to be stabilised by allowing the colourant to bind to a metal. This ”complexation” is traditionally done with aluminium salts such as Alum. Kirby et al. (2014, pp. 28-30) give the most common recipe for making a pigment from a dye. First the dye is extracted by heating the material in an alkali solution, often a mixture of potash and water. The coloured solution then needs to be filtered to remove any insoluble traces of the colouring material. If Alum is then added to the mixture, it will react with the alkali and together with the colourant precipitate. The now insoluble particles can be filtered from the solution and can be used as a pigment.

A very important aspect here is the properties of the water used to make the pigment. The presence of metals in the water can have a big impact on the chemical process and alter the colour of some pigments severely. This is most strongly seen in the production of cochineal. Thus, for the experimental replication, demineralised water was used. In precolonial times, the paint makers would have had to select water from the best source. Many springs produce water that contains all sorts of minerals and metals, making rain water probably one of the best sources for water for this particular application.

Washing of the pigment has an effect on the colour, but also on the properties of the paint. A comparison of the damaged areas of the Codex Añute and the Codex Ñuu Tnoo-Ndisi Nuu shows this most clearly. In case of the codex Añute, the red colour has leached through the gesso down to the leather, while on the Ñuu Tnoo-Ndisi Nuu the red paint flakes off leaving no trace (see also chapter 3). For the experimental replication, a mixture was made of a store-bought, perfectly washed, carmine red and a red pigment made in the lab from cochineal insects (see Table 4 no. 10) This mixture best approximated the colours seen in the codices and had some of the bleeding effects seen in codex Añute.

The yellow pigment used in these reconstructions was a substitute for Zacatlaxcalli. A sample of this plant was obtained directly from Mexico and was analysed using HPLC (Hofenk de Graaff, 2004) by A. Ness Proaño Gaibor. This technique allows for the identification of organic colourants on the molecular level. Since Zacatlaxcalli is a parasite for trees that do not grow in the Netherlands, a substitute, buckthorn, was found that contained the same colouring molecules: quercetin. The colour that these paints give to a surface is heavily dependent upon the thickness of the applied layer. One very thin layer results in a lemon yellow colour, while a thicker layer or more layers result in a darker brown colour.

The source of the blue paint was the flowers of the Commelina coelestis, which with proper care can grow in the Netherlands. This dayflower produces dozens of flowers each day, which have to be plucked before the flower wilts. By plucking only the flower petals the purest colour can be obtained as the pistils of the flower give off a bright yellow colourant. These flower petals need to be dried quickly or the colour will deteriorate. However, after drying the flowers can be stored for, as experiments have shown, at least a year without losing their colour. This means that although the flower is seasonal, this paint can be used all year round. The Maya Blue used in these experiments was also store-bought.[30] The process of making Maya Blue is relatively well understood (see Chiari, Giustetto, Druzik, Doehne,

30. Supplied by Kremer Pigmente.

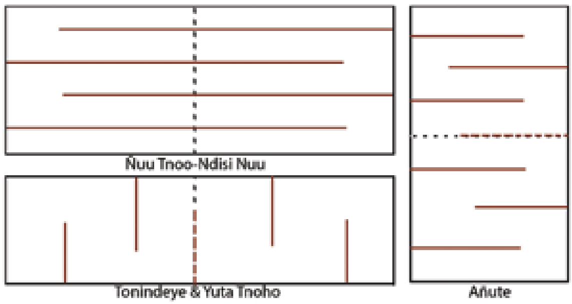


Figure 2.2: Schematic representation of basic types of reading lines as found in the Mixtec historical codices, Codex Iya Nacuaa mixes elements of all three these types.

& Ricchiardi, 2008; Domenech et al., 2011; Polette-Niewold, Manciu, Torres, Alvarado, & Chianelli, 2007) and the raw materials are difficult to come by. The process of making Maya blue is, therefore, not further discussed in this work.

Each of these insoluble lakes and pigments needs to be bound to the writing surface using a binder. For these replications, a mixture was made of gum Arabic with an orchid glue substitute. A bulb of the epiphytic orchid Lycaste lasioglossa was cut, dried, and ground. The resultant powder made for a very good glue. The orchid glue was analysed using HPLC by A. Ness Proaño Gaibor and was shown to be about 80% starch. As these orchids are not easily accessible in the Netherlands, a substitute starch binder had to be found. Multiple tests were done by Ness after which potato starch was selected as the best option. Also Gum Arabic was used as a substitute for mesquite as it is readily available, also comes from a species of acacia, and has similar properties.

2.3 THE PROCESS OF WRITING

Much more than alphabetic texts, both the Maya and the Central Mexican codices are works of composition. Like paintings, they require a process of advanced planning to make sure that proportions are correct and that the available space is used in the best way possible. It is clear that many of the known codices are copies of earlier versions. At the same time, each scribe has his own style of writing. The sizes of the surviving codices show that the size of the support was in no way standardised. This means that the page on which the script is copied is most likely different in size and proportion from the page containing the copied text. In the remaining codices, a number of strategies can be observed to deal with such problems. The first aid for setting up the composition is the division of the page into sections using the writing lines. Figure 2.2 gives a schematic overview of the types of divisions as they are found in the Mixtec historical codices. These texts required a continuous reading order as they are true narratives, with events preceding and being causative for other events. Of the five Mixtec documents that have survived, four use the support horizontally. While the sample is too small to function as statistically significant evidence it is suggestive that of the total corpus, including the Maya books, only the codex Añute and a small part of the Codex Yoalli Ehecatl use the support in a vertical fashion. The Codex Iya Nacuaa is difficult to categorize in the basic schemes as it incorporates elements of all three systems almost eclectically throughout the document. The support is used horizontally like in most codices, and divided into three horizontal bands. These run either over two pages or only over one page like in the Codex Añute. On page 8 of the Becker I section of the codex Iya Nacuaa vertical lines, such as used in the codex Tonindeye and Yuta Tnoho, are incorporated to subdivide one of the three horizontal bands.

The large variation in the codex Iya Nacuaa suggests that the thick red lines were drawn after the composition was completed. Whether or not the lines were first set up using thin red lines, as can be seen on Codex Añute, is difficult to establish given the extent of the damage on the codex itself. For the codex Ñuu Tnoo-Ndisi Nuu, however, it is clear that the scribe first divided the whole document using thick red reading lines. What is more, it seems that during writing he or she discovered that in some places more space was needed to draw all the figures. The reading lines are in these places removed and new lines are drawn (see figure 2.3).

The Central Mexican religious manuscripts do not contain single narratives, but are often combinations of table-like structures. For these tables the pages are again divided into sections using red lines. At times, these also need to be adjusted. For example, in the

Figure 2.3: Codex Ñuu Tnoo-Ndisi Nuu page 9 and 10 showing alteration of the reading line (after Jansen & Pérez Jiménez, 2005, pp. 62-63).

Codex Yoalli-Ehecatl, pages 9-13 were originally divided into 8 sections per page. The horizontal lines dividing the four quadrants were, however, removed when it was noticed that some figures took up a whole quadrant.

Once the page is divided up, the process of planning the individual figures can commence. Close observation of the codices shows the use of underdrawings on some of them. Grey or very thin black lines can be seen on the codices Tonalpouhqui (p. 18), Iya Nacuaa (p. 51), Tlamanalli (only on one side, pp. 21-31), and Yoalli Ehecatl (c.f. p. 25). What tool was used to make these very thin lines is unclear. The lines are so thin that they are most reminiscent of a pencil. Perhaps some soft mineral with a grey streak was used to make these lines, though this would require that it naturally had, or could be sharpened to, a thin point. Codex Añute and one side of the codex Tlamanalli exhibit thin red lines used to further divide the page and set up the larger figures. The underdrawings are mostly visible if a change in composition is made and if the underdrawing is not erased. That lines can and have been removed to perform corrections is clearly visible in the codex Ñuu Tnoo-Ndisi Nuu on page 31 line II. The gesso is here removed in the place where at first a leg was drawn. Also on the codex Añute page 2 there are traces of the removal of gesso to correct a mistake (below the head of Lord 2 Grass being born from the tree). On the Codex Yoalli Ehecatl gesso is used to correct mistakes. This new layer of gesso that is locally applied has over the last five centuries remained whiter than the surrounding writing surface, making these sections easy to spot today. This may indicate that this precolonial "tipp-ex" had a different composition than the original writing surface.

The three Maya books are content-wise similar to the central Mexican religious manuscripts. They also contain much calendrical information. It is, therefore, not surprising that their pages are often divided into sections using thick brown-red lines. These sections are in all three Maya codices subdivided, often into columns or into a grid, using a very transparent and light brown-red line (see figure 2.4).

For the reconstructions, two different strategies were followed. For the first reconstruction, that of select pages of the codex Tonalpouhqui, it was decided to start with the division of the pages using cochineal red paint. These lines were drawn with a thin brush.[31]

31. The brushes were store-bought synthetic hair brushes,

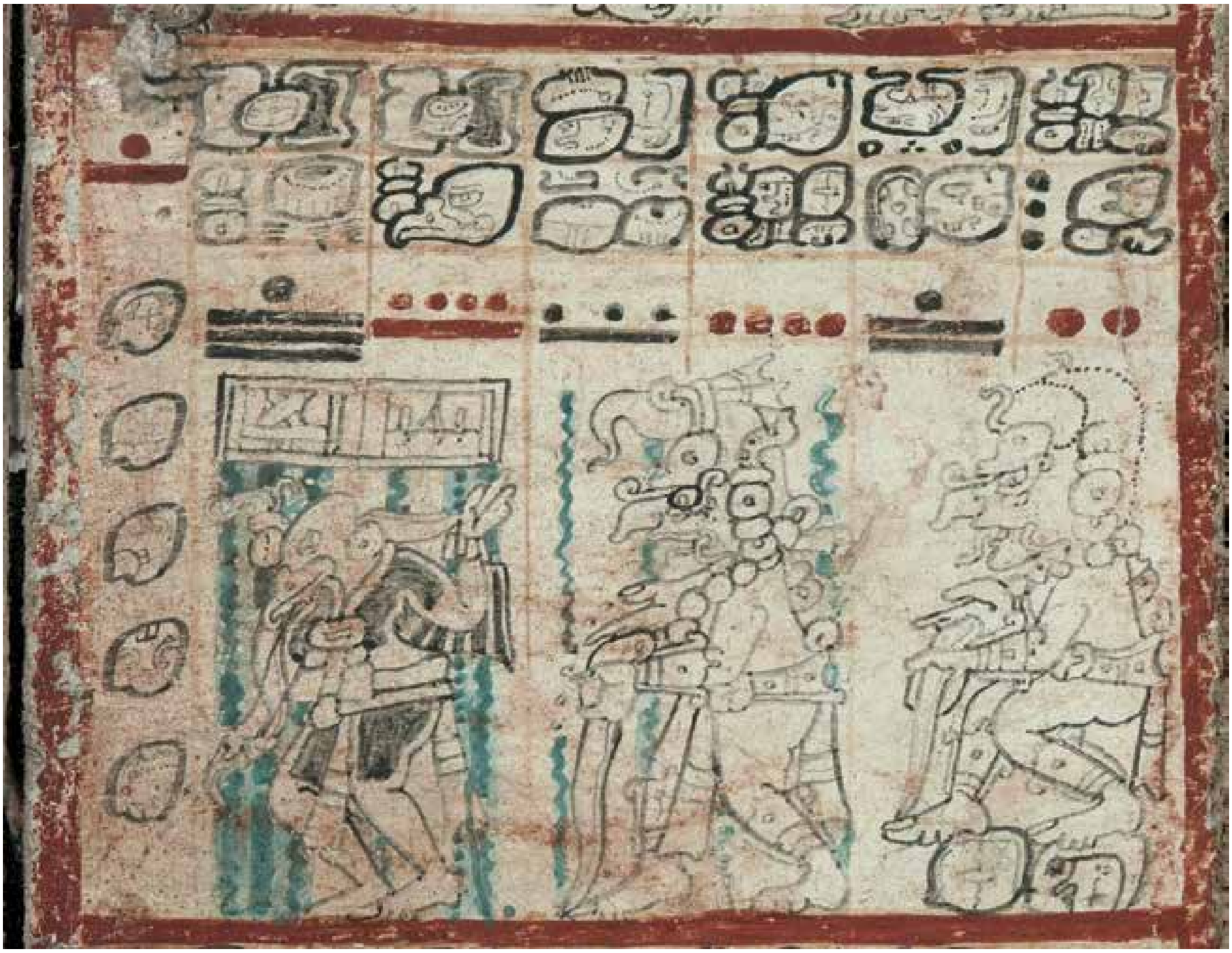


Figure 2.4: Codex Dresden: page 41 mid-section, showing the transparent and light brown-red lines used to divide the page into columns (image from digital.slub-dresden.de, accessed 29-02-2016).

After this graphite tracing paper was used to copy the outlines of the images onto the gesso. Although this was not the technique originally used to make the codex, it did provide a correct intermediate point in the process, by providing the underdrawings which can be seen in the original document. As the codex Tonalpouhqui is highly detailed, it would take years of practice to make these underdrawings by hand. The thin grey lines were subsequently traced with carbon black ink using a fine paintbrush. After the black outlines were completed, these were coloured in using Cochineal, Maya Blue, Matlallin, and the Zacatlaxcalli replacement pigments. The decision to use both Maya Blue and Matlallin was motivated by the fact that two different types of green are to be found in the original codex.

The second set of reconstructions was made in the Museum Volkenkunde. Two pages of the Codex Ñuu Tnoho-Ndisi Nuu were reconstructed by A. Ness Proaño Gaibor using a procedure similar to that used for the first reconstruction. Here, however, only the rough outlines of the figures were traced. Once completed the figures were coloured in using Cochineal, Matlallin, Zacatlaxcalli replacement and Achiotte. The last of these pigments was added to give a better matching skin colour.

size 1 for the black lines, size 1 and 2 for colouring in the figures.

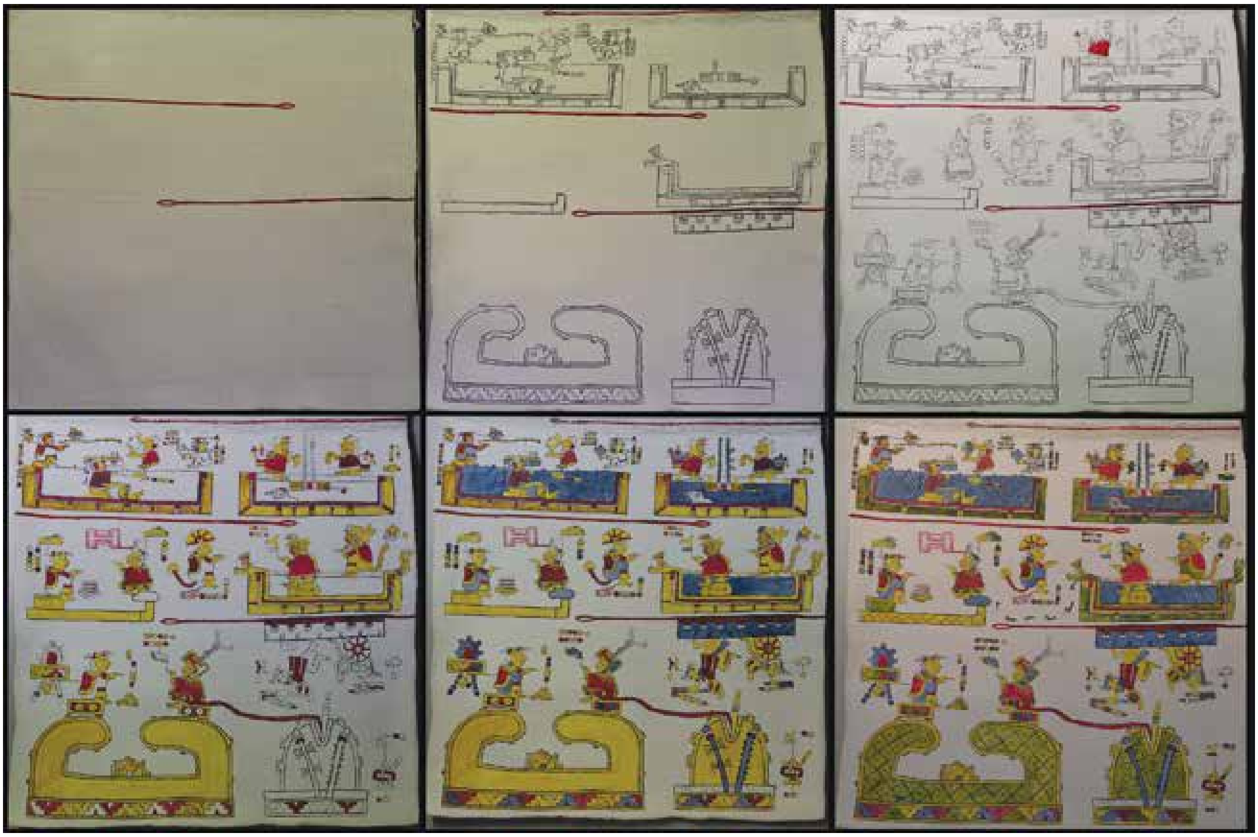


Figure 2.5: Stages in the reconstruction process (images by the author).

Two pages of the Codex Añute were copied by the author using a different system (see figure 2.5). According to this system, the pages were first divided using the thick red reading lines. After this the pages were divided using a watered-down cochineal paint. The thin pink lines gave the dimensions of the figures that were to be put in these places. This strategy is especially helpful when copying segments of the composition in other locations or at a different size from the original scene. The Mixtec historical codices are largely composed of persons and places. As the place-glyphs are often relatively large in the codex Añute, designating space for these glyphs already largely structures the composition.

During the replication process, the first things drawn were these place glyphs. It quickly became clear, however, that in some cases the persons seem to have been drawn before the place glyph was completed. This is especially the case for people sitting in rather than on glyphs such as happens with rivers. After the persons and the places have been made, the calendar signs and personal names, if these are not already incorporated in the dress of the persons, can be used to fill in the empty spaces. As the reconstruction is of a slightly different dimension than the original first two pages of the codex Añute, there are small variations in the orientation of some of the calendar glyphs to better fit them in the available space. After all the outlines are drawn and dry, the figures can be coloured in. Since the paints used are water colours, care should be taken that two wet paints do not come into contact and mix. In the reconstruction, cochineal red was used first, followed by yellow and blue. As can be seen in figure 2.5, the colour green was created by applying a layer of blue over yellow. After all figures are coloured in, details in black can be added. It was important to do this after the colours, as these watercolours will dissolve and blur the fine

Figure 2.6: Comparison of a facsimile of the Codex Añute (from Jansen & Pérez Jiménez, 2007b) and the reconstruction made by the author.

black lines. At this time any black outlines that have been covered with paint can be traced in black again. The end result is very different from the present-day visual appearance of the codex (see figure 2.6). Restoring the original vibrancy of these books therefore helps appreciate the original visual impact.

Not all codices are equally precise in their execution, though a few are true masterpieces. What has been baffling is that some of these contain figures on different pages that are exactly alike (see figure 2.7). It requires a true master painter to execute the same exact figure multiple times. The Aztecs also had a form of tracing paper, however, which may have expedited the process. A description of this is found in the Nahuatl text of chapter 21 of book 9 of the Florentine codex that deals with featherworkers. This section does not have a Spanish translation in the book and the translation of the Nahuatl here followed, was made by Dibble and Anderson (1959). This tracing paper was made by laying out a very thin layer of cotton on a very flat surface like a maguey leaf. The thin layer of cotton was glued together to form a thin transparent sheet. This could be pulled of the maguey leaf, and the design could be traced on this thin paper. After this it was done, it was glued on a thicker piece of paper to reinforce it, and then the design could be cut out. This stencil could then be used to transfer the design to some other medium. Since the codices are made with closed figures, stencils cannot be made of whole figures, as this would mean that the centre of the figure, which is completely enclosed by the outline, falls out. This might explain why in, for example, the codex Mictlan, only parts of the heads perfectly match up with other figures (see figure 2.7). The use of a stencil should be possible to detect microscopically. When a stencil is used, paint is applied to all empty parts of the stencil. Thus the striations in the paint, caused by the brush applying it, would all be going in the same direction rather than following the direction of the line itself. This hypothesis requires further investigation of the original object.

2.4 COVERS

As described in the previous chapter, there are only three original covers which have been securely identified. The one of the codex Tonalpouhqui which was made from wood with turquoise inlays; one from the Codex Mictlan which was made from jaguar fur; and one from the Codex Tonindeye which originally had feathers. No experimental replication of these types of covers has been undertaken as these materials are very rare and the techniques needed for them so sophisticated that this would require a separate research. In the case of feather work, extensive experimentation has already been performed (Berdan et al., 2009). The general production process that must have been part of the creation of these objects, can be reconstructed here based on artefacts made from similar materials. For each of the types of cover postulated in the previous chapter, the acquisition of raw materials and their subsequent processing can thus be discussed. Besides these three types of material, a fourth likely cover type, gold, is also discussed. Although none of the codices contain gold, this material was extensively used in both feather works (Haag, Maria y Campos, Rivero Weber, & Feest, 2012, p. 50) and mosaic artefacts (McEwan et al., 2006, p. 31). Considering the European appetite for this precious metal, it is a likely material for the covers that have since been completely removed.

The production of the wooden cover of codex Tonalpouhqui can best be understood in comparison with more complex and more complete mosaic-

Figure 2.7: Comparison of two figures in the codex Mictlan (pages 34 and 38) showing the similarity between the faces of the two figures (after Anders, Jansen, & Cruz Ortiz, 1994).

decorated pieces. Recent investigation of the turquoise mosaics in the British Museum (McEwan et al., 2006) has given clear insight into the technology behind these artefacts, which is equally applicable to the codex cover. Although the cover of the Tonalpouhqui is relatively simple, wooden boards found in Cueva Cheve (González Licón & Morfín, 1994, pp. 230-235) (see figure 2.8), as well as mosaic decorated shields (see McEwan et al., 2006, pp. 59-66) give an indication of how a complex cover may have looked and what its composition may have been. One of these boards depicts a complex battle scene, completely in the style of a codex (figure 2.8 top). The other board portrays what may have been a shield and arrows. It may be that these mosaic-covered boards were in fact once the covers of a codex. They were recovered stacked, with two fragments facing up and two facing down, as described by Steele and Snavely (1997). However, it is unclear from this publication how they were arranged exactly, and if there were traces of gesso between them, which could be expected if a codex was once kept between these boards. Even if there was, it may have escaped notice as the abundance of white minerals in a limestone cave is to be expected.

Not much research has been done on these tablets. The few remaining shields covered in mosaic show similar styles and codex scenes, and have received more scholarly attention. The materials identified thus far on these mosaics (see McEwan et al., 2006, pp. 24-41) are five types of mineral tesserae (Turquoise, Malachite, Pyrite, Gold and Lignite); three types of shell tesserae (Strombus spp., Spondylus princeps and Pinctada mazatlantica); three types of adhesives (Pine resin, Copal and beeswax); and two main types of wood substrates (Cedar and Pine). These materials come from very different areas. A Mesoamerican source of turquoise has not yet been identified, although the presence of large quantities of the material on artefacts from the Mixtec area is difficult to explain without a local source. Melgar (2014) argued that the mosaic objects from the Mixtec area and those recovered at the Templo Mayor in Tenochtitlan show differences in material composition. Where the Mixtec objects are composed of a mixture of turquoise and other materials, such as shells, the Templo Mayor objects are made almost exclusively out of turquoise (Melgar Tisoc, 2014, p. 286; Ruvalcaba-Sil et al., 2013). At the same time though, the Mixtec turquoise itself is chemically similar, while the Templo Mayor objects are made with blue and green stones with differing composition, some of which have to be classified as minerals other than turquoise (Melgar Tisoc, 2014, p. 194).

All the sources of turquoise that have been securely identified are located in the southwest of what is today the United States of America (McEwan et al., 2006, pp. 27-30). Turquoise manufacturing techniques on Templo Mayor objects investigated by Melgar Tisoc and Solis Ciriaco (2009) show two distinct patterns. The difference is the way in which the individual tesseracts are abraded. One type is made with sandstone, while the other is made with basalt. This may reflect differences in location of the manufacture of the tesseracts (Melgar Tisoc & Solis Ciriaco, 2009, p. 123). The sandstone type would be made in the South-west of North America, while the basalt type reflects a technology seen on other, locally produced, Central Mexican objects.

The other minerals found in mosaics are all volcanic and can be found in the central Mexican highlands. Both types of wood are also found in the same areas. The shells, however, require access to coastal waters. In order to create the individual tesserae the minerals and shells need to be cut and ground to size. In the mosaics investigated by McEwan et al. (2006), some pieces of mosaic have decorations that were not part of the mosaic design, indicating that these pieces were not originally designed for this purpose. It may well be that these pieces were moved pre-processed from mines and workshops in the north. The mosaic tesserae are attached to the wooden surface using a strong resin. In the artefacts of the British Museum, this resin has been shown to be pine resin or copal (McEwan et al., 2006, pp. 35-37). Resin could also be moulded to form relief on the surface. In the case of the cover of the codex Tonalpouhqui, traces of resin are found in the holes in the centre of the cover. The diverse materials found in some of these mosaic objects were all part of the tribute system of the Aztec empire. In the Codex Mendoza, shells are shown coming in from two areas. The coastal areas in Veracruz supplied conch shells (Berdan & Anawalt, 1997, p. 123), while on the Pacific side (Codex Mendoza, 1541 folio 38r) the province of Çihuatlan provided Spondylus shells (Berdan & Anawalt, 1997, p. 84). Turquoise was brought in from Veracruz (Codex Mendoza, 1541 folio 52r.), most likely following an eastern route from mines in Cerrillos (today in the south of the United States) down along the coast of the bay of Mexico (see Melgar Tisoc, 2014, p. 130). It was also paid in tribute from the western provinces of Quiauhteopan and Yoaltepec (Codex Mendoza, 1541 folio 41r), where it also must have been obtained through trade from the north.

Making a mosaic required true mastery. Evidence of advanced techniques including those of woodworking, lapidary, glue making and shell working can be seen in the exquisite artefacts that still remain today (see McEwan et al., 2006, pp. 38-41). If the codices had indeed once such elaborate mosaic covers, then these would have been made by specialists. As symbolic significant and integral protective parts, they must nonetheless be considered part of the production process.

The fur cover of the codex Mictlan has been shown to be jaguar (see chapter 1). Creating this cover would have consisted of three steps: obtaining raw material; preparation of the fur; and creation of the fur cover. Obtaining such a dangerous animal was never a simple task. The range of the jaguar is smaller than that of the deer used for normal leather, as jaguars prefer forested areas in the highlands. As the jaguar is today still seen as a very dangerous animal, especially threatening to livestock, its range has been significantly reduced since precolonial times. Historically, the jaguar was prevalent throughout

Mesoamerica, preferring areas away from daily human activity; i.e. mountaintops and dense forests. The jaguar makes a home in caves, further adding to the symbolic importance of the animal (Miller, 2011).

In the description of the jaguar by Sahagún (1577c fo. 3r.), it is clear how dangerous this animal could be. Next to the practical constraints that it would be unwise to try and pierce the valuable skin of the animal with countless arrows, this description shows that the speed and strength of the jaguar would make the hunt very dangerous for the hunter. Although it is not very clear from the translation by Dibble and Anderson (Sahagún, Dibble, & Anderson, 1963, p. 3), the original Nahuatl text gives a very concise description of the way to hunt a jaguar:

"Auh in mozcalia tlamjnquj, in ce qujtlaxilia, acatl, intla oqujmacuj:njman concuj, in quaoacazoatl, in quauhxioatlapalli: yiacac qujtllia, yiacac qujço, in acatl: njmã qujtlaxilia, papatlacatiuh: in acazoatl. Iuhqujn chapolin: ic iauh, aço tlatlaco, aço ie itlan: in patlanj, in vetzi, in quaoacazoatl, ic qujxpatilia : ic vel qujmjna, in tlamjnquj: ic vel câci"
(Sahagún et al., 1963, p. 3)

"Y se el cazador bien entendido, el coloca con la mano, Después toma el quaoacazoatl,[32] la madera de colores para cubrir, en la esquina la coloca. En la esquina la hizo la caña: después coloca hojas de papatla[33] en la trampa. Y así salta: bien sólo por dentro se daña cuando cae del vuelo, la trampa de madera, en frente: bien se esconde el cazador, bien llega.[34]"

"And the hunter who understands it well, he traps it (the jaguar). He takes a hollow and flexible wood and coloured wood to hide (the trap) and he puts it (sets it up) in a corner. In the corner he puts up the rod and he covers the trap with large leaves. And when the wooden trap springs, (the jaguar) will fly through the air and hit the ground, damaging his insides. If the hunter is patient, it will go well"
[free translation by the author].

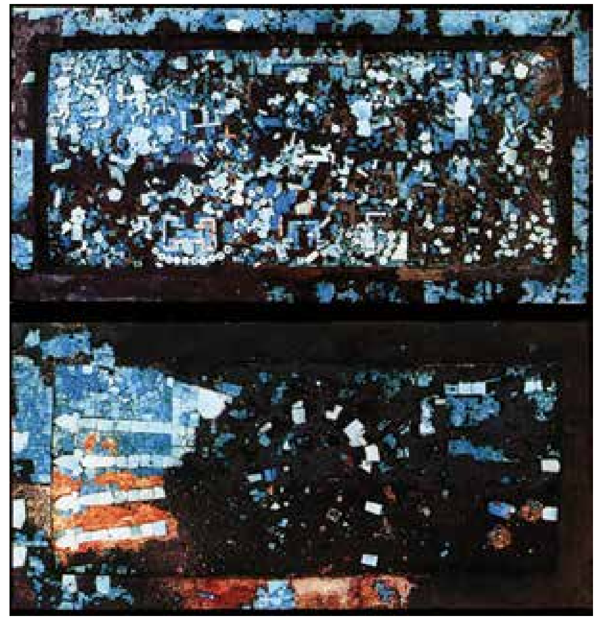


Figure 2.8: Two wooden boards covered in fine turquoise mosaic discovered in a cave in the Cañada de Cuicatlán (after González Licón & Morfín, 1994).

The trap described is similar to the one depicted in the Madrid codex for catching deer (see figure 2.1), although it provides even more details, such as the need for covering it up with leaves. It is unclear if the wood that needed to be brought was used to cover the trap itself or perhaps was merely used as a shelter for the hunter. The passage on damaging the insides of the jaguar can be understood when considering the objective of the hunt: the collection of the precious skin of the jaguar. By using this method the jaguar can be caught and killed without posing any danger to the hunter and without any damage to the fur. In contrast to the trapping of a deer described above, a jaguar will not go into shock that easily when caught and will still put up a fight. The alternative would be to wait once the cat is caught, in order for the animal to weaken and eventually die. This option may, however, have a detrimental effect on the fur. As such, it is better to have a trap that can safely kill the animal.

32. This word is a contraction of the words for wood, hollow, and elongated, combining to describe properties of the wood itself; i.e. it can be understood as a hollow and flexible wood.
33. Hojas de papatla refers to a type of large leaf, similar to banana leaves.
34. Translation into Spanish by Raul Macuil Martinez.

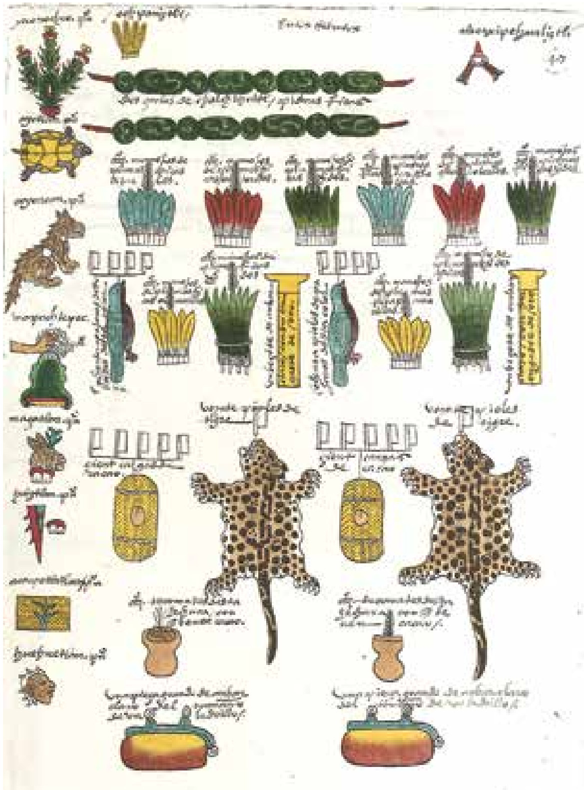


Figure 2.9: Codex Mendoza folio 47 r. (from Clark, 1938 folio 47r.).

Once a skin is acquired it needs to go through a similar process as is needed to make leather. The big difference is that now the hairs need to be preserved in an aesthetically pleasing manner. As was stated in chapter 1, one of the dangers to preserving fur is that when it dries out, the hair follicles will open up and the hair will fall out. Furthermore, furs are first and foremost valued for their aesthetic appeal. Thus, while it would not matter so much what the colour of the leather of a codex is – as there would eventually be a gesso layer that would cover it – furs needed to keep the natural appearance of the animal. While for leather making often tannin from tree bark is used, fur makers resort to oils, alum, and salt (Kite, 2006b, p. 148). As with leather making, the profession of the fur maker was not one of great interest for Spanish chroniclers. Thus, exactly which materials were used is not known. To obtain this information, invasive methods may have to be used, which is not possible at the moment. Jaguar furs were also paid in tribute and probably traded throughout Mesoamerica. In the codex Mendoza, the outpost province of Xoconochco is recorded as paying part of the tribute in jaguar skins (see figure 2.9). Seeing as the transport of such skins would take quite some time, it seems likely that these were processed furs rather than skins.

Once fur was obtained, an appropriate part needed to be cut out. In the case of the Codex Mictlan, the fur cover is slightly larger than the pages of the codex. Therefore, it also slightly protects the sides of the cover page. This also has the advantage of preventing foreign material sticking between the cover and the codex page, thus breaking the bond between the two. In depictions on Classic Maya vases, codices are often depicted with thick jaguar covers. It may be that this is simply the result of painting convention. In order to show that these books had jaguar covers, then, one would need to depict the document from a somewhat oblique direction. The alternative explanation is that indeed these books had larger covers that overlapped the sided of the manuscript more completely, thus forming a complete wrapping of the book. The latter is suggested by the depiction of the codex on the famous so-called Princeton Vase. The third type of cover is encountered on the codex Tonindeye. This codex contains imprints of feathers in a resin or glue-like material (Anders & Troike, 1987, pp. 39-40). There is also a square imprint of what may have been a piece of stone that was inlayed. Although there are only a few traces left on this codex, the use of feathers to make highly complex feather mosaics is well known. Like stone mosaics, feather mosaics can also be found on shields. Though not many originals remain, the few original feather mosaics and headdresses that still exist have been studied (Filloy Nadal, Solís Olguín, & Navarijo, 2007). The bright feathers found in many of these come from birds found in the tropical lowland regions, either on the coasts or the lowland Maya regions (Haag et al., 2012, pp. 83-94).

How the featherworkers made these works of art is extensively described in the Florentine codex. Though it is one of the most extensive descriptions of one procedure, the Spanish text does not give any translation. Instead, it states that people who want to know more should go and visit the featherworkers themselves. The Nahuatl text, as translated by

Figure 2.10: Overview and detail of an engraved and embossed golden disk currently held at the MNA (Mexico) (images by the author).

Dibble and Anderson (1959), shows some important insights into the creation of featherworks. First of all, two different types are described: one on a flat surface, such as the codex cover; and another three-dimensional type, made on a wooden frame. For the flat surface version, the previously described tracing paper was used to transfer a design that a scribe had made to the medium that the mosaic was made on. The first feathers to be applied to this were glue-hardened feathers. These were inferior feathers that formed the background for the design. A whole process of colour-matching is described for these feathers (Sahagún et al., 1959, pp. 94-95). It may be that the creators of feather mosaics were also one of the prime consumers of tzacutli orchid glue (see chapter 1), as this glue is colourless and thus does not mar the iridescence of the feathers. The depictions in the Florentine codex suggest that a bulbous plant such as this orchid was used as glue. Though there are many bright colours of feathers available, especially from the tropical lowlands, a process of dyeing feathers is also known. Some of these feathers seem to have been dyed using Zacatlaxcalli, and the addition of alum and saltpetre, both mordents, is mentioned for this process (Sahagún et al., 1959, p. 95).

Feathers were a common form of tribute in the Aztec empire, as seen in the Codex Mendoza and the Matricula de Tributos. The provinces of Coayxtlahuacan and Tlachquiavco, both in the Mixteca Alta, are reported to have paid tribute to the Aztec empire in the form of rare green stones, gold, and dyes, as well as quetzal feathers (Berdan & Anawalt, 1997, pp. 102-105, 110-111; Codex Mendoza, 1541 folio 43r. and 45r.). Quetzals do not live in these highlands, thus these feathers must have been imported from tropical areas, either at the coast or further east in the Maya area. Feathers were also paid in large numbers by the tropical coastal provinces of Tochtepec (Veracruz) and Xoconochco, the outpost in the far south-east of the empire. As can be seen in figure 2.9, there were feathers of different colours and sizes. The design that was outlined on the surface was made by carefully placing feathers of the right length and colour and gluing them on the surface. To do this a special elongated tool, made of bone or wood, was used. This tool is also depicted in the Florentine Codex (Sahagún, 1577a fo. 65v.-66r.).

Though at least fifteen codices have survived, only three contain traces of their original cover. The exposed codices most likely had their covers intentionally removed, in some cases probably taking with it part of the book. This allows for some speculation about the nature of these removed covers. They must have been either attractive to the Europeans or so appalling that they were removed and thrown away. The latter could be the case if they

Tool	Use	Raw Material	Evidence
Making the support			
Bow and arrow/ atlatl	Hunting for skins	Wood, flint, string	Archaeological, Iconographic, Historical
Traps	Hunting for skins	Wood, rope, leaves	Iconographic, Historical
Axe, adze, or knife	Cutting tree bark	Obsidian or flint and wooden handle	Inferred
Scrapers	Scraping hides	Obsidian, flint, or bone	Experimental
Container	Tanning hides	Ceramic, excavated pit?	Inferred
Rack	Stretching hides	Flexible wood and string	Experimental
Blades	Cutting of skin and amate	Obsidian or flint	Inferred
Fuel	Chalk/gypsum dehydration	Wood (Pine?)	Inferred
Container	Storage of gesso	Ceramic	Inferred
Paper beater	Felting together of amate fibres	Stone	Archaeological, Ethnographic
Coarse brush	Application of gesso	Hair, rope/adhesive, and handle	Inferred
Polishing stones	Polishing the gesso surface	Smooth hard stone	Archaeological, Inferred
Paint making			
Grinding stone	Grinding the colourant source	Coarse stone	Historical
Container	Boiling of pigment source	Ceramic	Inferred
Firewood	Fuel for fire	Pine?	Inferred
Sieve/filter	Filtering the colourant from	Cotton?	Inferred
Painting			
Containers	Paint storage/palette	Shell, ceramic	Archaeological, Iconographic, Historical
Fine Brush	Application of paint	Fine hair, adhesive/string, wooden handle	Iconographic, Inferred
Blade	eraser	Obsidian or flint	Inferred
Cotton “paper”	Tracing and transferring paper	Cotton and glue	Inferred
Pen	Writing fine lines	Bone, wood	Inferred

Making a stone mosaic cover			
Blade	Carving wood	Obsidian, flint	Inferred
Abrasive	Polishing stones/ tesseracts	Emery?	Historical
Lubricant/coolant	Polishing stones/ tesseracts	Water	Inferred
Brush	Application of adhesive	Fine hair, adhesive/string, wooden handle	Inferred
Cotton “paper”	Tracing and transferring paper	Cotton and glue	Inferred
Tweezers/other positioning tool	Placement of tesserae in glue	Wood?	Inferred
Container	Storage of adhesive	Ceramic	Inferred
Making a feather mosaic cover			
Blade	Cutting feathers	Obsidian, flint	Inferred
Container	Dyeing feathers	Ceramic	Historical, Inferred
Fuel	Dyeing feathers	Wood	Inferred
Dye	Dyeing feathers	Zacatlaxcalli/water	Historical
Container	Storage of adhesive	Ceramic, shell?	Inferred
Tweezers/other positioning tool	Placement of feathers in glue	Wood?	Historical
Cotton “paper”	Tracing and transferring paper	Cotton and glue	Historical
Making a fur cover			
Preservative	Fur making	Salt, Alum	Inferred
Rack	Stretching the fur	Flexible wood, rope	Inferred
Blade	Cutting fur to size	Obsidian, flint	Inferred
Container	Storage of adhesive	Ceramic	Inferred

Table 5. Tools used in each of the production processes.

were made of fur which was severely degrading and putrefying, or if they were worked with imagery that needed to be destroyed; i.e. images of the "devil" (see chapter 5). This last option is rather strange though, as the rest of the documents certainly contained images that could be considered "evil" as well. A more likely alternative is that these covers were decorated with materials that the Europeans coveted. It is well known that many objects that were either decorated with, or made out of, precious metals were destroyed. From the viewpoint of the Europeans this was simple recycling, the metal being molten down to fuel European economies. A few delicate examples of gold work on a flat surface have survived, giving some insight into how these covers may have looked. The golden disks held at the National Museums of Anthropology in Mexico City are good examples (see figure 2.10). They are very thin and thus must have originally been attached to a strong surface such as a wooden base in order to survive. They are finely engraved or embossed and show elaborate figurative scenes.

Gold work was, for obvious reasons, a category of interest for the Spanish conquerors. Thus, like feather working, the processing of gold is described in the work of Sahagún (1959, pp. 73-78). Much of this description is, however, focused on the creation of complex three-dimensional objects, using the lost wax method. When making a cover the work would have to be more or less two-dimensional, requiring the work of a gold beater. In Sahagún et al. (1959, p. 76) it is further mentioned that it is the feather worker who makes the design. It is likely that he would do this using a stencil made after the work of a scribe, similarly to the way that the feather mosaic was made. Once copied, the design was then traced by the goldbeater using a flint knife. These descriptions of the feather worker and the goldbeater show the intimate relations between these crafts and the scribes.

2.5 TOOLS

A category of material culture that is not physically present in the codices, but nonetheless essential for their creation, is the toolset needed for each of the production steps. Not all these tools have been recovered archaeologically, though some are known from depictions or have left interpretable traces on the codices. For some rare cases, such as the production of amate paper, the production process can be observed. Based on the understanding of the processes gained from experimentation and the archaeological and historical data that was presented in this and the previous chapter, it is possible to infer what other tools would be needed in each step of the process. Table 5 gives an overview of all of these objects. For each tool the specific use is given, as well as the materials needed to make the tool in question. The final column shows on what evidence the identification is based. Direct archaeological evidence is scarce, as many of the steps in the production process leave little traces that are archaeologically preserved. Thus, although there are plenty ceramic pots which could have been used for the boiling of cochineal, there is no direct evidence – for example, through residue analysis – that shows that a vessel has been used for that purpose. Other tools are not preserved at all, such as sieves, pens, brushes, and stencils, which were themselves made of perishable materials.

What this table shows is the large dependency of the codex maker on other people. The series of different containers, for example, integrate the making of codices with the production of ceramics, but also shell fishing. While paint may be stored in a shell, glue which needs to be heated before use cannot. In order to heat it, fuel is needed, linking the profession of the scribe with that of the woodcutter. The cutting of wood, but also the hunt, the cutting of paper, fur, leather, and the grinding of pigments and polishing of gesso and mosaic tesseracts link it with another industry: the mining and processing of stone objects. Such cross-craft interaction (Rebay-Salisbury et al., 2014, p. 2) has not been a major focus of study for the Mesoamerican world, though this deserves more attention. All these links show the integration not only of multiple crafts, but also of the Mesoamerican world in the geographical sense. In part, this can be seen as the result of the expansion of empire. As empires grew, more materials become accessible that could be incorporated in the available corpus of material culture. However, in some cases the expansion of empire is caused by the desire to have access to new or at least previously inaccessible tools. Durán gives a very explicit example of this:

> *"Los lapidarios de la ciudad de México y de Santiago (Tlatelolco), y de todas las demás provincias tuvieron noticia cómo en la provincia de Tototepec y Quetzaltepec había una arena apropiada para labrar las piedras, y que también se hallaba allí el esmeril para bruñirlas y ponerlas muy limpias y resplandecientes. Lo cual dieron noticia al rey Moctecuhzoma y significaron la dificultad con que los de aquella provincia lo daban y el mucho precio con que se compraba."*
> (Durán, 1967, p. 425)

The chapter continues with a description of the war with the Mixe people that ensued and that was ultimately, though not without difficulty, won by the Aztecs. Although this material plays only a small part in the production of codices, it is clear that the need of a tool can have far-reaching consequences.

DISCUSSION AND CONCLUSIONS

This chapter started out with a list of materials identified as ingredients for precolonial codices by scientific investigation, or suggested as likely ingredients by historical and ethnographic sources. Through experimentation an attempt has been made to expand this list to include materials that are not clearly identifiable on the codex' surface, but which are essential to obtain a comprehensive understanding of the codices and of codices making traditions. A lot was learned about the process of writing, which only came to light by trying to replicate the entire process. First of all the experimental replication has also shown the difficulty of the writing itself. At the same time, some small discoveries, such as the realisation that a sharp stone makes for a perfect eraser when writing on gesso, revealed aspects of the material that made life easier for the precolonial scribe. Furthermore, the replicas made illustrate the vibrancy of the materials when they are fresh. These bright primary colours give an indication of the colourful world that the Mesoamericans inhabited. The extraordinary material complexity of these books is in no way a natural given. The often exotic materials incorporated are a first indication of the special place these books held in Mesoamerican society. Although some limitations of the experimental method have already been mentioned in the introduction, a more thorough critical reflection is in order. The first point of discussion could begin from the following question: Were the experiments significantly authentic? There are a number of factors that were not taken into account in relation to the experiments, either because of limitations in availability of raw materials, practical limitations, or because inclusion of these factors would introduce an unacceptably high level of uncontrollability or uncertainty. For instance, the extraction and heating up of dyes was done on an electric stove rather than on a wood fire. Although the use of a wood fire would have increased the authenticity of the procedure, it would have been impractical and the temperature could not have been as easily controlled. A second significant deviation from the original procedure is that the pigments were made in glass containers to ensure that no trace chemicals would enter the paint. This was important to ensure that the paints can in the future be analysed using HPLC, to become part of a standard reference collection. However, this does mean that an interesting line of research is not yet explored: the interaction of Mesoamerican pottery with paint creation. It would be interesting to see if this type of paint production could be inferred from residue analysis in pottery vessels. This would be yet another step towards a better understanding of cross-craft interaction.

From a theoretical perspective, it is complex to situate the experiment. In the typology proposed by Mathieu (2002, pp. 2-6), elements of the experiment can be distinguished from three different typologies. First of all the objective was to make a visual replica, while using materials and techniques available in precolonial Mesoamerica. As such, the experiments were also a form of technological replication. In the process and especially the last stage where the drawings had to be made, the experiments also became phenomenological, as the intense two-week effort to create two pages of such a book left a deep impression of the skill of the original authors that would not have been attained without this experience. Throughout the experiment there remained a tension between a desire to create an object that looked like a pristine codex, while at the same time trying to mimic the original creation process. The creation of the paints from natural materials is a delicate process. All credit for the creation of the colours used for the replicas has to be given to A. Ness Proaño Gaibor who with his extensive knowledge of colour chemistry and precise formulas was consistently able to create high quality paints. From a theoretical perspective, however, A. Ness Proaño Gaibor's preacquired skills and expertise simultaneously created a control and also undermined the authenticity and phenomenological experience of the replication itself. In ancient times, without the knowledge of chemistry and the use of scales and beakers, uncertainty was as much part of the process as the ingredients themselves. It is very likely that such uncertainty prompted the performance of certain rituals to help guide the process. To truly mimic the production process of the codices thus would not only require as Ingold (2013, pp. 28-29) suggests a return to alchemy, but also a complete immersion in precolonial ceremonial life. Obviously, then, the experimentation remains an incomplete approximation, which was nonetheless informative.

In trying to understand the production technology of these books, it also has to be taken into account how people acquired certain materials. Not all of the materials identified are readily available in the areas where these books were made. Some of these codices, such as the otherwise rather unassuming codex Tonalpouhqui, are by their incorporation of cochineal, Maya Blue, and turquoise, material manifestations of a network of interactions that must have bound together areas that are thousands of kilometres apart. As shown in chapter 1, the amount of data is too small to draw statistically significant conclusions about this, though it is rather striking that Maya Blue has not been identified in the Mixtec codices, nor does cochineal appear in the Maya books. This fits in the idea of the world that the Aztecs would like to portray, with their empire as the central hub for all goods. The incorporation of Maya Blue and Turquoise in this network raises the question of what went back out of the empire to the areas producing this material. Although the codex Mendoza shows that certain provinces under control of the Aztecs paid tribute in turquoise, they lacked the natural resources to produce it. Thus, the codices are evidence of the activity of trade. The material dependences shown throughout this chapter also imply dependences on human behaviour. It can be inferred, therefore, that the raw materials for the codices depended upon activities such as hunting (hides, furs, bones, feathers), mining (turquoise, gold, mineral pigments), farming (cochineal), fishing (shells), gathering (flowers, orchids), and woodcutting (firewood, hardwoods). Archaeological evidence for some of these activities does not exist and the practice of, for example, gathering or perhaps even a type of farming of Commelina flowers can only be reconstructed based on these rare artefacts. Some differences may be observed here again between the Maya books and the rest of the corpus, as the activity of hunting does not play a major role for the production of these books, except possibly for the creation of their covers. Many of these activities have different geological or ecological requirements. Thus, the role of the merchants comes to the fore. All of these raw materials also needed to be processed. Most of this processing must have been specialised work that was outside of the domain of the scribe. The making of a codex, then, may have involved a trip to the lapidary, the featherworker, the tanner, the fur maker, the glue maker, and the gypsum seller, assuming the scribe would be tasked with making his own tools and paints. It is unknown how all of these materials would come together. Did the scribe have to go to a market and buy his supplies? It is possible that some books were so important that craftsmen contributed to this work freely or as a form of tribute, but this is only speculation. Regardless, what this chapter has shown is that from whatever perspective one takes on codices and codices making, there must have been a vast amount of people and skills involved in making one of these books. What made these books so special, then, is not only their material composition, but what their contents made possible. Once a book was finished it would become an instrument for some very specific contexts of use. The next chapter explores the use of these books as a series of very important affordances.