# A Quest for the Golden Fleece

Rarely have I encountered an entangled mat of cellulose fibers I didn't appreciate in one way or another. Whether textured or smooth, precious or disposable, these hardy amalgams of hydrogen-bonded fibers have changed the world many times over. For centuries, human history has been both literally written on the surface of paper and embedded deep within its structure. In folded and bound form, mats of cellulose fibers ushered in the Enlightenment; by enabling multiple iterations and revisions of an idea, they have facilitated the design of airships and skyscrapers, or the blueprints and calculations that made possible the first human footsteps on the moon.

Generally speaking, we continue to recognize paper by a few basic characteristics: it is most often thin, portable, flexible, and readily accepting of ink or inscription. There is, however, a particular sheet that is superlatively impressive, exhibiting an unintentional and unpretentious type of beauty. At first glance and in direct light, it may trick you into thinking it is merely ordinary paper; when backlit, the careful viewer may detect subtle hints of its historical pedigree via telltale watermarks or chain and wire lines. Only when viewed under a raking light does its extraordinary surface emerge with clarity, containing endlessly variegated impressions of the fibrous felts between which it was made: a galaxy of fibers, ready and waiting for a collaboration with an opportune stroke of chalk or splash of paint. What follows is the story of a quest to make this specific incarnation of paper: a sheet

chosen specifically by artists for its friction points – literally its highs and lows – comprising an unmistakable, fibrous topography that collaborated with and influenced the chalk drawings and ink washes of the Old Masters. I refer here, my friend, to the textured papers of the Italian Renaissance.

What, you may ask, is so special about a fibrous texture in paper? After all, fibers are the substance that defines paper. True, all paper is made of fibers; upon seeing an entangled surface texture in any paper, we might assume that it was directly generated by the fibers which make up the sheet. In the case of Japanese papers made from gently cooked kozo, we would be correct: the beautiful swirl of streamers in the surface texture is indeed the kozo bark. But in the textured linen and hemp sheets created in Italy between the 14th and 17th century, the paper's fibers -- integral as they are to the sheet -- have conformed not only to themselves, but to the larger matrix of the wool fleece against which they were pressed. The next time you find yourself in front of a 16th-century drawing, admiring the play of chalk strokes upon its fibrous surface, look very closely: as you behold the distinguishing marks, you will witness a texture imparted under the force of a mechanical screw press, as woolen felt was pressed some five hundred years ago against a wet mat of cellulose fibers.

The recreation of such papers in the present day is a slippery slope. The influence of our own time taints our intentions, creeping in and asserting itself like a secret mutiny. Our modern technological age with its "better living through chemistry" will almost certainly sub-

vert and change our course, even as it helps us find the way. Might it still be possible, in our changed world, to make Italian Renaissance paper? As I once heard artist Wayne Thiebaud explain: "There is no such thing as a bad question – only bad answers."[1]

I first encountered the possibility of recreating age-old papers at Berkeley's Daedalus Paper Conservation Laboratory, my day job while studying printmaking at the San Francisco Art Institute.[2] By teaching me how to conserve paper from centuries-old antique documents, Daedalus founders Robert Clifford and Stephen Shapiro set me afloat on a voyage of discovery that continues to this day. I recall in particular my excitement at working with Bob Clifford on a two-hundred-year-old piece of paper upon which George Washington had penned a letter to his stepson. We scraped fiber off a rag paper of similar character; stirred the fibers into a beaker with methyl cellulose (a type of paste); formed micro-sheets; and carefully, deftly infilled the irregularly-shaped holes in the document.[3] Washington's letter looked almost as good as new. Admiring the successful infill, I marveled aloud: We made paper! "So what?" replied Bob. True, we had made less than a square inch of paper; nevertheless, my interest was piqued. "Could we make handmade paper," I wondered, "at a much bigger scale?" "Whatever for?" asked Bob, nonplussed. I had no answer to his question, but my journey had begun.

Just as Jason and the Argonauts sailed in search of a mythical golden fleece only to encounter adventures unknown, so I began to seek my own elusive treasure without yet fully realizing all of the obsta-

1. *Wayne used this aphorism to put the audience at ease while asking for questions after a slide presentation at CCAC. Interestingly, none of the slides depicted his own painting; instead, he presented slides of other artists' work and explained how each had influenced him. I remember Wayne was asked: "Was it you or Mel Ramos who first started painting bright edges around painted elements?" His answer: "I believe it was Vincent van Gogh."*

2. *The conservators at Daedalus persuaded me to supplement my art school curriculum with chemistry classes. Though I had loathed chemistry in high school, my desire to catch up to the conservators made me a surprisingly enthusiastic student the second time around. I highly recommend the study of chemistry to any serious artist or student of art; it will change your life.*

3. *In a forward-thinking move for the early 1970s, we placed silicon release paper on both sides of the document to keep the infill from sticking to anything but the paper.*

cles and variables related to the successful production of large format, Renaissance-style paper. Like Jason, my quest would take me across oceans, bringing me into contact with larger-than-life figures from antiquity and the 21st century; I, too, would be subject to the perpetual distraction of adventures tangential to the quest.[4] What's more, though unknown to me at the outset, my success also depended upon the acquisition of rare fleece -- literally: the pelts of 500-year-old breeds of sheep ultimately proved crucial to recreating the elusive surface texture of 16th-century Italian paper.

By a stroke of luck, I met Editions Press master printer Lloyd Baggs in the early 1970s while attending one of his stone lithography demonstrations. My companion and fellow SFAI student Marcy Klepp,[5] a striking beauty, was invited by Lloyd to a party at after the demonstration; as an afterthought, he conceded that I could come along too. That night, I stood against the wall at Lloyd's Berkeley house; as a lowly printmaking student, no one at the party would give me the time of day. Just then I noticed Lloyd, a cello player, attempting to play a newly-purchased acoustic guitar. Having played since childhood (and having taken a few lessons from a young Jerry Garcia), I offered some tips and instruction. Lloyd was receptive; thanks to the universal language of music, I suddenly had a foot in the door.[6]

This encounter eventually led to a position sponging lithography stones at Editions Press, where I worked under Lloyd, a veteran of Gemini G.E.L. and the Tamarind Institute of Lithography, as well as Tamarind alumni Ernesto de Soto and Richard Newlin. Lloyd in

4. *The many distractions from my paper passion stem from, in no small part, the work we produce at Magnolia Editons, an art projects studio. Alongside papermaking, we have facilities for intaglio, woodcut, UV-cured acrylic printing, sewing, and ceramics; other tools include an automated laser cutter, 3-D printer, and an automated pigment grinder. In this ever-distracting environment we produce editioned and public art, such as a pair of ceramic tile murals by Chuck Close which just opened to the public in the 2nd Ave. Subway line in New York. Other fun distractions include mixed-media and intaglio prints with Enrique Chagoya, Guy Diehl, and Mildred Howard; woodcuts with Mel Ramos and Don Ed Hardy; and UV-cured printing/painting hybrids with Deborah Oropallo. We use a Jacquard weave file creation process developed in-house to make tapestries with Chuck Close, Kiki Smith, Squeak Carnwath, William Wiley, April Gornik, Bruce Conner and many others. David Kimball retired from the paper studio in 2012, leaving me room to re-model and focus on 16th century paper.*

5. *Marcy Klepp later became a model and dated our classmate, artist David Ireland.*

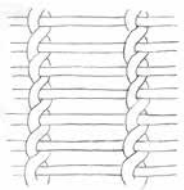
6. *This moment proved to be a turning point for Lloyd as well; he subsequently became a luthier, building guitars for the likes of Ry Cooder, and went on to invent the wildly successful L.R. Baggs series of acoustic guitar pickups.*

particular became an invaluable mentor, whose uncanny sixth sense in the studio left a lasting impression. To this day, I strive to emulate his seemingly supernatural ability to understand how materials will behave and to ascertain the precise moment when each step of a given process had reached its apex. Lloyd seemed able to peer into the future in order to evaluate the potential outcome of a given set of criteria; e.g., staving off a "fill-in", "floaters", or "dry-roll" in litho printing.[7]

As I worked my way up to printing at Editions Press, I established Farnsworth & Company Papermakers, where I had the good fortune to make paper for various titans of the contemporary art world including Claes Oldenburg, John Cage, and Chris Burden.[8] I acquired moulds, including two lovely antique laid paper[9] moulds used by the Hayle Mill, built in England by E. Amies and Sons, with elegant "F" watermarks; the F was for industrialist Henry Clay Frick, but conveniently stood for my surname as well. I purchased a laboratory Hollander beater built in 1906 by the American firm Noble and Wood. The president of the Simpson Paper Mill provided me a handsome roll of woven and needled wool felts from their Fourdrinier paper machine. I built wooden vats waterproofed with fiberglass and cobbled together a makeshift hydraulic press; the couching table I built was nicely constructed, though sadly I had oriented its curve backwards.[10] I purchased a spinning blade cloth cutter,[11] a 300-lb bale of pure cotton rag half-stuff (only to find out later that it contained optical brighteners), and another of cotton linter. For chemical additives, I used an internal sizing called Aquapel, pigments, cationic and anionic retention aids, and carboxymethyl cellulose for special occasions.

7. *Cheating the impending disasters that always lay in wait when printing from a stone, Lloyd would, without warning, call for a "wet-wash," a "sponge gum," a "tight gum," or a blotting and "snap roll" followed by all of the above. These common stone-litho terms are processes designed to keep the hydrophilic non-image area and oloephilic image area in the ideal state of equilibrium.*

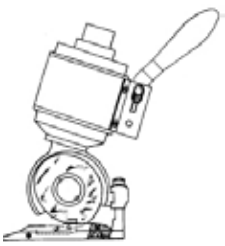
8. *Kathan Brown of Crown Point Press brought Claes Oldenburg to my first paper mill in an old West Oakland warehouse. Karel Appel and Sam Gilliam also came by and made pulp-on-pulp paintings, squeezing wet paper pulp through ketchup bottles onto freshly formed sheets. I was also the printer and papermaker for Bauhaus pioneer Herbert Bayer, published by Walter Maibaum of Editions Press.*



9. *The "laid" pattern is caused by the copper wire screen on which the paper is formed, leaving a shadow of chain and wire lines in the finished sheet. The paper moulds were purchased from Muir Dawson of Dawson Books; Lloyd Baggs was kind enough to transport the moulds from Los Angeles to San Francisco.*

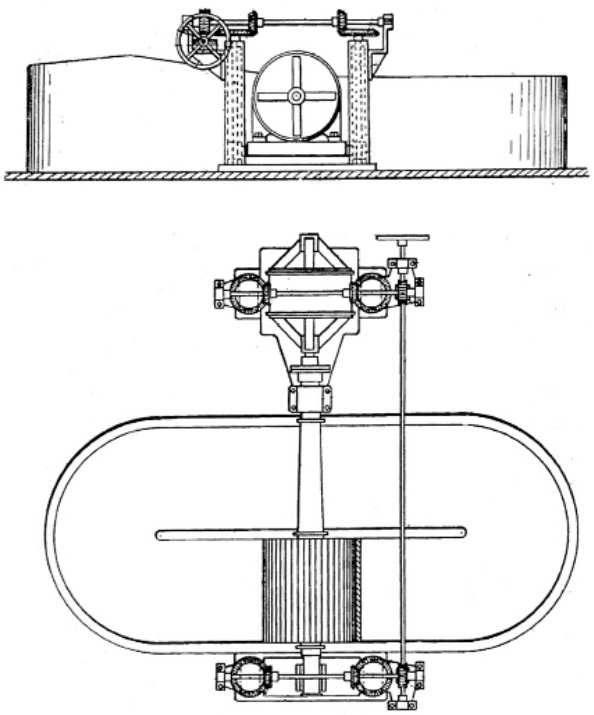
10. *As an SEAI exchange student at the Art Institute of Chicago for a semester, I payed a visit to Upper US Papermill, where Joe Wilfer set me straight by showing me the correct movement of couching: ribs perpendicular to the curve of the post or curved couching surface. I also stopped at Twin Rocker; I had tried to visit them years earlier in San Francisco, only to find all their paper equipment packed into a moving van bound for Indiana.*

11. *The cloth cutter, designed to cut patterns from a one-inch stack of fabrics.*

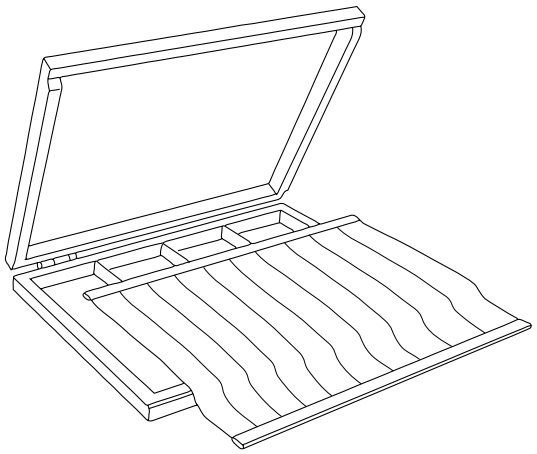


At the time, I believed I was essentially making traditional handmade paper, using methods approximating those of the 14th-17th centuries. Looking back, it seems clear that given the early 20th-century nature of my tools and techniques, I was actually under the spell of the Arts and Crafts movement. Obviously, beating engines such as the now-ubiquitous Hollander beater were not used in the Renaissance era; nor were mechanized pumps or most of the other refining equipment employed by William Morris and his contemporaries. Needled felts, too, did not yet exist in the 16th century. Though it is possible that Renaissance papermakers used blankets which were woven and then carded, needle felting was not invented until 1866,[12] and I have found little evidence suggesting the use of woven blankets in the 16th-century surface textures I have examined. Nor did the 16th-century papermaker utilize mechanized cloth cutters or hydraulic presses, and certainly no Renaissance vatman would have conceived of using internal sizing and pigment retention aids. Without realizing it, I had become part of the revival of the Arts and Crafts Movement – itself a revival.

12. *Needle felting, a process of poking batting into a woven blanket, was an industrial method intended to produce felt fabric without the use of soap and water.*



*Hollander beater*



*Su and keta*

In 1977 I was introduced to a different but equally rich tradition of papermaking when Tim Barrett[13] stopped at my paper studio in San Francisco on his way back from a Fulbright Fellowship in Japan. My paper studio at that time was on the fourth floor of the American Can Co. building (converted into artist's lofts) in San Francisco; my wife Era and I lived in the adjacent loft. Tim demonstrated washi, Japanese papermaking, forming and couching few sheets of kozo paper with the su, keta and pulp he had in his suitcase. Although it would take my own subsequent journeys to Japan[14] to fully grasp the intricacies of Japanese papermaking, I immediately recognized that there were many lessons to be learned from the masters of Japanese washi – many rightfully considered living national treasures. At a glance, some parallels were evident between Eastern and Western Renaissance papermaking: for example, both cultures use bast fiber[15] and gently processed stock. Once the pulp is made, however, the differences in technique become obvious. Because kozo, mitsumata and gampi[16] are not processed long, we might expect the Japanese pulp to drain quickly; however, the Japanese add a mucilage (neri) called

13. *Paper expert Tim Barrett is a professor at the University of Iowa School of Library and Information Science, where he also served as director of the school's Center for the Book.*

14. *A homestay in Toyoma, Japan with Yoshida-san and family in 1984, and two papermaking stays at the Awagami Paper Factory, one in 2014 and the other in 2016, where the kind and talented Fujimori family acquiesced to my desires and allowed me to work on the factory floor in the handmade paper building alongside their master papermakers.*

15. *Bast fiber is the fibrous material from the phloem (living tissue of a plant) – the inner bark "skin" fibers that surround the stem. Bast fibers are soft with nodes for flexibility. Cotton is not a bast fiber but rather a seed hair fiber with little hemicellulose and no nodes.*

16. *Kozo, mitsumata and gampi are the three main paper species whose inner bark fibers are used in Japanese papermaking. Hemp, mulberry, bamboo and straw are used to make washi.*

17. *Tororo-aoi (neri) is derived from the Abelmoschus manihot root, a flowering plant in the mallow family Malvaceae; it acts as a formation aid, but does not size the paper.*

tororo-aoi[17] to the vat to slow drainage and to keep the long mulberry fibers from tangling. Their bamboo screen is not attached to the mould and Japanese papermakers use no felt, electing instead to slowly and carefully press paper against paper, then separating and deftly brushing the damp paper onto flat boards to dry. The finished product is unexpectedly strong considering that, unlike the West, their paper is not sized with skin glue and rarely with starch. Unsized, water-loving paper is called waterleaf. This Asian mulberry paper (sometimes misrepresented as "rice paper") is beautiful, fortified with the natural hemicellulose[18] found in bast fiber, and well-suited for brush painting and mokuhanga (water-based woodcuts) -- in short, perfect for their cultural paradigm.

18. *Hemicellulose is embedded in the cell walls of plants and consists of polysaccharides, like cellulose, but arranged in shorter, branched chains. As water is removed during sheet formation, pressing and drying, the pulp's fibers "zipper" together due to hydrogen bonding between hydroxyl groups (oxygen and hydrogen atoms) in the cellulose and hemicellulose. The electrostatic interaction of polar water molecules with hydroxyl groups of contiguous fibers is the key to understanding why paper is paper and not just tangled fibers (i.e., felt). The hydroxyl groups in hemicellulose contribute to the strength and continuity of the paper's fiber network, creating a stronger, crisper sheet without additional beating. For more details, see "Contribution of Hydrogen Bonds to Paper Strength Properties" by Przybysz et al., 2016.*

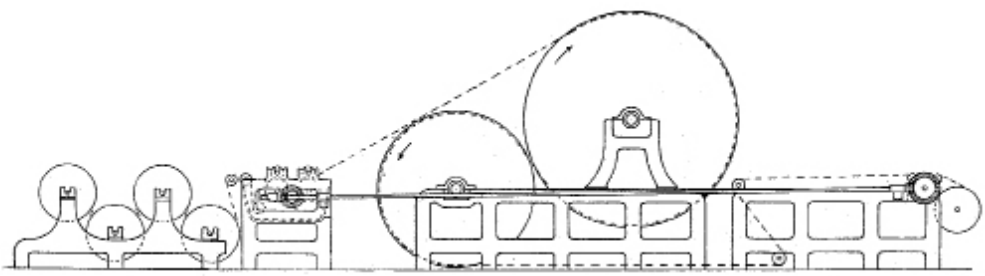
In fact, the realm of traditional Japanese washi offers us the opportunity to make a truly 16th-century paper, albeit in a wholly Japanese style. Before the second world war, the Japanese had tens of thousands of mills that never stopped making the paper of their ancestors, adhering closely to time-honored techniques and materials; hundreds of these mills remain today. This unbroken continuum from past to present in Japanese papermaking stands in stark contrast to the West. Our production marches along to the din of machines, driven in large part

by the Machine Age's demand for countless reams and endless rolls of paper. The enormous volume of production made possible by the Industrial Revolution proved unstoppable and irresistible to the West, creating a dragnet that left no surviving purely stamper mill-based 16th-century technique in its wake. The handful of Western mills that did survive produced handmade paper for niche markets; in order to remain competitive, they adopted Hollander beaters, woven felts, steam-heated mechanical drum dryers, conveyer-belt sizing troughs and other processes which have in turn fundamentally changed the nature of the paper. This is not to say that their papers are not exquisite -- most are exceptionally beautiful; but given their means of production, they could not possibly satisfy my search for the unique textures and characteristics that drew me to 16th-century papers.

A few years after Barrett's visit, I had the opportunity to visit two British Arts and Crafts-era paper mills. While teaching papermaking at the California College of the Arts – at the time, ironically enough, called California College of Arts and Crafts – my fellow instructor Bella Feldman introduced me to a program that sought to use papermaking to aid the struggling economy of Makonde carvers in Tanzania.[19] I soon found myself on a plane to Dar es Salaam, where I designed and built a small handmade paper mill with the aid of my wife Era. En route, I took advantage of the opportunity to stop in England, where I visited Wookey Hole in Bath and J Barcham Green Ltd (formerly Hayle Mill) in Kent.[20] The latter provided me with valuable firsthand experience forming a sheet of paper in a true Arts and Crafts-style, first-generation paper revival mill. Looking back, their monumentally-scaled industrial equipment should have struck

19. *Located in SIDO (Small Industries Development Organization), Nyumba ya Sana (House of Art) sought to enable Makonde carvers to transfer their wood-carving technique to woodcuts, allowing them to conserve their ebony, a precious natural resource, and to sell prints instead. The carvers needed quality paper to print on, as the only paper available was imported Xerox paper. We built our own paper molds by hand using copper wire and local hardwood, hand-forming sheets made with cotton scraps.*

20. *That same year, I received an NEA grant to document open-air paper mills in Nepal; on my return from Africa, I also stopped in France to visit Moulin Richard de Bas and Moulin du Verger.*



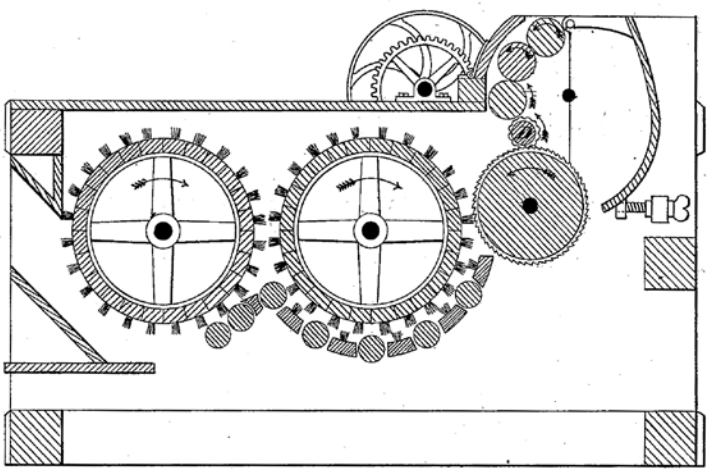
*Industrial Revolution-era sizing machine, similar to those adopted for use in Arts and Crafts movement paper mills*

*Washing away the perfidious influence of the Arts & Crafts movement*

me as odd – or at least antithetical to my original goal of making 16th-century paper. Instead, I was awestruck and impressed; they were making beautiful, cotton-content paper, formed by hand – albeit in an Industrial Revolution-style, mechanized factory setting.

It is difficult to reconcile William Morris's rejection of mechanized equipment and his advocacy for hand-craftsmanship with the papermaking methods he actually championed. Morris's papermakers used giant Hollander beaters, automated sizing machines, woven felts and steam-heated paper dryers. The only part of the papermaking process actually done by hand was the forming, couching, and separating of the sheet. Increasingly, Morris's definition of 'handmade' paper seems conveniently tailored to his particular production needs: to wit, letterpress and wallpaper. The Arts and Crafts Movement can also be held responsible for the 19th-century ascension of cotton as the main fiber in Western papermaking. Until the Industrial Revolution, paper was made from linen and hemp, whereas Arts and Crafts papermakers often substituted (or blended in) cotton rag. Made affordable by the American slave trade and the cotton gin, cotton lacks the critical bonding capacity of the hemicellulose found in linen and flax; although cotton papers may demonstrate a similar permanence, they possess inferior tensile and tear strength. In the end, despite its soft and porous nature, cotton nevertheless came to define fine art papers.

*Cotton*



*Cotton Gin*

In the mid 1980s, my colleague and artist friend Joseph Goldyne, an Old Master graphic expert and collector, had in his possession numerous blank sheets of antique papers acquired over time from various sources. Joseph graciously donated a few of these sheets for a drypoint I had scratched into copper as a demonstration for a printmaking class I was teaching at the UC Berkeley Art Department. The paper took the impression very well, especially after Joseph had my plate wiped and printed by expert intaglio printer Kay Bradner. Would that I could make such a paper, I thought to myself.

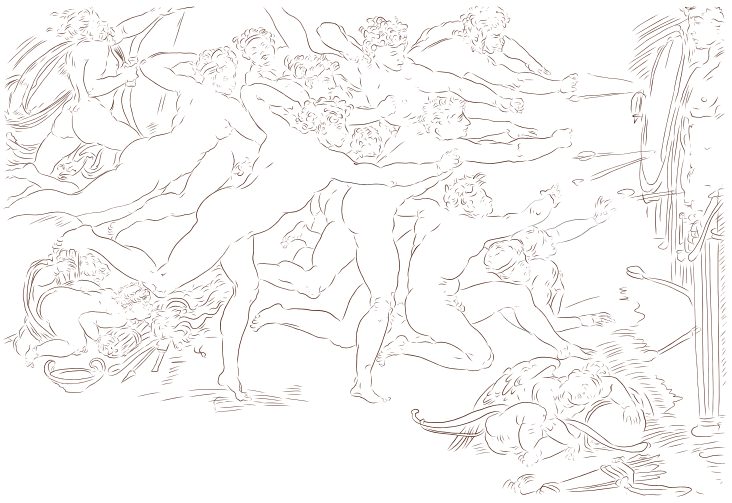
I gifted the Rembrandt still life print I had pulled at Berkeley to my friend Robert Johnson, the curator of the Achenbach Collection, during a class tour to that museum's study room. This gift was something of a private joke: as Robert knew that my history of hitchhiking and cycling in Europe as a youth included an episode when I had accompanied Old Master graphic dealer David Tunick (Robert's former employer) on his first buying trip, it was almost plausible to think I had unwittingly purchased a rare, three-million-dollar Rembrandt print as a teenager. I signed *Rembrandt van Farnsworth* on the back in ball-point pen to prevent it from being passed off as a forgery; Robert framed the print in a Dutch Master frame and displayed it at his home, where it proceeded to fool many a good curator.
In hindsight, I played the fool as well: even with sheets of authentic

*Drypoint of Rembrandt's shell by Donald Farnsworth,* 1988

16th-century paper in hand, I had missed something subtle but tremendously important. True, I was drawn to the crisp rattle of these papers, and the great strength and flexibility belied by their thinness. However, dear reader, I am loath to admit that I was not yet in the habit of illuminating antique papers with a low-angle raking light, which would have allowed a more thorough consideration of the fibrous textures embedded in their surface. My only excuse is that cell phones equipped with bright LED lights did not yet exist: what handy things they are. In any case, the unique qualities of these sheets haunted me for years; how could I produce more of this marvelous paper, I wondered, and in a larger format?

The illuminating potential of raking light finally revealed itself in 1987, during an exhibition of drawings from the Royal Collection Trust at San Francisco's Legion of Honor Museum. Curator Robert Johnson invited a lucky selection of guests to view the show one night after the Museum had closed, giving us an extended and very private viewing.[21] Our group wandered the French Neoclassical galleries and soon dispersed as each member lingered in front of an Old Master favorite: a Durer here, a Raphael there. I repeatedly found myself returning to Michelangelo's magnificent presentation drawing *Archers Shooting at a Herm*. This work possessed an extraordinary texture and a degree of detail I would never have thought was possible

21. *Era and I practically had the museum to ourselves that night; the only others in attendance besides Robert Johnson were Wayne and Betty Jean Thiebaud and Joseph and Debbie Goldyne.*

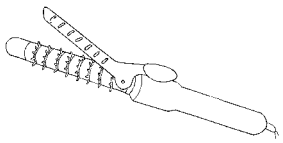


*Archers Shooting at an Herm (vector sketch for testing our papers and chalk)*

to achieve with chalk; I imagined an assistant continually sharpening chalk as the maestro deftly made his marks. The lighting on the piece was slightly more raking than other works and as my eyes searched its surface, something struck me like the song of a mythical harpy. It dawned on me that although I had intended to make 16th-century laid paper, I had actually been producing something else entirely. In *Archers Shooting at a Herm*, I discovered one of the key elements lacking in my attempts to date: surface texture. The paper's texture was brilliant, intricate, and complex; an endless entanglement of fibers from the papermakers' felts had left their impressions on the surface of the sheet selected by Michelangelo for his chalk to dance upon.

As the weeks went by, however, my memory of this paper began playing tricks on me.[22] When I pictured in my mind the paper that had so enlivened and complemented Michelangelo's chalk strokes in *Archers Shooting at a Herm*, its hairy felt marks grew deeper and stronger, longer and curlier. Months turned to years and from time to time I made attempts at recreating the paper as imagined in my distorted memory. Soon after viewing Michelangelo's *Archers*, I tried sprinkling thick horse hair and boar bristle onto my felt to achieve the deep, long, curly hair marks I thought I had seen. This only resulted in paper covered with loose horse and pig hairs, which had to be rubbed and picked off the dry sheet. Decades later in 2014 and 2015, assisted by Heather Peters, we began actually carding and felting. Using a combination of heritage wool, donkey forelock hair, and goat hair, we poured soapy hot water on layers of freshly batted fleece, then repeatedly rolled it with (of all things) bubble wrap. We permed horse tail

22. *The first principle is that you must not fool yourself and you are the easiest person to fool.*
*-Richard Feynman*



hair with a hot curling iron and acrid chemicals to achieve more curl and even experimented with looped nylon filament, but seemed to be getting nowhere fast (and by fast I mean quite slowly). In the throes of a misguided vision of imagined paper texture, I had convinced myself that the felt fleece necessary to make 16th-century paper had been lost to modernity. After all, the heritage wool we acquired was very fine and silky; at the time, I had no idea that not all fleece from a given sheep is created equal. My that my attempts, interesting as they might be, were coarse and crude; I had failed to achieve the rich, subtle texture put to good effect by Renaissance masters.

My wife Era wisely suggested that I re-familiarize myself with the particular character of Old Master papers and in 2016, she designed and scheduled a trip for us to numerous relevant study rooms and museums in New York, London, Windsor, Oxford, and Italy. It was on this trip that our good friend Elizabeth Wholey, an American expatriate, chef, author and truffle specialist living in Umbria, introduced us to Gianni Berna, an Italian alpaca shepherd and an advocate for regional wool and alpaca handcrafts.[23] At our first meeting in Umbertide, I expressed my concern to Gianni that 16th century fleece had disappeared, and with it, the possibility of producing 16th century-style paper. Due to the cross-breeding of sheep over the last 500 years, I suggested, the coarse fleece of the ancient breeds must have long since vanished. After all, when was the last time we saw scratchy wool scarves offered for sale? Wool seemed to have gotten softer, even in my own lifetime. In response, Gianni produced a greasy fleece[24] which he often uses for talks, wool conferences, and basic education. In this fleece

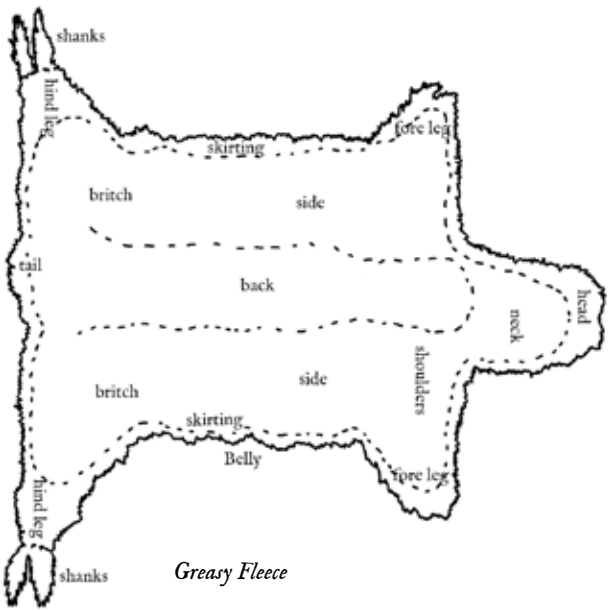
*23. Gianni's house, office and herd of alpaca were situated on a beautiful hill across the road from Elizabeth's converted tobacco barn.*

24. *"Greasy fleece" refers to freshly sheared, raw material. "Washed fleece" has been de-greased and cleaned; "carded fleece" has been washed and carded.*

-- the product of shearing an entire sheep continuously from head to toe (hoof) -- one could compare the variety of textures corresponding to various parts of the sheep. I observed that the leg (shank) hairs were far thicker in diameter and coarser than fleece from other parts of the pelt. "Is this too fine?" Gianni asked me. Actually, the leg hairs looked rather coarse -- perfect for my designs.

Knowing that thrifty papermakers often rented and converted wool stampers from wool producers, I wonder if early papermakers might also have asked their wool-producing landlords to make felts for them as cheaply as possible. To further minimize the cost of making the hundreds of felts necessary for a mill, perhaps they might also have requested that the coarse, less costly fleece from the pelts be used. An alternate theory of mine is that the paper I am attempting to recreate -- the coarse-textured paper I so often found employed by Renaissance artists -- may have been caused by generations of papermakers using worn-out, passed-down felts. Since felt was traditionally made by using higher quality, more finely textured wool for the outer layers and coarser, cheaper wool in the felt's interior, perhaps the heavily used felts of a 16th-century paper mill had lost fibers through heavy use, thereby exposing the coarser interior wool which would uninten-

*Fulling wool stampers*




*Greasy Fleece*

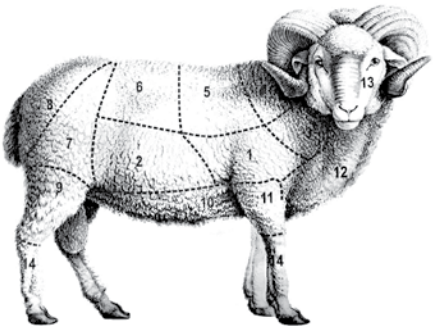
tionally yield papers well suited for chalk drawing. Either way, I could sense that I was getting closer to the desired complexity of Michelangelo's paper texture.

*DNA*

I asked Gianni if there might still be breeds today whose DNA remains unchanged since the Enlightenment, and he placed a genial phone call to his friend, the sheep geneticist Professor Carlo Renieri, a member of several wonderfully-named International Societies including Anthropozoologica (French) and the Committee on Genetic Nomenclature of Sheep and Goats (COGNOSAG). Carlo's answer was an emphatic yes: the Fabrianesi and Apenninica breeds both possess DNA which has not changed for half a millennium. Excited, I mused that I would need test felts to proceed; as luck would have it, a good friend of Gianni's named Cristina Biccheri was the daughter of a shepherd and a felt maker herself, living only 20 minutes from where we were staying.

Our impromptu felt consortium took place at Gianni's converted barn office, where curious llamas walked the grounds like personal pets. We expressed our desire to Cristina for coarse wool[25] from the specified breeds. She said it could be done and that she would demonstrate the making of a small sample the next evening at her heritage house in Cittá Di Castello. The investigation was in high gear: on only the first week of our trip, Era and I were already witnessing the production of felts from sheep with pure 16th-century DNA. That evening, we watched as Cristina slowly poured hot water and soap over carded, 500-annum DNA wool which was carefully placed, rolled, combined with more batting, and subjected to numerous baths of hot water and

*25. Coarser wool can be founad on the shank, breast, underbelly, and face.*




*Higher numbers = coarser fleece.*

yet more rolling. In English I begged that she use only the coarser fleece. With Elizabeth and Gianni acting as translators, Cristina explained that the coarser leg hairs pose a difficulty. While the finer fleece has cuticles[26] that open upon contact with the hot water, inducing the catching and tangling we associate with felt, the leg hair and other coarser hairs do not have as many cuticles. She feared that the coarse hair would fall out onto the paper. My prior experiences with pig hair and horse hair substantiated her concerns, and we agreed that she would use finer hair in the center of the felt and coarser wool on the surface. We postulated that, with luck, the fine fleece would entangle and hold the coarser hairs. With Cristina's samples (and the 24 x 34 inch samples she sent later), I was finally able to begin my tests using an authentic 500-year-old DNA texture.

*26. The outside of the wool fiber has a protective layer of scales called cuticle cells, which overlap like tiles on a roof. Felts are made when fibers are aligned in opposite directions and become entangled.*

*Cuticles found in different breeds of sheep; coarser on right.*

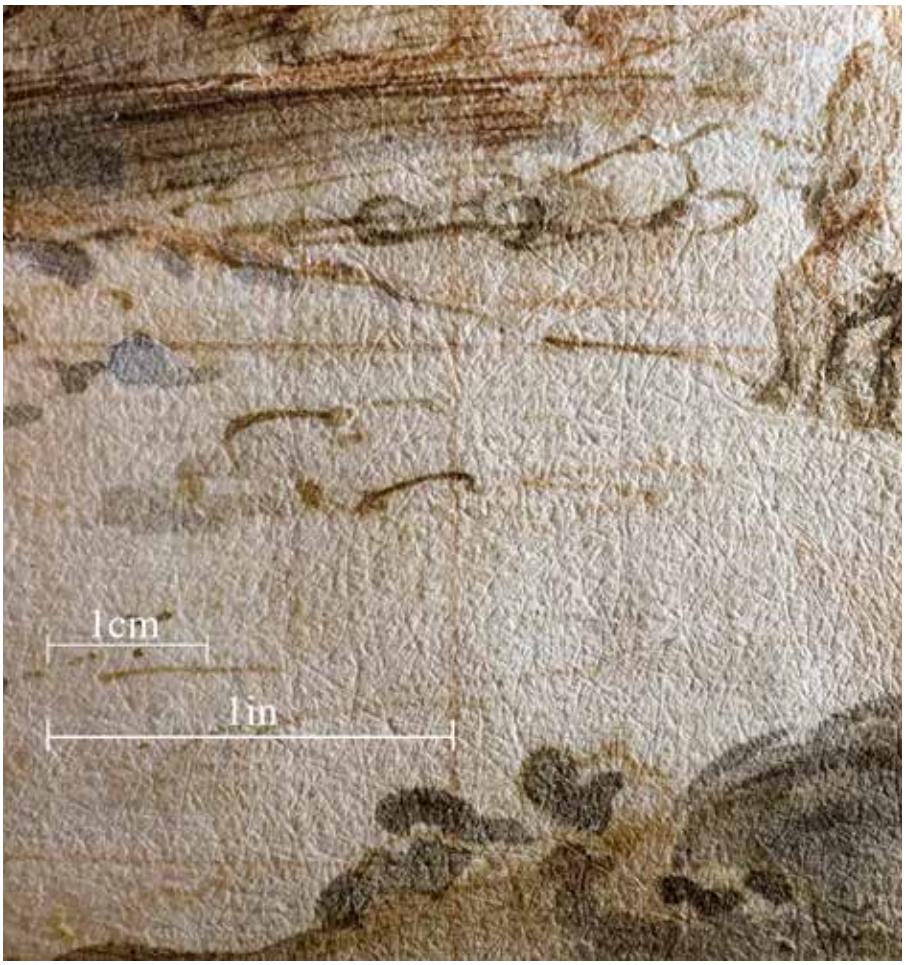
At each location on our itinerary, Era and I were met with an exceptional generosity of time and knowledge. From California[27] to New York, England and Italy, every felt maker, wool producer, museum director, conservator, curator and archivist to whom we explained our mission accommodated us with grace and generosity. The director of the Fabriano Paper and Watermark Museum[28] gave us a private tour, flipping major electrical circuits to turn off the backlights which had illuminated multitudes of watermarks so that Era and I could shine raking light across the papers, bringing out every detail of their surface texture. Print and drawing study departments from the Met in New York and the Ashmolean in Oxford to the V&A in London and the Royal Collection Trust in Windsor all graciously allowed Era to shine a low-angle raking light upon drawings by Tiepolo, Leonardo da Vin-

*27. At the California Legion of Honor, paper conservators Victoria Binder and Debra Evans searched their archives to find 16th-c. Italian works for me to study while I was still experimenting with pig and horse hair.*

*28. Giorgio Pelligrini of the Museo della Carta e della Filigrana.*

ci, Michelangelo and many other masters. We were allowed to illuminate both front and back, revealing not only watermarks and screen patterns, but also imperfections of formation and pieces of rag knotted or partially processed. Multiple light angles and a 42-megapixel camera allowed us to capture in high resolution the surface texture records left to us by the hard-working artisans of antiquity.

This ink wash by Pier Francesco Mola, photographed under raking light by Era and myself at the Victoria & Albert Museum study room, retains the impression of even more felt marks than the carefully selected sheets of Michaelangelo. Personally, I am completely smitten with this texture:




*Pier Francesco Mola: Adonis Departing for the Chase, ca. 1625-1666. Victoria & Albert Museum*

The paper selected by Cristoforo Roncalli for this red chalk drawing uses its texture to good advantage. The process of its making is evident in the detail view, showing both the felt hairs and the visible chain and wire lines left by the paper mould's laid screen:

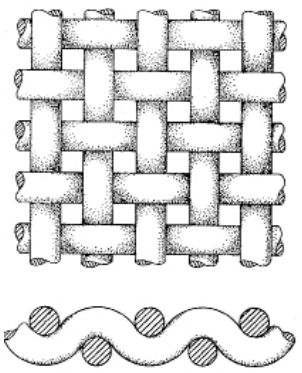
*Cristoforo Roncalli, called Il Pomarancio: Half-Length Study of a Youth with a Raised Left Arm, c. 1609. Victoria & Albert Museum. Below: detail view of laid lines and felt texture*

Bolstering my conviction that Renaissance artists were highly experimental by nature,[29] Leonardo's *Study of an Old Bearded Man in Profile* (documented at the Royal Collection Trust in Windsor) shows just how far out and creative the maestro could be. The paper is possibly a mere wrapping paper, made from the sweepings from the mill floor; here a large recycled scrap has become the old man's eyelid, while embedded shards of underbeaten cloth make for a wild sheet.

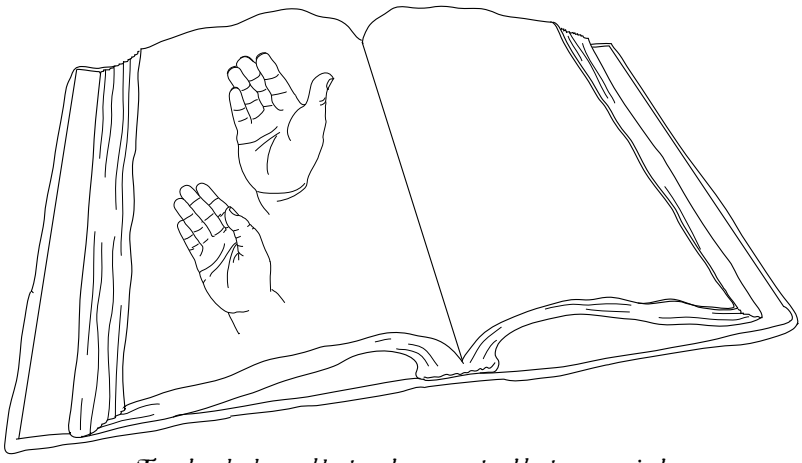
*29. The majority of the contemporary artists I have worked and collaborated with at Magnolia over the years have shown similar experimental predilections.*

*Left: Leonardo da Vinci: Study of an Old Bearded Man in Profile, c. 1513. Royal Collection Trust, Windsor. Above: detail with backlight*

The dozens of paper surfaces that Era and I documented were surprisingly diverse; one texture we almost never came across – so common in today's papers – was the regular bump of a woven felt leaving the imprint of its warp and weft intersections ("knuckles") on the paper. Woven blankets may have been used in some mills, but the term "felt" refers to an entangled structure – not usually a woven structure – and as noted above, needled felts did not exist in the 16th century. When purchasing felts for today's handmade or machine-made papermaker, we automatically think of needled fabric felt: a product perfectly suited for papermaking, maybe – but not for 16th-century-style papermaking.



*Knuckles*



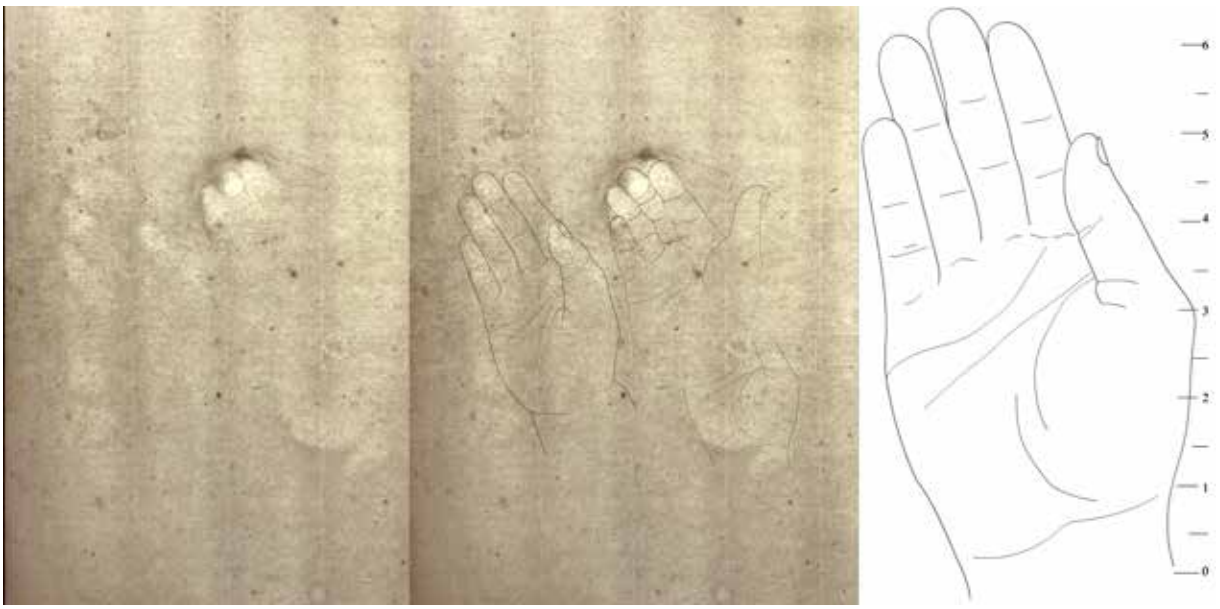
*Two-hundred-page blank 17th century sketchbook; 11 x 17 inches.*

*Tim Bryar*

*Angus and myself*

While in London, we paid a visit to our longtime friend Angus O'Neill at Bryars & Bryars, an antiquarian book shop on Cecil Court. There, surrounded by historical books, maps and prints, we described our quest in detail to Angus and Tim Bryars while enjoying the very drinkable white wine offered by our hosts. Even before the first bottle, Tim produced from the shop's basement various leaves from books he saves for study and conservation. We inspected the leaves under raking light, looking for evidence of coarse felt. Halfway through the second bottle I was regaling my audience of three with the possible scenarios behind each paper object held to the light, describing the beating, the sheet forming, the mould flaws, and the couching imperfections due to speed; I pointed out the horse hair rope marks and evidence of loft drying (referred to as the "back" of the sheets), describing the general mayhem of high production handmade paper -- a story frozen in time within any given sheet. Towards the end of the second bottle, Tim was feeling kindly towards Era and myself and produced a 17th-century blank sketchbook; he could not bring himself to put it up for auction,

for fear some forger might use it for nefarious purposes. We purchased (and were gifted) many items including this blank sketchbook. Months later, inspecting each sheet and imagining the inferences each imperfection suggested, I found a few sheets indicating that the coucher had started each post flat instead of using a curved couching surface. When couching flat, the first few sheets of the post often trap air bubbles. In one particular sheet, the coucher's assistant seemed to have attempted to flatten the air pockets with the fingers of his right hand. Comparing the scale marks left to my hand, even after reducing my hand by 10% to account for shrinkage, it seems child labor was most certainly used at this mill. Here again, the paper's surface and density bears faithful witness to the realities of human history -- even those troubling aspects we may wish to forget.



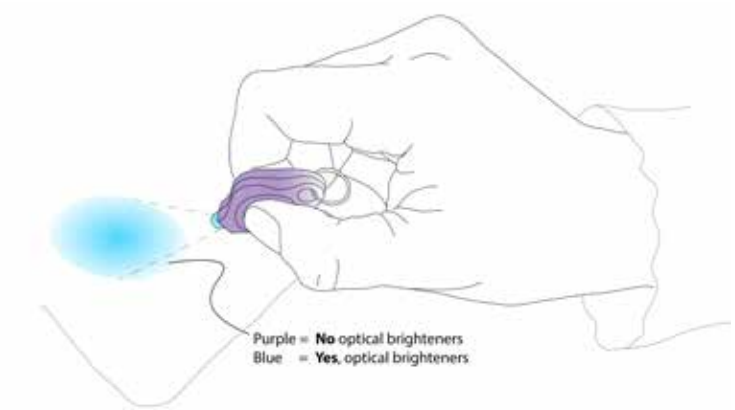
*Marks in page of 17th c sketchbook (left) compared to child's hands (center) and my hand (right)*

Returning to my paper studio at Magnolia Editions in Oakland, California, I began the (seemingly) simple task of forming small linen[30] and hemp sheets on an antique laid paper mould, couching and pressing between Cristina's felts and achieving my perfect test sheets. This, I reasoned, would prove my point; from there, I could simply order larger felts and move up in scale. Unfortunately, I was soon confronted with the diverse problems and variables faced by the 21st-century papermaker.

30. *Linen is a textile made from the fibers of the flax plant. Flax is a bast fiber one to six inches in length and 12-16 microns in diameter. Words derived from linen: line, lining, lingerie, linseed oil and linoleum.*

First, while I was pleased to find numerous suppliers of linen rags via eBay, I was dismayed to discover that they all contained 20th-century optical brighteners[31] -- permanently attached to the fibers and impossible to remove. Shine a UV light on the papers I made with these rags and they appear bright blue, demonstrating the fluorescent behavior of the brighteners' harmful chemical compounds. Eventually, I was able to locate environmentally conscious companies on the West Coast that make products using natural linen and hemp without optical brighteners. The scraps left over from cutting out their patterns have been a key ingredient, allowing me to approximate the use of Old World raw material.

31. *Optical brightening agents (OBA) are chemical compounds that absorb light in the ultraviolet and violet region of the electromagnetic spectrum (invisible to the human eye), and re-emit light in the blue region (visible to the human eye) by fluorescence.*

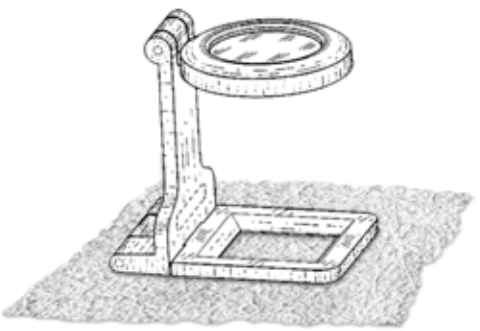


Next, my paper only showed the impression of the coarsest fibers of the felts. Where was all the subtle detail I had anticipated? My paper's textures were detailed not by the fibrous elegance I had seen in the study rooms, but rather a pebbly landscape of cold press (i.e., air-dried paper) micro bumps – beautiful, yes, but nothing like that magnificent texture seen in works of the 16th century masters. Again I wondered where I had gone wrong: should I forego the Hollander beater and build a stamper mill?[32] Was it the processing of the rags? The pressing? The drying? The felts? Or all of the above? I made hundreds of tests, allowing some of the papers to dry on the felts to ensure the texture transferred; it did not – at least, not in the manner I craved. I tried hot-pressing newly pressed sheets between the Fabrianesi felts until dry, but the surface texture was still wrong. Many formulations of pulp and many tests later, my paper was still lacking in subtle fiber-impression detail.

*32. We did eventually make a modern-style pneumatic earth stamper/compactor fitted with stainless steel stamping heads. With the trough still under construction, we have yet to evaluate its ability to make pulp.*

As the winter of 2016 approached, I expanded my focus to include assembling the necessary equipment to accurately test and process the paper. The goal of making 32 x 42 inch[33] 16th-century style paper for artists (including Era and myself) necessitated extensive remodeling, additions, and modifications at my Oakland studio. David Reina of Carriage House Paper in Brooklyn spent six months building me a beautiful large format 50-ton hydraulic press, which arrived just in time for large scale tests in late December. A cycle beater – a Hollander beater with an auger for beating pulp with denser stock, possibly simulating stamping – had to be installed. I found a used Canadian Standard Freeness tester, which I used to measure the hydration

*33. The large 32 x 42 inch antique paid papermould I built with the late woodworking master Miles Karpalo in the 1980s is still in excellent condition and may yet make the paper it was designed to create. Miles also made sets of 22 x 32 and 20 x 28 inch moulds. The latter, made so many years ago, was finally finished in 2017 when Arlene Kim Suda, using fine copper wire, laboriously sewed the laid screen to the 28 ribs, stitching every half-inch.*



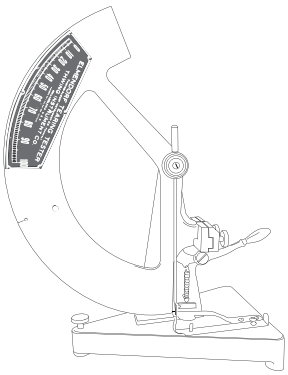
and fibrillation[34] of my paper stock prior to sheet formation. A new 8 x 10 inch antique laid paper mould for making small test sheets was made for me by Britt Quinlan. I sourced sizing tubs and a calibrated hot plate, as well as a tear strength tester to augment my trusty M.I.T. Folding Endurance Tester. I collected Avery Standard Paper Testing Waxes for testing surface strength and asked a woodworker colleague directly across Magnolia Street to fabricate handheld hardwood burnishers.

On and on the project grew; with daily testing, various new ideas were tried and discarded. One outstanding aspect of *Archers Shooting at a Herm* is the impressive detail achieved by the maestro using only chalk; while in Italy, Era and I searched art supply stores for the Italian and German chalk Michelangelo was said to have used. Returning to Magnolia, artist Guy Diehl, master printer Tallulah Terryll and I experimented with fabricating our own hard chalks in an effort to approximate Michelangelo's marks. Recreating the highlights with a modern-day gum eraser is possible; although using an eraser made of stale bread (as reportedly practiced in the Renaissance) was a failure, the highlights produced using fresh bread were almost believable.

Amid the chaos of my paper studio assembly and modification, Tim Barrett and I traveled to New York to deliver a talk to conservators at the Metropolitan Museum. Tim is a resourceful and deserving MacArthur fellow, to whom I can show new schemes and ideas and always receive a well-considered opinion. A video Tim showed me of him and his students at the the Book Arts Department at University of Iowa, attempting to recreate the pace of a 16th-century mill by

*Bread eraser*

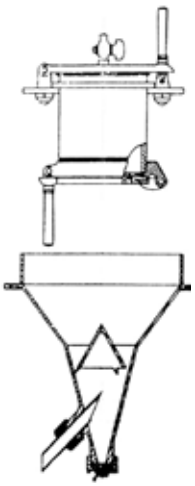
34. *Fibrillation is the fraying of the cellulose fibers during processing. Increased fibrillation results in more bonding potential between the fibers, making a stronger, harder and eventually a more translucent paper, as highly fibrillated pulp makes a sheet with fewer interstices, allowing light to pass through the translucent cellulose fibers. As water is removed during sheet formation, pressing and drying, the cellulose fibers "zipper" together due to hydrogen bonding between the hydrogen and oxygen in the structure of the cellulose polymer. The polar attraction of the two elements (electronegativity) is the key to understanding why paper is paper and not just tangled fibers (i.e., felt).*



*Tear strength tester*

making thousands of sheets in one day was more edifying than a hundred academic studies; in the actual doing, problems are solved and important details reveal themselves. Tim and his students succeeded in their high production goal in part by making a very "free"[35] cotton linter pulp: this freeness allowed them to form, drain and couch sheets in seconds. This was a major clue. Making a handful of large sheets per day, I had not concerned myself with quick drainage; I was more concerned with sheet clarity – that is, beating the linen rags until they were broken down to the point where there would be few if any knots in the furnish. After all, strongly influenced by the Arts and Crafts handmade paper revival, where paper could be force dried flat on large industrial drying machines, I had only a passing concern for dimensional stability; durability, acceptance of chalk and watercolor, and printability were my main concerns. Like the revivalists, I needed only a good-looking sheet that would easily accept the inks of fine art printers and the marks of an artists.

*35. The freeness of pulp measures the effectiveness of the refining process, i.e., the swelling of the pulp fibers as a result of beating. A freer pulp drains faster on the mould; more refinement causes more swelling, yielding a slower draining pulp.*



*Canadian Standard Freeness tester*

My linen pulp-making method up to this point had been to boil the linen and hemp in soda ash in the Japanese style, thereby removing lignen still present in the rag, and then to beat and "clear" the pulp until it was knot-free. Tim's video indicated that hydration was to be avoided: beating the pulp in such a manner might be fine for the revival movement and modern papermaking, but it would be anathema to the 16th-century papermaker. The hydration, a swelling of the tubular cellulose fibers caused by the constant pounding in the beating and processing stage, not only makes slow draining pulp, but caused shrinking during drying; as the paper pulled away from the felt, it

was losing all of its wonderful felt fleece detail. Additionally, longer beating times increase the paper's sensitivity to humidity, resulting in paper with a tendency to curl and change dimension. This lesson of less-is-better when processing pulp in the 16th-century style is echoed by the example of lightly hand-beaten Japanese papers, which are also very dimensionally stable and many of which reflect the highly detailed wooden surfaces on which they were dried.

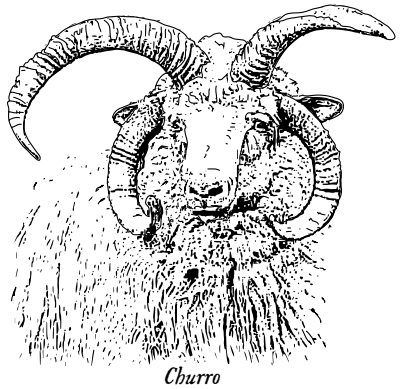
I happened to have a quantity of half-processed hemp and Spanish flax in my raw materials stash at the Magnolia paper studio. These partially processed wet-lap[36] sheets can be beaten quickly and broken down without over hydrating, producing a more dimensionally stable sheet. Trying this method and noting my freeness with the Canadian Standard Freeness tester, I found that I could make a nearly knot-free pulp in the 400ml freeness range, instead of the low hundreds of my previous tests. The lack of shrinkage was promising and a clear improvement, but I wondered how this freeness could ever be achieved with linen rags and hemp rope, which require hours of laborious beating to break the threads apart -- thereby producing more hydration, more shrinkage and lower freeness.

*36. "Wet-lap" or "half-stuff" is available as sheets, rolls, or bales, all generally dry; the name wet-lap comes from the Fourdrinier process of manufacture. Typically more refinement is necessary to make various grades of papers.*

As I considered the relation of freeness, beating and shrinkage, I was reminded of an occasion in 1974 when Bella Feldman asked me to beat some pulp to cast a paper piece – a life-sized young carp – in a latex rubber mold. Per the standard Arts + Crafts Movement procedure, I beat the rags in my Nobel and Wood beater for an hour so as to guarantee a nice, firm paper. Bella took the pulp and returned after a few days

to show me the unfortunate results: the youthful carp she had produced earlier as an example using other, freer pulps had been transformed by my pulp into an ancient, wrinkled fish. Not being free, my pulp had shrunk away from the mold as it dried; the million tiny facets in its surface made it appear to have aged by a hundred years. I proceeded to make a second batch of humble, "low-quality" pulp, only "clearing" (whipping, not beating in my Hollander beater) and adding methyl cellulose. Though at the time I turned up my nose at this pulp, I realize now that such a pulp, especially if a bast fiber is used, is more closely suited for making a Renaissance-style paper that faithfully retains the richly textured impressions of felt fibers: as it dries, a free pulp will not shrink away from the felt, which one might think of as a kind of mold.

In 2016, Janice Arnold, an artist and felt maker from Washington State, organized a felt exhibition at the Crafts Museum in San Francisco, for which she requested the loan of some paper, felt, and a 500-year-old manuscript page. Knowing far more than I do about sheep, wool and felt, she asked me during a visit to Magnolia Editions why I had not considered Churro fleece as a source. "Churro... fleece?" I asked, envisioning a deep-fried Mexican pastry covered in cinnamon and sugar. Janice kindly enlightened me: the Churro variety of sheep was introduced to the Navajo by Spanish conquistadors 500 years ago, and the Navajo have since kept the breed pure. There are fewer than 1,000 registered Churro sheep in the US and less than 5,000 globally. Moreover, the breed is known for its coarse fleece. Since the Italians originally received their papermaking techniques from the Spanish Iberian Peninsula, it is not farfetched to think that such a breed could have been

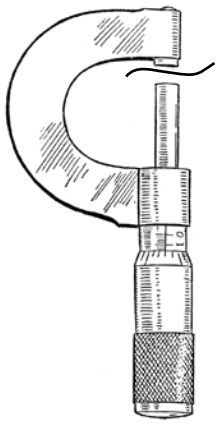


*Churro*

used in the earliest days of Italian papermaking; papermakers fleeing the Inquisition in Andalusia may even have brought Spanish felts when they established paper mills in Italy.

Searching the internet, I located a Churro felt maker in Taos, New Mexico named Minna White and wrote to her asking if she could make me a set of large, 3 x 4 ft. coarse Churro felts. She informed me that her Churro sheep produced a relatively fine wool, but she knew where she could procure some coarse Churro wool better suited for my desired felt. When I wondered how she could be so certain she could find such wool, Minna informed me that her friend and neighbor Connie Taylor is the official sheep registrar for the breed and a specialist in wool color and genetics. What serendipity!

The hairs of the coarse Churro felt she sent me measured 50 to 60 microns in diameter – similar to my estimations of the marks in Renaissance paper, and a far cry from the 11.5 to 24-micron diameter measurements found in fine wool garments. As I write this, spring has just arrived and shearing season has begun; high quality wool – or in my case, low quality wool – will soon be available. However, wool harvesting poses the same degree of unexpected complexity as any other venture in life. When I called Minna to inquire about shearing progress and the availability of new pelts, I learned that a shearing had taken place not far from her; however, she had elected not to purchase the wool due to flaws and circumstances such as scratching by the sheep, which indicated damaged wool and the possibility of lice. I also learned that the "greasy wool" Minna does purchase must first



*Caliper*

*Sheep shearing hand clippers*

be shipped to a wool washing company back east, and the washing process can take months: apparently there is a schedule and a waiting list. Luckily for me, the washing company owed Minna some favors and my turnaround was fast. The Churro breed felts I received from Minna were large, coarse and felted, not woven; paper couches nicely on these felts and they spring back easily from 50 tons of pressure.

With wool felts from both Spanish and Italian breeds assembled in the studio, I continued the process of retting, beating, forming, couching, pressing, drying, sizing, and curing, followed by close scrutiny under magnification and raking light. One morning, after beating Spanish flax and hemp half-stuff and charging the vat with the resulting free draining pulp, Magnolia master printers Tallulah Terryll, Nicholas Price, and I formed the usual small 8 x 10 inch test sheets and pressed them to 50 tons. Releasing the pressure, we removed some of the sheets from between the felts for air testing under conditions and placed the remainder back in the press. On a hunch, I brought the press up to pressure and left the "post" (alternating stack of felts and paper) pressing at 50 tons overnight.

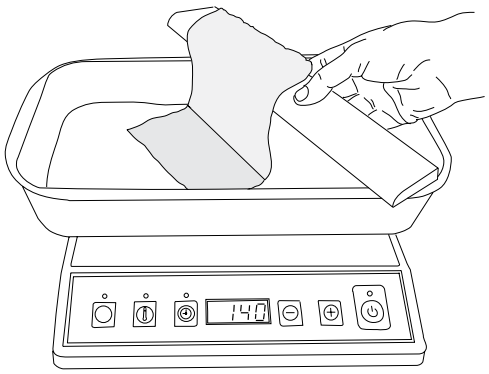
The following day I separated the damp sheets and stacked them, sheet upon sheet, for a gentle 100-lb. pressing, using just enough pressure that the sheets would dry gently stuck together in so-called 'spurs.' Once dry, the result of overnight pressing was marvelous, surpassing the quality of the quickly pressed sheets I had removed from the press as a baseline comparison. Fine and coarse fleeces both left their mark on the paper in splendid detail, cre-

ating the endless, heterogeneous surface pattern I had sought for decades. Though pleased at my success, I soon realized that this was only a small sheet; scaling would present new challenges.

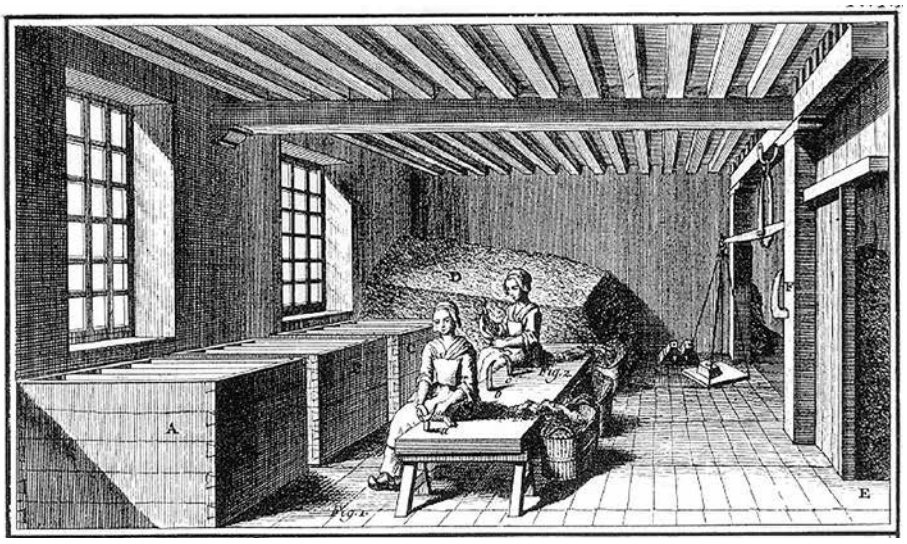
As my test sheets dry, I have sized them with hide glue (rabbit skin glue).[37] This is an important step in making the paper more hydrophobic, crisp, and rattly, while improving its receptiveness to water-based media like the ink of a quill pen or watercolor. Hide glue also adds tensile and folding endurance strength important to book publishers and contributes to the surface strength that is essential for chalk drawing.

*37. Not including the few baseline sheets, or those used in etching experiments.*

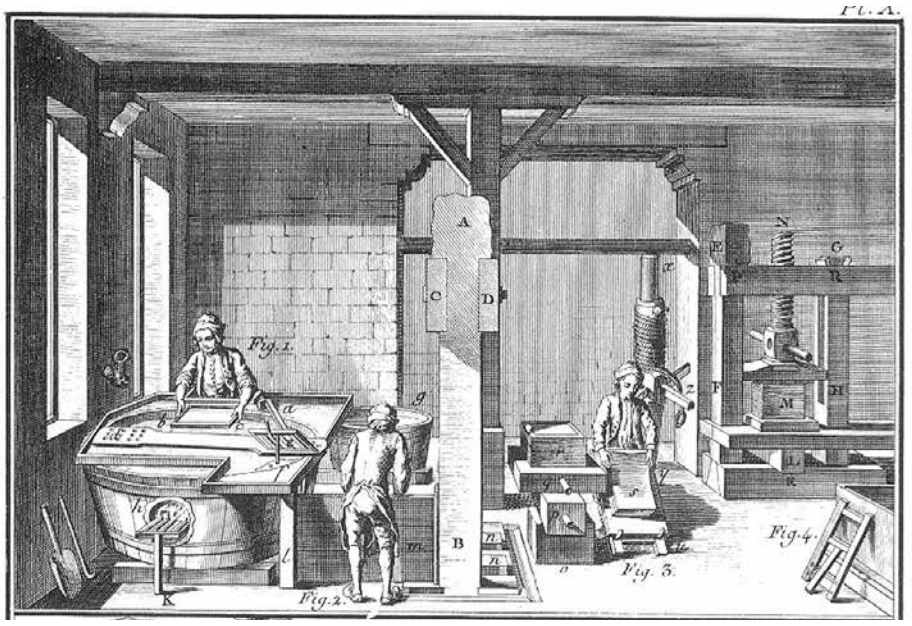
There are various recipes and methods for sizing paper. At my studio, an iron tub large enough to accomodate the sheet(s) is brought to a temperature of 140° to 150° and rabbit skin glue crystals at a concentration of between 3% and 5% are then added and stirred until dissolved. Alum is added at about 0.1% solids, making the hide glue harder and more hydrophobic. Higher concentrations of size increased these characteristics and so percentages are based on the intended use of the paper: etching, woodcut and letterpress seem more suited to lower concentrations, while painting, drawing and calligraphy call for high concentrations. After submersion of the waterleaf paper in the hot size, the sheets are drained and spread out to air dry on sheets of porous cloth. Sizing poses many opportunities to damage your carefully made sheet: poor handling can tear the sheet, while underdrainage can cause the size to puddle and form brown stains. Large 32 x 42 inch sheets become very heavy with size and lifting them out of the size tub while wet with size, even using a slice, can pull, distort and tear the sheet.




*Lifting paper from size tub using a slice*

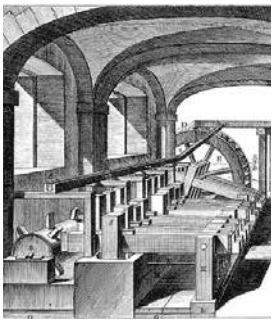



*Encyclopédie de Diderot: linen rag sorting and cutting*

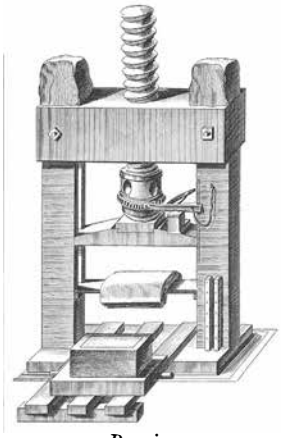



*Encyclopédie de Diderot: - left to right: sheet forming, couching, separating and pressing*

In navigating these challenges, one begins to realize the daunting number of variables at play. The successful realization of a thin, flexible 16th-century-style sheet, with its satisfying rattle and subtle but unforgettable surface texture, depends upon a host of critical factors: from fiber selection, sizing and equipment to the multitude of choices made from moment to moment in the process of making paper. Rather than overwhelming the reader by detailing the minutiae of every aspect, the following list may help us wrap our heads around the key variables involved in the task at hand:



*Stampers*



*Pressing*

1. The fiber type and quality of rags (new or used).
2. Retting, including the duration, bacterium, temperature, moisture, and pH.
3. Techniques used in the cutting, tearing or shredding of the rags.
4. The time, pressure and chemicals used in the boiling and removal of lignin, as well as rinse water quality.
5. Processing: forces applied and duration in the beating engine; speed of the beater roll; the ratio of roll to bed plate pressure; the size of the beating engine and the type of blades (steel or pumice roll); and pulp concentration (ratio of fiber to water). All processing variables effect freeness, fiber length, hydration and fibrillation. Stamper mills, I assume, share similar and unique variables: hammer weight and force; duration in the troughs where various head finishes apply different forces; and rinse flow during stamping.
6. Additives to the pulp: $CaCo_3$, $MgCo_3$, clay, pigments, etc. can all effect opacity and longevity.
7. Vat temperature, viscosity, and agitation, which can effect

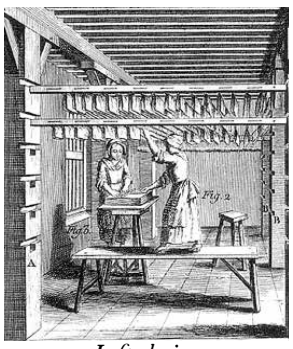

*Separating building choir*

freeness, paper weight, and sheet clarity respectively.

8. The surface and quality of the paper mould: wove or laid, wire lines per inch, wire gauge, rib spacing, and watermarks. New and older moulds also behave differently: uneven wire lines have a tendency to tangle, catching fibers and requiring constant cleaning.
9. Experience and technique of the vatman.
10. Quality of felts: coarse or fine, woven or felted, wool or synthetic.
11. The ability of the coucher: Transferring a sheet from the mould to the felt with a light touch or heavy-handed or uneven pressure can create flaws visible when a sheet is backlit.
12. The pressing force, speed coming up to pressure, and hours under pressure; use of a screw or hydraulic press.
13. The skill and technique used to separate the damp sheets from the post after the first pressing (i.e., using a slice or not, or lifting the felt to free a corner[38]) and re-stack them into spurs or choirs.
14. The amount of pressure applied in the second (choir) pressing; possible second and third pressing for a smoother finish.
15. Air drying: humidity and air movement, as opposed to pressure or hot press drying.
16. Technique of separating sheets in the spur.[39]
17. Sizing: skin glue and alum concentration, temperature, duration submerged and handling technique.
18. Finishing and Curing under pressure: Variables of calendering – use of roll (moist, hot or cold number of nips), hammer or hand burnishing. The force and length of time curing.

38. *One of my pet peeves; I avoid this particular move as it causes wrinkles in the corner of the wet sheet.*

39. *When separating the eight-sheet spur, I like to separate four from four, two from two and one from one -- separating one from seven, then one from six, etc. creates cracking flaws.*



*Loft drying*

*Sizing*

The slightest change in one variable (or sub-variable) may cause subtle or overt changes to the characteristics of your paper. Overretting or cooking too long reduces hemicellulose; overbeating creates a paper potato chip. Forming your paper poorly by dipping and over- or undershaking creates a wild sheet (which can also be called art). Work all day forming and pressing perfect sheets only to over- or undersize them and you have made blotter or waterproof paper. That is to say, with time, effort, and experimentation, a wide and wonderful range of results are possible; this sense of boundless possibility provides yet another reason to love entangled, matted and compressed cellulose fibers.

Returning to my quest: I began to move from flax roving to the real thing of the ancients – linen rags. However, many hurdles exist when using either linen rags or flax roving. First, although I was able to remove the lignin[40] from these raw materials by boiling them in soda ash for days, breaking down the fibers to the degree that they would not tangle in a Hollander beater proved difficult at best. Second, the resulting pulp is "greasy" (not free), resulting in dimensional instability as the pulp sheet pulls away from the felt during drying, and reducing the degree of detail in the texture. Many papermakers who use raw flax have resorted to cutting the roving into one-half inch or shorter lengths. My problem with this approach stems from lessons learned from my paper scientist mentor in the 1970s, John Peckham, a senior research fellow at the Institute of Paper Chemistry (when it resided in Appleton, Wisconsin). He informed me that whole bast fibers are naturally tapered at both ends, like a capsule. Chopping (or the cutting action of a Hollander beater) exposes oxidation sites wherev-

40. *Lignin is a class of complex organic polymers that fill the spaces in the cell wall between cellulose, hemicellulose, and pectin in plants. Flax has about 2% lignin whereas hardwood is comprised of approximately 29% lignin and softwood 22%. Lignin is removed during the cook - (usually in an alkali solution.*

*Bast fibers*

er the intact fiber is cut. Thus degraded, the fiber grows shorter and shorter over time from these points, accelerating the eventual demise of the finished sheet. If you do cut your fibers, he advised me, add $MgCO_3$ as an antioxidant; although less effective as an antioxidant, $CaC_{03}$ could also be added as a buffering agent and to make the paper more opaque.

To make a free draining linen furnish for the vat from rags, I rely on research done by Tim Barrett. He investigates retting time and its influence on beating and freeness in charts that indicate an approximate retting duration of two months. Retting is similar to composting: much like the heat generated by compost, one can tell if a pile of rags is retted to perfection when you cannot hold your hand in the hot pile of rotting rags for more than a few seconds. With this in mind, one of my recent additions to Magnolia's menagerie of equipment is a rotating compost bin, now filled with linen and hemp. In a few months, if all goes well, this fragrant mixture may provide a new route to the glorious imperfections of 16th-century paper.

The paper we will be making from retted linen and hemp will be thinner and lighter than the typical weight[41] of the modern-day papers sold at the art supply store, measuring approximately 60 gsm where today's art papers range from 100 to 300 gsm. For Michelangelo and his contemporaries, paper was expensive, somewhat scarce and thin – designed not for artists but rather for book publishers, manuscripts, and wrapping produce. Thinness will suffice if we can create a dimensionally stable paper that does not expand and contract when

41. *The weight of paper is expressed in grams per square meter (gsm): that is, if any given sheet could theoretically be enlarged to a one-meter square without changing other variables such as density, what would it weigh?*

*The gsm of a rectangular sheet can be calculated by this relatively straightforward equation:*
*mass (g) ÷ sq cm x 10,000 = gsm.*

water-based media are applied; again, this hinges on freeness. With retting we hope to greatly reduce refinement (beating) times. Our goal is to make a paper that is thin, strong, and lays flat even with the application of water-based paints.

I have come to realize upon my journey that perfection is more often found in nature and less often in the slick world of machine-made productions. A myopic view contends that we control nature. I say quite the opposite: nature controls everything. Like wily Odysseus besting the Cyclops, clever Renaissance artists used "imperfect" textures as the ground for their timeless expressions of humanity's twists and turns. Consider the beautiful, natural imperfections of the deckle edge; although it is celebrated today as evidence of a sheet's handmade status, we can still hear the voices of our predecessors calling from the spirit world: *Cut off the deckle and burnish the sheet. Minimize the texture: that's how you make quality paper!* The deckle was once widely considered a flaw to be removed. Today, in an age where we can purchase products that have never been touched by human hands, the deckle adds both spiritual and monetary value to paper as a manifestation of natural beauty to be celebrated, not shunned. Predictably, machines have for decades formed endless rolls of paper with deckle edges created using water jet spray and by tearing cross cuts, mimicking the real thing in an attempt to give us our comfort at an affordable, machine-made price.[42]

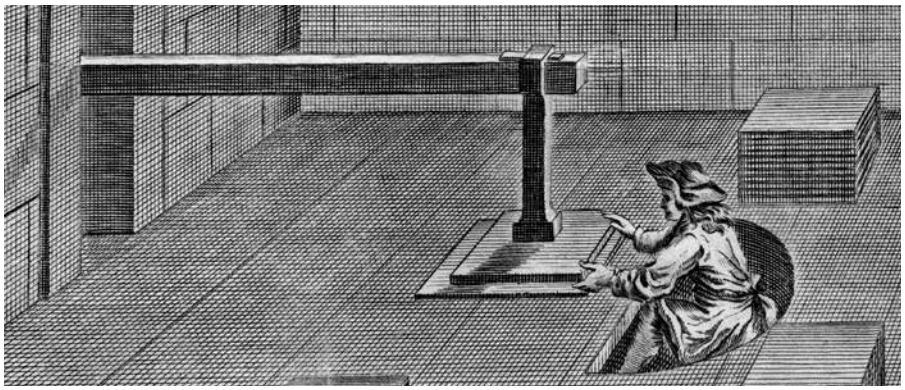
In a similar tenor, I have realized that much of my work has been an effort to recreate another maker's flaw of Renaissance papers: the tex-

*42. One art store chain advertises its mid-grade paper using this bizarre description: "One step up is cold-pressed paper, sometimes confusingly referred to as 'Not paper,' meaning not hot-pressed. It is the most versatile and popular texture, suitable for beginners and experienced painters alike, because its semi-rough surface is suitable for both detailed work and smooth washes."*
*A more accurate term for such a product might be Corporate Cold-Press (or Modern Art Paper).*

*Removing deckle edge*

ture of coarse wool. After all, most 16th-century papermakers would have preferred better quality wool to create smoother paper (or, if old felts were the cause of coarseness, to have newer felts). As frustrating as it was for me to try to recreate this flawed texture in the 21st century, it must have been equally upsetting to European papermakers, longing for finer and more expensive woolen felts, to be forced to use the more affordable wool of the shank, face, breast and belly -- or to have to use coarse, worn-out felts due to poor economic times. Of course, there were remedies; Renaissance-era techniques for smoothing "flawed" papers included the repeated re-shuffling and re-pressing of the damp paper in choirs and spurs; the placement of paper against paper (without felts); and finally, the burnishing and calendering of the dry sheet.

*Finishing: Curating, sorting and burnishing*

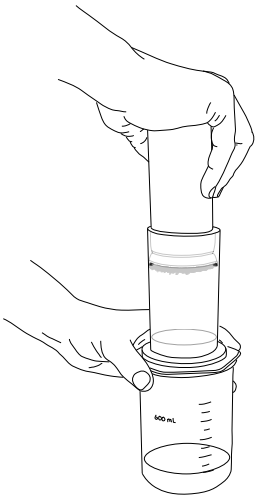


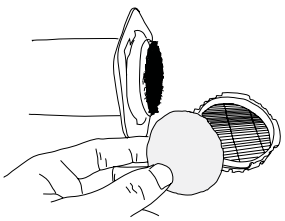
*Calendering*

Looking back across five centuries, we are finally able to grasp what is truly golden about this fleece, perceiving that – as with many experimental missteps, accidents, and defects – the textural "flaws" produced by coarser fleece were used to great effect by the masters of the Renaissance. Like the veins in marble, the patina that stains bronze, or the curving grain in exposed wood, Mother Nature provides comfort, complexity, and harmony in what we consciously or unconsciously covet. Man's desire to sterilize, bleach, and optically brighten our Apollonian hubris of gridded, imagined perfection, labeled by corporations using terms like *hot press* or *cold press, natural,* and *mould made* (paper made on a cylinder machine) – in short, our foolish attempts to control nature – give way to the underlying, Dionysian truth of the world of nature.

Which is not to say, of course, that one must never attempt to control nature via technology (i.e., knowing how to make paper) and science (i.e., knowing the chemistry in the paper); in fact, Apollo has often

*3D printed plastic mould & Deckle*





*Converted AeroPress*

provided crucial aid on our journey toward the golden fleece of Renaissance-style paper. For several years now, we at Magnolia Editions have been producing watermarks using a 3-D FLA printer, exactly extruding its polymer to our will via that quintessential Apollonian device, the computer. More recently, Canadian paper maker Brian Queen generously provided Magnolia with his hard-fought 3-D object files of a paper mould, deckle and laid screen. With minor modifications, Nicholas Price has made them compatible with our Type A 3-D printer, and we are now 3-D printing small but very usable plastic paper moulds.

Meanwhile, our attempts to precisely measure and control the gsm weight of paper have given rise to new technologies in both the digital and the analog realm. We have also modified and repurposed a handheld AeroPress coffeemaker to produce 2.25-inch-diameter disks of handmade paper.[43] Any laid pattern or small watermark can be incorporated by printing the desired pattern (using a UV-cured acrylic printer) on a small disk of silkscreen fabric and using this printed disk in conjuction with the AeroPress. With coding help from Jordan Grelling, we have created a free, web-based app called *PaperWeight* which makes calculation of gsm and density fast and easy.[44]

All told, the thinner, stronger, coarsely textured papers found in the Renaissance[45] may not meet the requirements of every occasion; certainly they did not necessarily provide the preferred texture for quill pen, letterpress, or woodcut in their day. Nor could any Renaissance-era vatman possibly have dreamed (even in his overworked,

43. *View the AeroPress instructions (PDF format) at http://www.magnoliaeditions.com*
44. *Try the app in your mobile or desktop web browser: http://bit.do/paperweight*
45. *Typically exemplified by sheets that were minimally burnished or not calendered.*

sleep-deprived, and probably drunken state) of the range of media and techniques brought to bear by 21st-century mark-making technology – much less the possibility of 3-D printed paper moulds, or watermarks generated from UV-cured acrylic. Nevertheless, Italian Renaissance papers remain unmatched in their capacity to provide an exquisite, endlessly heterogeneous surface of permanently remembered entangled hairs, thereby continuing to inspire the boundless innovations of the contemporary artist.

- Donald Farnsworth, 2017

*With thanks to co-writer Nick Stone and the current staff at Magnolia Editions, Oakland, CA:*
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*Directors: Donald and Era Farnsworth*
*Artist in Residence: Guy Diehl*
*Tapestry Finishing: Alyssa Minadeo*
*Interns: Arlene Kim Suda and Jordan Grelling*

*http://www.magnoliaeditions.com*