HOW TECHNOLOGICAL CHANGES AESTHETICALLY DEFINED PRE-1900S MAPS:

A STYLISTIC LOOK AT WOODBLOCK, COPPERPLATE & LITHOGRAPH PRINT MAPS

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

(Cartography & GIS)

at the

UNIVERSITY OF WISCONSIN-MADISON

2014

Acknowledgements

I need to send a shout out to my family and friends that supported me on the past two years. In particular, I want to acknowledge *everyone* from the Cartography Lab. There have been many names passing through the past two years so I won't list them all: but you all know who you are. Without our constant school, thesis *and* life questions and conversations, I know I would not have finished this yet. Thank you all.

I also want to thank my advisor, Robert Roth, for constantly pushing me towards the finish and listening to everything I wanted in my thesis since the beginning. We made it! And thanks so much for taking so much time the past month to continuously give me your feedback, advice, and answer all my endless research questions.

Finally, I want to thank Tanya Buckingham. Thank you for providing a space like the Cart Lab for all of us to listen and grow with each other, but more importantly, I want to thank you for being an amazing teacher *and* role model. You not only vastly expanded my cartographic education but you gave me so many valuable life lessons: your thoughts and conversations have turned me into a better person with a better purposed "over analysis". Thanks for teaching me to *not be perfect.* ;) I am honest in saying that our conversations are truly the most valuable pieces I am taking away from the past two years, and they will stay with me my whole life.

TABLE OF CONTENTS

1. INTRODUCTION

Since the 1950s, the search for new, easier, and faster production methods of aesthetically pleasing, legible, clear, and communicative maps has been constant (Robinson 1952; Edney 2007). During the 1950s, Robinson and fellow cartographers called for a more **objective** (unbiased), **empirical** (based on studied observations of maps and map readers), and **scientific** (discursive and reason-based) approach to creating maps. While this call for change did improve the accuracy and consistency of map representations, it is not the first time such empirical considerations for mapping have been considered. An empirical approach to mapmaking dates at least to the Renaissance, at which time Da Vinci drew maps at planimetric viewpoints to produce a more accurate depiction of the landscape below and John Ogilby made widely recognized strip map plates of various Great Britain locations that also portrayed relative spatial accuracy (Rees 1980; Haft 2012). Additionally, the idea of a scientific approach to mapmaking reaches as far back as Ptolemy's time in ~100 AD, when he became the first geographer to consider mathematically-derived map projections to produce more accurate depictions of geographic phenomena (Rees 1980).

Thus, empirical, objective, and scientific approaches to mapmaking have long been on the mind of cartographers, and these efforts have contributed to Cartography considerably. However, Cartography in practice remains an artisan craft as well as an empirical science: where do aesthetics and style fit within this cartographic initiative? Are there specific styles that work better than others for accurately depicting geographic information, and were these styles defined along with the changing technological methods for creating geographically and statistically accurate maps? More importantly, what is today’s relationship between aesthetic/artesian Cartography and objective/scientific Cartography?

Since the 1950s, the above questions about producing beautifully styled maps that objectively portray geographic information have been addressed by cartographers through both empirical research and practical recommendations. An assortment of aesthetic map design **techniques**—or skills, procedures, and methods used to produce an aesthetic element—have been studied from perceptual, cognitive, and semiotic perspectives and defined for map production (MacEachren 1995). Such technical, graphical, and empirical choices range from the placement of text, the size and type of font, color scheme options, texture variances, line weights, and design embellishments, among others (Robinson 1952; Raisz 1962; Keates 1973; Brewer 2005). However, while most cartographers today acknowledge these aesthetic/artesian design decisions as a part of the map creation process, there is no definition for styling a map overall; there is no set of 'correct' or 'incorrect' artistic or aesthetic rules for combining production means and design elements to establish a certain 'look and feel'. This is largely due to the fact that map design varies depending on how much generalization is needed or wanted, what cognitive and social reactions are desired, and many other non-empirical factors (MacEachren 1995; Cosgrove 2007).

As mentioned above, there are few formally defined styles in Cartography, so a definition of style and its relationship with aesthetics is needed before considering how to describe and eventually reproduce aesthetic cartographic styles. If the definition of **style**, or "a distinctive, formal, or characteristic manner of expression or taste", is combined with **aesthetics**, or "a set of principles governing the idea of beauty at a given time and place", then, accordingly, **aesthetic style** can be defined as "a distinctive or characteristic manner of expressing beauty," or "the expression or application of human creative skill and imagination" (Collins 2009: 1); perhaps one could be so bold as to say this is a close definition to **art**. This definition of aesthetic style can be applied to the techniques mentioned above, causing the cartographic design goal to be a combination of technical and graphical principles to create an *empirically-derived yet aesthetically-styled* depiction of geographic information. But how does the cartographer achieve a harmonious combination of the above if there is no set of cartographic styles to reference, learn from, or choose? Furthermore, how does the cartographer solve the conundrum of combining the empirical with the aesthetic?

This conundrum is the reason why researching and defining cartographic styles is so pertinent. In a world so consumed by—and rapidly changed and changing because of—technology, it is not surprising that the production cycle of Cartography today is entirely within the technological realm. Most, if not all maps are produced on digital screens, which is both a blessing and a curse: from the collection and manipulation of the datasets (whether data points collected on small GPS units or downloading data from online sources), to the computed analysis of these data (Systat, AutoCAD, ArcGIS, Microsoft Excel, etc.), to the final product design and creation (Adobe Suites, Corel Draw, etc.). This move to computer-aided, **Automated Cartography** has allowed for faster means of data collection, sharing, and manufacturing processes, in addition to an increase in the quantity of output, all of which result in a cheaper means of production, and thus, a more cost-friendly product for both the producer and consumer (Visvalingam 1990). However, this move to the computer screen, combined with the many different sources and 'places' (software) of production and with many various computer-automated/'automatic' outputs, often results in a common negligence: the aesthetics of the map itself. For these automated maps, graphical principles derived from empirical research often are achieved—as these are built into the mapping tools—but graphical principles derived from aesthetics are forgotten. In other words, Cartography today has emphasized accurate and clear communication, but often, the unique aesthetic elements and overall aesthetic style of the map are largely ignored because of the constant attention needed to keep pace with the changing software technologies involved in map production (Hurni & Leuzinger 1990).

Thus, today's heavily automated cartographic production calls for the need to ask the aforementioned question: How does one combine objectivity, empirics, science, and aesthetics into design decisions to create a map product with a distinct aesthetic style? To address this issue, I will investigate the development of aesthetic styles in cartographic history and define specific cartographic styles based on technological eras. Since cartographic production and design is dependent on available technologies, as are the technical skills and media choices (Keates 1977; Cosgrove 2005), technological change is a logical starting point for identifying and articulating unique cartographic styles and their respective, broader cartographic style eras. Defining these styles allows for an easier explanation and education of the aesthetics side of Cartography, which is the ultimate goal for this thesis: to provide a broad reference point of several older aesthetic styles for cartographers to use in conjunction with already existing graphical principles to produce *an overall, cohesive style*. Three printing technologies are reviewed, which commonly are imitated to produce an antique style: woodblock, copperplate, and lithograph. These three technologies were the most widespread geographically and well-known cartographic production techniques historically, allowing for more sampling options and examples of maps (Woodward 1975).

Specifically, this research approaches the following questions:

1. *Were the general aesthetic styles of maps produced within the different printing technologies dissimilar enough to say that styles were dependent on the technology?*

2. *If aesthetic styles were dependent on technology, what are the notable aesthetic elements that combine to define these styles?*

This research will not only contribute to academic and applied Cartography, but also the cartographic community in general because currently no broadly defined design styles exist in Cartography. Additionally, with the artistic and aesthetic history that exists within the cartographic field, it is a topic that *should* be researched for enriching the cartographic annals and history books, and also is a subject that hopefully will receive more attention in the future. Most of all, this research hopes to begin to make up for the *lack* of cartographic design aesthetic reference points within the formal education of Cartography as a discipline.

The following chapter describes the general history of Cartography, and then details woodblock, copperplate, and lithograph printing method histories, in addition to how the respective technologies affected the appearance and production of map prints. Chapter 3 discusses the research methods used for collecting and analyzing data to answer the above questions, and Chapter 4 discusses the research findings. Finally, Chapter 5 concludes with a discussion on the importance of the findings in addition to defining the woodblock, copperplate, and lithograph map styles.

2. LITERATURE REVIEW

2.1 Historical Relationship between Art and Cartography

As previously mentioned, the relationship between Art and Cartography historically has influenced the expectation of aesthetically pleasing, or beautiful, maps. Before Cartography came into its new critical, methodological, and analytical era, maps and mapmakers were a popular source of artistry (Rees 1980; Krygier 1995; Cosgrove 2005). That is not to say that the resulting maps were not spatially useful. They very much were, depicting cities, the countryside, newly discovered lands or imagined ones as well, and used many different media, from painted to woodcut to engraved forms (Rees 1980; Hurni & Leuzinger 1990). While none of these maps were **absolutely accurate** (i.e., spatial depiction of elements at a continuous scale, with correct spatial relationships), these maps still conveyed a **relative accuracy** in their sense of space or direction, and most additionally served as forms of decoration (Edney 2007). Over time, Rees (1980: p67) explains that maps improved their spatial accuracy due to new scientific surveying techniques such as triangulation, in addition to a new sense of proportion through the "laws of linear perspective" during the beginning of the Renaissance. Rees pointed out that eventually, mapping gained a "systematic organization of space" through 'modern' 15th century *artistic* interpretations of Ptolemy's 2nd century suggestion of using meridians and parallels to represent the Earth (Rees 1980; Robinson 1979; Friendly 2009). Moving into 16th century Renaissance, the *artist* Leonardo Da Vinci again changed Cartography by creating extraterrestrial maps from "vertical viewpoints" based on "mathematical perspective[s] in an effort to preserve accuracy" (Rees 1980: 69; Friendly 2009). Rees (1980: 73) notes that it also was during the 16th century (1569 CE) that Mercator published his now very well known world map, based on "empirical information furnished by land surveys and astronomical observations". While Mercator's map was much more empirically designed than past maps, it still contained aesthetically beautiful map elements, consequently continuing Cartography's strong relationship with Art and Science.

Between the 1950s and 1980s, informally described as the ‘Robinson Era’, a change occurred in Cartography: the **communication model** became a new standard in which the final *map product* should objectively communicate spatial relationships in the real world to the *map reader* as a result of the careful investigation, generalization, and production by the *cartographer* in the map production process (Koláčný 1969). In other words, the cartographer ought to design a map for the transfer (perception and interpretation) of data (the mapped information) to the map reader; ergo, the ‘communication’ model (MacEachren & Kraak 1997). This linear practice of cartographer to map to map reader caused a big concern: there was no set of consistent and objective cartographic rules or processes for the design of informative maps (Wood 1972). Hence, importance at this time was placed on researching and defining universal cartographic principles of design and symbolization based on the perceptual and cognitive limits of map readers (Robinson 1952). In this fashion, the process of **reductionism** facilitated the use of the communication model: a constant search for objective truths in conjunction with the reduction of information and map elements down to their essential elements, removing extraneous map elements to allow for more efficient map production *and* interpretation (Wood 1972; Bertin 1983; Kent 2005).

During this Robinson Era of Cartography, there also were many technological improvements that led to ever faster and more efficient means of geospatial data analysis and map production (Keates 1977; Visvalignam 1990; Kent 2005; Edney 2007). With the rise of the computer age in the late 80s and early 90s, scientists developed automated methods for cartographic production using efficient spatial databases as well as mathematical formulas for creating complicated map projections within software programs, precursors to today's almost entirely automated and screen resolved process (Visvalingam 1990). Before these advances, map production was a labor intensive process of hand measuring, drawing, and carefully painting, in addition to the slow and tedious transfer of any other geographic information (Visvalingam 1990). Ultimately, and as previously mentioned in Chapter 1, design and production methods in Cartography became computer automated. Today, most maps are disseminated across the Internet, becoming quickly and easily available with any Internet connection.

The remainder of Chapter 2 is used to summarize variation in the design affordances and limitations across historical cartographic production technologies as a way to chart the evolution in aesthetic styles over time, and to determine their influence on cartographic design today. Specifically, three production techniques are treated: (1) woodblock printing, (2) copperplate printing, (3) lithography. The popular timespan of each of these techniques subsequently is referred to as a **Technology Era**, or period of time in history characterized by a dominant technology and the resulting aesthetic styles of maps produced during this period. The following subsections treat the aesthetic design elements of each of these production technologies to give an overview of how the technologies changed production and printing over time. Additionally, it is important to note that in the following discussion, unless otherwise noted, cartographers designed the initial map drafts, but handed off the production of the maps, and elements within them, to already established drafters, engravers, publishers and other printing related professionals (Woodward 1975).

2.2 Woodblock printing

Woodcutting, otherwise known as **xylography**, was used predominantly between the fifteenth century and the first half of the sixteenth century. The word **woodcut** is a generic term for printmaking and as such requires a distinction between the two printing methods, woodcutting and wood-engraving, when describing woodcut maps or print products (Woodward 1975). **Woodcutting** involved cutting/carving wood from a woodblock plank using knives, gouges, and chisels, leaving only the lines and/or areas that provided the final ‘print’ of a map. In other words, this relief method showed blank/non-map space in the carved away areas, and the map content in the non-carved, inked areas (Lister 1965). Additionally, woodcutters often used apple, cherry, pear, sycamore, beech or boxwood blocks when carving because of their medium-grain quality (Woodward 1975).

Wood-engraving is done on the end grain of the wood, and is *sometimes* defined as an **intaglio printing** method, a process where the ink carrying lines are cut or etched into the printing surface (Beguin 2000; Lister 1965; Verner & Woodward 1975). ‘Sometimes’ is stressed because there is much debate over whether wood-engraving should be categorized as a relief or intaglio printing method (Lankes 1932; Woodward 1975). Many opine that that the tools used in the process are what differentiate the two, because wood-engraving tools on the close-grained wood, such as boxwood, gave cleaner lines (Lankes 1932; Woodward 1975).

2.2.1 Ink

The pressure on woodblocks during a relief printing process such as woodcutting could result in an uneven ink spread known as **ink squeeze.** It did not always occur, but when it did, the ink on the raised printing surface became forced out towards the edge of the inked area, causing the color at the edges of the inked area to become more intense than the color at the center (Lister 1965).

2.2.2 Lines and Tools

The smoothness of the printed line helps to determine whether a map was produced via woodcutting or wood-engraving. Wood-engraving tools and techniques create smooth lines. While woodcutting attempted to create lines as smoothly as possible, the lines appear jagged in comparison to wood-engraved lines. Although the wood planks chosen for woodcutting were 'softer' in comparison to other wood choices, the **flat-bladed knives** that woodcutters used to create lines were difficult to control and maneuver, resulting in uneven thickness, sharper angles, and general irregularities (Woodward 1975). Moreover, recall that woodcutting is a relief printing method: the desired lines are created not by carving them from the wood, but by carving away any wood that are not the desired 'area' of the line using **v cutters** and **gouges**. Thus, there are more opportunities to cause line imperfections.

Wood-engravings generally produced smoother and more detailed lines using a **graver** tool (Woodward 1975). These are sharpened at a less than a 90 degree angle, varying in their acuteness depending on the drafter's purpose. The gravers with a wider cutting face, or nose, required more pressure and thus were more difficult to control (Lankes 1932). Gravers with a more acutely angled nose were easier to push and maneuver, and most likely were used in creating curved lines or rounded figures.

2.2.3 Wood

In both woodcut and wood-engraved prints, the wood grain of the woodblock often is visible in the final print. This does not mean that there are large gaps in the ink, but generally the inked lines and areas have a grainy, textured appearance as a result of the wood soaking up some ink in its fissures after the ink is rolled onto the woodblock. Additionally, woodblock map prints generally were not produced at a very large scale (in terms of the size of the paper). Wood was a resistant medium in terms of creating linework, but it also was not ideal for larger prints because after a certain size, depending on the wood, the wood began to warp and bend (Lister 1965; Woodward 1975). This did not allow for a flat printing surface, and thus was generally avoided. The few larger map prints that exist were created using multiple woodblocks printed alongside each other to create the final larger map (Lister 1965; Woodward 1975).

2.2.4 Paper Indentation

Whether the woodcut is a relief or intaglio print, the pressure on the woodblock during printing causes an indentation in the paper, where the indented surface is the inked surface in relief, and the non-inked in intaglio (Lister 1965; Woodward 1975). In relief printing, the paper distortion caused by the pressure is called the **bite**, and shows more clearly on the back of the map (Lister 1965). Paper distortion also occurs in intaglio printing, but this type of distortion does not have a formal name or term. Additionally, paper distortion may become more obvious over time if the print is placed in a pressured area, such as in a bound book. The pressure causes the indented surfaces to flatten out, resulting in a more visible distortion and diminished sharpness (Lister 1965).

2.2.5 Point Symbols, Shapes, and Tone

On account of wood being a resistant medium, point symbols generally did not resemble round or circular marks. Dots and shapes tended to be square or angled because, regardless of the talent of the drafter, the tools available did not allow for the easy creation of curves (Lankes 1932; Woodward 1975). Creating a specific **tone**, such as different patterns, textures, or hues, for differentiating distinct areas also was a difficult task. Dot, line, or cross hatching patterns required a lot of attention not only to the detail of the tone itself, but also the underlying detail of the map; an area requiring tone also could have trees, bodies of water, etc., that needed to remain visibly distinct to the tone. Because of this complication, drafters often avoided using tone altogether (Woodward 1975).

2.2.6 Lettering: Handcut, Slot, and Stereotype Handcut

Woodcut type could be cut directly into the wood. The type was square, angular, and straight in form. Type also required even finer detail, making any attempts at rounder edges even more difficult and thus less likely in woodcut typfaces (Woodward 1975). Additionally, inconsistencies in letter shape, size, spacing, and angles were common because of the resistant medium and tools available. While inconsistencies were common, defined typefaces did exist (Lankes 1932; Woodward 1975). Early printed maps using the square and straight type requirement had wholly or partially gothic letters, or **black letter** (Lister 1965). The most common type used in many woodcut maps was a medieval lettering style known as *Textur,* which changed slightly as stylistic changes occurred over time. The softer art styles of the Renaissance pushed for a more rounded influence on typeface characters on maps, causing headaches for drafters at the time and resulting in the use of *Schwabacher* and *Fraktur* instead of *Textur* on maps during much of the Renaissance (Woodward 1975).

2.2.7 Slot

Type also could be placed directly into the map via chiseling a slot into the wood plank (Woodward 1975). This saved drafters a great deal of time on lettering the map, because the type blocks could be created once and then re-used. Additionally, the slot method allowed text edits to be made as well as changing a label to a differently styled typeface. However, this method had to be done carefully, because if too many holes were cut into the woodblock, the block would split or warp, thus destroying the map. Drafters attempted to evade this issue by creating maps with both handcut letters and slot letters.

2.2.8 Stereotyping

Stereotyping method is similar to the slot method, but involves the creation of entire words on a printing plate for map placement, and is identifiable by noting the relationship between the type and its surroundings. On the printed map, the woodcut detail is as close as possible to the type, following the type's shape, as opposed to the woodcut detail stopping abruptly in a rectangular shape near the type.

2.3 Copperplate printing

Copperplate printing was most prevalent between 1600 and 1850, and is a form of intaglio printing. Copperplate prints are much finer in detail than illustrations created with woodblock printing because of the new methods for creating lines, shading, hatching, typefaces, etc. (Lister 1965). Since the medium and tools allowed for finer detail in printed pieces, cartographers realized that copperplate printing was better than woodblock printing due to the improved geographic accuracy and precision afforded by the production process. Additionally, the plates used in the process could be used for a long time, often allowing for 3,000–4,000 impressions before becoming worn. Even after wear, cartographers could re-engrave the plates and consequently prolong printing life (Lister 1965). Additionally, metal plates did not have the same issues that woodblocks had, which warped and broke with large map prints, therefore granting the opportunity to print larger, more detailed maps (Verner & Woodward 1975). In copperplate printing, designs were created via etching or engraving.

In **etching**, a metal plate was heated and rubbed with a white wax, sometimes referred to as **ground**, over its entire surface (Benguin 2000). Once hardened, the engraver scratched the desired design through the wax coating using a needle. Acid then was applied to the plate, where it ate away all areas not covered in wax, a process called **biting** by some specialists (Verner & Woodward 1975; Beguin 2000); biting is not to be confused with the bite artifact in woodcutting. This method was very useful for detailed features, and was used often for the decorative features on maps, but was not used much for the map designs themselves (Verner & Woodward 1975). Etched plates could not create as many re-prints as an engraved plate, and so were not useful for map plates (Lister 1965; Verner & Woodward 1975). Copperplate **engraving** is the same intaglio method described in the woodcut section above, except the printing surface is a copperplate instead of wood. Graver tools also were used for copperplate engravings and the less resistant medium allowed for a variety of effects to be produced by the same tool. The more workable copper also led to the creation and use of many other tools that helped to give more detail and precision to copperplate designs.

The final difference between wood-engraving and copperplate engraving is that, while woodcut prints were produced on a **flatbed press** using perpendicular pressure, metal plates were printed using a **rolling press** (Lister 1965; Verner & Woodward 1975). While pressure is the main function in both printing methods, the rolling press gave an evenly applied pressure to the inked plate. With a protective padding on top of the paper and plate, the heavy cylinder of the press rolled over the paper and inked the copperplate evenly. It could apply pressure repetitively simply by pulling the cylinder back and forth for any given number of times (“Printing from” 1769). If the rollers applied uneven pressure or pull, or if there was not enough padding over the copperplate, the plate would become damaged, so choosing a skilled printmaker was an important decision to cartographers of the time.

2.3.1 Copperplate

Before etching or engraving, the copper plate required preparation. First, the copper was hammered to remove holes or flaws, and to make a homogeneous density (Beguin 2000). Then, the copper was polished continuously using different polishing methods until it shined with a "mirror-smooth finish" (Verner & Woodward 1975: 52). If the copper was not polished correctly, it left an uneven surface, which limited the number of successful impressions, or re-prints, of the plate. Additionally, poor polishing also affected the aesthetic of the final printing, resulting in a "dusty appearance" (Verner & Woodward 1975: 52).

2.3.2 Tools

Copperplate printing also used the graver, as defined in the discussion wood-engraving, for design production. In literature on copperplate and intaglio printing, the graver also is referred to as a **burin**. While these terms are interchangeable, for the purpose of differentiation between printing technologies, burin henceforth will be associated with copperplate engraving, and graver with wood-engraving. In copperplate printing, there were two main types of burins used: one was more squarely designed, and created larger, broader, and shallower strokes. The other was a lozenge design, or diamond shaped, and created more delicate, deep, and narrow strokes (Verner & Woodward 1975). The more malleable metals used for rolling presses allowed engravers to create more types of burins for detail, allowing for even smoother lines and curves in map elements, in addition to tools that produced special effects, such as tints, shading, and stippling (Beguin 2000).

2.3.3 Symbols

Many symbols were created as punches, especially conventional, repeated symbols such as those made for cities (Verner & Woodward 1975; Beguin 2000). Punching allowed for consistency across symbols, in addition to a faster production of design.

2.3.4 Corrections

There were two ways to correct imperfections or to update a plate with new information. If the correction in question involved scratches or shallow lines, the plate was polished with a **burnisher**, a polished tool that was rubbed continuously against the copper until the copper spread into the unwanted scratches or lines, making the etched lines unable to take in ink and therefore ‘disappearing’ from the print (Verner & Woodward 1975; Beguin 2000). If the correction needed was on a larger or deeper scale on the copper, then the copper was pounded from the back with a hammer until any deep cut lines or areas were level with the rest of the copperplate, ‘deleting’ the unwanted content (Lister 1965, Verner & Woodward 1975). Then, corrections were fixed or new lines and areas were carved into to the now ‘new’ surface. However, in both these instances, the fix was not forever. If the plate was used enough to wear down, then lines would open again and print faintly alongside the corrections, resulting in a **ghost print** (Verner & Woodward 1975). It is important to note that the more corrections made to a plate, the weaker it became, a concern for cartographers and printers when making corrections. In 1857, a process called **steel-facing** solved this problem. Electrolysis was used to cover the plate with a deposit of steel, producing a much harder surface and prolonging the plate life almost permanently (Verner & Woodward 1975).

2.3.5 Pressure Border

There is often an obvious plate mark impression on copperplate prints, caused by the pressure of the copperplate on the paper during printing (Lister 1965).

2.4 Lithography

Lithography is a printing method that uses stone as its printing surface. Invented in Germany in 1796 by Alois Senefelder, it was originally a means to cheaply produce and publish books. This printing method is a **planographic process**: a flat printing process that used a chemical, not physical, reaction to attach ink to paper and thus left no raised or incised marks on the print (Lister 1965; Ristow & Woodward 1975; Holden 1984). While lithography has existed since 1796, it did not become a popular map printing choice until the early 1820s, and by 1825 lithography was an established choice for cartographic printing (Ristow & Woodward 1975). Printers reversely drew maps onto specific types of stone, mainly limestone, with special **hydrophobic** (water repellent) crayons, pens, or oil-based inks (Holden 1984). After inking in the desired areas, the **etching** process began, in which the stone was treated with a mixture of nitric acid, helping to increase the porosity and water absorbency of the un-inked areas. The stone then was washed with gum arabic, protecting un-inked areas from future ink penetration, allowing the stone to last beyond a single use, consequently increasing the number of potential prints and thus also allowing the prints to be more affordable to publish and sell. After washing the stone to aid its longevity, printers applied an ink roller to the stone. The gummed areas repelled the ink, while non-gummed area—the original, reverse drawn map—attracted the ink and repelled water (Ristow & Woodward 1975; Holden 1984). The stone then was applied to paper to produce the final, correctly oriented map. While a long process, lithography was less costly than woodcut and copperplate printing methods not only in terms of time and plate life, but also in terms of the amount of labor, technical skills, and general materials needed for production (Lister 1965).

In the 1840s, Senefelder developed a new lithographic technique known as **transfer lithography**. This technique allowed for an image to be drawn directly onto paper, rather than first drawn in reverse on the stone. This technique used paper coated with specific concoctions such as glue, gum tragacanth, gamboge, starch, and French chalk, and ink made out of tallow, soap, shellac, lampblack and wax (Ristow & Woodward 1975; Woodward 1977). After an image was drawn using this ink and paper, the paper then was dampened with a nitric acid solution and ran through a press where the stone surface had direct contact with the drawn image, simplifying the stone etching process into less steps (Macdonald & Hart 1945; Ristow & Woodward 1975; Woodward 1977). In 1837, **chromolithography** further advanced the lithographic process by allowing colors to be added into the creation process. Rather than hand coloring a print, printers could add color to all or portions of a lithograph by adding hydrophobic colored inks into the process, and running a piece of paper through the press as many times as there were colors desired (Kieley n.d.). Printing methods continued to evolve and change using lithographic methods, eventually creating a printing process in 1875 called **offset printing**, a process in which the inked image is transferred from a plate to a rubber cylinder, and then transferred to paper off of the rubber. This method, while eventually used to create map prints as well, will not be included in map analysis, as many of the maps created used this printing method for the most part were made in the 1900s.

2.4.1 Typefaces

Perhaps the most notable difference between lithograph maps and their predecessors is the increase in typeface variation, not only in regards to using multiple typefaces within a map or title, but also in regards to the use of sans-serif type. Additionally, as lithography was a far less resistant medium than woodblocks and copperplates, type began to show more aesthetic variation (Woodward 1977; Mumford 1999). **Kerning**, the deliberate and precise adjustment of spacing between letters, became noticeable. Labeling also began to follow map features' curvatures: rivers, oceans, and mountain ranges tended to have labels curving along with them while maintaining their spacing and baseline alignment (Woodward 1977; Mumford 1999).

2.4.2 Paper

A lithograph print is equally smooth to the touch across the entire print. The smoothness is because, as previously mentioned, lithography is a planographic process and thus does not create any distinct raised or depressed areas on the printed paper, unlike the woodblock and copperplate printing methods (Woodward 1977; Mumford 1999).

2.4.3 Ink

Pre-1920s lithographs have a consistent, smooth appearance in their printing and ink appearances. In other words, they do not have a very dotty or grainy appearance in any of their lines, areas, or general coloring (Kortelainen n/d).

2.4.4 Detail and Type

There is even more detail and variation in lines and areas on lithograph maps because of the easier and more accessible production method (Woodward 1977; Mumford 1999). Additionally, there is a large increase in detail and variation of typefaces (Mumford 1999). Finally, lithograph prints almost always have solid lines and fills, again because of the printing method (Kortelainen n/d; Mumford 1999).

3. METHODS

This research followed tenets of **quantitative content analysis** (QCA) to investigate the aesthetic qualities of 60 historical maps, 20 for each of the three technologies reviewed in Chapter 2. QCA, when applied in Cartography, describes the process of counting and measuring the number of graphic composition and aesthetic elements found on a sample of maps, and allows for quantitative comparison of different compositional and aesthetic traits across groupings within the sample of maps, such as Technology Eras (Suchan & Brewer 2000; Muhlenhaus 2011). The QCA determined the frequency of design elements across the analyzed maps, which then were used to define their aesthetic styles.

The analyzed maps were sampled from nine cartographic digital archives: Antiquariat Reinhold Berg, Historic Cities, Osher Map Library, Afriterra: The Cartographic Free Library, Hemispheres: Antique Maps and Prints, Princeton University Library, David Rumsey Map Collection, Barry Lawrence Ruderman: Antique Maps Inc., and Paulus Swaen Old Map Auction and Galleries. Appendix A lists the abbreviated reference name (used as a unique identifier within research and analysis), archive source, cartographer, date of creation, and title for each of the 60 sampled maps. Maps were sampled based on the denoted production methods; maps that were not explicitly marked in the archives as woodblock, copperplate, or lithograph prints were not included in the analysis, resulting in a map sample drawn from ~1400s to pre-1900s. Additionally, availability of a high resolution scan of the map was required to allow analysis of smaller details within maps. If smaller items such as labels and type were pixilated, then the map was not included in the sample. An effort was made to include only a single map from a given city, region, country, or cartographer to allow for broader variation of styles across Technology Eras. However, two maps created by the same cartographer were allowed in the sample if the styles of the maps were notably different from each other, in terms of either the denoted Technology Era or the aesthetic elements within the map itself.

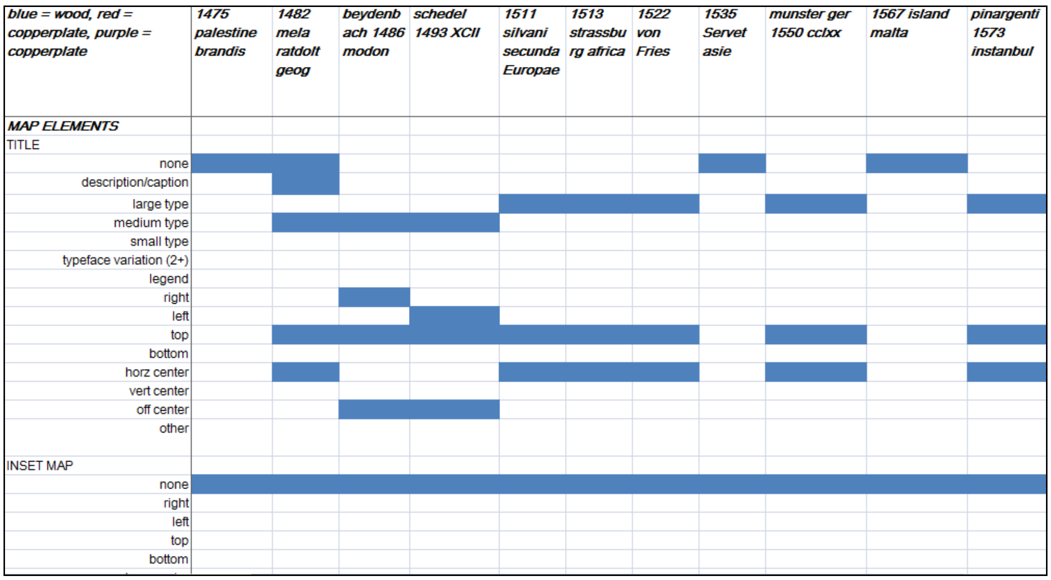


Figure 3.1: A portion of Excel spreadsheet created for the first stage of QCA coding.

The QCA was divided into two stages, with each stage looking at a different design influence on the overall aesthetic styles of the maps. In the first stage, the map sample was coded based on the **map composition**, or the inclusion and layout of specific map elements, such as a scale, graticule, etc. (Robinson 1995). QCA by map composition has been used effectively in prior work in Cartography (e.g., Kessler & Slocum 2011; Muehlenhaus 2011), and serves as an important baseline in map design against which technology-specific aesthetic elements can be compared. In total, with 114 map composition key codes were defined for the first stage of analysis, organized according to the following categories: map elements (with sub-categories of title, orientation, legend, scale, neatline/border, and overall type), overall design, and marginalia (with subcategories of water, land, and periphery). Appendix B lists and defines the map composition key codes used in the first stage of analysis. Key codes in the first stage of analysis were designed to be binary; a colored cell in the QCA table signifies the presence of the map element and a blank cell signifies the absence of it. Figure 3.1 illustrates an example of the QCA coding in Microsoft Excel.

1475 palestine brandis	*Wood Grain*	*Paper Indent*	*Tools*	*Lettering*	*"ink"*	*Correc tions*	*Hand drawn*	*Stamp/ Stencil*
thick			inconsistent _t,					
medium			inconsistent _t					
thin								
other								
POINTS								
proportional symbol								
pictorial symbol								
city dot								
other								
AREA/SHAPE								
border								
roads			stippling, linear, i_spacing_t, inconsistent _t,		watercolor, yellow, light_i, splotchy, desaturated, leaking, grainy			
building			detailed, linear_hatching, stippling, inconsistent _t, i_spacing_t		watercolor, red, yellow, blue, brown, saturated, desaturated, light_i, strong, dark_i, splotchy, leaking, grainy			

Figure 3.2: A portion of Excel spreadsheet created for the second stage of QCA coding

In the second stage of the QCA, the map sample was coded according to the **aesthetic elements** indicative of the three Technology Eras reviewed in Chapter 2. In total, 111 aesthetic element key codes were defined for the second stage of analysis, organized according to the following overarching categories: ink (key codes describing ink or color related aesthetics), tool (aesthetic elements directly caused by a particular tool or technology), form/description (descriptive key codes of form or design), and type (key codes relating to type). Appendix C lists and defines the aesthetic element key codes used in the second stage of analysis. A unique table was established for each of the 60 maps, with the table organized according to the aforementioned categories of aesthetic elements and the type of map feature to which the given aesthetic was applied in the map. In this stage of the QCA, multiple key codes could be recorded in a single cell, if multiple aesthetic elements were used for representing the given map feature. Figure 3.2 illustrates an example of the second stage of QCA coding in Microsoft Excel. Following coding of each map, the frequency of each aesthetic element key code across all map features was tallied and key codes with zero occurrences were removed.

Statistical analysis of the key codes also was completed in two stages. First, the non-parametric **chi-square independence test** was applied to key code summary tables to determine if the distribution of key codes across the Technology Eras were statistically significant (Burt et al. 2009). Two chi-square tests were performed: a 3x3 chi-square test was done on the binary map composition key codes (title, inset, orientation, legend, scale, neatline, type, layout, overall design, characters), tallied by Technology Era, and a 3x4 chi-square test was done on the aesthetic element key codes (ink, tool, form/description, type), again tallied by Technology Era. The tests on both stages of coding determined if the map composition and aesthetic elements were dependent or independent on woodblock, copperplate, and lithograph technologies, respectively. The null and alternative hypotheses for each chi-square test were as follows:

Map Composition Key Codes:

- H0: The overall map composition is independent of Technology Era.
- Ha: The overall map composition is dependent on Technology Era.

Aesthetic Elements Key Codes:

- H0: The aesthetic elements are independent of Technology Era.
- Ha: The aesthetic elements are dependent on Technology Era.

After establishing the significance of the key code distribution using chi-squared tests, hierarchical cluster analysis was applied on the key code **agreement** (i.e., the similarity and dissimilarity of coding) across all pairings of analyzed maps (Mesa & Restrepo 2008). **Hierarchical cluster analysis** calculates the agreement between pairs of sampled maps based on shared key codes in order to incrementally group the maps into clusters from the bottom-up (O'Sullivan & Unwin 2003). Such hierarchical cluster analysis therefore helps to determine what, if any, stylistic clustering occurred, and if so, what map composition and aesthetic elements caused the clustering relationships within particular clusters.

Clustering was completed in Excel using Ward's method of hierarchical clustering in the XLSTAT statistical analysis plugin. Euclidean distance was used to measure agreement between pairs of cards, resulting in a bottom-up hierarchical clustering. A pair of dendrogram statistical graphics were generated to facilitate interpretation of the hierarchical clustering results, one for the map composition key codes and one for the aesthetic element key codes. A **dendrogram** orders the maps along the horizontal axis according to their relative distance in attribute space and then uses vertical lines of varying length to indicate the distance between two maps (i.e., the agreement threshold required to place the pair of maps into the same cluster) (Mesa & Restrepo 2008). Figures 4.3 and 4.5 illustrate the dendrograms generated for the 60 sampled maps based on key code agreement.

4. RESULTS AND DISCUSSION

4.1 Summary and Significance of Map Composition Key Codes

In total, 1,363 map composition codes were applied across the 60 sampled maps, an average of 22.72 map composition codes per map. Within Technology Eras, 21.00 key codes were applied per woodblock map, 23.95 per copperplate map, and 23.20 per lithograph map. Figure 4.1 provides a visual comparison of the map composition key codes across the three Technology Eras. The most commonly applied key codes to the woodblock maps include *inone* (inset: none; 20/20 maps), *odbalanced* (overall design: balanced; 19/20), *snone* (scale: none; 17/20), and *lnone* (legend/key: none; 16/20). The most frequently applied key codes to the copperplate maps include *odbalanced* (overall design: balanced; 18/20), *nminimal* (neatline: minimal; 17/20), *inone* (inset: none; 16/20), and *oddecorative* (overall design: decorative; 14/20). Finally, the most commonly applied key codes to the lithograph maps include *cpnone* (character periphery: none; 19/20), *tlarge_type* (title: large type; 18/20), *odbalanced* (overall design: balanced; 18/20, and *toextensive* (overall type: extensive; 17/20).

The chi-squared test applied to the map composition key coding was significant at alpha=0.01, returning a p-value of 1.5209E-07. Therefore, the null hypothesis (H0) that the overall map composition is independent of Technology Era was rejected: the map composition key codes were dependent on Technology Era.

There are several interesting patterns or misclassified maps in the key coding that may explain a portion of the variation in map composition across Technology Eras. Several map elements common today were not common during past Technology Eras. No sampled woodblock map included a scale, either graphic or verbal; there were, however, seven woodblock maps that included a graticule. More than half (11/20) of the woodblock maps were

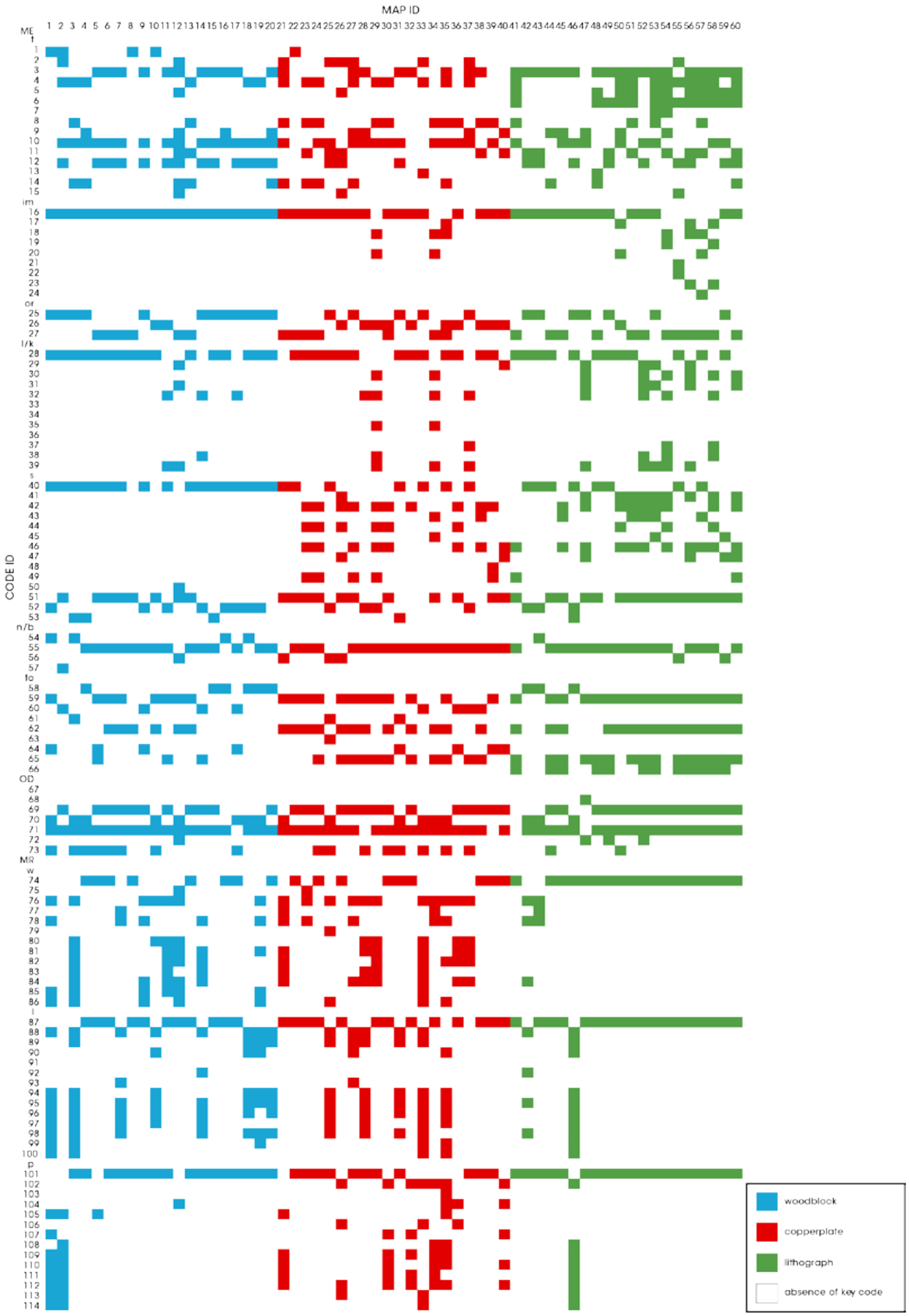


Figure 4.1: A visual comparison of the map composition key codes across the three Technology Eras. The unique identifiers along the horizontal axis relate to the 60 sampled maps; these identifiers are provided in Appendix A. The unique identifiers along the vertical axis relate to the map composition key codes; these identifies are provided in Appendix B.

drawn at large cartographic scales (i.e., maps with a small geographic extent), most likely because of a combination of the size restriction of the printing medium as well as the detail restrictions imposed by the tools used to work with the medium, both of which were discussed in Chapter 2 (Lister 1965; Woodward 1975). Finally, there was no typeface variation across the woodblock maps, which matches the description of woodblock typography provided in Chapter 2 (Lankes 1932; Lister 1965; Woodward 1975).

Unlike the woodblock maps, half (10/20) of the sampled copperplate maps included a graphic scale. Use of orientation indications also was more common, with 7 of the 20 maps including a graticule and 10 of the 20 maps including north arrows. As with the woodblock maps, there was no typeface variation across the copperplate maps.

Interestingly, there was a notable visual difference in typeface across the lithograph maps, and many (13/20) included both sans serif and serif type in addition to having general variation in typography within characters. Nine of the lithograph maps included a verbal scale in addition to a graphic scale, a pairing that was not found in the woodblock or copperplate maps. Lithograph maps maintained detailed illustrations, but lost the intricately detailed marginalia that woodblock and copperplate maps often included (e.g., ships, humans, animals). In accordance with the review in Chapter 2, detail in the linework—and therefore the ability to maintain absolute spatial accuracy—increased as technology changed from woodblock printing through copperplate printing to lithography. Intricate detail in the overall visual design, however, did not change, as designs in woodblock from the 1400s were as visually complex as lithograph maps from the late 1800s.

4.2 Summary and Significance of Aesthetic Element Key Codes

In total, 7,005 aesthetic element key codes were applied across the 60 sampled maps, an average of 116.75 aesthetic element key codes per map. Within Technology Eras, 110.65 key codes were applied per woodblock map, 143.85 per copperplate map, and 102.20 per lithograph map. Figure 4.2 provides a visual comparison of the aesthetic element key codes across the three Technology Eras. The most frequently applied key codes to the woodblock maps include *inconsistent_t* (tool: inconsistent, 20/20), *i_spacing_t* (tool: inconsistent spacing, 20/20), *linear_hatching* (tool: linear hatching, 20/20), *contour_hatching* (tool: contour hatching, 19/20), and *ink_squeeze* (ink: ink squeeze, 18/20). The most commonly applied key codes to the copperplate maps include *linear_hatching* (tool: linear hatching, 20/20), *persistent* (tool: persistent, 20/20), *contour_hatching* (tool: contour hatching, 19/20), *tapering* (tool: tapering, 19/20), and *watercolor* (ink: watercolor, 11/20). Finally, the most commonly applied key codes to the lithograph maps include *c_spacing_t* (tool: consistent spacing, 20/20), *c_xheight* (type: consistent x-height, 20/20), *c_ccapheight* (type: consistent cap height, 20/20), *thin* (tool: thin, 19/20), and *consistent_t* (tool: consistent, 17/20).

The chi-squared test applied to the aesthetic element key coding was significant at alpha=0.01, returning a p-value of 5.63E-34. Therefore, the null hypothesis (H0) that the overall aesthetic elements are independent of Technology Era was rejected. The aesthetic elements key codes were dependent on Technology Era.

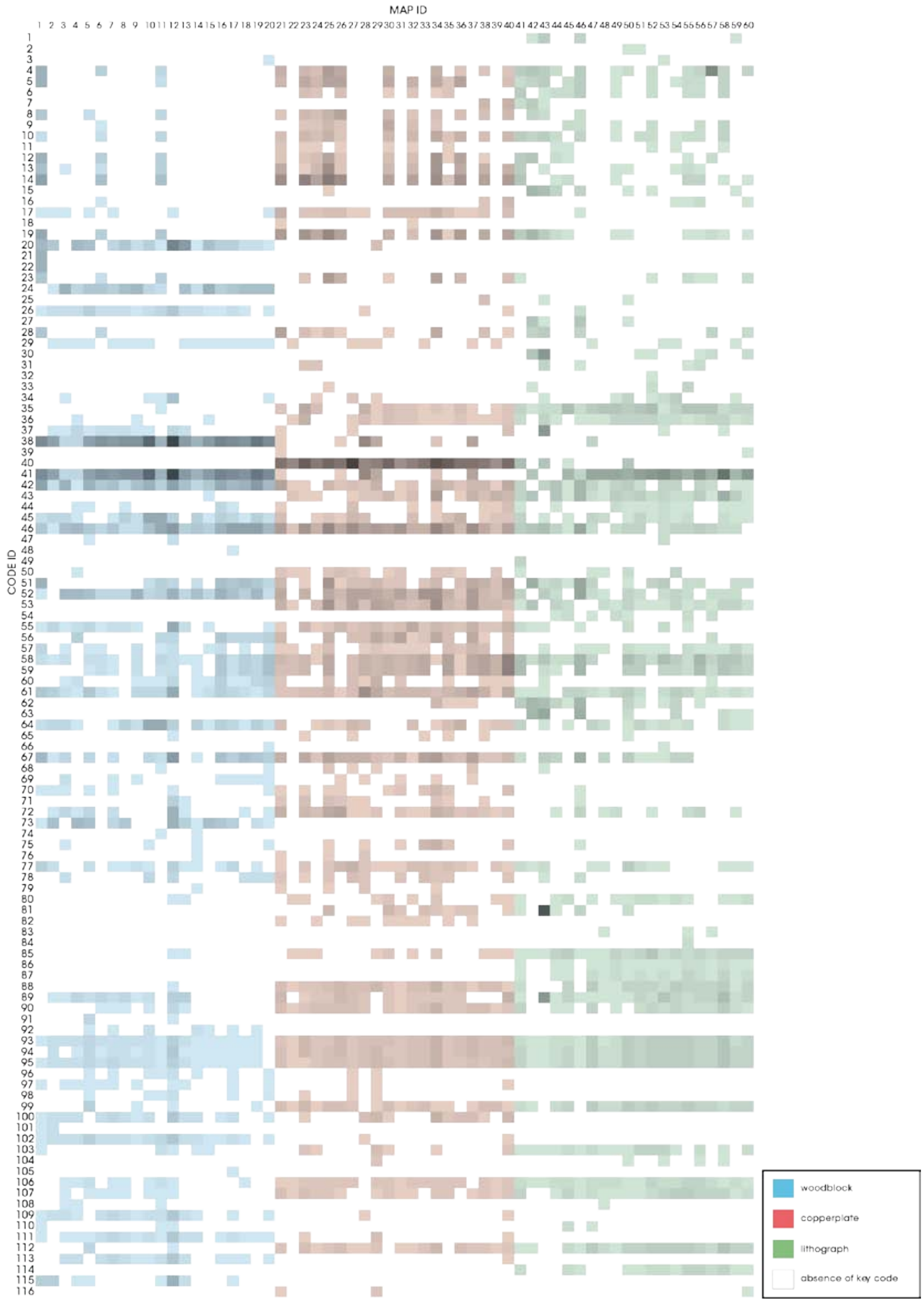


Figure 4.2: A visual comparison of the aesthetic element key codes across the three Technology Eras. The unique identifiers along the horizontal axis relate to the 60 sampled maps; these identifiers are provided in Appendix A. The unique identifiers along the vertical axis relate to the aesthetic element key codes; these identifies are provided in Appendix C.

As with the map composition key codes, the three technologies did have overlapping use of several aesthetic element key codes within each Technology Era. The five most frequently *shared* aesthetic key codes were: *watercolor* (ink: watercolor; woodblock: 22 occurrences, copperplate: 102 occurrences, and lithograph: 17 occurrences), *linear_hatching* (tool: linear hatching; woodblock: 120 occurrences, copperplate: 141 occurrences, and lithograph: 57 occurrences), *detailed* (form/description: detailed; woodblock: 58, copperplate: 83, lithograph: 33), and *contour_hatching* (tool: contour hatching: woodblock: 92, copperplate: 103, and lithograph: 39). Despite these commonalities, however, there was variation in the manner in which these shared aesthetic elements were applied to the sampled maps across technology. Coding by map feature—and tallying the frequencies of codes across map features—revealed an evolution by Technology Era in the pervasiveness that a common aesthetic element was applied to different map features as well as the manner by which this aesthetic element was applied. For example, while a majority of the sampled maps included the *linear_hatching* and *contour-_hatching* key codes, regardless of Technology Era, the frequency of their application across map features and the overall intricacy in their detail increased as technology advanced from woodblock through copperplate to lithography, a finding that is consistent with the Chapter 2 summary. An important key code that decreased over time that also showed increase in technological abilities in regards to detail and line intricacy was *inconsistent_t*: from 232 occurrences in woodblock to 28 in copperplate, to only 3 occurrences within lithograph maps. As discussed in Section 4.4, the signal in these differences across aesthetic element key code frequency ultimately was strong enough to develop clusters within the map sample according to Technology Era.

4.3 Clustering by Map Composition Key Codes

As described in Chapter 3, hierarchical clustering was applied to the map composition key codes to identify key codes specific to each Technology Era. The dotted line in Figure 4.3 represents the recommended cluster truncation, or the optimal place for aggregating the maps into clusters given high internal agreement within each cluster and high disagreement between clusters. This truncation resulted in three clusters marked Cluster A (including 30 maps), Cluster B (6 maps), and Cluster C (24 maps) in Figure 4.3; delineation of these clusters is represented by the white lines.

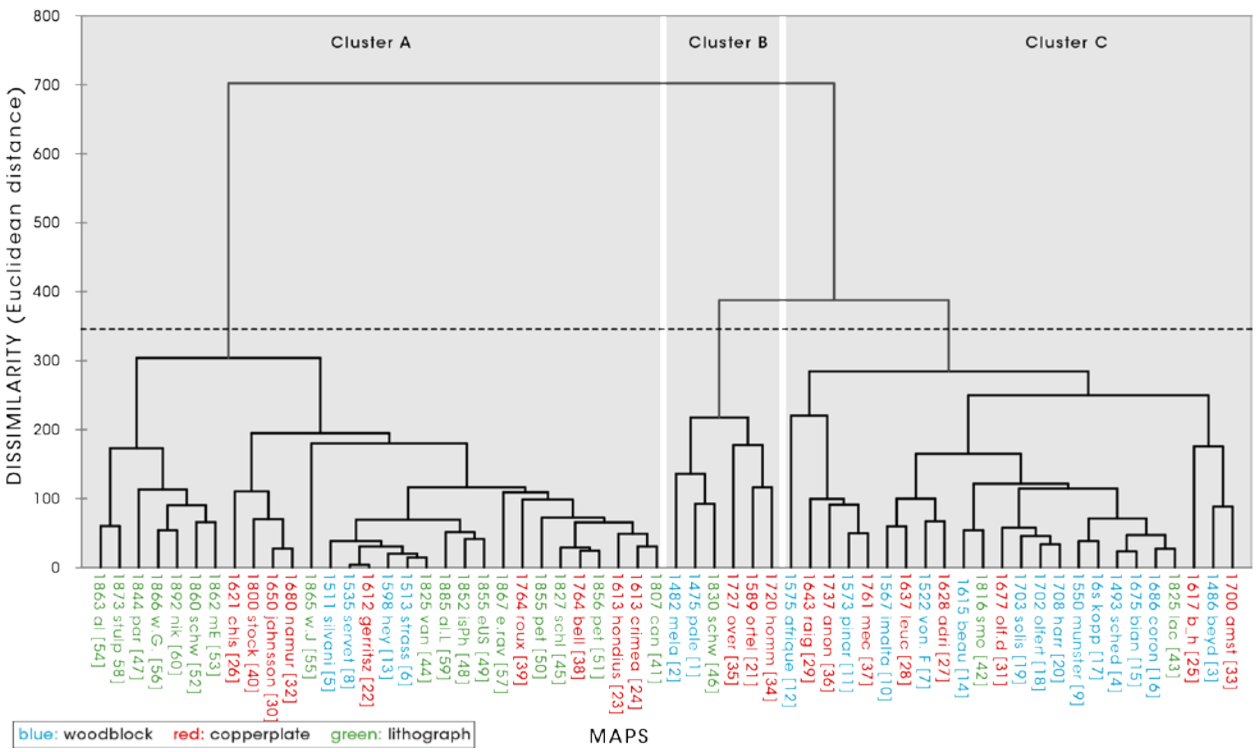


Figure 4.3: A dendrogram of clustered map composition key codes agreement between maps. Green signifies lithograph maps, red: copperplate, and blue: woodblock. [#] coincides with the Map ID #'s from Figures 4.1 & 4.2.

Overall, there was minimal association between the three map composition clusters and the three Technology Eras. Cluster A was a mixture of all three Technology Eras: just over half are lithograph maps (17/30), with the rest of the cluster consisting of copperplate (9/30) and woodblock (4/30) maps. Cluster B, the smallest of the three map composition clusters, again consisted of a mixture of Technology Eras: three copperplate, two woodblock, and one lithograph. Finally, the just over half of the maps in Cluster C were woodblock (14/24), with the remainder of the cluster comprising copperplate (7/24) and lithograph (3/24) maps. Thus, while Cluster A and Cluster C had a majority of lithograph and woodblock maps, respectively, these were only slight majorities and the remainder was mixed between the other two Technology Eras. While the aforementioned chi-squared test on map composition key codes suggested that there was a significant difference in map composition based on Technology Eras, the specific combinations of map composition key codes within each Technology Era were not consistent enough to result in homogenous clusters based on technology.

While Cluster A and C primarily comprised lithograph and woodblock maps, respectively, the sampled copperplate maps were split relatively evenly between Clusters A and C. Thus, copperplate maps shared compositional elements with both woodblock and lithograph maps, functionally portraying a transition in map composition between woodblock and lithographs. For example, half (10/20) of the sampled copperplate maps contained an indication of scale, while no woodblock maps did (0/20) and more than half of the lithograph maps did (14/20). Therefore, lithograph and copperplate maps shared this compositional style. However, copperplate shared marginalia map elements with woodblock: both woodblock and copperplate had some form of marginalia in all sampled maps, while only 2 of the 20 lithograph maps included any form of marginalia. Returning to insights generated in Section 4.1, these clustering results may be explained by the suggested transition or evolution in the complexity in map composition from woodblock through copperplate to lithograph. Therefore, it is possible that the map composition chi-square test was significant at alpha=0.1 because of the large differences in cartographic design conventions over time, rather than stylistic affordances and constraints of the dominant technology at any given time.

4.4 Clustering by Aesthetic Element Key Codes

As with the map composition key coding, hierarchical clustering was applied to the aesthetic element key codes to identify key codes specific to each Technology Era. Figure 4.5 illustrates the results of clustering on aesthetic elements as a dendrogram. The clustering algorithm recommended three clusters, which largely relate to each of the three Technology Eras. Cluster A in Figure 4.5 entirely comprised woodblock maps (20/20), Cluster B primarily comprised lithograph maps (16/18), and Cluster C primarily comprised copperplate maps (18/22) Thus, only 6 of the 60 maps, or 10%, were incorrectly clustered, providing further evidence that aesthetic elements coincided closely with Technology Era. Is important to note that the agreement between Cluster A (woodblock) and Clusters B (lithograph) and C (copperplate) is considerably less than the agreement between Clusters B and C, suggesting that the sampled copperplate and lithograph maps share more aesthetic elements than either share with the sampled woodblock maps. Accordingly, all six of the misclassifications occur between the copperplate and lithograph clusters.

Because the clustering results based on aesthetic element key codes match the three Technology Eras closely, it was useful to inspect the aesthetic elements most commonly associated with each of the three clusters. Table 4.3 enumerates the top ten most common aesthetic element key codes for each of the three clusters. Several aesthetic element key codes were common to multiple clusters, as illustrated by the Figure 4.4 Venn diagram. Importantly, the Venn diagram provided further evidence that the sampled copperplate and lithograph maps shared more aesthetic elements (*contour_hatching*, *curvy*, *detailed*) than either share with the woodblock maps. Figure 4.4 also identified common codes that are technology specific and therefore may be useful in defining broader aesthetic styles by Technology Era. These include *grainy, light_i, ink_squeeze, non_circular, partial, book, stereotype, slot, calligraphy, tittle, angular,* and *handcut* for woodblock, *press* and *pressure_border* for copperplate, and *_g_, gradient, relief, spongy, pattern, contours, curved,* and *kerning* for lithograph.

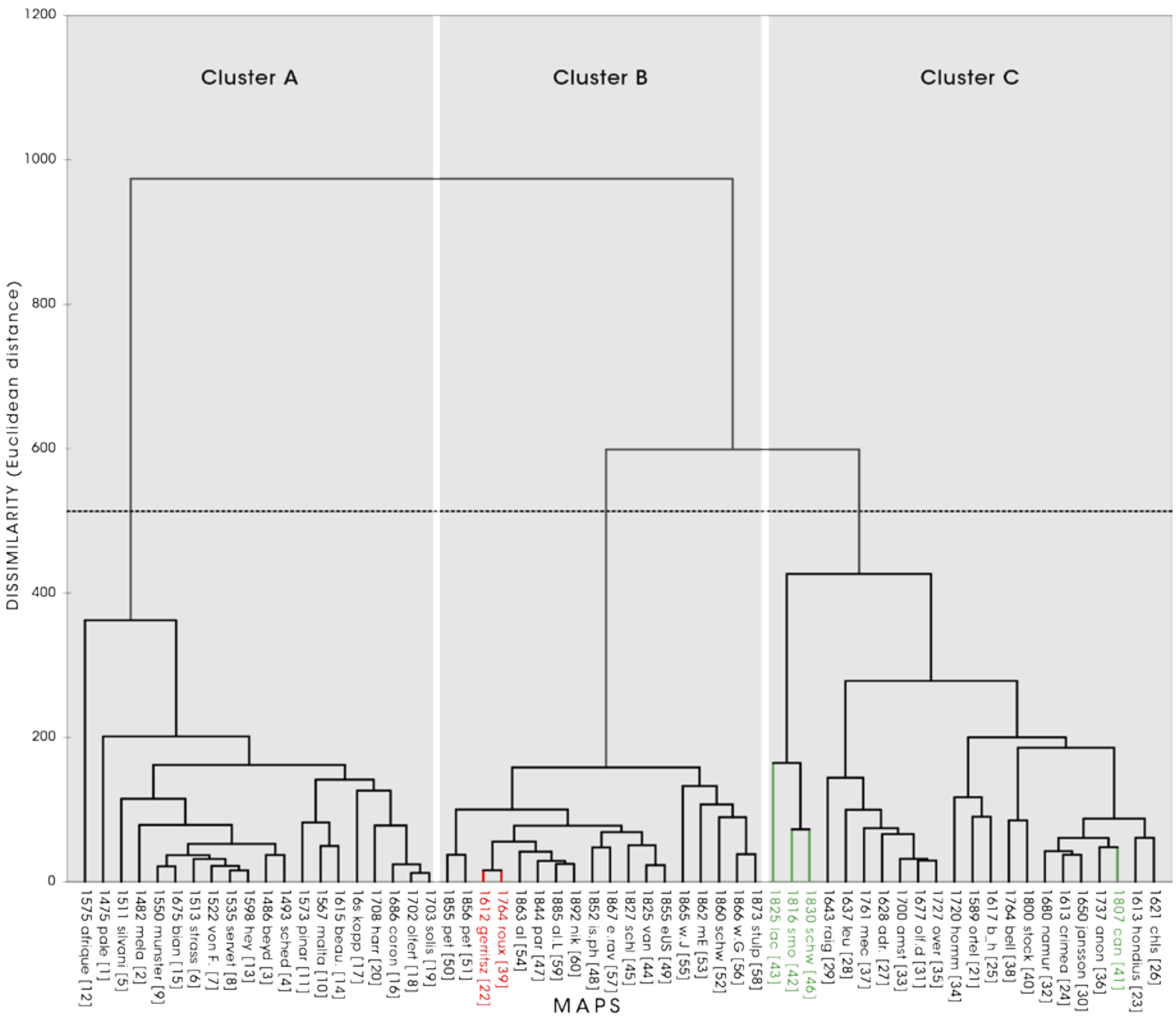


Figure 4.4: Dendrogram created from aesthetic key code agreement between maps. Green signifies misclassified lithograph maps and red signifies misclassified copperplate. [#] coincides with the Map ID #'s from Figures 4.1 & 4.2.

Cluster A ('Woodblock')		Cluster B ('Lithograph')		Cluster C ('Copperplate')	
linear_hatching	20/20	c_baseline	20/20	linear_hatching	20/20
ink_squeeze	20/20	c_xheight	20/20	fill	19/20
inconsistent_t	20/20	c_capheight	20/20	detailed	19/20
contour_hatching	19/20	c_spacing_t	20/20	persistent	18/20
grainy	18/20	thin	19/20	contour_hatching	18/20
i_spacing_t	18/20	c_spacing_l	18/20	tapering	17/20
stippling	18/20	fill	18/20	line_fill	16/20
curvy	18/20	linear_hatching	17/20	saturated	15/20
minimal	17/20	consistent_t	17/20	leaking	13/20
detailed	14/20	line_fill	16/20	watercolor	13/20

Table 4.3: The top ten most frequently identified aesthetic element key codes per cluster.

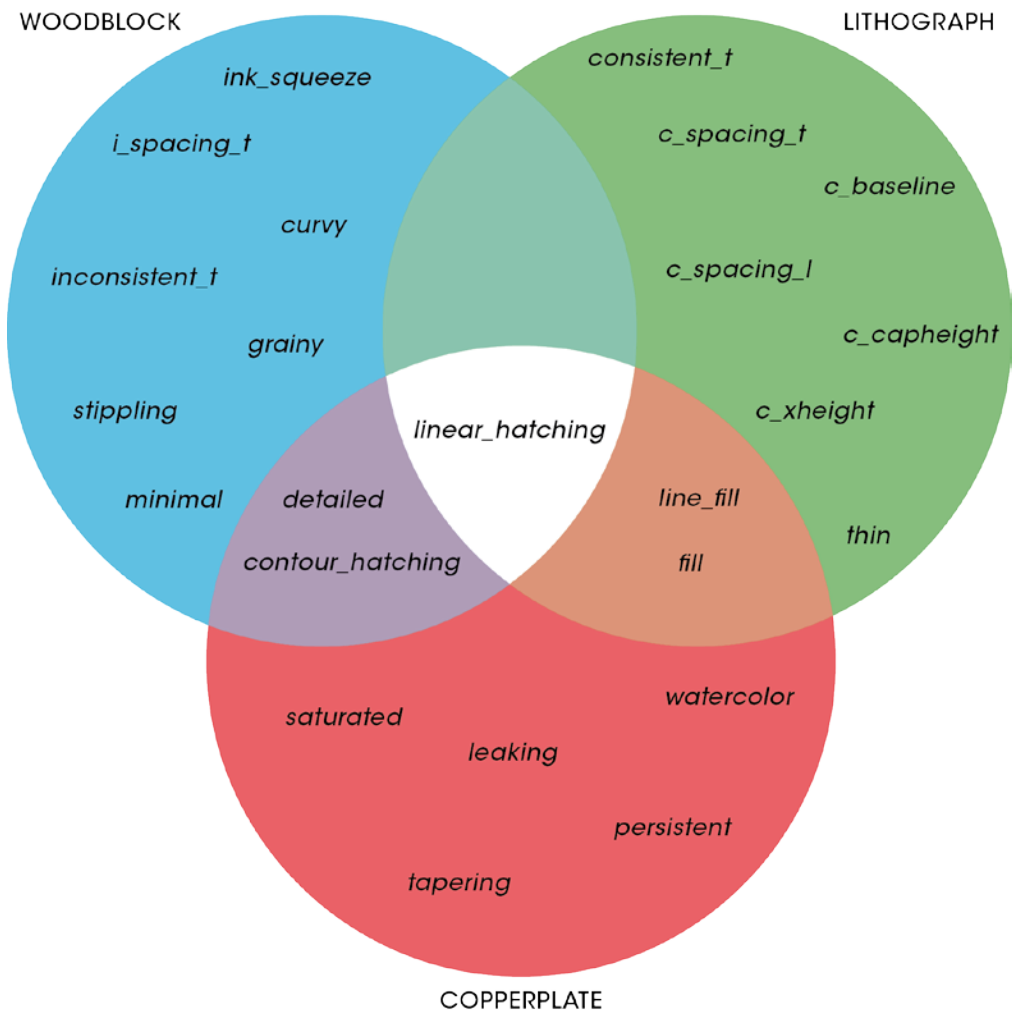


Figure 4.5: Table 4.3 represented as a Venn diagram showing overlapping and technology specific aesthetic element key codes

The nuanced differences across clusters further can be exposed by examining those key codes that may be infrequent, but only ever occur within a single Technology Era sample. Table 4.4 provides the name and frequency of aesthetic element key codes found within only one technology. The woodblock maps had 12 unique key codes: *ink_squeeze* (87 occurrences overall), *grainy* (85), *handcut* (26), *angular* (22), *non_circular* (19), *slot* (9), *light_i* (8), *tittle* (5), *stereotype* (4), *calligraphy* (3), and *book* (2); most of these unique aesthetic styles agree with the Chapter 2 review of woodblock printing (Lankes 1932; Lister 1965; Woodward 1975). The copperplate maps had only two unique aesthetic element key codes: *press* (44 occurrences) and *pressure_border* (10), the latter of which was identified as an important aesthetic element of copperplate printing in the Chapter 2 review (Lister 1965; Verner & Woodward 1975; Beguin 2000). Finally, lithography had five distinctive aesthetic elements: *kerning* (27), *gradient* (22), *curved* (21), *contours* (3), *pattern* (3), *relief* (3), *spongy* (2), and *_g_* (1), most of which also speak to what was discussed in the Chapter 2 review regarding lithograph printing, especially in regards to increased ability for intricate detail in design (Woodward 1977; Mumford 1999; Kortelainen n/d). Ultimately, it is the combination of aesthetic elements that were common in or unique to one Technology Era (Tables 4.3 and 4.4), but not the others, that come to define the unique aesthetic style associated with the Technology Era.

Technologies	Key Codes
woodblock	*grainy, light_i, ink_squeeze, non_circular, partial, book, stereotype, slot, calligraphy, tittle, angular, handcut*
copperplate	*press, pressure_border*
lithography	*_g_, gradient, relief, spongy, pattern, contours, curved, kerning*

Table 4.4: Unique aesthetic element key codes per technology.

Finally, aesthetic element key codes shared by only two clusters were identified, as these aesthetic element key codes serve as confounders that may explain the six misclassified maps. These confounding codes supplemented broader stylistic definitions, as these overlapping codes eliminated several common aesthetic element key codes from consideration within the definition of each Technology Era style (see Section 4.5). Table 4.5 lists the aesthetic element key codes that were found in only two of the three Technology Eras, while Table 4.6 lists the aesthetic element key codes that were found in only two of the three clusters. The combined clusters from Table 4.6 include almost all of the key codes from their related combined technologies in Table 4.5, with the exception of the key codes *tan* and *varying* from the combination of copperplate and lithograph technologies. Table 4.6 does, however, include more key codes within the combined clusters than the key codes Table 4.5. This is likely due to the fact that the clustering emphasized certain key codes that were in fact used within the three technologies, but also only marginally were used in one of the three technologies. For example, the aesthetic key code frequencies show that *foreground_detail* was present in all three technologies (Table 4.6) and so does not show up within Table 4.5, but *foreground_detail* was only present once within the lithograph map sample: within *1825 lac*, one of the misclassifications. Further, several aesthetic element key codes present in the combination of Clusters A (woodblock) and C (copperplate)—including *red*, *expressive*, *plaque, armed, action* (Table 4.6)—were not present in the combination of woodblock and copperplate technologies list within Table 4.5. Similarly, the aesthetic element key codes *dotty* and *varying* were present in both Clusters B (lithograph) and C (woodblock), as shown in Table 4.6, but not in the combination of lithography and woodblock in Table 4.5. Such key codes present in either Table 4.5 or 4.6, but absent in the other, therefore are those codes confounding appropriate identification of one Technology Era over the others.

Combined Technologies	Key Codes in Common
Woodblock & Copperplate	*ribbon, cannons, smoke, i_baseline, i_xheight, i_capheight, i_lettering, black_letter, textur, i_spacing_l*
Copperplate & Lithograph	*pink, tan, inner_glow, mixing, purple, grey, varying, persistent, tapering, rippling, subtle, soft, sans_serif*

Table 4.5: Aesthetic element key codes shared by only two technologies.

Combined Clusters	Key Codes in Common
Cluster A (Woodblock) & Cluster C (Copperplate)	*red, foreground_detail, ribbon, expressive, plaque, armed, cannons, action, smoke, i_baseline, i_xheight, i_capheight, i_lettering, black_letter, textur, i_spacing_l*
Cluster C (Copperplate) & Cluster B (Lithograph)	*pink, inner_glow, mixing, dotty, purple, grey, persistent, consistent_t, tapering, rippling, subtle, depth, soft, sans_serif*

Table 4.6: Aesthetic element key codes shared by only two clusters.

The prototypical aesthetic elements of each aesthetic style then were used to interpret why six of the maps were incorrectly classified in the hierarchical cluster analysis. The incorrectly classified maps included two copperplate maps (*1612 gerritsz* and *1763 roux*) that were clustered with the lithograph maps and four lithograph maps (*1825 lac*, *1816 smo*, *1830 schl*, and *1807 can*) that were clustered with the copperplate maps. Table 4.7 shows the misclassified maps and Table 4.8 lists the aesthetic element key codes that were used at least once per misclassified map in addition to highlighting the common and unique key codes discussed throughout Section 4.4.

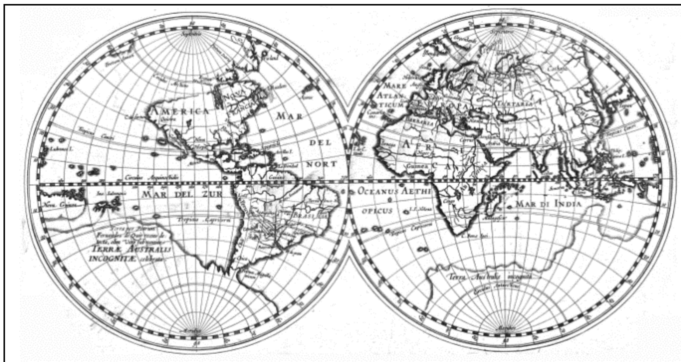
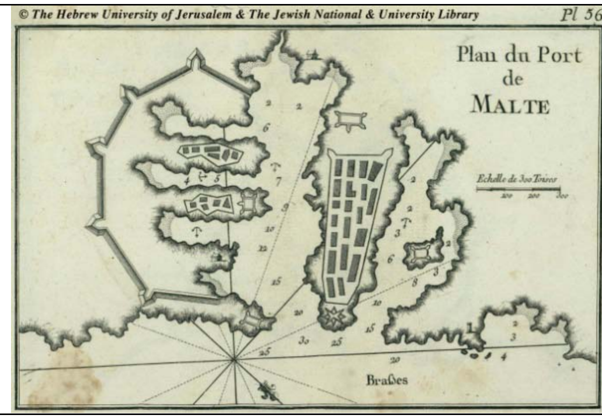
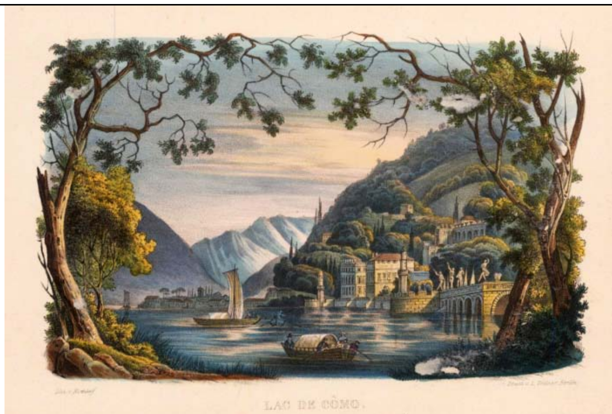
	
1612 gerritz	1764 roux
	
1825 lac	1816 smo
	
1830 schl	1807 can

Table 4.7: The misclassified maps

Lithograph categorized as Copperplate		**Copperplate categorized as Lithograph**			
1612 Gerritz	1764 roux	1825 lac	1816 smo	1830 schl	1807 can
_bw_, thick, persistent, i_spacing_t, c_spacing_t, linear_hatching, straight, tapering, wavy, fill, line_fill, curvy, blocks, block, roman, italic, c_baseline, c_xheight, c_capheight, c_lettering, caps, lowercase	_bw_, thin, thick, i_spacing_t, c_spacing_t, dotted, linear_hatching, straight, stippling, contour_hatching, tapering, pointy, fill, line_fill, angled, curvy, minimal, detailed	blue, yellow, pink, tan, red, green, leaking, gradient, saturated, mixing, white, brown, dotty, purple, varying, thick, irregular, persistent, i_spacing_t, minimal, linear_hatching, thin, stippling, contour_hatching, pointy, wavy, fill, line_fill, angled, curvy, subtle, depth, minimal, detailed, foreground_detail, repetitive, action, block, regular, c_baseline, c_xheight, c_capheight, serif, caps	blue, yellow, tan, red, green, desaturated, gradient, saturated, white, brown, dotty, grey, thin, consistent_t, c_spacing_t, linear_hatching, stippling, tapering, pointy, fill, curvy, subtle, depth, detailed, action, block, c_baseline, c_xheight, c_capheight, c_lettering, serif, caps c_spacing_l	highlight, blue, yellow, pink, red, orange, green, gradient, press, black, white, brown, purple, thin, thick, consistent_t, i_spacing_t, c_spacing_t, linear_hatching, stippling, contour_hatching, pointy, wavy, fill, line_fill, curvy, subtle, depth, detailed, expressive, plaque, decorative, armed, action, soft, black, regular, c_baseline, c_xheight, c_capheight, c_lettering, serif, caps, lowercase, c_spacing_l, multiple	Blue, yellow, pink, tan, green, desaturated, leaking, watercolor, saturated, splotchy, thin, thick, persistent, i_spacing_t, c_spacing_t, dotted, minimal, linear_hatching, straight, contour_hatching, tapering, pointy, fill, line_fill, curvy, subtle, minimal, detailed, repetitive, blocks, soft, block, curved, kerning, roman, regular, italic, c_baseline, c_xheight, c_capheight, c_lettering, serif, caps, lowercase, c_spacing_l, multiple

Table 4.8: Misclassified maps and their key codes: depicting key code relationships to Technology Eras, as described throughout Section 4.4. **Brown** signifies a key code that lithograph and copperplate share within their top 10 frequencies, as determined by Tables 4.5 and 4.6**.** Coloring of **green** or **red** signifies Table 4.3's most frequent key code (green = lithograph, red = copperplate). Key codes not italicized signify uniqueness to a technology (Table 4.4). Purple signifies that that particular key code is unique to the key codes in common between copperplate and woodblock, but still is important because it is a key code shared with copperplate not a lithograph. Everything else is shared by all three technologies.

While the clustering by aesthetic element key codes does reflect different technological styles, the six misclassified maps illustrated that different aesthetic styles still can be produced, either through human will or human error. A talented copperplate engraver potentially could engrave much smoother lines than his or her competition, or alternatively, a lithograph printer could make a map that contained less detailed and rougher lines for artistic purposes. It is likely that the latter issue in part explained the misclassification of the *1825 lac*, *1816 smo*, and *1807 can* lithograph maps as copperplate maps. Table 4.9 compares these misclassified lithograph maps alongside lithograph maps that were clustered correctly into Cluster B (Figure 4.4). The side-by-side comparisons were selected to include similar mapping characteristics: *1825 lac* and *1885 a.L* both share mountainous features, *1816 smo* and *1855 PetCham* both share water features, and *1830 schl* and *1852 IslesPhil* both share a fragmented layout. In all three pairings, the misclassified maps were more visually distinct than their properly classified counterparts. One obvious difference was that the misclassified lithograph maps were at a large cartographic scale, while the correctly classified lithographs were at a small cartographic scale. Cartographic scale was not an aesthetic element key code, but clearly had an impact on the aesthetic elements leveraged in design of the map. The large scale maps allowed for more intricate detail in map features and marginalia, explaining the increase in aesthetic element key codes related to copperplate printing, such as: *detailed* (copperplate: 83, lithograph: 33), *curvy* (copperplate: 80, lithograph: 37), *pointy* (copperplate: 57, lithograph: 10), *action* (copperplate: 21, lithograph: 3), *expressive* (copperplate: 18, lithograph: 1), *armed* (copperplate: 16, lithograph: 0), and *foreground_detail* (copperplate: 6, lithograph: 1). While the correctly clustered lithographs have intricate detail as well, the key coding of “detailed” was not used for multiple map features or marginalia because there were fewer kinds of features depicted on the small scale maps (e.g., no trees, no humans, no ships). Thus, while the level of detail in the linework related to tools (e.g., *subtle* [lithograph: 37, copperplate: 7], *depth* [lithograph: 33, copperplate: 0], *thin* [lithograph: 72, copperplate: 35], *gradient* [lithograph: 22, copperplate: 0]) did in fact represent a relationship between the misclassified lithograph maps and lithograph printing, the misclassified lithograph maps overall shared more aesthetic elements with copperplate printing (e.g., *foreground_detail*, *detailed*, *action*, *expressive*, *armed*, *pointy*, and *curvy*).

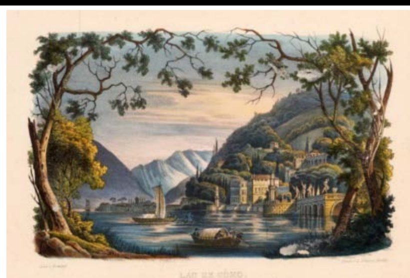
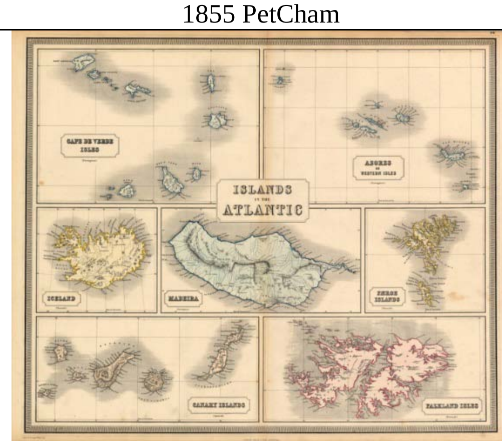
Misclassified Lithograph ('Copperplate')	Correctly Clustered Lithograph
 1825 lac	 1855 a.L
 1816 smo	 1855 PetCham
 1830 schl	 1852 IslesPhil

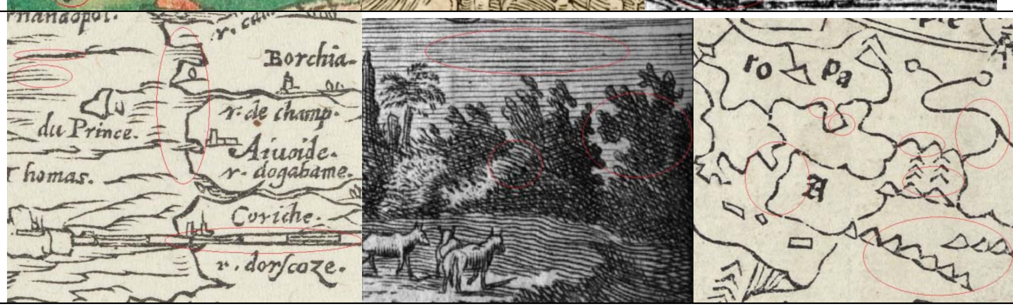
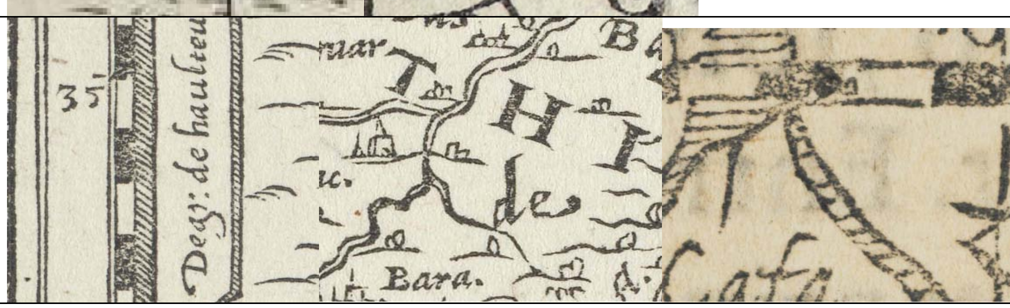
Table 4.10: Comparing three of the lithograph misclassified maps with 3 correctly clustered lithograph maps.

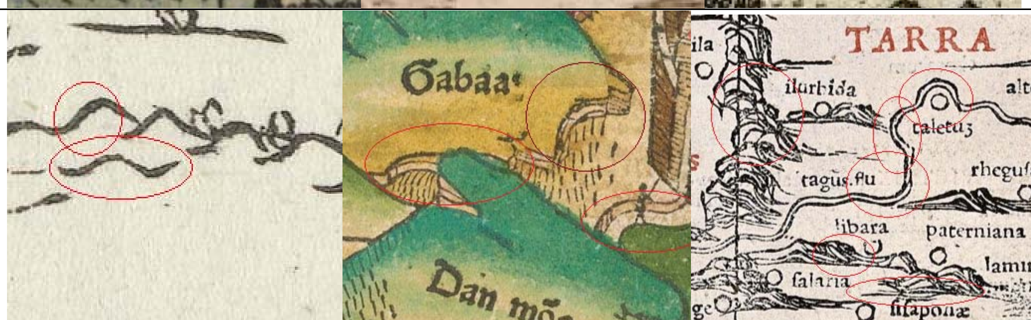
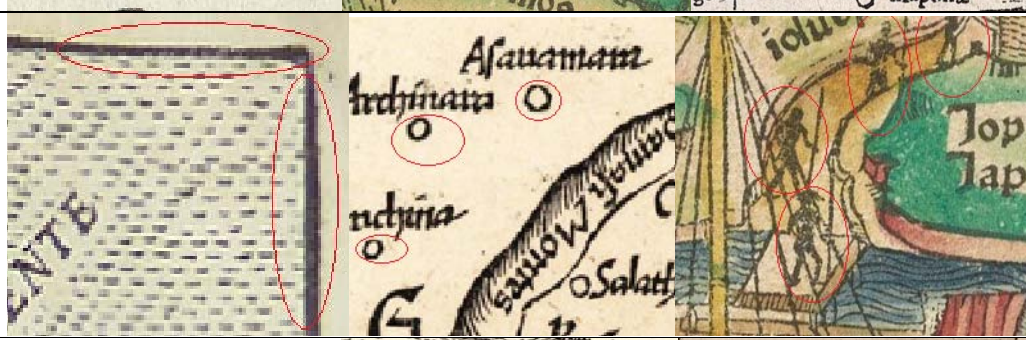
4.5 Defining Aesthetic Styles by Technology

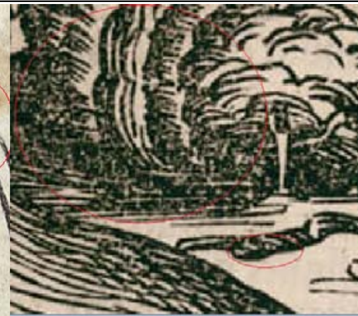
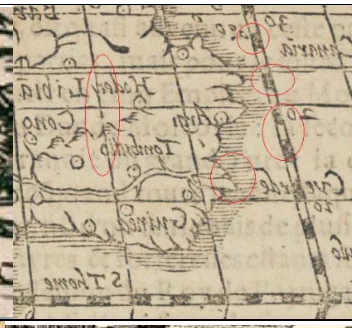
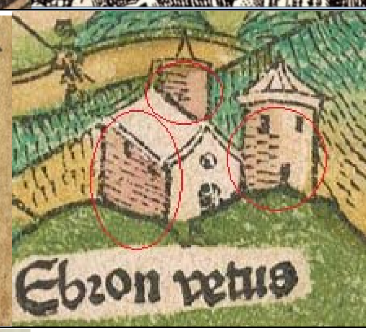
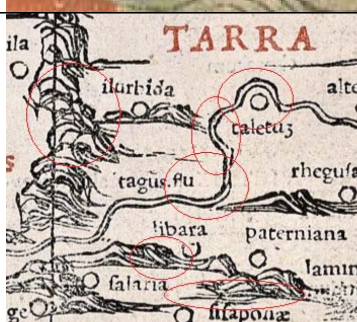
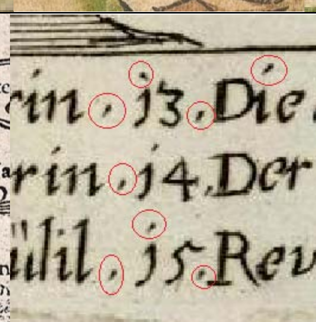
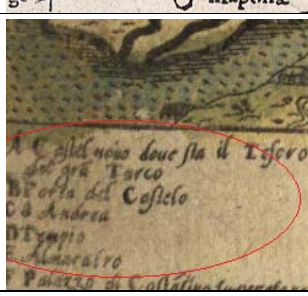
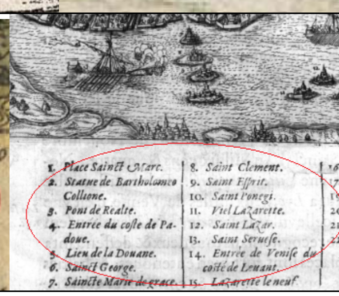
The ultimate promise of the key coding by map composition and aesthetic elements is to establish broader aesthetic styles that are indicative of different Technology Eras. As discussed in Section 4.3, clustering on map composition key codes did not reveal a strong relationship between composition and Technology Eras, but rather a broader transition or evolution over time. However, clustering on aesthetic element key codes did relate closely to the different Technology Eras. Therefore, it was possible to establish the prototypical aesthetic styles of each Technology Era by synthesizing aesthetic elements that are both common and unique to a given technology. In the following, the aesthetic styles for each Technology Era are defined using visual examples of the constituent aesthetic element key codes.

Tables 4.11, 4.12, and 4.13 combines the key codes in Table 4.3 with the unique key codes from Table 4.4 to create the final defined styles for woodblock, copperplate, and lithograph technologies. It shows multiple portions of maps as examples for each of these key codes, demonstrating the visual definition of the woodblock, copperplate, and lithograph styles.

The **Woodblock Style** (Table 4.11) comprises linework that is thicker (*thick*), more irregular (*irregular*), and more angular (*angular*) and map elements that are inconsistently designed (*inconsistent_t*) and inconsistently spaced (*i_spacing_t*), all of which reflect the resistant medium and tools available, as discussed in Chapter 2 (Lankes 1932; Lister 1965; Woodward 1975). Another important stylistic element of the Woodblock Style is that type is not consistent (in capheight, x-height, baseline, and spacing elements), whether the type was creating through *handcut* means or by other tools (*slot, stereotype*), differences also noted in Chapter 2 (Woodward 1975).

Woodblock Style	
linear_hatching	
ink_squeeze	
inconsistent_t	
contour_hatching	
grainy	

i_spacing_t	
stippling	
curvy	
minimal	
detailed	

partial	  
fill	  
light_i	  
non_circular	  
book	 

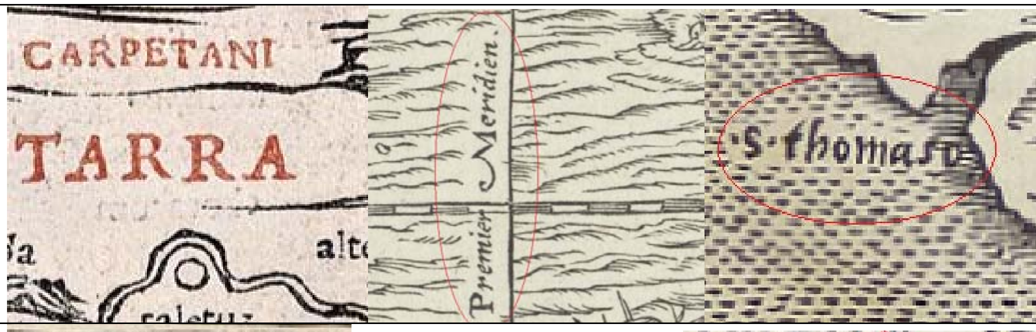
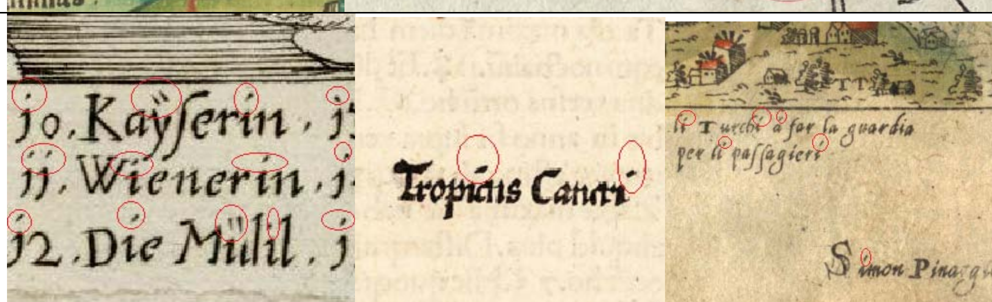
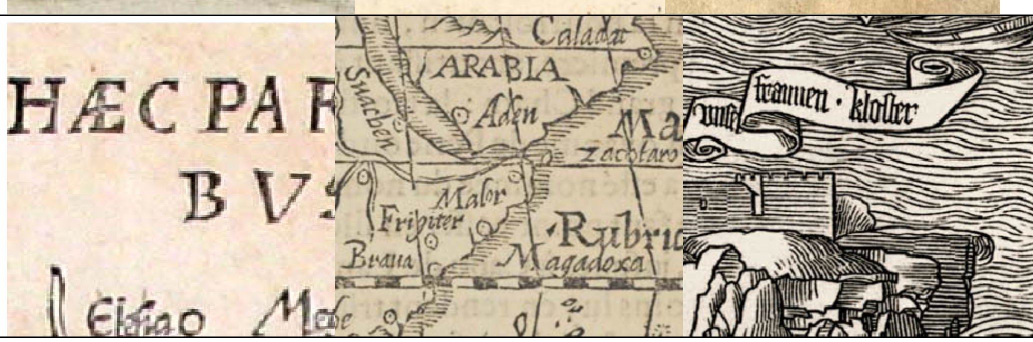
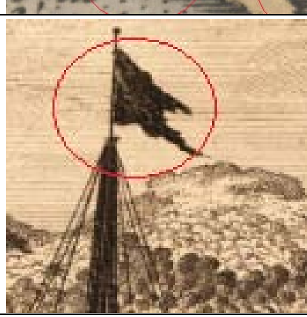
stereotype	
slot	
calligraphy	
title	
handcut	

Table 4.11: Woodblock style's visual definition

The **Copperplate Style** (Table 4.12) comprises intricately detailed map elements created with cleaner, smoother lines (*persistent*) in comparison to the woodblock linework, consistent with the discussion in Chapter 2 (Verner & Woodward 1975; Beguin 2000). Due to advances in the copperplate technology, the linework also includes rounder and consistent curves (*curvy*), more fills with linework (*fill, line_fill*), in addition to smoother transitions and more equal spacing within linear, contour, or cross hatched lines within map elements (*linear_hatching, contour_hatching, cross_hatching, persistent, curvy, straight, wavy*). Additionally in comparison to the Woodblock Style, there is a notable increase in watercolor (*watercolor*) usage for coloring map prints within the Copperplate Style. Finally, while marginalia was present within the Woodblock Style, the ability to provide more detailed linework led to an increased detail in marginalia elements (*expressive, armed, action, smoke*), providing a more decorative (*decorative, detailed, foreground_detail*) feel within the Copperplate Style (Verner & Woodward 1975; Beguin 2000).

Copperplate Style			
linear_hatching			
fill			

detailed	
persistent	
contour_hatching	
tapering	
line_fill	

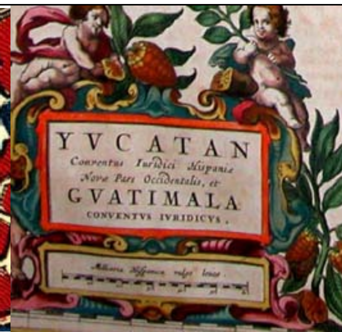
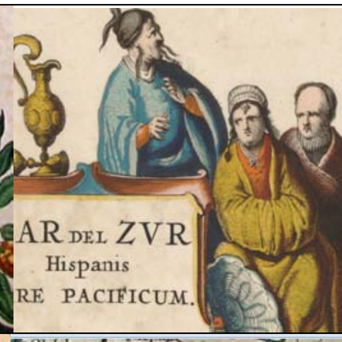
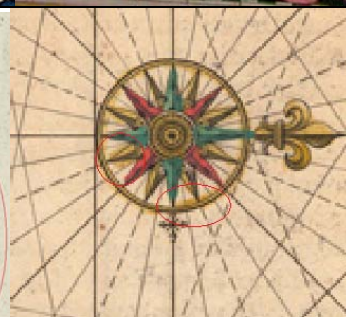
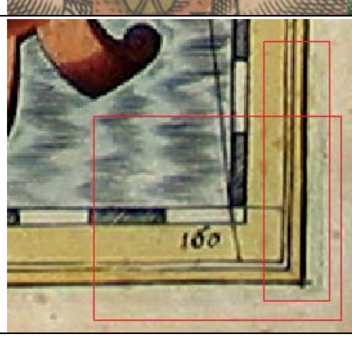
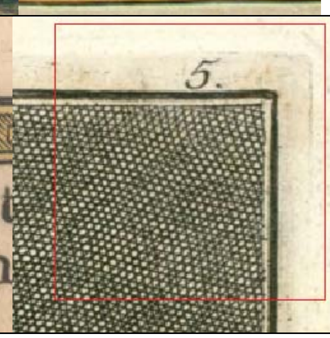
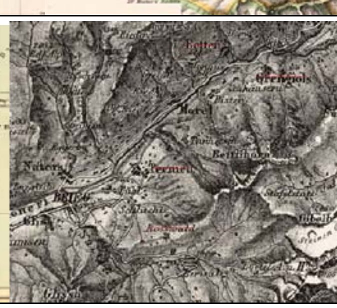
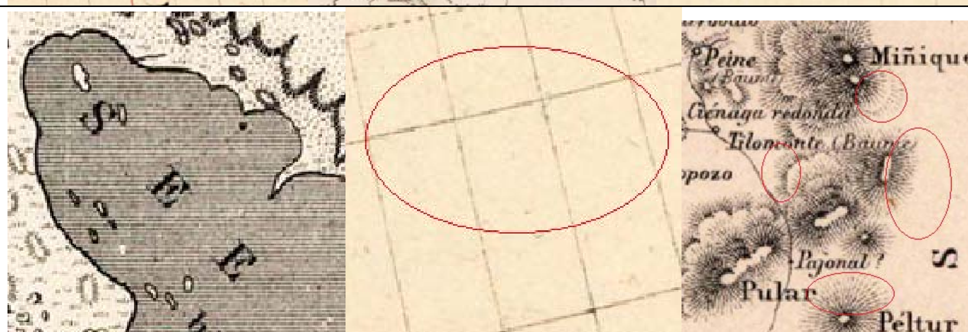
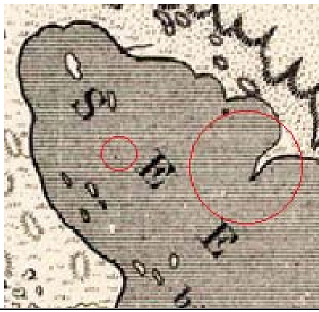
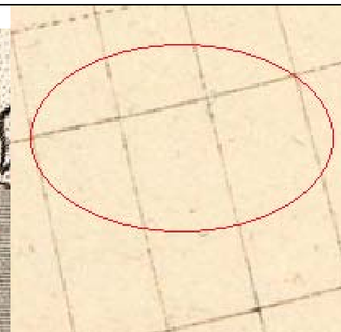
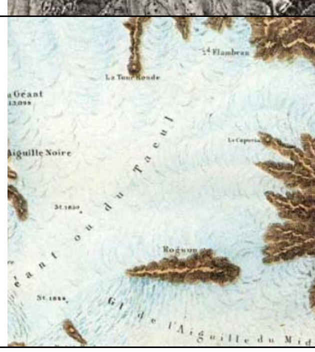
saturated			
leaking			
watercolor			
press			
pressure_border			

Table 4.12: Copperplate style's visual definition

Finally, the **Lithograph Style** (Table 4.13) comprises intricately detailed map elements created through very consistent (*consistent_t*) and smooth linework, but also linework that varied in terms of line width and smooth curvatures (*curvy, thin, thick, wavy, rippling*) compared to woodblock and copperplate maps. Again, the increase in line variation is consistent with the Chapter 2 discussion of lithography (Woodward 1977; Mumford 1999; Kortelainen n/d). Additional map aesthetics not found in the Woodblock or Lithograph Styles include smooth gradients *(gradient*) of color as well as contour lines (*contour*) and relief shading (*relief*), the latter two coinciding with an increase in cartographic design and map element conventions at the time. Finally, type elements changed considerably in comparison to the previous two styles (Woodward 1977; Mumford 1999; Kortelainen n/d). More than one typeface was common within the map itself as well as other elements of map composition (*typeface_variation(2+)*). The type changed visually as well through kerning and curving (*kerning*, *curved*) and sans serif or serif combinations usage (*serif*, *sans_serif*).

<table>
<tr><th colspan="2">Lithograph Style</th></tr>
<tr><td>c_baseline</td><td>  
</td></tr>
<tr><td>c_xheight</td><td>
  </td></tr>
</table>

c_capheight	
c_spacing_t	
thin	
c_spacing_l	
linear_hatching	

consistent_t	  
line_fill	 
*_g_*	
gradient	 
spongy	

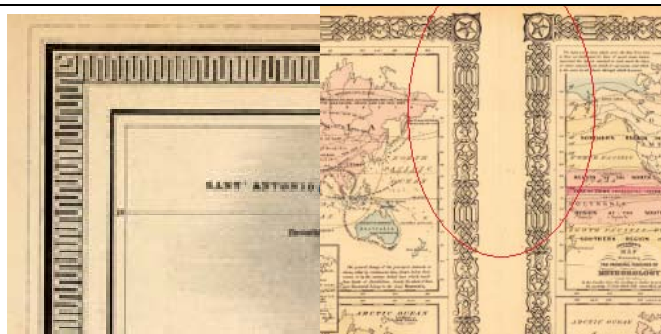
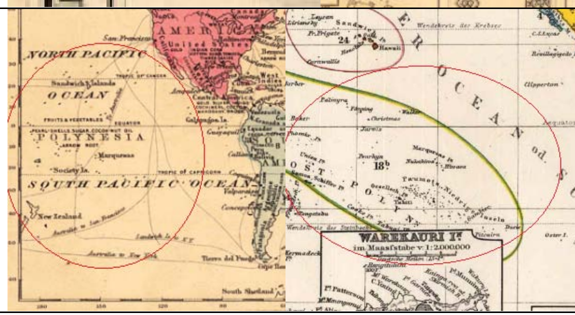
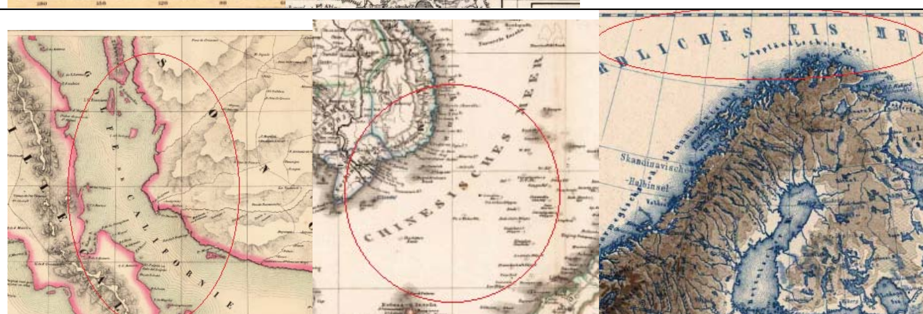
patterns	
contours	
curved	
kerning	

Table 4.13: Lithograph style's visual definition

5. CONCLUSION

5.1 Research Questions and Summary

5.1.1 Question 1: Were the general aesthetic styles of maps produced within the different printing technologies dissimilar enough to say that styles were dependent on the technology?

Both chi-squared tests for independence on the map composition key codes and the aesthetic element key codes indicated that styles were dependent on technology, as noted in Sections 4.1 and 4.2.

5.1.2 Question 2: If aesthetic styles were dependent on technology, what are the notable aesthetic elements that combine to define these styles?

Hierarchical clustering analysis on the map composition key codes showed that while the map composition was statistically dependent on technology, the map composition clusters had minimal stylistic relation to the three examined Technology Eras. Therefore, the map composition key coding did not provide sufficient differences among technologies for use as stylistic defining criteria, as discussed in Section 4.3. However, the aesthetic element clusters closely resembled the three examined Technology Eras, as discussed in Section 4.4., and were used to define three technology styles, as presented in Section 4.5.

5.1.3 Summary

The initial map composition analysis showed that the conventional cartographic design elements have changed notably over time. Woodblock maps included a graticule but no scale, and more than half of the 20 maps were drawn at large cartographic scale. In terms of labeling, all maps that included type used a black letter or *textur* typeface. Copperplate maps began using a graphical scale in addition and north arrows, and while type changed from *textur* to roman and serif typefaces, there was no typeface variation. Lithograph maps included serif and sans serif typefaces and also began using a verbal scale in addition to a graphical scale. Lithograph maps, however, lost the detailed marginalia (e.g., ships, humans, animals) that woodblock and copperplate maps often included. The hierarchical cluster analysis by map composition did not result in clusters representing each of the three technologies. Clustering instead indicated that copperplate maps shared many elements with both woodblock and lithograph maps, suggesting a transition or evolution in map composition complexity from woodblock through copperplate to lithograph, rather than stylistic affordances specific to each technology.

Initial aesthetic element analysis showed that the most common key codes applied to Technology Eras were the following: woodblock: *inconsistent_t*, *i_spacing_t linear_hatching*, *contour_hatching*, and *ink_squeeze*; copperplate: *linear_hatching*, *persistent*, *contour_hatching*, *tapering*, *watercolor*; lithograph: *c_spacing_t*, *c_xheight*, *c_ccapheight*, *thin*, and *consistent_t*. When hierarchical cluster analysis was applied, these key codes also were some of the most frequent key codes within the resulting three clusters, demonstrating a high dependency of aesthetic elements on technology. The top ten most frequent key codes per cluster were as follows: Cluster A (‘Woodblock’): *linear_hatching, ink_squeeze, inconsistent_t, contour_hatching, grainy, i_spacing_t, stippling, curvy, minimal, detailed*; Cluster B (‘Lithograph’): *c_baseline, c_xheight, c_capheight, c_spacing_t, thin, c_spacing_l, fill, linear_hatching, consistent_t, line_fill*; Cluster C (‘Copperplate’): *linear_hatching, fill, detailed, persistent, contour_hatching, tapering, line_fill, saturated, leaking, watercolor.* These were important for the clustering of the technologies because they were the most frequent within each cluster, but there were other key codes that were unique to each respective technology and thus also very important in the clustering of the technologies. Key codes unique to woodblock maps include: *grainy, light_i, ink_squeeze, non_circular, partial, book, stereotype, slot, calligraphy,* *tittle, angular,* and *handcut*. Key codes unique to copperplate maps include: *press* and *pressure_border*. Finally, key codes unique to lithography include: *_g_*, *gradient*, *relief*, *spongy, pattern, contours, curved,* and *kerning.*

Section 4.4 also discussed key codes that were shared only between two specific technologies, which most likely aided in the clustering of the technologies as well. While the shared key codes did provide more insight to the clustering of the key codes and maps, the top ten most frequent key codes per cluster in addition to each technology's unique key codes already provided sufficiently distinct aesthetics that result in clear and definable styles. Additionally, the top ten key codes and unique key codes followed the holistic aesthetic style definition provided in Chapter 1: each Technology Era style is a set of distinctive or characteristic pieces that *together* create the overall aesthetic style. This is noteworthy because while all three Technology Era styles do share some key codes with each other (e.g., *linear_hatching, line_fill*), map elements using those shared key codes within each Technology Era do not look the same because of other key codes that aesthetically define a particular style. For example, *linear_hatching* looks different in the Woodblock Style than the Lithograph Style because a map element using *linear_hatching* within a woodblock also has inconsistent spacing, inconsistent linework, and most likely has a grainy appearance: a combination of key codes that lithograph maps do not contain and are not included within the defined Lithograph Style.

The analysis of the aesthetic element key codes resulted in definition of three aesthetyic styles based on Technology Era. The Woodblock Style is defined using the following key codes: *linear_hatching, ink_squeeze, inconsistent_t, contour_hatching, grainy, i_spacing_t, stippling, curvy, minimal, detailed, partial, fill, light_i, non_circular, book, stereotype, slot, calligraphy, tittle*, and *handcut*. The Copperplate Style comprises the key codes *linear_hatching, fill, detailed*, *persistent, contour_hatching, tapering, line_fill, saturated, leaking, watercolor, press,* and *pressure_border*. Finally, the Lithograph Style consists of *c_baseline*, *c_xheight*, *c_capheight, c_spacing_t, thin, c_spacing_l, linear_hatching, consistent_t, line_fill, _g_, gradient, spongy, patterns, contours, curved,* and *kerning*.

5.2 Limitations and Future Directions

5.2.1 Limitations

This research was limited in several ways. First, digital analysis of scanned maps allowed for more efficient analysis, as the sample maps were accessed through the Internet. However, some aesthetic elements discussed in Chapter 2 related to the feel and dimensions of the paper were not notable on a digital screen. This limitation may have impact the six misclassified maps discussed Section 4.4, as lithograph prints should feel smooth in comparison to copperplate maps (Kortelainen n/d). Additional limitations include the sample size of the maps (20 maps per technology) and the unknown original purpose of maps. Finally, the reliability of the results and interpretation would be improved with comparison of key coding reported in Figures 4.1 and 4.2 to the key coding of a second, independent coder.

5.2.2 Future Research

The QCA revealed several important issues or initiatives regarding aesthetic styles in Cartography that warrant future research. Regarding the abovementioned limitations, additional research should be completed to increase sample size, access paper maps, and enlist multiple coders to compare to this thesis' results. Additionally, similar QCA research should be done not only in terms of technology, but also in terms of regional or national production, to investigate potential region- or country-specific aesthetic styles.

Future research should be completed to leverage the defined aesthetic styles for automation analysis and identification of historical maps. Such research would enable computer recognition of specific aesthetic elements in order to identify the broader style, and thus the technology used to produce the map, the latter of which would be useful in map librarianship. Such an automated process could be used to validate the styles defined in this thesis, as well as provide insight into identifying and defining other aesthetic styles. Finally, human subjects research on emotional responses to different aesthetic styles would provide additional insight on the importance of aesthetics in Cartography.

The research reported in this thesis can be operationalized for professional and student cartographers by creating publicly available tilesets in these styles for use in web map mashups as well as developing tutorials, macros, codes, brushes, and/or other add-ons of important aesthetic elements for use in graphic design software. Providing various ways of recreating the Technology Era Styles in current production methods would aesthetically and stylistically expand maps that are in production today, and also allow for experimentation with, exploration of, and ultimately creation of new aesthetic styles.

5.3 Closing Statement

The switch to Automated Cartography in past several decades allowed for easier, faster, and cheaper data collection and manipulation, in addition to improved efficiency in and accessibility of methods for representing these data in map form. However, as discussed in Chapter 1, the rapidly changing technologies since the 1980s acted to automate not just the collection and analysis of data, but also the design of the maps themselves: software creates less than ideal aesthetics of linework and other map elements. Today, cartographers maintain cartographic design conventions as defined by Robinson, Bertin, and others, but aesthetic design largely has fallen by the wayside, perhaps in part because standard aesthetic styles were never wholly defined. Through identifying and articulating the aesthetic elements of Woodblock, Copperplate, and Lithography Styles in Cartography, this research hopes to provide a start to aesthetic references of design in Cartography, both for use in the education of cartographers, but also for practical cartographic use in whatever digital or paper medium cartographers wish to recreate old aesthetic styles.

In addition to providing aesthetic references for cartographers during map production, this research also supplies a useful base for the utility of aesthetics within cartographic curricula. Discussing the investigation process and resulting styles in this research not only offers an overall understanding of an aesthetic style created through the combination of separate aesthetic elements, but also then provides a teaching and learning base for the critical deconstruction and reconstruction of maps and their composition and aesthetic elements. Whether discussing the aesthetic styles defined in this research or discussing the methodology used to define them, students and professional cartographers alike can benefit immensely by implementing some form of critical aesthetic analysis on not only antique styled maps, but map styles in general (or art styles!). Understanding how to create and recreate desired styles will strengthen the already strong cartographic design techniques and principles cartographers use today.

APPENDIX A: Maps included in the quantitative content analysis.

Ref #	Ref Name	Archive	Map Name	Author	Technology
1	1475 pale	Osher Map Library www.oshermaps.org	Palestine	L. Brandis	woodblock
2	1482 mela	Osher Map Library www.oshermaps.org	Nouellae etati ad geographie viniculatos calles humano no viro necessarios flores aspirari votu bnmereti ponit	P. Mela	woodblock
3	1486 beyd	Historic Cities http://historic-cities.huji.ac.il/	Modon	E. Reuwich	woodblock
4	1493 sched	Historic Cities http://historic-cities.huji.ac.il/	Colonia	H. Schedel	woodblock
5	1511 silvani	Osher Map Library www.oshermaps.org	Secunda Europa Tabula	B. Silvani	woodblock
6	1513 strass	Hemispheres: Antique Maps and Prints www.betzmaps.com	Tabula Moderna Prime Partis Africae	M. Waldseemuller	woodblock
7	1522 von F.	Barry Lawrence Ruderman: Antique Maps Inc. www.raremaps.com	Tabla Nova Orbis	L. Fries	woodblock
8	1535 servet	Antiquariat Reinhold Berg e.K. www.bergbook.com	Tabula XI Asiae	M. Servet	woodblock
9	1550 munster	Historic Cities http://historic-cities.huji.ac.il/	Neapolis	S. Muenster	woodblock
10	1567 malta	Paulus Swaen Old Map Auction and Galleries www.swaen.com	untitled	A. Cirni	woodblock
11	1573 pinar	Historic Cities http://historic-cities.huji.ac.il/	Constantinopoli	S. Pinargenti	woodblock
12	1575 afrique	Afriterra: The Cartographic Free Library http://catalog.afriterra.org	Tabla d' Afrique	A. Thevet	woodblock
13	1598 hey	Afriterra: The Cartographic Free Library http://catalog.afriterra.org	AFRICA	Z. Heynes	woodblock
14	1615 beau	Historic Cities http://historic-cities.huji.ac.il/	Relation iournaliere de voyage de Levani	H. Beauvau	woodblock
15	1675 bian	Historic Cities http://historic-cities.huji.ac.il/	Pola	G.A. Romndini	woodblock
16	1686 coron	Historic Cities http://historic-cities.huji.ac.il/	Misitra o I: Sparta	V. Coronelli	woodblock
17	16s kopp	Historic Cities http://historic-cities.huji.ac.il/	Neuehaeuesel	J. Koppmair	woodblock
18	1702 olfert	Historic Cities http://historic-cities.huji.ac.il/	Betlis	O. Dapper	woodblock
19	1703 solis	Historic Cities http://historic-cities.huji.ac.il/	La ville de Mexique	A. de Solis	woodblock
20	1708 harr	Historic Cities http://historic-cities.huji.ac.il/	Bruxella	J. Harrewyn	woodblock
21	1589 ortel	Princeton University Library http://libweb5.princeton.edu	Maris Pacifici	A. Ortelius	copperplate

22	1612 gerritsz	Princeton University Library http://libweb5.princeton.edu	La Austrialia del Espiritu Santo	H. Gerritsz	copperplate
23	1613 hondius	Hemispheres: Antique Maps and Prints www.betzmaps.com	India Orientalis	J. Hondius	copperplate
24	1613 crimea	Hemispheres: Antique Maps and Prints www.betzmaps.com	TAVRICA CHERSONES: VS Nostra	G. Mercator	copperplate
25	1617 b_h	Historic Cities http://historic-cities.huji.ac.il/	Buda	Braun & Hogenberg	copperplate
26	1621 chls	Antiquariat Reinhold Berg e.K. www.bergbook.com	Channel Islands	J. Speed	copperplate
27	1628 adr	Antiquariat Reinhold Berg e.K. www.bergbook.com	Tribus Gad nempe, sea Terra Sncte pars	C. Adrichom	copperplate
28	1637 leu	Antiquariat Reinhold Berg e.K. www.bergbook.com	Grundtriss der Balagerung und Schlacht vor Leucate in Langue doc	M. Merian	copperplate
29	1643 raig	Historic Cities http://historic-cities.huji.ac.il/	Valletta citta nova diMalta	H. Raignauld	copperplate
30	1650 jahnsson	Princeton University Library http://libweb5.princeton.edu	Mar del Zur Hispanis Mare Pacificum	J. Jansson	copperplate
31	1677 olf.d	Historic Cities http://historic-cities.huji.ac.il/	Aleppo Ean Vermaerde Stadt in Syrien	O. Dapper	copperplate
32	1680 namur	Antiquariat Reinhold Berg e.K. www.bergbook.com	Comitatus Namurci Tabula in Lucem	F. Namur de Wit	copperplate
33	1700 amst	Antiquariat Reinhold Berg e.K. www.bergbook.com	Vertrek Van SKH Na Engeland	Mortier, Cornelius & Covens, Jean	copperplate
34	1720 homm	Historic Cities http://historic-cities.huji.ac.il/	Insular Maltae et Gozae	J.B. Homann	copperplate
35	1727 over	Hemispheres: Antique Maps and Prints www.betzmaps.com	Mapp of Africa	H. Overton	copperplate
36	1737 anon	Historic Cities http://historic-cities.huji.ac.il/	Plan of Sankt-Peterburg	anonymous	copperplate
37	1761 mec	Historic Cities http://historic-cities.huji.ac.il/	Prospetto del Vesuvio	G. Mecatti	copperplate
38	1764 bell	Historic Cities http://historic-cities.huji.ac.il/	Carte du Golphe d'Alexandrette	B. Jacques-Nicolas	copperplate
39	1764 roux	Historic Cities http://historic-cities.huji.ac.il/	Plan du Port de Malte	J. Roux	copperplate
40	1800 stock	Historic Cities http://historic-cities.huji.ac.il/	A Plan of the city of Rome	J. Stockdale	copperplate
41	1807 can	David Rumsey Map Collection www.davidrumsey.com	Upper & Lower Canada	J. Cary	lithograph
42	1816 smo	Antiquariat Reinhold Berg e.K. www.bergbook.com	Smolensko	R. Bowyer	lithograph
43	1825 lac	Antiquariat Reinhold Berg e.K. www.bergbook.com	Lac de Como	L. Kirchof	lithograph
44	1825 van	Antiquariat Reinhold Berg e.K. www.bergbook.com	Baja California	P. Vandermaelen	lithograph
45	1827 schl	Antiquariat Reinhold Berg e.K. www.bergbook.com	Sweden and Norway	Schlieben	lithograph
46	1830 schw	Antiquariat Reinhold Berg e.K. www.bergbook.com	Luzern in Switzerland	Anonymous	lithograph

47	1844 par	Antiquariat Reinhold Berg e.K. www.bergbook.com	Plan von Paris	R. Gross	lithograph
48	1852 isPh	Antiquariat Reinhold Berg e.K. www.bergbook.com	Atlantic Islands Philip	George & Son	lithograph
49	1855 eUS	Antiquariat Reinhold Berg e.K. www.bergbook.com	Special-Karte der Vereinigten Staaten von Nord-Amerika	J. Smith	lithograph
50	1855 pet	Antiquariat Reinhold Berg e.K. www.bergbook.com	Map of the Mer de Glace of Chamouni and of the Adjoining District	A. Petermann	lihtograph
51	1856 pet	Antiquariat Reinhold Berg e.K. www.bergbook.com	CR. r. A Philippi's Erfonschung der sogenannten Wuste Atacama	A. Petermann	lithograph
52	1860 schw	Antiquariat Reinhold Berg e.K. www.bergbook.com	Die Schweiz	C. Flemming	lithograph
53	1862 mE	Antiquariat Reinhold Berg e.K. www.bergbook.com	Tabula Asiae VII	C. Ptolemaeus	copperplate
54	1863 al	Antiquariat Reinhold Berg e.K. www.bergbook.com	Originalkarte zur Uebersicht von Dr. Julius Haast's Reise durch die Suedl, Alpen Neu-Seelands	A. Petermann	lithograph
55	1865 w.J	Antiquariat Reinhold Berg e.K. www.bergbook.com	Johnson's Map the Principal Members of the Animal Kingdom	Johnson and Ward	lithograph
56	1866 w.G	Antiquariat Reinhold Berg e.K. www.bergbook.com	Die Vegetations-Geiete der Erde	A. Grisebach	lithograph
57	1867 e.rav	Antiquariat Reinhold Berg e.K. www.bergbook.com	Oro-Hydrographische Karte Von Europa	L. Ravenstein	lithograph
58	1873 stulp	Antiquariat Reinhold Berg e.K. www.bergbook.com	Die Ostindischen Inseln entw. u. gez	F. Stuelpnagel	lithograph
59	1885 al.L	Antiquariat Reinhold Berg e.K. www.bergbook.com	Ober Wallis, Berner Alpen & Simplongebirge	R. Leuzinger	lithograph
60	1892 nik	Antiquariat Reinhold Berg e.K. www.bergbook.com	Die Insel Nikaria	L. Buerchner	lithograph

APPENDIX B: Map composition key codes used in the first stage of QCA.

ID	Key Codes	Description
ME	**MAP ELEMENTS**	
t	***Title***	
1	t_none	No title
2	tdescription/caption	Includes a description or caption
3	tlarge_type	Title includes large type (the largest type on map)
4	tmedium_type	Title includes medium type (type smaller than the largest type on the map but bigger than the smallest type on the map)
5	tsmall_type	Title includes small type (type is smaller than the rest of the type on the map)
6	Typeface_variation (2+)	Title includes more than one kind of typeface
7	tlegend	Title includes a legend
8	tright	Title is right orientated on the map
9	tleft	Title is left orientated on the map
10	ttop	Title is at the top of the map
11	tbottom	Title is on the bottom of the map
12	thorzcenter	Title is centered horizontally on the map
13	tvertcenter	Title is centered vertically on the map
14	toffcenter	Title is off center on the map
15	tother	Title is some other orientation on the map
im	***Inset Map***	
16	innone	There is no inset map
17	inright	Inset is right orientated on the map
18	inleft	Inset is left orientated on the map
19	intop	Inset is at the top of the map
20	inbottom	Inset is on the bottom of the map
21	inhorzcenter	Inset is centered horizontally on the map
22	in_vertcenter	Inset is centered vertically on the map
23	inoffcenter	Inset is off center on the map
24	inother	Inset is some other orientation on the map
or	***Orientation***	
25	ornone	There is no orientation on the map
26	orarrow	There is a north arrow or other arrow on the map
27	orgraticule	There is graticule on the map
l/t	***Legend/Key***	
28	lnone	There is no legend or key on the map.
29	lright	Legend/key is right orientated on the map
30	lleft	Legend/key is left orientated on the map
31	ltop	Legend/key at the top of the map

32	lbottom	Legend/key is on the bottom of the map
33	lhorzcenter	Legend/key is centered horizontally on the map
34	lvertcenter	Legend/key is centered vertically on the map
35	loffcenter	Legend/key is off center on the map
36	lother	Legend/key is some other orientation on the map
37	llargetype	There is large type within legend/key
38	lmediumtype	There is medium type within legend/key
39	lsmalltype	There is small type within legend/key
s	***Scale***	
40	snone	There is no scale on the map
41	sverbal	There is a verbal indication of scale on the map
42	sgraphic	There is a graphical representation of scale on the map
43	sright	Scale is right orientated on the map
44	sleft	Scale is left orientated on the map
45	stop	Scale at the top of the map
46	sbottom	Scale is on the bottom of the map
47	shorzcenter	Scale is centered horizontally on the map
48	svertcenter	Scale is centered vertically on the map
49	soffcenter	Scale is off center on the map
50	sother	Scale is some other orientation on the map
51	ssmallscale	The map is small scale (zoomed out/small objects).
52	slargescale	The map is large scale (zoomed in/large objects)
53	sextremelylargescale	The map is very zoomed in/very large objects
n/b	***Neatline/Border***	
54	nlnone	There is no neatline or border
55	nlminimal	The neatline/border is minimal (not intricate); one line or parallel lines
56	nldecorative	The neatline/border is intricately detailed, whether in linework or pattern, or added characters or colors
57	nlother	The neatline is something other than minimal or decorative
to	***Type (Overall Map)***	
58	tonone	There is no type within the map
59	toextensive	More than half to all of the map objects are labeled (ex: countries, rivers, mountains, ocean, cities, etc)
60	tolimited	Only basic reference labels: countries, cities, meridians, and oceans are labeled
61	toextremelylimited	Less than 5 basic reference labels
62	tomix	There are multiple sizes of type
63	tomaj "large"	The majority of the type on the map is the largest type on the map
64	tomaj "medium"	The majority of the type on the page is smaller than the largest type on the map but bigger than the smallest type of the map
65	tomaj "small"	The majority of the type on the map is the smallest type on the map
66	totypeface_variation (2+)	There is more than one type used within the map
OD	**OVERALL DESIGN**	
67	odextremely minimal	Only country borders, no labels, no decorative elements

68	odminimal	Overall design is minimal; a lot of negative space exists on the map; linework only for basic map elements (countries, cities, borders)
69	oddecorative	There is more than just basic linework of countries, cities, and borders; pictorial symbols, color and variance in color, texture, and patterns are used in over half the map elements: there are most likely characters included in the water, land, or periphery (such as ships, animals, humans, etc).
70	odextremely decorative	All the map elements include intricately detailed lines and shading, in addition to more complicating shadings with color (such as gradient); there is no negative space because all map space is filled with intricate with linework or color
71	odbalanced	Map is easy to read, whether it is minimal or decorative or extremely decorative
72	odcluttered	Map is hard to read because of overlapping or indistinguishable elements or objects
73	odpage indent (fold, book)	The map page has a page line indent
MR	**MARGINILIA**	
w	***Water***	
74	cwnone	There are no characters in the water
75	cwmonsters	There are monsters in the water
76	cwboats/ships	There are boats or ships in the water
77	cwother	Something else is in the water
78	cwless than 5	There are less than 5 characters in the water
79	cw5 to 10	There are between 5 and 10 characters in the water
80	cw10+	There are more than 10 characters in the water
81	cwright	The characters in the water are on the right side of the map
82	cwleft	The characters in the water are on the left side of the map
83	cwtop	The characters in the water are on the top of the map
84	cwbottom	The characters in the water are on the bottom of the map
85	cwhorz center	The characters in the water are horizontally centered in the map
86	cwvert center	The characters in the water are vertically centered in the map
l	***Land***	
87	clnone	There are no characters on land
88	clhumans	There are humans on land
89	clhorses	There are horses on land
90	clother_animals	There are other animals on land
91	clother	Something else is on land
92	cllessthan5	There are less than 5 characters on land
93	cl5to10	There are between 5 and 10 characters on land
94	cl10+	There are more than 10 characters on land
95	clright	The characters on land are on the right side of the map
96	clleft	The characters on land are on the left side of the map
97	cltop	The characters on land are on the top of the map
98	clbottom	The characters on land are on the bottom of the map
99	clhorz center	The characters on land are horizontally centered in the map

100	clvert center	The characters on land are vertically centered in the map
p		***Periphery***
101	cpnone	There are characters in the periphery
102	cphumans	There are humans in the periphery
103	cphorses	There are horses in the periphery
104	cpother_animals	There are other animals in the periphery
105	cpother	Something else is in the periphery
106	cplessthan5	There are less than 5 characters in the periphery
107	cp5to10	There are between 5 and 10 characters in the periphery
108	cp10+	There are more than 10 characters in the periphery
109	cpright	The characters in the periphery are on the right side of the map
110	cpleft	The characters in the periphery are on the left side of the map
111	cptop	The characters in the periphery are on the top of the map
112	cpbottom	The characters in the periphery are on the bottom of the map
113	cphorz center	The characters in the periphery are horizontally centered in the map
114	cpvert center	The characters in the periphery are vertically centered in the map

APPENDIX C: Aesthetic element key codes used in the second stage of QCA.

ID	Key Codes	Description
		Ink
1	highlight	color and/or ink creating distinct highlighting within map design element
2	spongy	soft painted area that appears painted by a sponge
3	patchy	ink within map design element is not consistent, similar to pixelation
4	blue	Map design element is of this color
5	yellow	Map design element is of this color
6	pink	Map design element is of this color
7	tan	Map design element is of this color
8	red	Map design element is of this color
9	orange	Map design element is of this color
10	green	Map design element is of this color
11	inner_glow	Map design element contains a heavier or thicker line following the area or outline of the element
12	desaturated	Color is light and soft: not very saturated
13	leaking	Color goes outside the lines or intended area of color
14	watercolor	Paint/ink is watercolor
15	gradient	A gradual continuous change in color
16	dry	Color created with watercolor using a dry brush
17	press	Ink/color pressed in a specific space, most likely leaking and not necessarily entirely filled
18	deliberate	Deliberate placing of color in very specific small area of detail
19	saturated	Saturated color/ink; strong in color
20	grainy	wood grain showing through printed ink
21	light_i	Light in color: similar to desaturated, but not as light as desaturated
22	splotchy	Watercolor differences; sudden circular changes in saturation due to painting with water color
23	ink_squeeze	Ink squeeze as described in Section 2
24	mixing	Mixing of two colors, generally on accident due to leaking
25	black	not related to line_fill: the actual color black painted on
26	white	Map design element is of this color
27	brown	Map design element is of this color
28	_bw_	Map is in black and white only
29	dotty	Lithograph coloring – similar to a graininess in the coloring
30	purple	Map design element is of this color
31	_g_	Greyscale coloring of map
32	grey	Map design element is of this color
		Tool
33	varying	Variance in lines and design of element
34	thin	Thin line – used when very notable difference in comparison to rest of lines
35	thick	Thick line – used when very notable difference in comparison to rest of map
36	irregular	Uneven; not continous

37	inconsistent_t	Similar to irregular, but used specifically for lines – especially when lines suddenly stop, are not smooth, etc
38	persistent	Lines are more than inconsistent but not as consistent as consistent; sometimes still vary
39	consistent_t	Always same thickness, no sudden stops
40	i_spacing_t	In consistent spacing in map design elements
41	c_spacing_t	Consistent spacing in map design elements
42	dotted	Dotted line
43	linear_hatching	Hatching using generally straighter lines
44	square	Square in appearance
45	non_circular	Design clearly meant to be circular, but isn't perfectly circular
46	straight	Line is perfectly straight
47	stippling	Dotty or quick linear repetitive lines, usually in an area
48	contour_hatching	Hatching using rounder lines, but still more linear in appearance
49	tapering	Lines vary in thickness, but consistently
50	rippling	Undulating lines that repeat after each other; appears like ripples in water
51	pointy	A pointy appearance
52	cross_hatching	Hatching that has continuous perpendicular crossing of lines
53	wavy	Undulates more than curvy: more likely to change direction or steepness of curve quickly
54	fill	An object that is filled
55	line_fill	An object that is filled with lines instead of color
56	angled	Angled lines, as opposed to horizontal or vertical: in reference to shading and line_fill
57	curvy	More consistent undulating lines; do not change abruptly
Form/Description		
58	subtle	Faint and slight differences in appearance that aren't quickly noticeable but do add to the general aesthetic
59	depth	Creating more than a flat appearance
60	minimal	Minimal appearance; not very detailed
61	frothy	Appearing like the froth of waves
62	patchy	areas where ink did not adhere to paper; sporadic, not continuous
63	detailed	intricate
64	foreground_detail	More intricate in the foreground of a map
65	ribbon	Writing that has a ribbon behind it
66	expressive	Characters that show emotion on their face
67	plaque	Writing that has a plaque behind it
68	decorative	Anything ornamental or embellishing in addition to detailed
69	partial	Limited; not complete
70	book	A part is part of a book (such as the legend)
71	armed	Humans with guns/arms
72	cannons	The weapon
73	repetitive	Repeats more than 3 times

74	action	Characters in obvious movement
75	smoke	Obvious depiction of smoke
76	blocks	The creation of blocks through linework
77	soft	Similar to subtle in faint appearance, however, also more blurred in appearance
78	pressure_border	Aesthetic element as defined in Section 2
79	pattern	Repetitive areas or linework
80	contours	Map contour lines
Type		
81	block	In reference to the appearance of type; blocky time
82	curved	Type that is curving, such as across a mountain range
83	kerning	Kerning in type
84	roman	Roman, as in type
85	regular	Regular, as in type
86	italic	Oblique, as in type
87	stereotype	Aesthetic element as defined in Section 2
88	slot	Slot, as defined in section 2
89	c_baseline	Baseline of type: consistent straightness of bottom portion
90	c_xheight	Of type: consistent straightness and height of certain parts of characters
91	c_capheight	Of type: consistent straightness and height of top portion
92	i_baseline	Baseline of type: inconsistent straightness of bottom portion
93	i_xheight	Of type: inconsistent straightness and height of certain parts of characters
94	i_capheight	Of type: inconsistent straightness and height of top portion
95	c_lettering	Of type: consistent repetition of the same exact letter shape and size across the use of the type
96	i_lettering	Of type: inconsistent repetition of the same exact letter shape and size across the use of the type
97	calligraphy	As in, calligraphy type
98	black_ letter	Black letter, as defined in Section 2
99	serif	Serifed type
100	sans_serif	Sans serif type
101	tittle	The dots of type, such as in 'i' and 'j', when they are NOT perfectly circular; as defined in Section 2
102	caps	All uppercase letters
103	lowercase	All lowercase letters
104	minimal_spacing	of type: minimum space between letters
105	textur	As defined in Section 2
106	i_spacing_l	Of type: inconsistent spacing between letters within a word and between words
107	c_spacing_l	Of type: consistent spacing between letters within a word and between words
108	handcut	Of type: as defined in Section 2
109	multiple	Multiple typefaces used within one map
110	angular	Of type: no smooth curve; angular curves
111	cursive	Cursive type – not calligraphy; round, connecting letters

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