Dating Old Maps with the Print Clock

By S. Blair Hedges

INTRODUCTION

The print clock is a method for dating early prints and maps that were produced by woodblocks and copperplates but which are poorly dated or undated. When a print is contained within an undated book, such as an atlas, it is possible to date the book. Prints produced before the invention of the printing press can be dated with this method, but it is most likely to be used with printed material produced by hand-operated presses between the mid-15th and mid-19th centuries. Any print, ranging from a centimeter-sized book ornament to a large wall map, can be used. Here I provide a brief overview of the method, and how it was used to date an undated 16th century atlas. Additional details can be found in the original description of the method (Hedges 2006).

In woodblock printing, the illustration to be printed forms raised relief which holds ink that is transferred to the paper. In early print shops this was accomplished with a large screw press (Fig. 1), although the pressure applied was not great and the same result can be obtained by laying the paper on the inked block and rubbing the surface. In printing from metal plates, usually copper, the illustration forms a depression in the metal—made by engraving with a steel burin or etching with acid—and paper is pressed into the ink-filled grooves to obtain a print. In this case, the more pressure was needed to force the paper into the narrow grooves, and the copperplate printing press consisted of a large roller to obtain that required pressure (Fig. 2).

The print clock is based on the hypothesis that woodblocks and metal plates (e.g., copperplates) deteriorated in a clock-like manner during their lifespan, which was often decades. In woodblocks, the deterioration occurred mainly with aging and random cracking of the wood relief, resulting in line breaks in the prints. In copperplates, grooves in the metal became thinner as the surface was polished before each print run, resulting in thinner lines and an overall faded appearance in the print. By measuring this change across different dated editions of the same print, it is possible to estimate the age of the undated work.

After an artist or cartographer produced the original drawing, a second person—an engraver—had to be hired to carve the woodblocks or engrave the metal plate. Consequently, woodblocks and copperplates were expensive to produce, which is why they were typically re-used for later editions despite their obvious deterioration. Remarkably, some blocks and plates are known to have been used for more than 100 years. For example, the same copperplates used to produce the maps in *L'Isole piu famose del Mondo* (Porcacchi 1572) were used 141 years later in *Universus terrarum orbis* (Savonarola 1713). However, by then most of the engraved lines had been touched up (re-engraved) at least once.

The print clock can be classified as a "probabilistic clock," a group that includes the radiometric clock that geologists use to date rocks and molecular clock that biologists use to date species divergences. The atomic clock used to measure global time differs in being a regular (deterministic) clock based on cyclic events at the molecular level (cesium atoms), and in that sense is similar to a mechanical clock or watch.

But how would random events such as the cracking of wood lead to clock-like change? Certainly, cracks—and corresponding line breaks in prints—did not occur at a regular rate, such as one per month. Several may have occurred in one year and none in the next year. That is the nature of random events. Radioisotope decay is also random, yet it is used as a clock with a relatively high degree of precision. As long as the average rate is unchanged, and a large number of events is sampled, probabilistic clocks can be excellent chronometers.

Like all clocks, the print clock must be calibrated. However, this does not mean that it is only useful for

Figure 1. An early book printing shop illustrated in a copperplate print by Stradanus (1590). Woodblock prints, including maps, that appeared in books were printed in shops like this one. From an original in the author's collection.

dating different editions of the same book, print, or map. Early printed books, including atlases, typically contained artwork in the form of a printer's mark (trademark), title page ornamentation, enlarged letters, and decorative elements (headpieces and tailpieces) and these often appeared in multiple books produced by the same printer and authored by different persons. Thus a single surviving copy of a rare book could be dated using this method, as long as other books by the same printer were available for comparison.

In describing the print clock method (Hedges 2006) I focused on several Renaissance atlases. I examined 2,674 prints (maps) mostly from multiple copies and editions of two "isolario" atlases (Italian books of island maps), the *Isolario* (Bordone 1528) and *L'isole più famose del mondo* (Porcacchi 1572), and a Ptolemy atlas, *Geographiae* (Magini 1596). I selected the Bordone atlas, which contains woodblock maps, because I wished to date the undated edition. I selected the other two atlases, both with copperplate maps, to see whether the observed change in copperplate prints across editions was also time-dependent.

THE WOODBLOCK CLOCK

Benedetto Bordone (ca. 1450–1530) was primarily a miniator, or book illuminator, although he also designed woodcuts and was a cartographer. He applied to the Venetian Senate in 1508 for a privilege (copyright) to print a map of the world, presumably globe gores, but no copies of it have survived. He is mostly known, at least among cartographic scholars, for his *Libro de tutte L'Isole del Mondo* ("*Isolario*") printed in Venice in 1528, which

Figure 2. An early copperplate printing shop illustrated in a copperplate print by Stradanus (1590). Copperplate prints, including maps, were printed using a large rolling press as shown in this illustration. From an original in the author's collection.

contains 112 different prints, almost all of which are maps of islands. The maps are mostly small (145 x 85 mm) and simple, but are aesthetically pleasing and have bold outer neatlines and narrow inner neatlines. Many of them are the first separately printed maps of various islands, including those in the West Indies (a region where I conduct biological research). The book was reprinted in Venice, essentially unaltered, in three later editions all bearing a new title: *Isolario di Benedetto Bordone*. Two of those later editions were dated, 1534 and 1547, but another edition has no date.

I first became interested in dating old prints several years ago when I noticed that there was considerable confusion over the date of the undated edition of the *Isolario*. Scholars had debated the date of that book since the early 1800s, arguing for dates ranging from 1537 to 1570, based mostly on the period of activity of its printer, Francesco de Leno of Venice. Even today, some libraries assign a date of 1537 and others 1561–1567 for this undated edition. The latter estimate was based on a "short title" survey by the British Museum, which listed only a few books by de Leno. But the survey was inadequate because de Leno published at least 37 books between 1542 and 1570, although most of them were between 1559 and 1570.

Admittedly, correctly dating this book would not be an earth-shaking discovery with broad implications. However, it led me to realize that there was an entire class of information contained in these old printed documents that was largely overlooked by scholars. I could see that the prints from the undated edition had considerably more line breaks than those from the 1547 edition, indicating—

unambiguously—the relative order of the editions (i.e., it was printed after 1547). Such relative dating had been done before with other books. But as a biologist who often applies a "molecular clock" to the dating of divergences among species, I considered the possibility that there may be a "print clock" which could provide additional accuracy in dating beyond relative order. Just as genetic mutations accumulate randomly in the genomes of organisms, perhaps the breaks in woodblock relief, which caused line breaks in prints, accumulated in a similar, random fashion.

During the next year I ended up examining 23 copies of Bordone's *Isolario* in various rare book libraries. In each case, I visually inspected the 112 different prints (2,576 prints total) for line breaks, which were gaps of any width in a line. I quickly realized how to distinguish false gaps in occasional under-inked prints (they have speckling and fuzzy boundaries) and over-inked prints (unusually thick, bulging lines) that should not be scored, and I did not score microscopic breaks (e.g., < 0.5 mm) caused by drying of the ink on the paper. Hairline breaks in the relief may have been present but they would not likely be expressed in the print because the ink would have filled in such small gaps before it dried. Also, I found no evidence that the woodblock damage was repaired by the printer, as sometimes was the case in early print shops, which would have caused line breaks to "disappear" in later prints. Instead, I found a logical progression of line breaks, increasing in number with time across dated editions of the book, which also suggested that I was scoring real line breaks and not artifacts from under- and over-inking of blocks.

The results (Fig. 3) showed that line breaks accumulated in a time-dependent fashion across the three dated editions of the *Isolario*. Using this relationship and rate of change, and the number of line breaks in the undated edition, I was able to date the latter to 1565 plus or minus about 15 months. Then, independently, I used the printer's mark on the title page of the undated *Isolario* for the purpose of dating. Although small (50 x 58 mm), it was a complex illustration with many lines that showed deterioration across dated books by that printer. I photographed a total of 20 prints in seven of the nine known books by de Leno having that particular mark, including the undated *Isolario*.

Because of the complexity and small size of the printer's mark, I used digital image analysis software to obtain a quantitative measure of change among different prints. After converting to black and white pixels by a process called "thresholding" I made six different types of measurements, including gray level (number of black versus white pixels) and fractal dimension (a measure of image complexity). After averaging all of these measures into a single deterioration index I was able to date the undated Isolario to 1565 plus or minus 12 months. The fact that both applications of the print clock method, completely independent of one another (using different prints), arrived at the same date (1565) convinced me that the print clock method worked and was probably generally useful. I also conducted an extensive watermark analysis of the *Isolario* and 40 other books by that printer, but as expected the results were inconclusive because all of the watermarks in the *Isolario* were unique.

After dating the undated *Isolario*, I wondered if anything else could be concluded from application of the method. I then realized that if the regression line were to be projected backward in time until it intersected the X-axis of the graph, by definition that would be the time when there were no breaks in the woodblocks. Intuitively you might think that the blocks should be perfect when used in the first edition, but in this case the prints from 1528 (first edition) had a considerable number of line breaks, indicating—at least according to the print clock hypothesis—that they had already aged some years. I dated the creation of the woodblocks at 1518 plus or minus 15 months (Fig. 3), which was a full ten years before they were used in the first edition. Because creating the woodblocks was a financial investment that normally would require selling the book to recover, this ten year gap was unexpected. However, contemporary documents show that Bordone's blocks were carved at least by 1521, with the exception of a single illustration of Temistitan probably added after 1524. The cartographic knowledge shown in his maps, including his famous oval world map, also dates from the first two decades of the 16th century. All but a very small fraction of actual Renaissance woodblocks have survived over the centuries (most were discarded or used as firewood), and therefore a method that can date the creation of the art or map in the wood opens up new possibilities.

The alternative and usual explanation for the accumulation of gaps in woodblock relief and their corresponding breaks in printed lines is that they occurred from damage during the process of printing, such as from the pressure of the printing press. Because this is

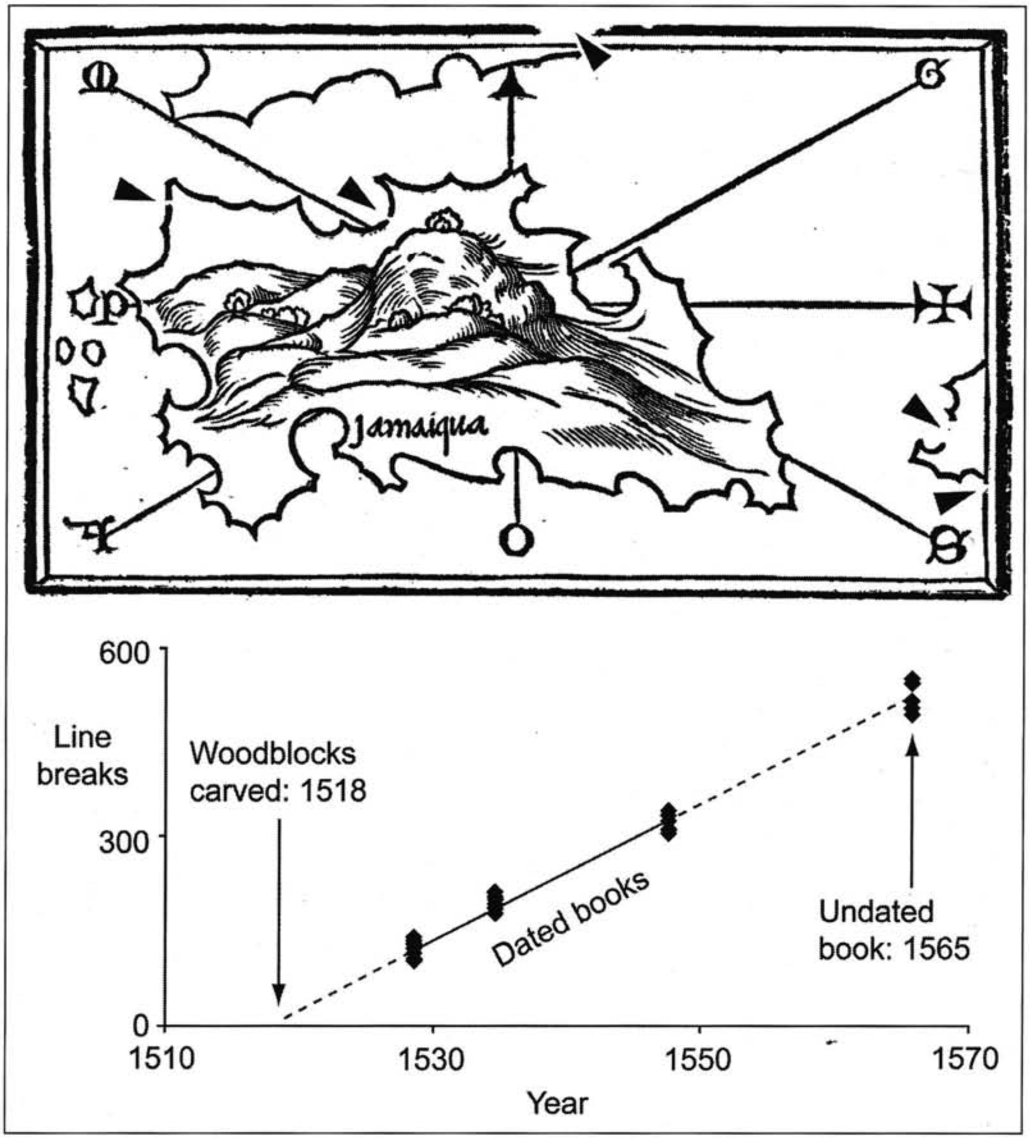

Figure 3. The first separate map of Jamaica, from Bordone's *Isolario* (1528). Line breaks in the print (arrowheads) are from gaps in the woodblock relief. The date when Bordone's woodblocks were carved and the date of an undated edition of the book have been debated by historians. The print clock indicates that the blocks were carved in 1518, a decade before they were first used, and also dates the undated book to 1565. Map from an original in the author's collection.

mentioned in all of the classic references for analytical bibliography—the field dealing with physical changes in books and printed matter—and is logical, I realized that it was my obligation to provide sufficient evidence to reject that alternative hypothesis. Using statistical tests with the line break data, I was able to do just that. I showed that the line breaks were statistically clumped, being associated with specific editions. According to the classical model, this would not be the case; the last print from one edition should have about the same number of line breaks as the first print of the next edition, no matter how many years had transpired between editions.

Schedel's *Nuremberg Chronicle* contained a large number of woodblock prints—including an important "pre-Columbus" world map—and, indirectly, offers some evidence bearing on these two hypotheses. Both editions appeared in 1493 and were printed concurrently, overlapping by about six months. The blocks were created about two years prior to that, so the total amount of time between creation of blocks and final printing was only a few years (Reske 2000). Yet the number of copies of the book made was unusually large (~2,500) for that time period. A total of 652 different woodblocks were created to produce 1,804 illustrations, and therefore many woodblocks were used multiple times in the book. Thus, in some cases up to 27,500 impressions were made from a single woodblock. Given this background, the classical hypothesis would predict that the *Chronicle* woodblocks should show a large amount of "wear" (line breaks) in the prints, especially in the second (German) edition, because of the large number of impressions made. Alternatively, the print clock hypothesis would predict that there should be very little deterioration of the woodblocks because of the short time period that they were used. It is too soon to draw any firm conclusions until a comprehensive and quantitative study is made of line breaks in the *Nuremberg Chronicle* woodblocks. Nonetheless, the most extensive study thus far (Reske 2000) has concluded that the woodblocks (as evidenced in the prints) underwent remarkably little deterioration during the printing of the *Chronicle*.

THE COPPERPLATE CLOCK

While woodblocks use relief to transfer ink to paper, copperplates have narrow (one-tenth of a millimeter wide, on average) grooves where the ink sits and is transferred to paper when the two are pressed together. Copperplates are obviously quite different from woodblocks, yet my preliminary observations showed that maps printed from the same plate in later editions appeared faded (paler), suggesting a possible copperplate clock. The fading of course is not from exposure to light over the centuries but from changes in the metal plate itself, hence they appeared faded on the day they were printed.

To test the print clock hypothesis I selected two Italian Renaissance atlases (Porcacchi 1572; Magini 1596) that are common enough in rare book libraries that I could get a large enough series for statistical resolution. The Porcacchi atlas was printed in five editions over 48 years (1572–1620), mostly without retouching of the plates. Two later editions (1686, 1713) are scarce and involved considerable retouching of the plates, so I omitted them. The Magini atlas was printed in three editions over 25 years (1596–1621), excluding the pirated edition of 1597. In both cases, editions were not evenly spaced in time, which allowed me to test the print-dependent (classical) and time-dependent models (print clock).

For scoring change in copperplate prints I subjected digital photos to image analysis, comparing gray scale values. To my surprise, the plot of gray scale versus time resulted in a virtual straight line (Fig. 4). Again, statistical tests rejected the classical model of change in favor of time-dependency. It was not immediately obvious why copperplates should "fade" with time, although I had a hunch that it had something to with the corrosion of metal, known to be a time-dependent process. First I had to compare prints from two editions under high magnification to determine exactly what was causing the fading. When I did this, it was clear that the lines were becoming thinner in later editions (rather than becoming faded), and engraved lines were thinning faster than etched lines (Fig. 5). After studying printer's manuals from the 16th and 17th centuries, such as the one by Bosse (1645), I was able to reconcile the different pieces of information into a single hypothesis to explain the copperplate print clock.

Buried in the old printer's manuals was a little known secret of the trade: copperplates that were to be re-used after years of storage had to be polished to remove the corrosion that built up over time, otherwise the corrosion would pick up the ink and be printed. This polishing was not like what you would do to a brass doorknob, but involved some major removal of metal from the surface using stones, charcoal, and other abrasives. Because a typical engraved line in the copper may be only one-twentieth of a millimeter deep, any amount of polishing would make the lines shallower. If grooves had straight walls, polishing the surface would not alter the width of the groove or resulting line in paper. However, engraved and etched grooves both are tapered, meaning that shallower grooves are necessarily thinner, which would explain the faded appearance of prints from later editions.

Again, the current literature in analytical bibliography explains the fading of copperplate prints in later editions as damage (compression) of the metal plate from the pressure of the rolling printing press. But the Porcacchi and Magini data that I collected argued against such a print-dependent explanation. In addition, even if plates were being compressed by the printing press, physics dictates that the engraved grooves would get wider, not narrower, and thus print wider lines in prints, something that is not observed. In other words, when you flatten a ball of pizza dough it expands in width and copper is no different. A copper penny placed on a railroad track will become flatter and wider after it is compressed by a train.

But because of the widespread notion that the printing press is the agent of change, and despite the logical arguments against it, I decided to conduct a simple test. I engraved lines with a burin on two small copperplates, subjected one to polishing of the surface and the other

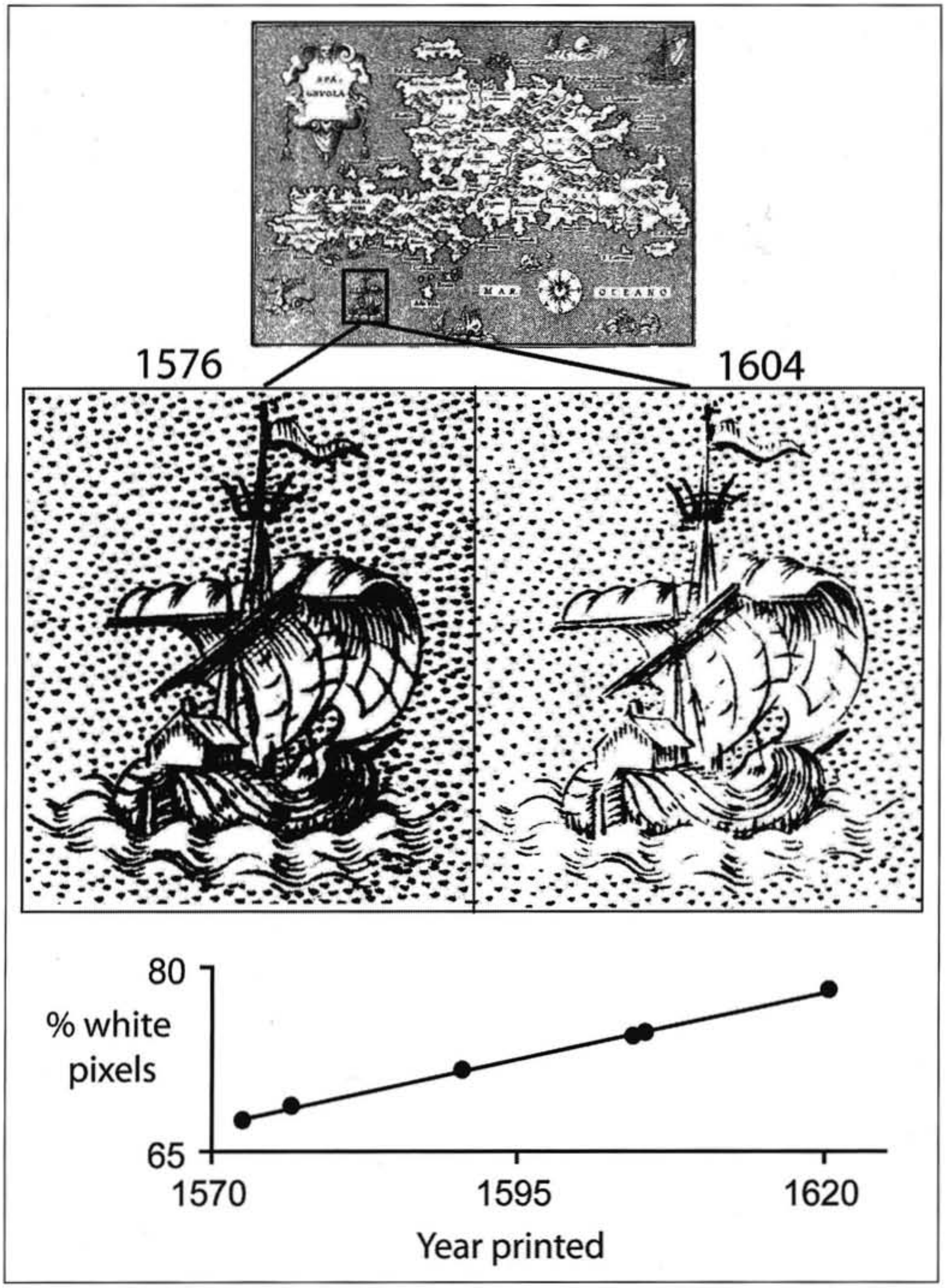

Figure 4. Time-dependent change in copperplate prints. Close-ups of a small section (one-half inch wide) of the map of Hispaniola from two editions of an Italian Renaissance book by Porcacchi illustrate time-dependent image fading. The graph shows mean gray-level data for two prints, Cuba and Hispaniola. Map from an original in the author's collection.

to compression, and then measured the change in the width of the grooves. The grooves were measured using a microscope fitted with an ocular micrometer. The result essentially proved the obvious: polishing the surface of the plate made the grooves thinner and compression of the plate made them wider (Fig. 6). Because real copperplate prints and maps have thinner—not wider—printed lines in later editions, the claim in the literature that the printing press flattened copperplates, creating paler prints, was flatly rejected. Instead, it appears that the

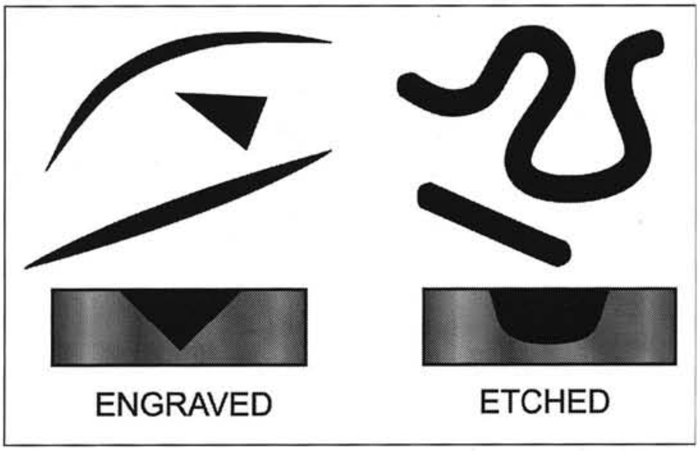

Figure 5. Characteristics of engraved and etched lines. Examples of lines in copperplate prints and maps are shown above enlarged cross-sections of corresponding copperplate grooves. Each line and groove is about one-tenth of a millimeter wide. Engraving is done with a steel burin that leaves a triangular-shaped groove and produces tapered lines with sharp points and gentle curves. Etching is done with acid and usually results in lines of even width and blunt ends, and which often make sharp bends. Etching is easier to do but harder to show detail. Most copperplate maps combine both methods: etching usually for neatlines and other bold internal lines of the image as well as lettering, with engraving for fine details.

time-dependency comes from corrosion building up over intervening years between print runs, which was eroded off (polished) before the prints were made.

FUTURE DIRECTIONS

The notion that line breaks in woodblock prints and thinning of lines in copperplate prints could have been caused by anything other than the printing process is a new concept that will rightly cause some skepticism. Although all of the data and analyses so far show that changes in the devices used to make prints and maps occurred over time (Fig. 7), and not from printing, more case studies would be helpful. For example, did rates of change vary depending on the region (e.g., southern versus northern Europe)? Can rates of change be extrapolated from one print to another to date a unique example? Concerning woodblocks, one possibility for this might be to use a neatline clock, because these borderlines are almost the only aspect of relief in common between different maps or different prints. If the rate of line breaks in neatlines of different prints shows some consistency, it might justify the use a common rate to date an undated print.

The online bibliographic resource *WorldCat* lists slightly over three million different books printed by hand operated presses between 1450 and 1830. The actual number is unknown but certainly larger. The fraction of those that are undated or poorly dated is difficult to estimate precisely but is probably between 10% and 30%,

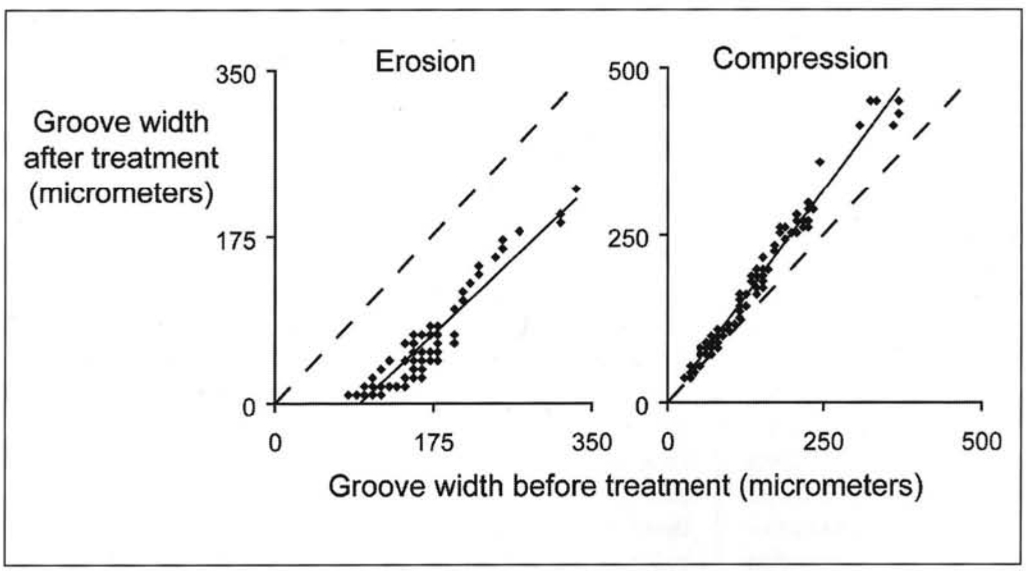

Figure 6. Graphs showing the results of two treatments applied to engraved copperplates. Dashed lines indicate the position of data points if no change occurred (1:1 slope). After erosion (polishing) of the surface, grooves are thinner (below dashed line) and this corresponds to the narrowing of lines of copperplate prints from later editions. After compression, grooves are wider (above dashed line), which does not agree with what is seen in real prints. This demonstrates that the fading (paling) of copperplates was not caused by compression—the widely held assumption—but rather by erosion of the surface. One micrometer is one thousandth of a millimeter.

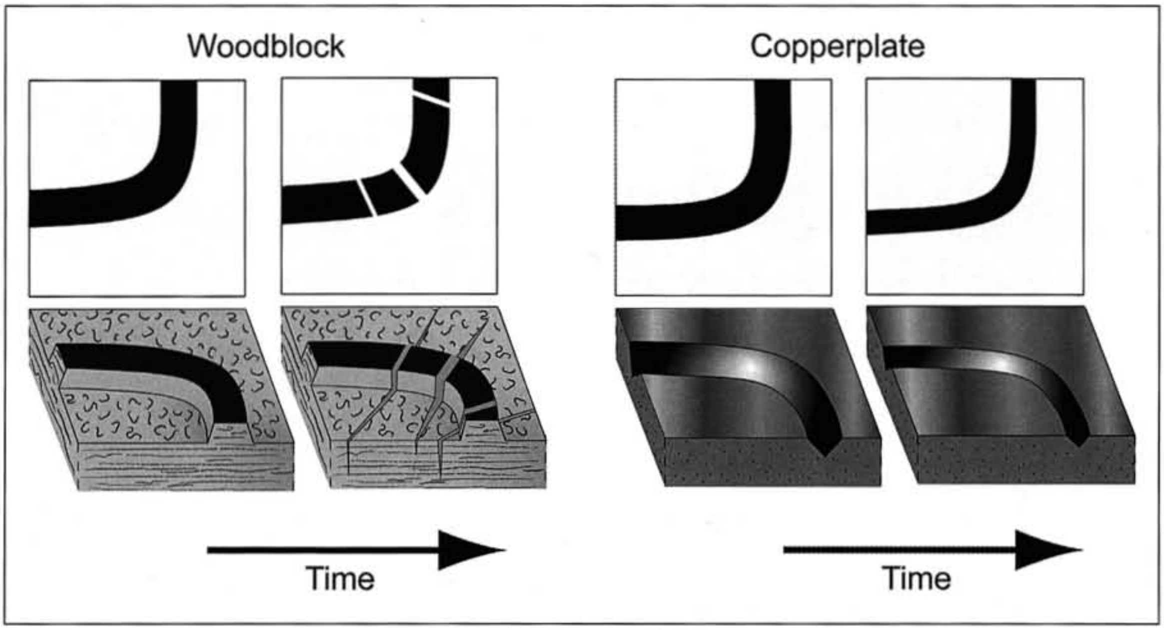

Figure 7. The print clock hypothesis. In these models, close-ups of a carved woodblock (above) and engraved copperplate (below) are shown, corresponding to a curved black line on the print behind it, at two time periods. Over time, cracks develop in the woodblock resulting in line breaks on prints. With copperplates, erosion of the surface produces thinner groves and thinner lines in prints. For both, the change is time-dependent.

or as many as one million books. A large but unknown number of loose maps and prints are likewise undated or poorly dated, including some of historical importance such as the early 16th century wall map that named America, by Waldseemüller, supposedly printed in 1507. It is too early to predict how useful the print clock method will be in dating these many undated documents. Some questions may require a combination approach using multiple dating methods to obtain a robust answer. Nonetheless, the early evidence is that the print clock is capable of providing new insights into historical questions.

—S. Blair Hedges is professor of biology at Pennsylvania State University where he teaches evolution. He has authored 190 research articles, many involving the dating of species divergences with molecular clocks. Earlier in his career he held a position involving mapping at the U.S. Geological Survey in Reston, Virginia, and has had a life-long interest in maps, especially of the Caribbean and its islands. This article is based on a presentation to the Washington Map Society on April 19, 2007.

ADDITIONAL INFORMATION

The original article describing the method, including a separate electronic appendix:

http://evo.bio.psu.edu/hedgeslab/Publications/PDF-files/176.pdf (article)

http://evo.bio.psu.edu/hedgeslab/Publications/PDF-files/176a.pdf (appendix)

A web site containing practical information for conducting a print clock analysis:

http://evo.bio.psu.edu/printclock/

A database of map images of the West Indies, maintained by the author:

http://evo.bio.psu.edu/caribmap/

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