Warping Waldseemüller: A Phenomenological and Computational Study of the 1507 World Map

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Abstract
The 1507 World Map by Martin Waldseemüller shows, for the first time, a depiction of the New World as a separate landmass detached from Asia. This study compares the outline of South America on the Waldseemüller map using several related computational methods. First, the projection is analysed, modelled, and compared with the modern outline of South America, which is found to be tantalizingly similar in form and location to the 1507 representation. Second, polynomial warping algorithms of the second order are applied to the world map and spatial interpolations are carried out. The newly produced regression surfaces and curves are analysed for inflection-point behaviour, and global and local correlation coefficients are calculated to give some indication of the geometric similarity between the 1507 and modern forms. The shape and location of the South American continent on the 1507 map is chronometrically problematic, since neither Balboa nor Magellan had reached the Pacific Ocean by this time. The study concludes that, based on these interpolations, it is probable that Waldseemüller had geographic information that is no longer extant or has yet to be discovered for his 1507 portrayal of the New World.

Keywords: Waldseemüller, polynomial warping, bi-dimensional regression, projection modelling

Résumé
La Carte mondiale de 1507 de Martin Waldseemüller a été la première à représenter le Nouveau Monde en tant que masse continentale indépendante, détachée de l'Asie. Dans l'étude, on examine la silhouette de l'Amérique du Sud telle qu'elle apparaît sur la carte de Waldseemüller à l'aide de plusieurs méthodes informatiques connexes. Premièrement, la projection est analysée et modélisée, puis comparée à la silhouette moderne de l'Amérique du Sud, qui est étonnamment très similaire à la forme et à l'emplacement de celle illustrée sur la carte élaborée en 1507. Deuxièmement, on a appliqué des algorithmes de déformation polynomiale de second ordre à la Carte mondiale et on a effectué des interpolations spatiales. Les aires et les courbes de régression ainsi produites ont été analysées en fonction des points d'inflexion, et des coefficients de corrélation globaux et locaux ont été calculés pour obtenir une certaine indication des similitudes géométriques entre la carte de 1507 et les formes modernes. Les contours et l'emplacement du continent sud-américain sur la carte de 1507 sont problématiques du point de vue chronométrique, puisque ni Balboa ni Magellan n'avaient atteint l'océan Pacifique à cette époque. La conclusion de l'étude est que Waldseemüller se serait probablement basé sur des renseignements géographiques qui n'existent plus ou qui n'ont pas encore été découverts pour élaborer sa carte du Nouveau Monde en 1507.

Mots clés : Waldseemüller, déformation polynomiale, régression bidimensionnelle, modèle de projection
Introduction

What does it mean to obtain a new concept of the surface of a sphere? How is it then a concept of the surface of a sphere? Only in so far as it can be applied to real spheres.

- Wittgenstein (1983, 259)

The word "phenomenological" in the title of this article is deliberately borrowed from the lexicon of the twentieth-century logician Edmund Husserl (1970). The word means "back to the thing itself" and here implies an inversion in normal historical methodology. Instead of asking what documentary evidence and historical context can tell us about Waldseemüller's 1507 World Map (Figure 1), we can ask what the 1507 map can tell us about itself, its sources, and, most importantly, its accuracy.

The question of accuracy in historical cartography is a vital one, and, according to M.J. Blakemore and J.B. Harley (1980, 54), it is also one of the least understood. Questions of accuracy and similarity in the case of early maps are especially complex, "for as maps are the end product of a chain of processes, so it is to be expected that several distinct types of accuracy may have to be accepted within a single map" (Blakemore and Harley 1980, 55). Blakemore and Harley identify three types of accuracy that are relevant to this study: (1) chronometric, (2) geodesic and planimetric, and (3) topographic. Chronometric accuracy has two related parts: (a) the date of the map's production and (b) the date of the geographic information that it displays.

Geodesic accuracy and topographic accuracy are broad categories that take into account the difference in metric distances between geographic locations on early and modern maps, the arrangement and shape of the various spatial entities displayed on the map, and differences in distinctive landscape features that may have changed over time. Accuracy of any type is especially difficult to define and quantify when dealing with early maps of small scale, such as Waldseemüller's 1507 World Map. The geographic sources used to create the map may no longer be extant, may have had varying scales and different degrees of geodetic accuracy, and may themselves have been made from composite sources. It is into this quagmire of questions of accuracy that this article shall wade.

The 1507 World Map shows, for the first time, a depiction of the New World as a separate land mass detached from Asia, and it was the subject of scholarly study and speculation even before the discovery of the only surviving copy by Joseph Fischer in the collections of the Wolfegg Castle in 1900.¹ Scholars, from Alexander von Humboldt (1837) and Marie D'Avezac-Macaya (1867) in the early and mid-nineteenth century, through the more modern studies of Fischer (Fischer and von Wieser 1968) himself, and later twentieth-century investigators (Karrow 1993), have all concentrated on the map's context and its place in cartographic history, showing little regard for its geometric accuracy, possible geographic sources, cartographic content, and structure.

The map, which now resides in the Geography and Map Division of the Library of Congress, displays

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Figure 1. Composite image of Martin Waldseemüller's 1507 World Map. Geography and Map Division, Library of Congress.
the continents of the New World with a shape that, when re-projected, is geometrically similar in form to the outlines of the continents as we recognize them today. The shape and location of these land masses, separated as they are from Asia, are chronologically and chronometrically problematic, in that in 1507, the map’s supposed creation date, neither Vasco Nuñez de Balboa nor Ferdinand Magellan had reached the Pacific Ocean. Waldseemüller discusses his portrayal of the New World in his Cosmographiae introductio, cum quibusdam geometricae ac astronomiae principis ad eam rem necessaries, printed in multiple editions in St. Dié under the patronage of René II, Duke of Lorraine, in 1507. According to Robert Karrow (1993, 569), “few books of its size have generated as much interest and speculation as the Cosmographiae Introductio.” All this attention and speculation stem mostly from the mention on the title page (Figure 2) of the two maps (descriptio tam in solido quam plano) that constituted part of the book, one a flat map (plano) and the other a globe (solido). Neither of these maps appears to have actually accompanied the book when it was produced, and they were unknown until Lucien Louis Joseph Gallois’s (1890, 1899) discovery of the first copy of the globe gores in the Lichtenstein Collections in the late nineteenth century and Fischer’s discovery of the Wolfegg Codex in 1900. The Cosmographiae Introductio (Waldseemüller and Ringmann 1507) describes the New World by saying,

Hunc in midu tere iam quadripartite connoscit; sunt tres prime partes cotinentes Quarta est insula cu omni quaque mari circundata cinspiciat.

The semantics of Waldseemüller’s Latin are extremely important here. The passage translates, “The earth is now known to be divided into four parts. The first three parts are continents, while the fourth part is an island, because it has been found to be surrounded on all sides by sea.”

Waldseemüller uses highly suggestive phrases such as “now known” and “has been found,” both of which imply some form of empirical evidence rather than mere speculation. Other sources also testify to the form of this evidence. In a letter dated 12 August 1507, the humanist historian Johannes Trithemius wrote to his friend Veldicus Monapius that he had

a few days before purchased cheaply a handsome terrestrial globe of small size lately printed at Strasbourg, and at the same time a large map of the world ... Containing the large islands and countries recently discovered by the Spaniard [sic] Americus Vespucius in the western sea, which extends south almost to the fiftieth parallel. (Trithemius 1536, 296)

Although there has been much discussion on the historical meaning and context of Waldseemüller’s cartographic and linguistic portrayals, no quantitative analysis has ever been performed that might give some indication of whether or not empirical evidence for this knowledge may have existed. The present article seeks to shed some light on this question by studying the geometric similarity between Waldseemüller’s portrayal of the coast of South America and its known form through the use of several related mathematical and geometric methods. The goal of these types of investigations was suggested by J.H. Andrews (1975) early in the development of historical cartometry. Andrews writes in his Motive and Method in Historical Cartometry that the point of such studies is

to measure such desirable cartographic properties as comprehensiveness of uniformity of content, or to investigate stemmatic relationships by quantifying the similarities between one inaccurate map outline and another. (1975, 12)
First, I shall analyse the projection on Waldseemüller’s 1507 map using a mathematical approximation that resembles a Bonne projection. After calculating the graticule of this approximation using Mathematica software, the modern coastline can then be re-projected on Waldseemüller’s projection for visual comparison. Second, applying polynomial warping algorithms to the digitized world map and carrying out spatial interpolations using Java Advanced Imaging Software and ArcGIS, the newly produced surfaces and regression curves can be analysed for inflection-point behaviour. Global and local correlation coefficients are calculated to give some measure of the geometric similarity between the 1507 map and modern forms.

Any discussion of the mathematical and statistical comparison of ancient and early maps with their modern equivalents must necessarily begin with the work of Waldo Tobler. Tobler produced a series of seminal articles, beginning in 1965 with the “Computation of the Correspondence of Geographical Patterns” and ending with his 1977 article and computer program “Bi-dimensional Regression,” that presented and developed the theory of statistical map comparison (see Tobler 1965, 1966, 1994). Bi-dimensional regression, essentially invented by Tobler, is a statistical regression technique that allows inferences to be made between two planes from point distributions on those planes. Of the many techniques used to analyse point patterns, Tobler’s regression is unique in requiring a one-to-one mapping between the points on the planes (Tomoki 1997). The requirement that the mapping function be injective assures that there is a correspondence between points on the two planes to be compared and that both surfaces are topologically genus-0, with no holes or singularities.

Tobler defined and investigated four kinds of bi-dimensional regression models: (1) the Euclidean transformation model, (2) the affine transformation model, (3) the projective transformation model, and (4) the curvilinear transformation model. The great utility of these models is that although they can be considered as elementary applications of empirical differential geometry or as studies of non-linear transformations in two-dimensional Euclidean space, they are defined by the maps that are to be studied rather than by abstract a priori properties. Tobler thought that his curvilinear models were of the greatest interest because the regression coefficients constitute a spatially varying second-order tensor field that was defined by the matrix of partial derivatives of the transformation (Akima 1984) between the two sets of points. In his computer program, he used a non-parametric approach that allowed visualization of the regression by automatically plotting scatter diagrams, drawing a displacement field, and producing a differential interpolation of warped coordinates that was essentially equivalent to Tissot’s Indicatrix (Tissot 1881). Tobler produced two studies using various forms of these techniques, one on the Hereford Map and the other on the 1360 Gough map of Great Britain (1965, 1966).

Tobler considered his methods to be prerequisites for other studies on ancient and early maps and just one more tool to be used by cartographic historians. Researchers such as Susan Evans and Peter Gould (1982) used these methods to investigate the simple correspondence between actual locations of settlements and those predicted by theoretical models. Several studies have focused on exploring the systematic components of cognitive map distortion and its theoretical explanation (Lloyd and Hevley 1987). Unfortunately, however, only a few cartographic historians have taken up these methods and applied them in a quantitative and statistically rigorous way to real historical problems. Gustav Forstner’s study of the errors in longitude on early maps and atlases (Forstner and Oehfli 1998) and T. Fuse’s study on the geometrical correction of historical maps (Fuse and Shimizu 1998) are notable exceptions.

Waldseemüller’s Projection

What any picture, of whatever form, must have in common with reality in order to depict it - correctly or incorrectly - in any way at all, is logical form, i.e. the form of reality.

- Wittgenstein (1921, 7)

Among the many technical and theoretical problems that Waldseemüller faced in the construction of his map, one of the least trivial, mathematically, was the problem of projection. Dealing with a greatly enlarged earth, compared with the Ptolemaic models at his disposal, Waldseemüller modified Ptolemy’s second conic projection in a way that, unfortunately, distorted the shape of the new continents, as they were forced to the far western portion of the map and hence greatly elongated (see Figure 1).

In Waldseemüller’s time new ideas were rapidly developing out of the theoretical discussions in Book I of Ptolemy’s Geographiae. Many commentators and cartographers realized that there was no reason to adhere to Ptolemy’s restriction of a correct representation of distances on three parallels, a restriction introduced in order to construct circular meridians. They found that by altering this arbitrary restriction on the form of the meridians and by applying Ptolemy’s methodology to any number of equidistant parallels, one could obtain a map correct on all parallels, with the meridians easily constructible as curves or polygons connecting points of equal longitude (Ptolemy 2000).

This type of generalization was used on Ptolemy’s second conic projection by Waldseemüller to extend his
Warping Waldseemüller: A Phenomenological and Computational Study of the 1507 World Map

world map, although not smoothly, as can be seen from the abruptness of the change in the meridians at the equator. A more continuous extension of the second conic projection was made in a less ad hoc way by Bernardus Sylvanus in a world map contained in his 1511 Claudii Ptolemaei Alexandrini liber geographiae cum tabulis universalis fugura et cum additione locorum quae a recentioribus reperta sunt diligenti cara emendatus et impressus. Sylvanus’s generalization of Ptolemy’s mapping represented an extension of the area of the globe to between −40 and +80 degrees in latitude and between 70° west and 290° east in latitude using undistorted parallels.

In 1514, Johannes Werner produced his translation of and commentary on Book I of Ptolemy’s Geographiae. Werner added to his translation a theoretical discussion of two generalizations of Ptolemy’s second conic projection in a section of his book entitled Libellus de quator terrarum orbis in plano figurationibus ab codem Ianne Verneo novissime comertis et narratis. Werner’s Propositio IV (Figure 3) modifies Ptolemy’s methodology by requiring that lengths be preserved on all parallels, represented by concentric arcs, and on all radii.

Werner further modified the projection in a way that makes the North Pole the center of what in modern terms would be called a system of polar coordinates. In Proposito V, he also requires that a quadrant of the equator have the same length as the radius between a pole and the equator.

The modifications of Sylvanus and Werner were the first solutions to the problem of representing the surface of a sphere within a finite area. Waldseemüller’s projection can be graphically approximated (Snyder 1993) using the transformation equations that also can be used to represent an infinite series of projections, including Sylvanus’s, Werner’s, and the later Bonne projection, shown below:

\[ x = \rho \sin \theta \]
\[ y = \rho - \rho \cos \theta \]
\[ \rho = R(\cot \varphi_1 + \varphi - \varphi) \]
\[ \lambda \cos \phi = (\cot \varphi_1 + \varphi - \varphi) \]

Figure 3. Johannes Werner’s commentary on Book I of Ptolemy’s Geographiae. Geography and Map Division, Library of Congress.
The value of the central parallel $\varphi_1$ and an additive parameter $f$ can be changed in such a way that an approximation to Waldeemüller's projection results. The Sylvanus, Werner, and Bonne projections in polar coordinates all contain an arbitrary parameter $f > 0$ such that $r = \varphi_1 + f$. The image of the North Pole, accordingly, lies on the central meridian at a distance $f$ below the centre of the parallels. In the Bonne projection $f$ is assigned in a way that the radii touch the meridian curves always on a given parallel. Sylvanus unknowingly uses a similar value to Bonne, $f = 10$, and if we assign $f = 0$ we arrive at Werner's projection.

Waldeemüller's map can be approximated in this same way using values of $f$ between 7 and 8.5. The actual projection of the 1507 map differs from that represented in the above equations in that it has bends in the meridians at the equator and the meridians are shown as segmented circular arcs rather than as continually changing curves. The modern coast of South America is portrayed by a series of linear features and is labelled "terra ultra incognita." These straight lines have been interpreted as Waldeemüller's way of picturing regions for which he had no specific geographic information to make a more accurate representation. These same features, however, appear when the modern coast is projected on the approximate projection.

Waldeemüller's representation of the continent and the re-projected outline of modern South America are strikingly similar visually. Even though it is clear that Waldeemüller's projection elongates the shape of the

Figure 4. Comparison of Waldeemüller's 1507 map with modern South America projected on the calculated Waldeemüller projection.
continent, it is also apparent that its width is close to that of the modern form.

**Polynomial Warping and Spatial Interpolation**

We can only substitute a clear mathematical symbolism for an imprecise one by inspecting the phenomena that we want to describe, thus trying to understand their logical multiplicity - not by conjecturing about a priori possibilities.

- Wittgenstein (1929, 29)

The process of polynomial warping is essentially a mathematical transformation or mapping from a distorted image, such as an early map or a map with an unknown scale or geometric grid, to a target image that is well known. The objective is to perform a spatial transformation, or warp, so that the corrected image can be measured or have a metric placed upon it relative to a known map or grid. The process is ideal for comparing modern maps with historical representations of the same geographical area. The mathematical functions used in the process are polynomials of an arbitrary order that depend on the amount of distortion in the unknown map.

The warping process includes all deformations that can be modelled by global bivariate transformations of the following form:

\[ u = \sum_{i=0}^{N} \sum_{j=0}^{N-i} a_{ij} x^i y^j \]
\[ v = \sum_{i=0}^{N} \sum_{j=0}^{N-i} b_{ij} x^i y^j \]

In the above equations, \( x \) and \( y \) are the coordinates of the reference image, in our case the known map of South America, and \( u \) and \( v \) are the coordinates on the Waldseemüller image (Wolberg 1990). An example of a second-order or quadratic transformation using the above equations can be written as follows:

\[ u = a_{00} + a_{10} x + a_{01} y + a_{11} x y + a_{20} x^2 + b_{02} y^2 \]
\[ v = b_{00} + b_{10} x + b_{01} y + b_{11} x y + b_{20} x^2 + b_{02} y^2 \]

The constant coefficients \( a_{ij} \) in the above polynomial equations can be associated with particular types of distortion, as shown in Table 1.

The values for the polynomial coefficients are found by the use of tie points that represent corresponding positions in the known and distorted image whose locations can be defined precisely. In our context, the tie points came from the common latitude and longitude points found on the two maps. The coordinates from the Waldseemüller map were normalized to their modern equivalents because the 1507 map employs a coordinate scheme that runs from 0 to 360 degrees with the 280-degree meridian representing the western border of the map. Because the number of polynomial coefficients to be calculated is much less than the number of tie points in any reasonable-order polynomial warp, a least-squares error fit was used (Ahn 2004; Lawson and Hanson 1974).

For application to the Waldseemüller map, non-linear transformations were required - in other words, transformations that could not be modelled by simple affine polynomials. Affine transformations have only first-order terms and can shift, rotate, and scale an image but cannot introduce bending or stretching. Figure 5 shows an example of an affine transformation using Waldseemüller's sheet for the northern part of South America. The inclusion of higher-order terms in the transformation allows for much more flexibility and much more image distortion than affine forms would. The coefficients for a second-order transformation on the Waldseemüller map can be determined by minimizing

\[ E = \sum_{k=1}^{M} s_k^2 \]
\[ = \sum_{k=1}^{M} [U(x_k, y_k) - u_k]^2 \]
\[ = \sum_{k=1}^{M} [a_{00} + a_{10} x_k + a_{01} y_k + a_{11} x_k y_k + a_{20} x_k^2 - u_k]^2 \]

Minimization is achieved by determining the partial derivatives of \( E \) with respect to coefficients \( a_{ij} \) and equating them to zero. For each coefficient \( a_{ij} \):

\[ \frac{\partial E}{\partial a_{ij}} = 2 \sum_{k=1}^{M} s_k \frac{\partial s_k}{\partial a_{ij}} = 0 \]

By solving for the partial derivatives of \( E \) with respect to all six coefficients, we obtain a 6 x 6 symmetric system of

<table>
<thead>
<tr>
<th>Polynomial Coefficients</th>
<th>Distortion Type</th>
<th>High Order Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_{00} )</td>
<td>shift in ( x )</td>
<td>rotation</td>
</tr>
<tr>
<td>( b_{00} )</td>
<td>shift in ( y )</td>
<td>rotation</td>
</tr>
<tr>
<td>( a_{10} )</td>
<td>scale in ( x )</td>
<td>rotation</td>
</tr>
<tr>
<td>( b_{10} )</td>
<td>scale in ( y )</td>
<td>rotation</td>
</tr>
<tr>
<td>( a_{11} )</td>
<td>( y )-dependent scale in ( x )</td>
<td></td>
</tr>
<tr>
<td>( b_{11} )</td>
<td>( x )-dependent scale in ( y )</td>
<td></td>
</tr>
<tr>
<td>( a_{20} )</td>
<td>nonlinear scale in ( x )</td>
<td></td>
</tr>
<tr>
<td>( b_{20} )</td>
<td>nonlinear scale in ( y )</td>
<td></td>
</tr>
<tr>
<td>( a_{nn}, ..., b_{mm} )</td>
<td>higher order non-linearity</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Polynomial coefficients and related distortion
linear equations, whose coefficients are summations from
$k = 1$ to $M$ and can be evaluated from the original tie
points. This system of equations can be written in
compact form as

$$
\sum_{i=0}^{N} \sum_{j=0}^{N-1} a_{ij} \left[ \sum_{k=1}^{M} x_i x_j y_i y_j \right] = \sum_{k=1}^{M} u_k x_i y_k
$$

The least-squares procedure in this case is operating
on an overdetermined system of variables and linear
equations, meaning that the number of tie points is
greater than the number of coefficients to be calculated.
As a result of this overdetermination, we are calculating
a polynomial warp that is only an approximate mapping
and hence a best-fit minimization.

A second-order quadratic warp of the north section
of South America on the 1507 map with the modern
continent overlaid is shown in Figure 6. The figure,
while graphically inconclusive, does display an overall
average correlation coefficient of 0.69. The sheet showing
the southern part of the continent is slightly better at
0.73. Most of the error in these two transformations
comes from shear and non-linear scale coefficients. It is
important to note that these transformations compare
the entire surface of the transformed image with the
target image and give a best fit for the entire surface. The
correlations, while not extremely high, are at least
suggestive of something that is statistically significant
and not due purely to chance operations. Because this
type of warping takes into account the whole surface,
the meaning of the transformation coefficients is limited.
Better correlations might be achieved by performing
an analysis using only the coastal outlines in the image
regressions. This is the emphasis of the techniques that
follow here.

In order to compare the coastlines of our two figures,
100 points were selected at equal intervals along the
parallels that cut through both images. The distances
between two points along the parallels on each side of the
continents were digitally measured to yield the width
of the continent at each of these points. Distances along
lines of constant latitude appear similar in the two maps
(see Figure 4 above) and were selected as regression
variables because we know that Waldseemüller knew to
a high degree of accuracy the distance of a degree of
longitude at various latitudes. In his *Cosmographiae
Introductio* he provides the table of values shown in
Figure 7. The table gives the distance over intervals of
latitude in both Italian and German miles (Waldseemüller
and Ringmann 1507; Engels 1985; Rickey 1992). In
Figure 8, we have graphed these intervals along with
the modern equivalents (Robinson 1953). The two curves
are remarkably similar in form and are well correlated,
giving us some confidence that Waldseemüller could
display distances along parallels at any scale if in fact he
knew these values.

The measured distances for each map were graphed
and subjected to standard polynomial regression
techniques in order to yield smooth curves. The
curves individually displayed high correlation coefficients, which,
of course, is not unexpected, since, given any set of point
data, a polynomial fit of reasonable accuracy can be
generated if one uses polynomials of a high enough
order. Normally one wants to use the lowest-order
regression, but in this case we are not interested
in the individual curves but only in a comparison.
Figure 6. Second-order transformation of northern portion of South America on Waldseemüller’s 1507 map.

Figure 7. Latitudinal distance table from *Cosmographiae introductio*. Geography and Map Division, Library of Congress.

The two resulting curves, shown in Figure 9, display some interesting features. First, the overall shapes of the curves are comparable, with inflection points and minima and maxima occurring in the same regions. Second, the correlation coefficient between the two curves is 0.76, which is fairly high and comparable to that found using polynomial warping. Third, the intersection points on the two curves represent the locations in which the widths of the two figures are exactly correlated. Points of intersection occur near the equator at 1.4703° latitude and at -21.308° latitude, closely corresponding to the place at which the western coast of South America changes from its North-South direction and expands west. The modern geographic location of this point is the city of Arica, Chile. These extremely high correlations occur at geographically significant points if one considers the overall geometry of the continent. Fourth, the maximum points on both curves, which represent the location of greatest width of the continent, are along the same parallel.

Discussion of Techniques and Conclusions

What we cannot speak about we must pass over in silence.

- Wittgenstein (1921, 74)

The results of this study must be considered cautiously and carefully. The language used by Waldseemüller in the *Cosmographiae introductio*, the overall correlation of the warped images, the visual structure and form of the projected surfaces, and the coastal regression points
of high correlation, while not conclusive individually, together do represent something that, in all probability, is not attributable to pure coincidence and shows a geometric similarity between Waldseemüller’s representation and the modern one. While these results make it more probable that Waldseemüller had geographic information that is no longer extant, it must be emphasized that there is not a single piece of documentary evidence that would support a more definitive claim.

The 1507 map remains a mystery for many reasons, perhaps none more important than Waldseemüller’s apparent retraction of the shape and location of South America on his later cartographic works. In both his 1513 edition of Ptolemy and his 1516 *Carta marina navigatoria*, ... the new world becomes reattached to Asia and the Pacific Ocean disappears. In a paste-down text on the 1516 map, Waldseemüller tells us that he printed 1000 copies of the 1507 map, yet in the same text he tells us that it was based on old sources and that the 1516 map, of which there appears to have been only one, reflects the modern geographical arrangement. We can only speculate as to why.

The mathematical and theoretical tools outlined in this study are useful, but they can never be the entire story in the study of early and ancient materials. In order to apply these models intelligently, we need to formulate and think through historical questions in a way that makes the results relevant to a particular historical problem. Application of any model to ancient or Renaissance materials, especially of such small scale as the Waldseemüller 1507 World Map, is a process fraught with errors. If used without care, it can lead to the possible over-interpretation of results and false conclusions. Composite sources used for world maps and atlases make distance and scale errors difficult to quantify. For this reason, global techniques, those that take in the whole map, must be avoided in favour of more local models whereby correlations can be calculated over smaller areas. Moreover, the deterministic form of these methods makes the statistical results descriptive in nature, as it is difficult to determine the meaning of the various transformations and whether or not any historical meaning can be derived from them. R.A. Skelton, in his *Looking at an Early Map* (1965), observed many of the same general problems when considering the Vinland
Warping Waldseemüller: A Phenomenological and Computational Study of the 1507 World Map

Figure 9. Polynomial regression curves comparing width of South America on the 1507 map with known distances.

Map, and his thinking remains a model of the thought necessary when approaching early cartographic materials (Blakemore and Harley 1980, 56):

The content of the map, as a whole, cannot be assigned confidently to a single phase or horizon of geographical knowledge. Its outlines are in part transcribed from a map prototype or prototypes not precisely identifiable with any extant work; in part they illustrate texts, not all of which have come down to us. The information taken by the author of the map from these sources (graphic and textual) relates to events and concepts of various periods . . . for the mapmaker was working always at one remove . . . and it is evident that, to a degree and in senses which it is difficult for us to divine, he exercised his judgment in selection from and in adaptation of his sources, which are themselves . . . unknown to us. (Skelton 1965, 228)

Finally, this study leaves only probabilities and whatever confidence we can place in our interpolations. When we apply these techniques carefully and thoughtfully, however, as has been the case here on Waldseemüller’s World Map of 1507, these probabilities become just what Tobler hoped for when he developed his early regression techniques— one more piece of an extremely complex historical puzzle.

Acknowledgements

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Notes

1. For a survey of Fischer’s discovery, a summary of the provenance of the map, and a discussion of the contents of the Wolfegg Codex, see Hebert (2005).
2. D’Avezac-Macaya, in his Martin Hylacomylus Waltzeumuller ses Ouvrages et ses Collaborateurs, makes an argument for four editions, which he distinguishes based on the first line of the title and the colophon (1867, 112). Henry C. Murphy, in the catalogue of the Carter-Brown Library (1853, i, 35), opines that two of these are simply made up from the original May and September editions of 1507. Henry Harrisse’s opinion differs from Murphy’s; Harrisse maintains that there are in fact three real editions from 1507 (see 1958–1960, no. 24).

3. Wolfram (1999). Data were analysed using the FIT function in the Mathematica mathematics software produced by Wolfram Associates.


5. ArcGIS software, version 9.0, by Environmental Systems Research Institute.

6. Waldseemüller and Ringmann use a value for the circumference of the earth here that is substantially larger than the Ptolemaic value of 180,000 stades, reflecting a value closer to Eratosthenes’ 252,000 stades (Engels 1985). For explanation of the effect of Eratosthenes’ measurements on age of exploration notions of the size of the earth, see Rickey (1992).

7. Polynomial and multiple regression analysis was carried out using the Multivariate Descriptive Statistics Package in Mathematica.

References


Ptolemy, Claudius. 1511. Claudii Ptolemaei Alexandrini liber geographiae cum tabulis universali fugura et cum additione locorum quae a recentioribus reperta sunt diligenti cura emendatus et impressus. Venice: Jacobus Pentinus.


Warping Waldseemüller: A Phenomenological and Computational Study of the 1507 World Map


Werner, Johannes. 1514. Libellus de quator terrarum orbis in plano figurationibus ab codem Ianne Verneo novissime compertis et enarratis. Nuremburg: Johannes Stuchs.


